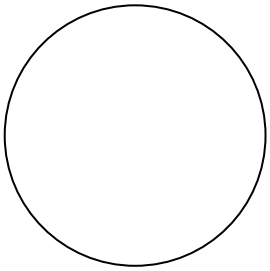
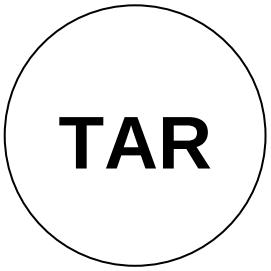




The IPSI BgD Transactions on Advanced Research

Multi-, Inter-, and Trans-disciplinary Issues in Computer Science and Engineering

A publication of
IPSI Bgd Internet Research Society
New York, Frankfurt, Tokyo, Belgrade
January 2006 Volume 2 Number 1 (ISSN 1820-4511)

Table of Contents:

Call for Papers for the IPSI BgD Conferences

www.internetjournals.net

The IPSI BgD Internet Research Society

The Internet Research Society is an association of people with professional interest in the field of the Internet. All members will receive this TRANSACTIONS upon payment of the annual Society membership fee of €100 plus an annual subscription fee of €1000 (air mail printed matters delivery).

Member copies of Transactions are for personal use only

IPSI BGD TRANSACTIONS ON ADVANCED RESEARCH

www.internetjournals.net

Bit and Power Loading for Wireline Multicarrier Transmission Systems

Ahrens, Andreas; Lange, Christoph

Abstract— ***The partitioning of transmit power and the allocation of bits per symbol to the modulation schemes within the subchannels of multicarrier systems essentially affect their performance capability. Here a two-stage optimization setup is proposed: Firstly, the bit rate is maximized using the Lagrange Multiplier method, which in general leads to non-integer numbers of signalling levels. Based on given practical constraints by e. g. the rounding of the number of signalling levels, an interesting extension is investigated: A second optimization step is applied to improve the system performance further in terms of decreasing the bit-error rate or in terms of increasing the bit rate. For the rounding of the number of signalling levels two different approaches are investigated. Exemplary results are obtained for the multicarrier transmission over twisted wire pairs.***

Index Terms— ***Multicarrier transmission, power allocation, bit loading, filtered multitone modulation, Lagrange multiplier method, quadrature amplitude modulation.***

1. Introduction

MULTICARRIER transmission techniques are powerful alternatives compared with single-carrier or baseband transmission techniques [3], [4]. On the one hand they are used for the transmission over copper cables with strong frequency-dependent attenuation in the local cable area (e. g. ADSL, asymmetric digital subscriber line) and on the other hand they are successfully applied in digital transmission systems for frequency-selective radio channels (e. g. DVB, digital video broadcasting or DAB, digital audio broadcasting). Multicarrier systems divide the available frequency range into narrow subchannels. The allocation of signalling levels (i. e. bits per symbol) and the partitioning of transmit power to the subchannels are degrees of freedom, which essentially affect the performance capability of multicarrier transmission systems [5].

Manuscript received September 19, 2005. This paper was presented in parts at the 10th OFDM Workshop, September 2005 [1] as well as at the XXI Krajowe Sympozjum Telekomunikacji, September 2005 [2]. The authors are with the Institute of Communications Engineering, University of Rostock, Richard-Wagner-Str. 31, 18119 Rostock, Germany (email: {andreas.ahrens}{christoph.lange}@uni-rostock.de).

Known bit loading and transmit power allocation techniques are often based on a fixed target bit rate. Examples can be found in a huge variety in the literature: The allocation scheme according to [6] allocates the signalling levels of the subchannel modulation schemes based on the channel capacity. The transmit power after rounding the signalling levels towards integer numbers of bits per symbol is assigned in such a way that equal error rates in the subchannels arise. The approach according to [7] is based on maximizing the signal-to-noise ratios per subchannel. The algorithm [8] successively assigns the signalling levels to the subchannels in such a way that the next bit per symbol is allocated to the subchannel, which requires the least additional transmit power until the target bit rate is reached. The aim of these methods is an increase of the transmission quality at a fixed overall bit rate. This is particularly appropriate, when the reliability of a transmission at e. g. a standardized bit rate should be increased or a transmit power reduction is desired at a given bit-error rate and a fixed bit rate.

In this contribution the allocation of the number of signalling levels and the transmit power to the subchannels is considered under the aspects of maximizing the overall bit rate at a fixed required quality (e. g. bit-error rate or signal-to-noise ratio) or of minimizing the bit-error rate at a given bit rate. The former is of great practical interest in wireline and wireless transmission, respectively, since the demand for high data rates is growing very fast. The latter one is often required, if the transmission reliability has to be improved at a standardized bit rate.

The intention of this contribution is not to develop a new bit and power loading algorithm, which outperformes existing ones. Here, general aspects and interrelationships of bit and power allocation in multicarrier systems are considered. The effects of complementary optimization targets such as bit rate maximization or bit-error rate minimization are investigated under given (fixed) boundary conditions.

The contribution is organized as follows: In section 2 the transmission model is introduced and in section 3 quality criteria and possible directions of

optimization are briefly reviewed. In section 4 and 5 different power and bit allocation schemes are investigated, where the focus lies on a two-stage optimization scheme in order to make efficient use of the transmit power. In section 6 numerical results are presented. Some concluding remarks are given in section 7.

2. System model

The considered N channel multicarrier transmission system is shown in Fig. 1. The transmitter consists of N bandpass filters, whereas the first subchannel is not executed as a baseband channel but also as a bandpass channel in order to allow a unique description and enable the usage of the low frequency range for the analog telephone transmission (e. g. voice) [9]. The subchannel's

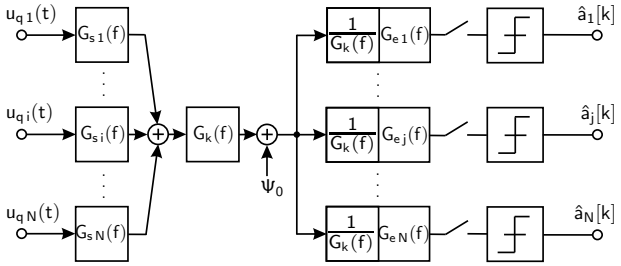


Fig. 1. Multicarrier transmission system

source signal is described by

$$u_{\mathrm{q}\,\mu}(t) = U_{\mathrm{s}\,\mu}\, T_{\mathrm{s}} \sum_{k=-\infty}^{+\infty} a_\mu[k] \cdot \delta(t - k\, T_{\mathrm{s}}) \ , \qquad (1)$$

whereby a sequence of Dirac pulses is weighted by the amplitude coefficients $a_\mu[k]$. The value $U_{\mathrm{s}\,\mu}$ indicates the half-level transmit amplitude and the symbol duration is denoted by T_{s}, respectively [2]. Furthermore the pulse shaping concept is based on the filtered multitone modulation (FMT). Transmit and receive filters $G_{\mathrm{s}\,\mu}(f)$ and $G_{\mathrm{e}\,\mu}(f)$, respectively, are two-fold lapped base functions as proposed in [10] and investigated in [9]. Compared with a multicarrier system, which uses a rectangular pulse shaping (e. g. OFDM, orthogonal frequency division multiplex) a guard interval can be avoided here. This leads to an increase in the spectral efficiency with the drawback of a slightly increased complexity (e. g. equalization unit) [11]. The influence of different pulse shaping concepts (e. g. FMT, Wavelet) and their behaviour under non-ideal channel conditions were investigated in [12] and [9].

The cable is described by the transfer function

$$G_{\mathrm{k}}(f) \approx \frac{1}{2} \frac{1}{\prod_{\nu=1}^{\infty} \left(1 + \mathrm{j}\frac{f}{f_\nu}\right)} \text{ with } f_\nu = \frac{\pi^2\,(2\,\nu - 1)^2}{4\,l^2} f_0 \ , \qquad (2)$$

where l denotes the cable length (in km) and f_0 is the characteristic cable frequency (in $\mathrm{MHz} \cdot \mathrm{km}^2$), respectively [13]. Based on the choice of the combined equalizer-receive filter function $G_{\mathrm{e}\,\mu}(f)/G_{\mathrm{k}}(f)$, intersymbol and interchannel interference can be avoided completely (Fig. 1). Other equalization concepts in combination with FMT modulation were investigated exemplarily in [14] or [12].

3. Quality criteria and optimization setups

The quality of the data transmission can be evaluated by using the well-known signal-to-noise ratio (SNR) definition (e. g. [12], [15])

$$\varrho = \frac{(\text{Half vertical eye opening})^2}{\text{Noise disturbance}} \ . \qquad (3)$$

With this definition a SNR per subchannel can be defined in the following form:

$$\varrho_\mu = \frac{U_{\mathrm{s}\,\mu}^2}{U_{\mathrm{R}\,\mu}^2} \qquad \mu = 1, 2, \cdots, N \ . \qquad (4)$$

Here, the half vertical eye opening at the sampling instant is identical with the half-level transmit amplitude $U_{\mathrm{s}\,\mu}$ since intersymbol and interchannel interference can be avoided completely after receive filtering (with equalization) and sampling (Fig. 1). Further, the noise disturbance per quadrature component after receive filtering and sampling is denoted by $U_{\mathrm{R}\,\mu}^2$ [12]. With this definition a symbol-error rate per subchannel using QAM (quadrature amplitude modulation, e. g. [16], [17]) can now be formulated as a function of the number of signal points M_μ and the SNR ϱ_μ

$$P_{\mathrm{f}\,\mu} \approx 2 \left(1 - \frac{1}{\sqrt{M_\mu}}\right) \operatorname{erfc}\left(\sqrt{\frac{\varrho_\mu}{2}}\right) \ . \qquad (5)$$

Assuming gray coding [17], the bit-error rate per subchannel yields to

$$P_{\mathrm{b}\,\mu} = \frac{1}{\log_2(M_\mu)}\, P_{\mathrm{f}\,\mu} \ . \qquad (6)$$

Combining (5) and (6), the bit-error rate of the whole multicarrier system can be evaluated by taking all subchannel bit-error rates $P_{\mathrm{b}\,\mu}$ into account and results in

$$P_{\mathrm{b}} = \frac{1}{N} \sum_{\mu=1}^{N} \frac{2}{\log_2(M_\mu)} \left(1 - \frac{1}{\sqrt{M_\mu}}\right) \operatorname{erfc}\left(\sqrt{\frac{\varrho_\mu}{2}}\right) \ . \qquad (7)$$

The optimization requires not only the consideration of the bit-error rate but also the data-rate and their mutual impact on each other. In many cases the data throughput

$$f_{\mathrm{B\,ges}} = \sum_{\mu=1}^{N} f_{\mathrm{B}\,\mu} = f_{\mathrm{T}} \sum_{\mu=1}^{N} \log_2(M_\mu) \qquad (8)$$

has to be maximized, where the boundary conditions of a restricted transmit power P_s and a required error-rate $P_{\mathrm{b\,ref}}$ have to be fulfilled. These constraints can be defined as follows

$$\mathrm{a)}\quad P_\mathrm{s} - \sum_{\mu=1}^{N} P_{\mathrm{s}\,\mu} \geq 0 \quad \text{and} \quad \mathrm{b)}\quad P_{\mathrm{b\,ref}} - P_\mathrm{b} \geq 0 \ . \tag{9}$$

Throughout this contribution it is assumed that the number of subchannels N and the total transmit power P_s are fixed. The remaining parameters like the symbol pulse frequency $f_\mathrm{T} = 1/T_\mathrm{s}$, the partitioning of the transmit power $P_{\mathrm{s}\,\mu}$ to the subchannels and the expected error-rate $P_{\mathrm{b\,ref}}$ as well as ϱ_μ and M_μ are degrees of freedom. Unfortunately they are not independent and mostly have a strong impact on each other. A cost function can now be defined

$$\begin{aligned} J \;\; = \;\; & f_{\mathrm{B\,ges}} + \lambda_1 \left(\sum_{\mu=1}^{N} P_{\mathrm{s}\,\mu} - P_\mathrm{s} \right) \ldots \\ & \ldots + \lambda_2 \left(\frac{1}{N} \sum_{\mu=1}^{N} P_{\mathrm{b}\,\mu} - P_{\mathrm{b\,ref}} \right) \end{aligned} \tag{10}$$

using the Lagrange multiplier method, where λ_1 and λ_2 are the Lagrange multipliers [18]. Unfortunately the solution of this cost function is highly complex. That is why in most cases only one of the two boundary conditions is considered in the optimization process by the search for closed-form analytic solutions. The use of the Lagrange multiplier method in combination with power allocation schemas has already been considered in a lot of publictions for wireline and wireless channels, respectively [19]–[23].

4. Throughput maximization at a fixed SNR per subchannel

A. Basics

Ignoring the boundary condition error-rate defined in (9 b), the cost function defined in (10) can be simplified to

$$J(M_1, M_2, \cdots, M_N) = f_\mathrm{T} \sum_{\mu=1}^{N} \log_2(M_\mu) + \lambda \left(\sum_{\mu=1}^{N} P_{\mathrm{s}\,\mu} - P_\mathrm{s} \right) \ , \tag{11}$$

whereas the number of signal points M_μ should be chosen in such a way that the resulting bit rate $f_{\mathrm{B\,ges}}$ is maximized and the constraint of a restricted transmit power is maintained. In order to find a closed-form analytic solution a fixed SNR per subchannel ϱ_μ and a fixed symbol pulse frequency f_T are assumed.

Considering square signal constellations (e. g. 4-QAM, 16-QAM, 64-QAM) the transmit power per subchannel $P_{\mathrm{s}\,\mu}$ according to [24] or [16] yields to

$$P_{\mathrm{s}\,\mu} = \frac{2}{3}\, U_{\mathrm{s}\,\mu}^2\, (M_\mu - 1) \ . \tag{12}$$

For cross constellations (e. g. 32-QAM, 128-QAM, 512-QAM) the transmit power yields to

$$P_{\mathrm{s}\,\mu} = \frac{1}{48}\, U_{\mathrm{s}\,\mu}^2\, (31\, M_\mu - 32) \ . \tag{13}$$

Since the error between (12) and (13) can be neglected with increasing M (e. g. $M \geq 32$) only (12) is used for further calculations. Figure 2 shows on the one hand the exakt powers of the signal constellations (calculated according to (12) for square constellations and to (13) for cross constellations) and on the other hand the approximate powers calculated according to (12) for all constellations. It becomes obvious, that the equation (12) provides a good upper bound for the power of cross constellations (13) and for square constellations it is the exact solution. Furthermore we exclude the 8-QAM from our investigations, since both equations (12) and (13) do not consider the transmit power of an 8-QAM accurate enough. In a practical system the usage of an 8-QAM should be possible if a separate calculation of the transmit power is being done [24].

Therefore with the assumption of a given SNR per subchannel ϱ_μ the transmit power calculations simplify with (4) to

$$P_{\mathrm{s}\,\mu} = \frac{2}{3}\, \varrho_\mu\, U_{\mathrm{R}\,\mu}^2\, (M_\mu - 1) \ . \tag{14}$$

The derivation of (11) with respect to the searched parameter M_μ leads to

$$\frac{\partial}{\partial\, M_\mu} J(M_1, M_2, \cdots, M_N) = \frac{f_T}{M_\mu\, \ln(2)} + \lambda\, \frac{2}{3}\, \varrho_\mu\, U_{\mathrm{R}\,\mu}^2 \ . \tag{15}$$

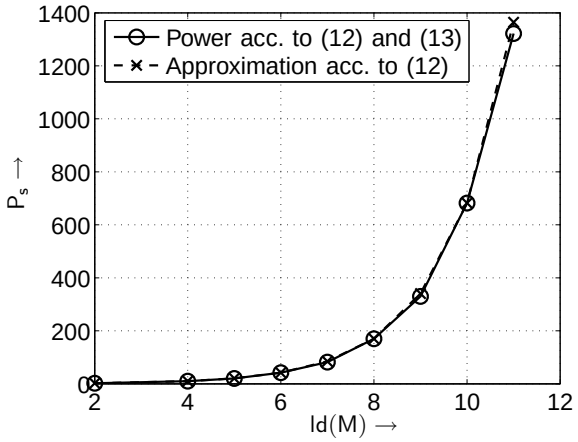


Fig. 2. QAM transmit powers as functions of the number of bits per symbol $\mathrm{ld}(M)$ (example: $U_\mathrm{s} = 1\,\mathrm{V}$)

With the assumption of an equal SNR per subchannel i. e.

$$\varrho_\mu = \varrho_0 \quad \text{for} \quad \mu = 1, 2, \cdots, N \tag{16}$$

and by setting (15) to zero, the searched M_μ are obtained:

$$M_\mu = -\frac{3}{2\,\ln(2)}\frac{f_\mathrm{T}}{\lambda\,\varrho_0\,U_{\mathrm{R}\,\mu}^2} \qquad \mu = 1, 2, \cdots, N \ . \tag{17}$$

The Lagrange multiplier λ can be determined with (9 a), (14) and (17) and results in

$$\lambda = -\frac{3\,N\,f_\mathrm{T}}{3\,P_\mathrm{s}\,\ln(2) + 2\,\ln(2)\,\varrho_0\sum\limits_{\nu=1}^{N} U_{\mathrm{R}\,\nu}^2} \ . \tag{18}$$

This solution now leads to the optimal real-valued numbers of signal points per subchannel

$$M_\mu = \frac{3\,P_\mathrm{s}}{2\,N\,\varrho_0\,U_{\mathrm{R}\,\mu}^2} + \frac{1}{N\,U_{\mathrm{R}\,\mu}^2}\cdot\sum_{\nu=1}^{N} U_{\mathrm{R}\,\nu}^2 \ . \tag{19}$$

Evaluating the expression $M_\mu\,U_{\mathrm{R}\,\mu}^2$, an important result for the multicarrier system design can be obtained as shown in [7]: With (19) it yields to

$$M_\mu\,U_{\mathrm{R}\,\mu}^2 = \frac{3\,P_\mathrm{s}}{2\,N\,\varrho_0} + \frac{1}{N}\cdot\sum_{\nu=1}^{N} U_{\mathrm{R}\,\nu}^2 = \text{constant} \ . \tag{20}$$

A capacity maximization requires a fixed $M_\mu\,U_{\mathrm{R}\,\mu}^2$ for all subchannels of the multicarrier transmission system with equal SNRs per subchannel as well as fixed P_s, N and $U_{\mathrm{R}\,\mu}^2$ (based on a fixed f_T). With (14) and (16) this leads to a transmit power per subchannel

$$P_{\mathrm{s}\,\mu} = \frac{2}{3}\,\varrho_0\,U_{\mathrm{R}\,\mu}^2\,M_\mu - \frac{2}{3}\,\varrho_0\,U_{\mathrm{R}\,\mu}^2 \ . \tag{21}$$

Here, the first term is fixed with the result formulated in (20) and also the second one for a given f_T, respectively. The capacity maximization therefore requires a uniform distribution of the transmit power to the subchannels.

B. Realization

The usage of realizable QAM setups requires a roundoff of the calculated optimum M_μ. In order to achieve required quality criteria the following two rounding operations were considered:

1) Non-iterative rounding: The choice of the next smallest power of two as a practically favorable number of signal points leads to the following integer number of bits per symbol and can be described mathematically as

$$\log_2(\mathbb{M}_\mu) = \lfloor \log_2(M_\mu) \rfloor \ . \tag{22}$$

The expression $\lfloor\cdot\rfloor$ delivers the next smallest integer value.

2) Iterative rounding: Next to the considered non-iterative rounding an iterative rounding was introduced as shown in [7] in order to make a better use of the system parameters. Here, the rounding is based on the following rule:

$$\log_2(\mathbb{M}_\mu) = \begin{cases} \lfloor \log_2(M_\mu) + 0.5 \rfloor & \log_2(M_\mu) > 1.5 \\ 0 & \text{otherwise} \end{cases} \tag{23}$$

whereby the minimum number of bits per symbol was limited to a value of two (based on the assumption in section 4.A). In cases where the calculated transmit power exceeds the given total transmit power the largest rate $\log_2(\mathbb{M}_\mu)$ is, according to [7], decreased by a value of one until the calculated transmit power is lower than the given total transmit power (e. g. $P_\mathrm{s} = 1\,\mathrm{V}^2$).

C. Effects for further optimizations

These rounding operations combined with the transmit power adjustment do not have an influence on the SNR per subchannel ϱ_μ, since the SNR can be expressed as

$$\varrho_\mu = \frac{3\,P_{\mathrm{s}\,\mu}}{2\,(\mathbb{M}_\mu - 1)\,U_{\mathrm{R}\,\mu}^2} \equiv \varrho_0 \tag{24}$$

and there exists a linear relationship between $P_{\mathrm{s}\,\mu}$ and $\mathbb{M}_\mu$. The transmit power per subchannel can now be calculated according to

$$P_{\mathrm{s}\,\mu} = \frac{2}{3}\,U_{\mathrm{s}\,\mu}^2\,(\mathbb{M}_\mu - 1) = \frac{2}{3}\,\varrho_0\,U_{\mathrm{R}\,\mu}^2(\mathbb{M}_\mu - 1) \ . \tag{25}$$

Upholding an equal SNR for all subchannels $\varrho_\mu = \varrho_0$ and taking (4) into account, the reserve in the transmit power

$$\Delta\,P_\mathrm{s} = P_\mathrm{s} - \frac{2}{3}\,\varrho_0\sum_{\mu=1}^{N} U_{\mathrm{R}\,\mu}^2\,(\mathbb{M}_\mu - 1) \tag{26}$$

is obtained. This power reserve depends on the constellation sizes $\mathbb{M}_\mu$, on the noise power $U_{\mathrm{R}\,\mu}^2$ (via the pulse frequency f_T) and on the desired SNR ϱ_0. The influence of the SNR on the arising power reserve at a fixed pulse frequency is illustrated in Fig. 3 and this power reserve can now be used in two ways in a second step of optimization: Either the throughput with an integer number of bits per symbol can be maximized or the bit-error rate at a fixed data rate can be minimized. These two ways are shown in the next section.

5. Mutual impact between bit-error rate and data-rate

A. Throughput maximization

With given constellation sizes and equal SNRs per subchannel, the resulting transmit power reserve (26) can be used to increase the overall

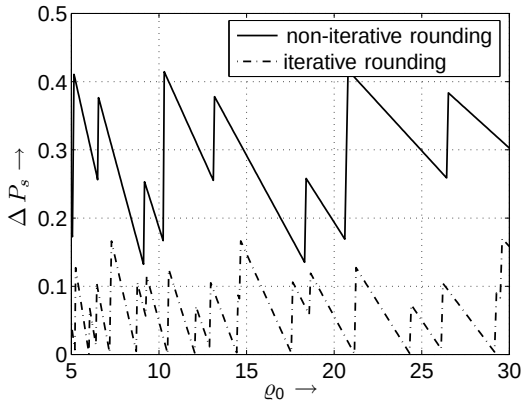


Fig. 3. Remaining power reserve ΔP_s as a function of the SNR at a fixed pulse frequency ($f_\mathrm{T} = 500$ kHz) using different rounding operations

bit rate via an increased pulse frequency. With a given integer number of bits per symbol the bit rate yields to

$$f_{\mathrm{B\,ges}} = f_\mathrm{T} \sum_{\mu=1}^{N} \log_2(\mathbb{M}_\mu) \ . \tag{27}$$

Assuming fixed values of P_s, ϱ_0 and $\mathbb{M}_\mu$, the pulse frequency f_T can now be increased and therefore the noise power $U^2_{\mathrm{R}\,\mu}$ is enhanced, until the boundary condition of a given total transmit power (9 a) is met. The expression $\varrho_0 = U^2_{\mathrm{s}\,\mu}/U^2_{\mathrm{R}\,\mu}$ remains constant in the case of a rising pulse frequency f_T, because the expression (24) is valid and there exists a linear relationship (25) between $P_{\mathrm{s}\,\mu}$ and $U^2_{\mathrm{R}\,\mu}$ via the factor $2/3\,\varrho_0\,(\mathbb{M}_\mu - 1)$.

Only the constellation size will affect the bit-error rate differently. Upholding an equal SNR for all subchannels, the differences in the bit-error characteristic will be determined by the parameter

$$\frac{2}{\log_2(\mathbb{M}_\mu)} \left(1 - \frac{1}{\sqrt{\mathbb{M}_\mu}}\right) \ , \tag{28}$$

which depends on the QAM subchannel constellation size $\mathbb{M}_\mu$. Therefore an equal SNR power allocation scheme cannot lead to the best possible bit-error rate, since the largest subchannel bit-error rate will dominate the overall bit-error characteristic.

B. Bit-error rate minimization

The transmit power reserve (26) originating in rounding the number of signalling levels can also be used to increase the overall bit rate, as shown in the preceding section. Alternatively, this power reserve can be used to correct the SNR per subchannel in order to minimize the overall bit-error rate (at a fixed f_T), now allowing different SNRs per subchannel. Starting from the bit-error rate per subchannel according to (5) and (6)

$$P_{\mathrm{b}\,\mu} = \frac{2}{\log_2(\mathbb{M}_\mu)} \left(1 - \frac{1}{\sqrt{\mathbb{M}_\mu}}\right) \operatorname{erfc}\left(\sqrt{\frac{\varrho_\mu}{2}}\right) \ , \tag{29}$$

the aggregate bit-error rate (7) has to be minimized with respect to a given total transmit power (9 a). The Lagrangian multiplier method leads to the cost function

$$J(U_{\mathrm{s}\,1}, U_{\mathrm{s}\,2}, \cdots, U_{\mathrm{s}\,N}) = \frac{1}{N} \sum_{\mu=1}^{N} P_{\mathrm{b}\,\mu} + \lambda \left(\sum_{\mu=1}^{N} P_{\mathrm{s}\,\mu} - P_\mathrm{s}\right) \ , \tag{30}$$

whereby the half-level amplitudes $U_{\mathrm{s}\,\mu}$ should now be chosen in such a way that the overall bit-error rate is minimized. Contrary to the number of bits per symbol calculated in the first step of the optimization, here the half-level amplitudes are searched. The transmit power per subchannel can be calculated via (25) for given QAM constellation sizes $\mathbb{M}_\mu$.

The derivation of the cost function with respect to the searched $U_{\mathrm{s}\,\mu}$ and setting it zero leads to the half-level amplitude of the μth subchannel

$$U_{\mathrm{s}\,\mu} = \frac{3\ln(2) \cdot \mathrm{e}^{-\frac{1}{2}A}}{\sqrt{2\pi} N \lambda \ln(M_\mu) \cdot U_{\mathrm{R}\,\mu} \cdot (M_\mu + \sqrt{M_\mu})} \tag{31}$$

with

$$A = \mathrm{W}\left(\frac{9\ln^2(2)}{2\pi N^2 \lambda^2 \ln^2(M_\mu) \cdot U^4_{\mathrm{R}\,\mu} \cdot (M_\mu + \sqrt{M_\mu})^2}\right) \ , \tag{32}$$

where $\mathrm{W}(x)$ denotes the Lambert W function [25]. Inserting these values into the boundary condition (9 a)

$$P_\mathrm{s} - \frac{2}{3} \sum_{\mu=1}^{N} U^2_{\mathrm{s}\,\mu} \, (\mathbb{M}_\mu - 1) = 0 \tag{33}$$

results in λ and the searched half-level amplitudes. This optimal set of half-level amplitudes for a fixed f_T (and therefore fixed $U^2_{\mathrm{R}\,\mu}$) and $\mathbb{M}_\mu$ leads to a minimal overall bit-error rate after (7) at a fixed data rate $f_{\mathrm{B\,ges}}$.

6. Results

For the following numerical evaluation the exemplary parameters $\varrho_0 = 30$ (in the first optimization step), $P_\mathrm{s} = 1\,\mathrm{V}^2, N = 4$, $l = 2\,\mathrm{km}$, $f_0 = 0.178\,\mathrm{MHz}\cdot\mathrm{km}^2$ (cable with a wire diameter of $0.6\,\mathrm{mm}$) were assumed. A white Gaussian noise with a power spectral density $\Psi_0 = 10^{-12}\mathrm{V}^2/\mathrm{Hz}$ is added at the cable output [26].

Figure 4 shows the influence of both rounding operations (iterative and non-iterative) on the achievable bit rate, when the bit rate is maximized: In both cases the maximum bit rate occurs at the

same optimum pulse frequency. According to (27) the overall bit rate can be maximized either by increasing the pulse frequency or by rising the sum of the numbers of bits per symbol in the subchannels. Thus, these variables are interchangeable in the sense of maximizing the overall bit rate: In case of iterative rounding the transmit power reserve (Fig. 3) is lower, but higher numbers of bits per symbol in the subchannels can be used, whereas in case of non-iterative rounding smaller numbers of bits per symbol are used, but the higher transmit power reserve allows a variation of the pulse frequency to higher frequencies. At the (fixed) optimum pulse frequency the same numbers of bits per symbol in the subchannels are obtained according to both rounding approaches for a maximum overall bit rate. The bit-error rates per subchannel are slightly different assuming a constant SNR in all subchannels, because of the dependency of the subchannel BERs on the number of signalling levels according to (28).

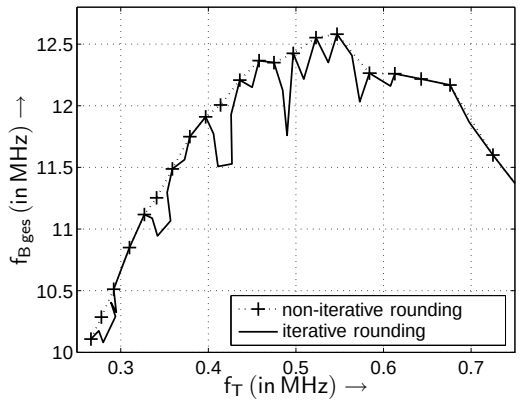


Fig. 4. Overall bit rate $f_{\mathrm{B\,ges}}$ as a function of the pulse frequency f_{T} for both rounding approaches in the first optimization step and bit-rate maximization in the second optimzation step

Figure 5 shows the overall bit rate $f_{\mathrm{B\,ges}}$ depending on the pulse frequency f_{T} for both investigated rounding operations and both strategies of optimization in the second stage (i. e. maximization of the overall bit rate and minimization of the aggregate bit-error rate for a fixed set of QAM bits/symbol in the subchannels).

Using non-iterative and iterative rounding, different amounts of transmit power reserves emerge. In case of BER minimization and non-iterative rounding, the relatively high transmit power reserve can be used for minimizing the BER in the second optimization step: That is why a smaller overall bit-error rate is obtained than in case of iterative rounding (Fig. 6), where a smaller transmit power reserve remains (at a higher overall bit rate).

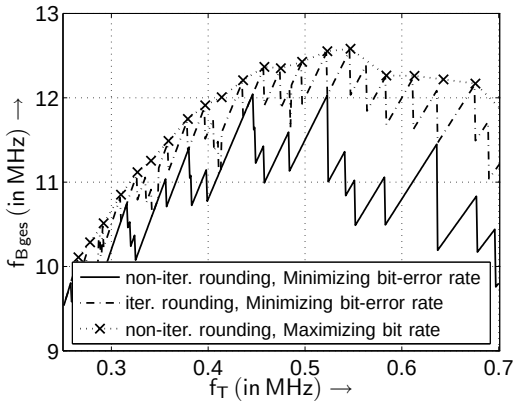


Fig. 5. Overall bit rate $f_{\mathrm{B\,ges}}$ as a function of the pulse frequency f_{T} for both power allocation approaches

7. Conclusion

In this contribution, strategies for allocating the transmit power and the numbers of bits per symbol to the subchannels of a multicarrier system using QAM were investigated. The main focus in this publication was to show the relationship between both aims of optimization: BER minimization and capacity maximization. Therefore a clearly defined reference system was considered.

Firstly, the numbers of bits per symbol were allocated to the subchannels based on an equal signal-to-noise ratio in all subchannels with the aim of a maximum overall bit rate. Here it could be shown, that a uniform distribution of the transmit power is necessary. From this, real numbers of signaling points of QAM constellations were obtained. For practical applications, the constellation sizes are rounded towards integer numbers of bits per symbol. Here, different rounding operations

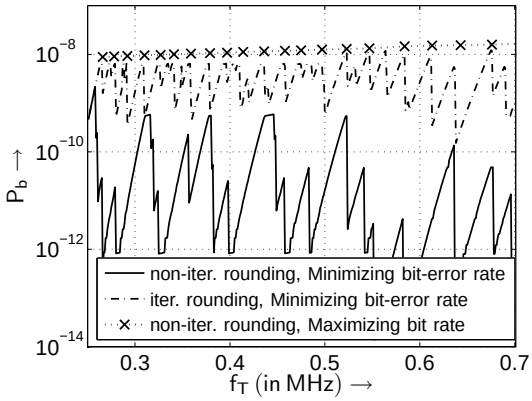


Fig. 6. Aggregate bit-error rates P_{b} as a function of the pulse frequency f_{T} for both power allocation approaches

and their effects were analyzed. In doing so, a transmit power reserve emerges, which on the one hand can be used to increase the bit rate (via a rising pulse frequency). On the other hand the drawback of different subchannel bit-error rates can be avoided using the second approach where the aggregate bit-error rate at a fixed bit rate is minimized. Here the iterative rounding with minimizing the bit-error rate in the second optimization step has lead to the lowest bit rate loss compared to the best results using the bit rate maximization.

For further optimization it might be fruitful to take other setups of bit and power loading into account. We expect, that similar results can be achieved, if they are compared to each other with respect to the optimization criteria considered here.

ACKNOWLEDGEMENT

The authors wish to thank Prof. (i. R.) Reiner Rockmann and Prof. (i. R.) Rainer Kohlschmidt from the University of Rostock for many valuable comments and interesting discussions on the topic investigated in this contribution. Furthermore the authors wish to thank the anonymous reviewers for bringing [27] and [19] into the considerations.

Moreover, the authors wish to thank Mrs. Susanne Merz for helping to improve their ”German” English.

References

[1] A. Ahrens and C. Lange, “Power and Bit Allocation for Twisted-Pair Multicarrier Transmission Systems.” in *10th International OFDM-Workshop*, Hamburg, August, 31–September, 01 2005, pp. 358–362.

[2] ——, “Power- and bit-loading for twisted-pair multitone systems.” in *XXI Krajowe Sympozjum Telekomunikacji (KST)*, Bydgoszcz (Poland), September, 07–09 2005, pp. 63–72.

[3] J. A. C. Bingham, “Multicarrier Modulation for Data Transmission: An Idea Whose Time Has Come,” *IEEE Communications Magazine*, vol. 28, no. 5, pp. 5–14, May 1990.

[4] ——, *ADSL, VDSL, and Multicarrier Modulation*. New York: Wiley, 2000.

[5] L. Hanzo, W. T. Webb, and T. Keller, *Single- and Multicarrier Quadrature Amplitude Modulation*, 2nd ed. Chichester, New York: Wiley, 2000.

[6] P. S. Chow, J. M. Cioffi, and J. A. C. Bingham, “A Practical Discrete Multitone Transceiver Loading Algorithm for Data Transmission over Spectrally Shaped Channels,” *IEEE Transactions on Communications*, vol. 43, no. 2/3/4, pp. 773–775, February/March/April 1995.

[7] R. F. H. Fischer and J. B. Huber, “A new Loading Algorithm for Discrete Multitone Transmission.” in *IEEE Global Telecommunications Conference (GLOBECOM)*, London (UK), November 1996, pp. 724–728.

[8] D. Hughes-Hartogs, “Ensemble Modem Structure for Imperfect Transmission Media,” U.S. Patents Nos. 4,679,227 (July 1987), 4,731,816 (March 1988), and 4,833,706 (May 1989).

[9] C. Lange and A. Ahrens, “Orthogonal Bases for the Design of Multicarrier Transmission Systems.” in *8th OFDM-Workshop*, Hamburg, September, 24–25 2003, pp. 254–258.

[10] H. S. Malvar, *Signal Processing with Lapped Transforms*. Boston; London: Artech Houser, 1992.

[11] I. Berenguer and I. J. Wassell, “FMT Modulation: Receiver Filter Bank Definition for the Derivation of an Efficient Implementation.” in *7th International OFDM-Workshop*, Hamburg, September, 10–11 2002, pp. 158–162.

[12] A. Ahrens and C. Lange, “Equalizer Design for Multicarrier Transmission Systems.” in *Nordic HF Conference*, Fårö (Sweden), August, 10–12 2004, pp. 6.3.1–6.3.11.

[13] D. Kreß and M. Krieghoff, “Elementare Approximation und Entzerrung bei der Übertragung von PCM-Signalen über Koaxialkabel,” *Nachrichtentechnik Elektronik*, vol. 23, no. 6, pp. 225–227, 1973.

[14] N. Benvenuto, S. Tomasin, and L. Tomba, “Equalization Methods in OFDM and FMT Systems for Broadband Wireless Communications,” *IEEE Transactions on Communications*, vol. 50, no. 9, pp. 1413–1418, 2002.

[15] D. Kreß, M. Krieghoff, and W.-R. Gräfe, “Gütekriterien bei der Übertragung digitaler Signale,” in *XX. Internationales Wissenschaftliches Kolloquium*. Ilmenau (Germany): Technische Hochschule, 1975, pp. 159–162.

[16] I. Kalet, “The Multitone Channel.” *IEEE Transactions on Communications*, vol. 37, no. 2, pp. 119–124, 1989.

[17] J. G. Proakis, *Digital Communications.* Boston: McGraw-Hill, 2000.

[18] D. Daly, C. Heneghan, and A. D. Fagan, “Power- and Bit-loading Algorithms for Multitone Systems.” in *3rd International Symposium on Image and Signal Processing and Analysis (ISPA)*, no. 2, Rom (Italy), September 2003, pp. 639–644.

[19] B. S. Krongold, K. Ramchandran, and D. L. Jones, “Computationally Efficient Optimal Power Allocation Algorithms for Multicarrier Communications Systems,” *IEEE Transactions on Communications*, vol. 48, no. 1, pp. 23–27, 2000.

[20] L. Goldfeld, V. Lyandres, and D. Wulich, “Minimum BER Power Loading for OFDM in Fading Channel,” *IEEE Transactions on Communications*, vol. 50, no. 11, pp. 1729–1733, November 2002.

[21] J. Jang and K. B. Lee, “Transmit Power Adaptation for Multiuser OFDM Systems,” *IEEE Journal on Selected Areas in Communications*, vol. 21, no. 2, pp. 171–178, 2003.

[22] J. Jang, K. B. Lee, and Y. H. Lee, “Transmit Power and Bit Allocations for OFDM Systems in a Fading Channel,” in *IEEE Global Telecommunications Conference (GLOBECOM)*, vol. 22, no. 1, San Francisco (USA), 2003, pp. 858–862.

[23] C. S. Park and K. B. Lee, “Transmit Power Allocation for BER Performance Improvement in Multicarrier Systems.” *IEEE Transactions on Communications*, vol. 52, no. 10, pp. 1658–1663, 2004.

[24] G. D. Forney, R. G. Gallager, G. R. Lang, F. M. Longstaff, and S. U. Qureshi, “Efficient Modulation for Band-Limited Channels,” *IEEE Journal on Selected Areas in Communications*, vol. 2, no. 5, pp. 632–647, 1984.

[25] R. M. Corless, G. H. Gonnet, D. E. G. Hare, D. J. Jeffrey, and D. E. Knuth, “On the Lambert W Function,” *Advances in Computational Mathematics*, vol. 5, pp. 329–359, 1996.

[26] R. Kohlschmidt and C. Lange, “Ein Beitrag zur Durchsatzerhöhung im Ortskabelbereich,” *Frequenz*, vol. 54, no. 5/6, pp. 119–122, May/June 2000.

[27] A. Leke and J. M. Cioffi, “A Maximum Rate Loading Algorithm for Discrete Multitone Modulation Systems.” in *IEEE Global Telecommunications Conference (GLOBECOM)*, Phoenix (Arizona), November, 3–8 1997, pp. 1514–1518.

Topological Consideration to the Development of Drawing in Children

MOTOYA, Yoshiko

Abstract—*The aim of this research is to understand the structure of children's "logic in thinking" by way of analyzing their coceptions of space. It is quite unique, and different from that of Geometry. We have examined the drawings of a model by children between 3 and 5 years old. In this research we take notice of the <pairs in opposition> by children. It is shown in the drawings of children, such as open and closed, intersecting and non-intersecting, inside and outside of the contour lines and domains. We may get some hints for mathematical education from this study.*

Index Terms—*geometry, logic, cognition, domains, contour lines*

1. Introduction

In the class of mathematics many teachers are liable to give the correct answers to the children without asking them the reason. Their interest is directed not to the thinking of children but to the teaching materials in mathematical education. The result is that children can not understand sufficiently the new materials they meet and are confused by them. Teachers should have strong interest in how children think about the materials and where they get into troubles. Children are easily confronted with many troubles and failures in the trials to grasp the new materials. And a hint to understand the way of thinking by children lies in these troubles and failures. The aim of our study is to ask about the structure of their thinking by means of finding the reason of these troubles and failures.

In order to understand the development of cognition of space, we should take notice of the <pairs in opposition > in children. For example, in the case of playing pee-ka-boo, a baby knows of his/her mother not at the moment he/she recognizes her existence because he/she misses her. So by way of recognizing < the negative of her>, the baby knows < the positive of her>. There are various opposite poles about the ways of thinking in children.

But this problem has not been fully analyzed in previous researches. We will try in section eight short discussion.

Author is with the Pedagogy Department, Miyagi University of Education, Japan. (e-mail: y-moto@miyakyo-u.ac.jp).

2. Task and Procedure

Why do differences occur when children draw one and the same model? We set forth a hypothesis to this question that there appear characteristics in their troubles in accordance with the stages of their development, and these characteristics are related to the topological understanding of the model.

The model (Figure1) consists of 4 domains; one blue domain in the outer side including 3 inner domains. How do children grasp the model? We have examined the drawings of Figures by 547 children (1628 sheets) from 3 to 5 years old. (Table 1: 2002.5 / 2003.5, Sendai, Japan)

a) Pretest: We asked children to draw the model without any suggestion.
b) After drawing, they played one of the following games .
GAME1: Children who were out of the closed line, throw a ball to children on the inner side of it. If a child in the circle cannot catch the ball, he must go out of the circle. He must change roles.
GAME2: When a child from one side of a whorled line met a child from the other side of it, they play the game of "paper, stone and scissors."

Figure 1: model

Table 1:number of children and sheets

	pretet		posttest	
2003	N	sheets	sheets	total
3 years old children	51	85	82	167
4 years old children	160	205	193	398
5 years old children	145	238	232	232
2002				
5 years old children	50	179		
4 years old children	141	414		
(N is number of children)				1628

The game1 and 2 are both "learning". During the game, children must distinguish the opposite

moments by themselves, such as open and closed, inside and outside of the contour lines and domains.

c) After playing the game, they were asked to draw the same model again.

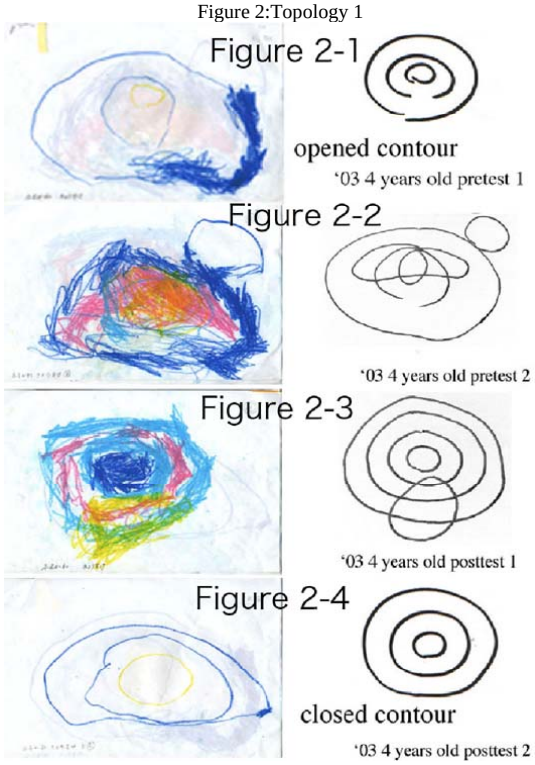
We could find changes in the drawings after they played games. We supposed the changes were caused by their own thinking and "discovery" while playing the games.

3. *OPEN AND CLOSED*

We'll take Figure 2, drawn by one and the same child. This child imitated the model by drawing 3 open contour lines. (Figure 2-1,pre test, 2003, 4 years old) The model consisted of 4 closed contour lines. Although the model has closed contour lines, he drew it with open ones.

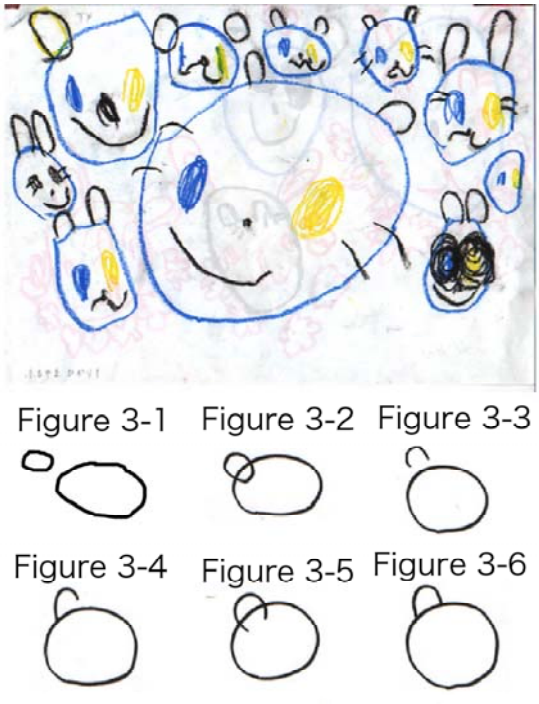
Next time he drew it, the lines were closed. (Figure 2-2, 2-3, 2-4) In order to draw the model closed, he had to think of the meaning of both the open lines and closed ones. By way of thinking of the opposite poles, he could draw them closed.

Figure 2:Topology 1



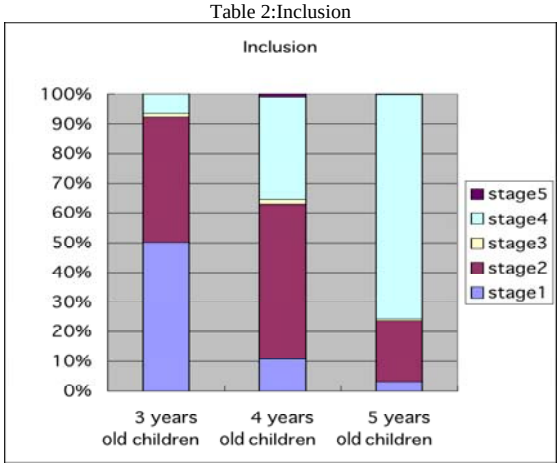
Comparing Figure 3-1 and 3-2, we can find the differences of understanding of the model by a child. This child drew the model as <a face of a bear> (Figure 3). We can take notice of the relation of the closed contour line of the face and that of the ear. The contour line of the face is drawn closed. The contour lines of the ear are drawn at the same time open and closed. Thus this child drew the lines both open and closed. (Figure 3-1~3-6) In this case he tried to vary the drowing of the ear. He might have thought about both extremes, and he'd soon find the right answer. Only by telling the correct answer to children, a teacher could not have expected to teach them the true relation.

Figure 3 :Topology 2



4. *INCLUSION*

Table 2:Inclusion



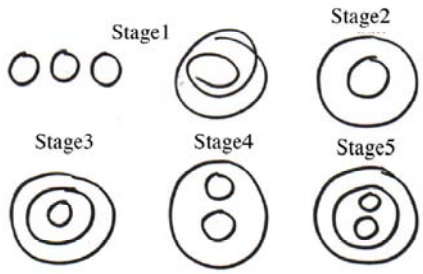
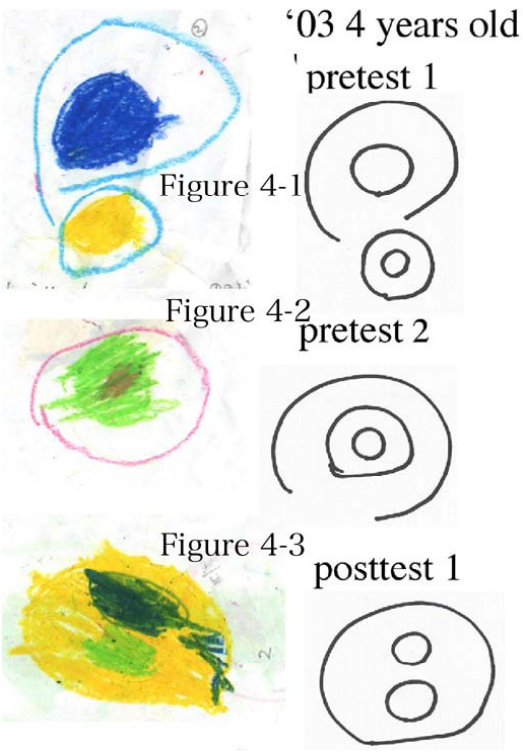


Table 2 shows the relationship of inclusion. It shows topological connections between domains. Stage 1 means that the idea of inclusion is not yet realized. In the drawing of 4 years old children,

many drawings are in Stage 2. The number of drawings in Stage 4 increases according to age. To understand Stage 4, a child must have both the idea of inclusion and non-inclusion, and it is difficult to have both ideas for children in at an earlier age.

Figure 4 shows what a child drew in the pre test as Figure 4-1 (this means Stage 2). In the post test after the play, he could draw it in Stage 3 (Figure 4- 2) and Stage 4 (Figure 4-3).

Figure 4:Topology 3



5. CONTOUR LINE

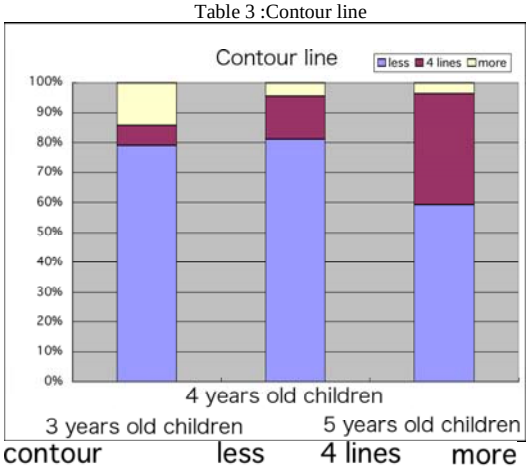
The graph in Table 3 shows how many contour lines were drawn by children. The model has 4 contour lines. For 4 years old children, it is difficult to draw the correct 4 contour lines. The rate of drawing with 4 contour lines increases by age.

In 2002, a child (4 years old) drew a drawing, such as a white domain that is enclosed by a blue contour line left empty (Figure 5-A, pre test). In the next year, she drew the correct drawing.

In the drawing 5-B the pink domain was drawn outside the blue domain. In the case of the drawing 2 (Figure 5-B, pre test), the pink domain is outeside the blue contour line. Why were the blue contour line and the pink domain left reversed?

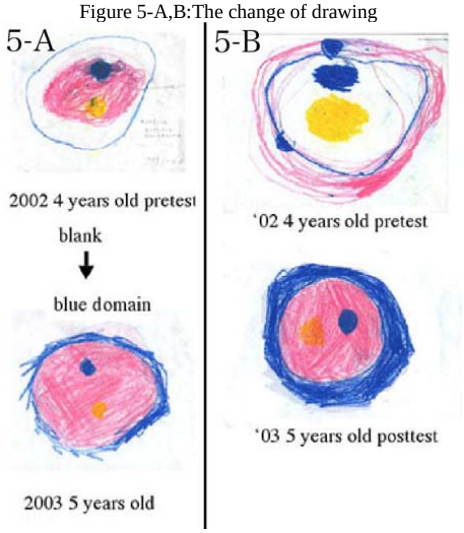
For many children the relation of contour lines and colored domains is not fully understood until they notice the opposition between contour lines and domains.

Table 3 :Contour line



contour	less	4 lines	more
3 years old children	61	5	11
4 years old children	356	64	19
5 years old children	170	107	10

Figure 5-A,B:The change of drawing

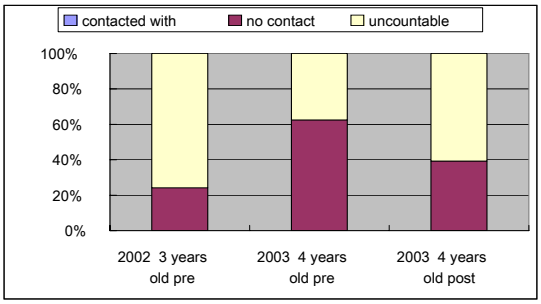


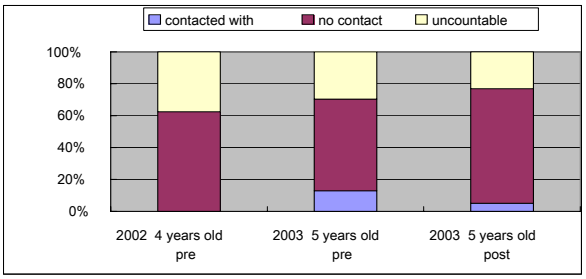
6. THE RELATION : CONTOUR LINES AND DOMAINS

Table 4 and Table 5 show the percentage of the stages of understanding between two domains. In the graph, <uncountable> means that a domain which is left undrawn exists and this domain cannot be counted (In the case of Figure 5-B, the small blue and yellow domain are not surrounded by the pink domain). <No contact> means a domain has only contour line, or even if a domain is painted, the contour line of the domain do not come into contact with the printed area.

It is difficult for children to show the relation of contour lines and domains. Most of the 3 years old children, it is difficult to draw it well, ie.the pink domain and the blue or yellow domain are not in contact with the contour lines. In 3 years old children, they grasp the pink domain and blue domains differently. They usually pay attention to the pink domain, and neglect the outer blue domain. Why? They will be fond of thinking about the complex problems (ie. pink domain which has the complex relation to other domains).

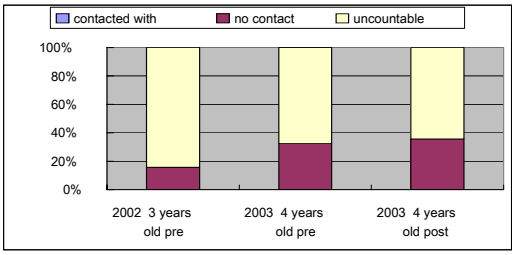
Table 4 :Contact with (pink & outer blue)



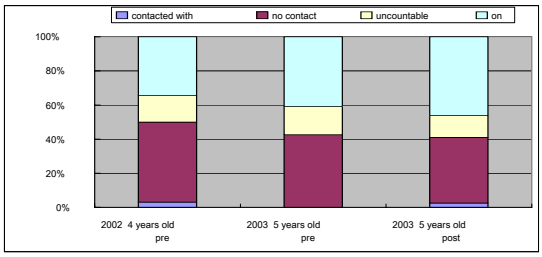


	contacted with	no contact	uncountable
2002 4 years old pre	0	40	24
2003 5 years old pre	7	31	16
2003 5 years old post	2	28	9

Table 5 :Contact with (pink & small blue)



	contacted with	no contact	uncountable
2002 3 years old pre	0	23	72
2003 4 years old pre	0	20	12
2003 4 years old post	0	11	17



	contacted with	no contact	uncountable	on
2002 4 years old pre	2	30	10	22
2003 5 years old pre	0	23	9	22
2003 5 years old post	1	15	5	18

And most children have not enough ideas about the existence of the blue domain. In the case of 4 years old children, although they drew both the pink domain and blue domains, the contour line did not contact the domain. In 5 years old children, about half of them distinguished both the pink domain and blue domains correctly.

From this result we can say that the relation of the domains and contour lines causes various kind of confusion in the thinking of children, but only if they notice “the opposite character” of them, they can draw them correctly, and their cognition of space will become consistent.

6. *THE CHANGE OF DRAWING*

A 3 years old child in 2002, drew the model as in Figure 6. Next year (2003) he drew the model as the drawings below. In Figure 6, drawings showed no change. In 2002, he drew the model relatively well as his other classmates. So he might have flattered himself that he was clever. This shows unless a 3 years old child notice his own troubles and make efforts, he will not change his thinking.

Figure 6: No change in the drawings

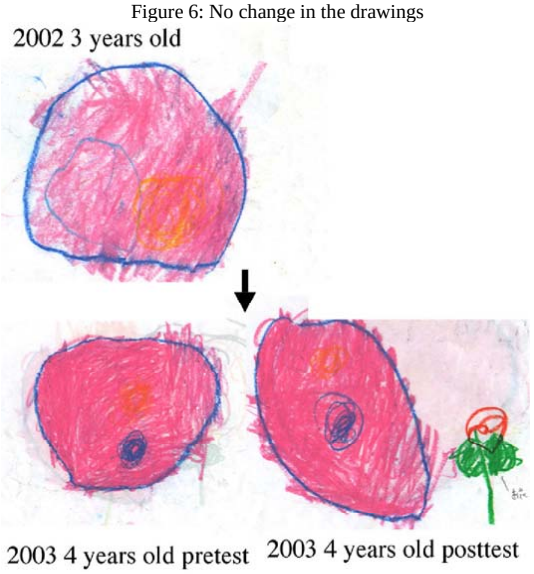
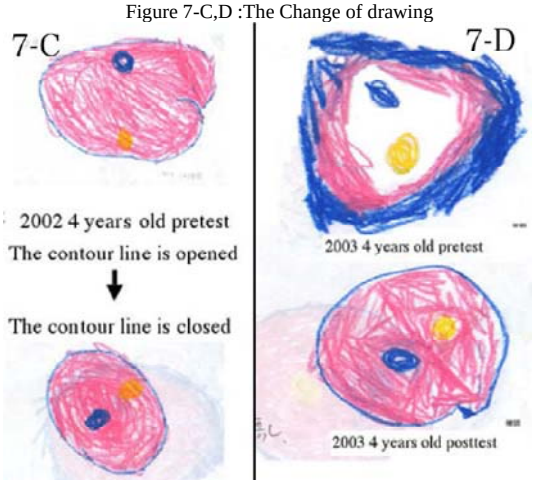


Figure 5-B shows a large change in the drawing. When the child was 4 years old, she couldn’t notice the relation of domains and drew conversely. Next year she could draw the relation between the domains.

In Figure 7-C, he showed a small but not unimportant change in the drawing, he drew the contour line from open to closed.

In Figure 7-D, he drew the model in which the blue domain has no contour line and small blue and yellow domain do not have contact with the pink domain. In the post test, though there is no blue domain,the pink domain contacts with the small blue and yellow domain. In this case he made some progress and lost some understanding.

Figure 7-C,D :The Change of drawing



8 WHAT IS NEW COMPARED TO PRIOR RESEARCHES ?

Our attempt has been carried out under three perspectives. First, by analyzing the drawings of geometrical figures by children with a topological method, we have intented to make the degrees of development in the cognition of space efficiently clear. Secondly, we took notice of the fact that the troubles and failures by children have 'logical cause', namely the lack of "an pairs in opposition ". Troubles and failures are not caused by accident or individualy. If they find the "pairs in opposition " by themselves, they will make great progress in learning. Third, one of the largest problems in the cognition of space by children is to distinguish the relations between contour lines and domains. If they clear this problem, they will acquire a stabilized cognition of space.

We are convinced that these three points have not yet been fully discussed. These points have been easily understood in the investigation into the cognition of space by children. In the classical study, "*The Child's Conception of Space*"(1948), J. Piaget and B. Inhelder [1] thought that the concept of space by children develops from a simple topological type to projective and euclidean. "We shall find that the child's space, ⋯invariably begins with this simple topological type of relationship long before it becomes projective or euclidean."(p. vii) But this understanding is not the case. Children don't go from easy to complex matters. They rather show their interest in complex problems and get into trouble without having any 'logic for solution'. Children always lunge out toward unknown world. When they find their 'logic for solution', they will make great progress, and this is also the case in their cognition of space.

Z. P. Dienes and E. W. Golding [2] had introduced some practical methods in the education of the cognition of space. (*Exploration of Space and Practical Measurement*, 1966) They thought that "a child, from the moment he is born, explores space", and they tried to devise many geometrical games using a topological method. But, I think, they didn't appreciate enough the role of trouble and failure in children, and applied directly a mathematical procedure to the result of games.

So we have tried to elucidate 'the structure of troubles', and introduced the method of combination of drawings and games, and to establish some criteria for the appraisal of development.

Recently a lot of researches is being carried out in the field of drawing-analysis for the understanding of the stages of develpomentment in children. It is natural that these attempts ware usualy made from the interest of cognitive psychology. For exemple, Analice Dutre Pillar [3] tried to demonstrate the relation between the stages of drawing and that of their <action and thought>. Aaro Toomela [4] tried to understand the development of children by the stages of drawing. According to her, drawings by a child develop with age from the category of 'scribble' to that of 'integrated whole'. But by this explanation we can't understand why and by what he/she changes the categories. To this problem asserted Annie Vinter [5/6] to pay attention to 'read' the drawing, and suggested to inquire '*how* lebel' of the problem. Children can be 'flexible and open to semantic influence', manage to meet the problem. Thus they grow from global sensibility to meaning. She also tried to clear the problem of 'implicit learning' using the method of drawing, and concluded that implicit learning is not related to age, but to the behavior manipulation. Similar issue was tried by I.A.Apperly ,E.Williams, and J. Williams [7]. They took notice of the role of symbols for the acquirement of stable meaning by children.

Investigations to clear the development of children by means of drawing are adopted to other theme, for exemple to the problem of emotion caused by colour [8], to that of learning from other peoples mistakes [9], to that of autism or learning disabilities [10], or to the exploitation of computational model [11]. For us it is also worth noticing that in the field of mathematical education many researches are made applicating figure drawing [12/13].

To these researches, our trial make much more of the role of topology for the illumination of drawing ability in children, especialy of the relation of domains and contour lines. One of the greatest trap for children lies certainly in this moment.

9. CONCLUSION

1 Development of learning in the cognition of space begins from noticing their own trouble and failure in understanding about the relation of domains and contour lines .

2 It is important for teachers to encourage a structured and systematic way of the thinking in the children.

We take notice of the <pairs in opposition > in the drawing and playing by children. Especially in the drawing, opposite problems such as open and closed, intersecting and non-intersecting, inside and outside play important roles for the overcoming of troubles by children.

REFERENCES

[1] Piaget J. & Inhelder B. *The child's conception of space.* .Rutledge & Kegan, paul London,1967(1948).

[2] Dienes Z.P. & Golding E.W. *Exploration of space and practical measurement.* ESA in association with University of London Press, 1966.

[3] Pillar A.D. What do children think about the drawing process ?. *National Society for Education in Art & Design, 1998*, 81-86.

[4] Toomela A. Drawing development: Stages in the representation of a cube and a cylinder. *Child Development, 70,* 1141-1150.

[5] Vinter A. How meaning modifies drawing behavior in children. *Child Development, 70*, 33-49.

[6] Vinter A. & Perruchet P. Implicit learning in children is not related to age: Evidence from drawing behavior. *Child Development, 71*, 1223-1240.

[7] Apperly I.A., Williams E. & Williams J. Three- to four-year-old' recognition that symbols have a stable meaning: Pictures are understood before written words. *Child Development, 75*, 1510-1522.

[8] Burkitt E., Barrett M. & Davis A. Children's colour choices for completing drawings of affectively characterized topics. *Journal of child psychology and psychiatry, 44:3, 2003,* 445-455.

[9] Want S. C. & Harris P.L. Learning from other people's mistakes: Causal understanding in learning to use a tool. *Child development, 72, 2001*, 431-443.

[10] Leevers H.J. & Harris P.L. Drawing impossible entities: A measure of the imagination in children with autism, children with learning disabilities, and normal 4-year-olds. *Journal of child psychology and psychiatry, 39:3, 1998,* 399-410.

[11] Burton E. Thoughtful drawings: A computational model of the cognitive nature of children's drawing. Eurographics, 14, 1995, Blackwell Publishers, 159-170.

[12] Osta I. Teaching Geometry in a changing world. in *Proceedings of the ninth international congress on mathematical education, 2000*, Kluwer Academic Pub., 186-187.

[13] Sheffield L. & Anderson A.(chief org.) WGA 1: Mathematical education in pre- and primary school. in *Proceedings of the ninth international congress on mathematical education, 2000*, Kluwer Academic Pub., 220-225.

[14] Yoshiko Motoya Understanding early years Geometry - Drawing development: from contour lines of figures. *The fifth five nations conference on mathematics education,* 1994..

[15] Motoya Y. Understanding early years Geometry - Drawing development: from domain of figures. *Workshop and 3rd international conference on cultural history of mathematics and informatics*, Freie Universität Berlin, 1995.

[16] Motoya Y. Early years Geometry - Projective Geometry. *Bulletin for mathematics education study*, 1996.

[17] Motoya Y. Drawing of two crossed band-Möbius: band and both sided band. *International federation for information processing*, Grenoble France, 1997.

[18] Motoya Y. Early years Geometry - The relation among the domains 2 " *The third international conference on mathematics education and cultural history of mathematics*, 2002.

Picture Script: Visualizing Graphical User Interface Commands for Recycling

Sasakura, Mariko; Iwata, Kenichi; and Yamasaki, Susumu

Abstract—*We propose a system that visualizes and records a command that is used in the graphical user interface. The basic idea is that the interface visualizes a movement of a mouse or pen and remains it on a screen. We represent our user interface as a kind of visual language, and construct a mechanism for the analysis of the language. In this paper, we show a small application using the user interface that performs the file transfer protocol (FTP). Recording a command used in the graphical user interface will be able to extend the interface as recycling a command and performing batch operations.*

Index Terms—*System Software, Application Software, Visual Language, Graphical User Interface*

1. Introduction

RECENTLY, the mainstream of the user interface for personal computers is the graphical user interface (GUI). The advantages of the GUI are expected:

- Users don't have need to remember commands or options because they are shown as icons or listed in menus.
- Operations, that are clicking or drugging by a mouse, are intuitive and easy to learn.

These advantages are not only for beginners but heavy users also. Major integrated development environment products, which are used to build application programs, are working under GUI. They are used by programmers widely, who are not beginners but heavy users.

The GUI has a disadvantage:

- When we have to repeat similar operations again and again, for example, when we manage plenty of files, the work is too boring and takes a lot of time.

We propose a user interface that allows a user to "recycle" previous operations of GUI commands. In this paper, we use the word "recycle" of which meaning is that we can reuse and modify the previous operations to make new operations.

In the character-based user interface (CUI), like the UNIX shell, the system can remember a history of commands and represent the executed command to a user in order to modify and recycle it. In the GUI, we have functions of undo and redo that are similar to the history of commands in the CUI. However, by the undo and redo functions, the system does not remember a history of commands or operations but just states. We can move to the previous states, but we cannot recycle previous operations that we executed.

Recycling operations is useful for a heavy user of the GUI. When we rename plenty of files or organize files in the appropriate folders, we do similar operations, clicking and/or drugging, a dozen times. If we can recycle the previous operations, these works may be easier.

To establish a new graphical interface in which we can recycle operations, we have the following problems:

- What operations are recycled?
- How do we recycle operations?

Our solutions are as follows.

- We formalize movements of a mouse/pen as a visual language.
- We remain a trace of a mouse/pen movement on a screen for further recycling.

In this paper, we mention *picture script interface* in which we can recycle a GUI operation, and *picture script* which is a visual language used in the picture script interface. We also show a small application of the picture script interface which represents the file transfer protocol (FTP) commands.

2. Problems And Related Works

In this section, we discuss the details of problems and show the solutions we proposed. Then we mention related works.

2.1 The Details of Problems and Solutions

We propose a new user interface which allows a user to recycle previously executed operations. The basic idea is visualizing a movement of mouse/pen and remaining it on a screen. In this subsection, we describe the details of problems.

There are problems:

(1) What operations of the graphical user interface are recycled?

(2) How do we recycle operations of the graphical user interface?

A general GUI shows icons for resources and operates them by a mouse/pen interface. It is hard

Manuscript received 28 July, 2005; revised 6 January, 2006

Authors are with Department of Computer Science, Graduate School of Natural Science and Technology, Okayama University, 3-1-1 Tsushima-Naka, Okayama, JAPAN
(E-mail: sasakura@momo.it.okayama-u.ac.jp).

This research is supported by the Okawa Foundation。

to recycle operations in the GUI because they are disappeared. Therefore for the first problem:

- We try to leave the trace of movements of the mouse/pen so that we can show the previous movements in the screen. Then, we can recycle them.
- We formulate a visual language in order to specify what operations are recycled. It gives the computer scientific basis for our approach.

For the second problem:

- We construct a mechanism of analysis of the visual language.
- We design no button or menu for the picture script interface because the interface is intended to be attached to the existent graphical user interfaces.

2.2 Related Works

2.2.1 Existing Solutions

We mention the researches which allow a user to recycle graphical operations and compose macro commands by them. Borg proposes a visual programming environment for UNIX shell [3]. It is a kind of iconic command language and can specify a script. Shigesada at el. propose an icon based user interface [27] which is worked on TRON [33]. It aims to perform batch operations on the graphical user interface. Modugno and Myers develop a visual shell which allows a non-programmer to construct a macro program [20]. The motivation of the researches is similar to ours, but they use icons while we use traces of movements of a mouse/pen. We think that recycling movements of mouse/pen is more convenient than learning new icons.

About grammars and parsers about visual languages, Chok and Marriott [6], and Helm and Marriott [11] propose a general one. We define a simple visual language which is based on the spatial relation between figures.

2.2.2 Related Visual Languages Works

Our research is regarded as one of the visual languages. The studies on visual languages started to provide programming languages that were easy to learn and use [5], [19], [21].

It is popular for visual languages or notations to be used for helping users understand programming languages that is difficult to understand. For example, a formal specification language LOTOS has its graphic form G-LOTOS [15]. Agusti at el. propose a visual logic programming language [1] to provide the graphical intuitions for understanding first order logic. Sasakura at el. propose a system that visualizes processes of reasoning by logic program [26] and the application system of it for a product managing system [16], [34]. There are many researches for providing languages with visual forms [2], [8], [12], [13], [17], [25],.

On the other hands, there are some researches that are apart from the concept of traditional programming languages but are suitable for simulation, especially by children. Viscuit [10], KidSim [7], and AgentSheet [23] are typical works.

Recently, the works on domain-specific visual languages are active [4], [30]. Visual languages for web services are also popular theme [22], [28].

The history of studies on visual languages shows that they do not take the place of the traditional textual programming language. They should have other roles by making good use of their advantage which is users can easily understand visual notations.

3. THE PICTURE SCRIPT INTERFACE

The condition for applying the picture script interface to an application is that the application needs mouse/pen movements. Especially in applications which have frequent movements of a mouse/pen, the interface should be useful: for example, managing plenty of files. In this paper, we show how we implement its interface with an example application.

In this section, we show the architecture of the picture script interface.

3.1 System Overview

The overview of the picture script interface system is shown in Figure 1. The system consists of two parts: the picture element analysis and the picture rule analysis.

The tasks of the interface are listed:

1. It recognizes a drawn figure. This task is done in the picture element analysis.
2. It interprets the figure according to rules which represent the correspondence between figures and commands for some application. This task is done in the picture rule analysis.
3. It sends the commands for an application, which are specified by the figures.

The first task corresponds to lexical analysis in compilers, the second to syntax analysis, and the third to code generation, respectively.

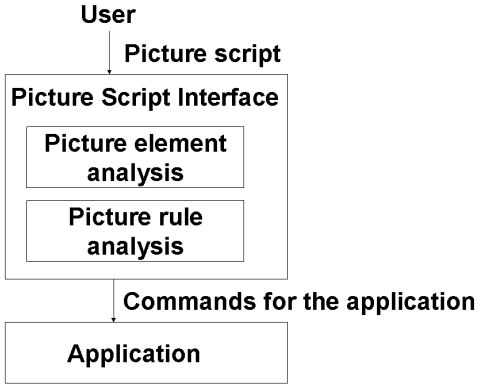


Figure 1 System overview.

3.2 Picture Element Analysis

The picture element analysis part is responsible to the recognition a drawn figure. It is to analyze a figure and recognize it as *elements*. An element is a line, an arrow or a string which is a sequence of characters.

At first, a user draws a figure on a canvas we provide. We call the all things written in a canvas as a figure. The picture element analysis part divides a figure into elements which corresponds to tokens in compilers.

3.3 Picture Rule Analysis

The picture rule analysis part is responsible to the interpretation of the figure and the translation of it to commands for an application. It translates a sequence of elements that satisfies a given syntax rule to commands for an application. We call the sequence of elements as a *picture*.

After recognizing elements in a figure, we check whether connections of elements are the same as one of given rules. Rules can be given by users. We mention what rules we make for an example application in section 4.2.2, and how we check a connection of elements in section 4.3.2.

4. The Picture Script Language and its Interpretation

The picture script is a kind of visual languages. Its target code is a set of commands for some application. Elements are regards of tokens of the language and rules specify its syntax. In this section, we describe a picture script language with a simple application in a formal way, and show how the language is interpreted.

4.1 A Simple Example

To explain the picture script language, we give a simple example that is an file transfer protocol(FTP) client. Since the aim of the example is demonstration of the picture script, our FTP client has limited ability. It knows only the following FTP commands:

- open a host
- get a file
- put a file
- close

4.2 Syntax

4.2.1 Elements

Elements are the elemental unit of the picture script. They may be regarded as tokens of it. In this application, we use the following four types of elements:

- a line
- a string which is a sequence of alphabet characters
- a left arrow and
- a right arrow

An arrow consists of a line and an arrowhead. A left arrow has its arrowhead on the left side of the line, and a right arrow has on the right side.

We design the system is robust in recognizing elements because the purpose of the system is not to draw beautiful or precise figures but to provide a convenient user interface. In this system, if more than one shorter line exists near of the start or end point of a longer line, we regard them as an arrow. Figure 2 shows examples of arrows in our system.

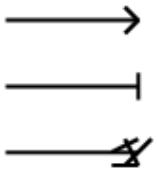


Figure 2 Arrows. Any of the elements shown in this figure is recognized as an arrow in the system.

4.2.2 Rules

In this subsection, we define rules for interpreting a picture to an FTP command in formal way. A picture is a sequence of elements that is defined by the following definition.

Definition 1 *A picture is recursively defined to be:*

(1) an element (a line, an arrow or a string), or
(2) **near**(A, B), **nearCenter**(A, B) or **overlap**(A, B), where A and B are pictures.

near, **nearCenter** and **overlap** are binary operators. The meanings of the pictures are represented by the operators:

- **near** (A, B) means that A is close to B and A places the left of B,
- **nearCenter** (A, B) means that the center of A is close to the center of B, and
- **overlap** (A, B) means that A overlaps B.

At most one of the operations is to hold between any two pictures.

Definition 2 *A rule is written by the following form.*

A command ::= a picture

where "::=" represents the translation from a picture to a command. A rule means if the picture is found in a figure, the command is sent to the application.

By these definitions, we represent FTP commands of the system as the following:

Definition 3 *The rules that we use for the FTP application are listed below.*

- open A ::= **near** (HERE, **near** (Line, A))
- get F ::= **near** (HERE, **nearCenter** (F, **near** (LeftArrow, A)))
- put F ::= **near** (HERE, **nearCenter** (F, **near** (RightArrow, A)))
- close ::= **near** (HERE, **overlap** (Line, **overlap** (Line, **near** (Line, A))))
- close ::= **near** (HERE, **overlap** (Line, **overlap** (Line, **near** (Arrow, A))))

HERE is a keyword that represents the machine adopted by the user. “Line” means a line. “A” and “F” represent strings. “LeftArrow” means a left arrow and “RightArrow” means a right arrow. “Arrow” means both of left and right arrows.

If a picture occurs in the right-hand side of the rule, we say the picture is interpreted by the rule.

Proposition 1 *A picture can be interpreted by at most one rule of Definition 3.*

Proof.

(1) *Any rule is not the same as another rule, and*

(2) *any rule is not implied by other rules*.

Therefore, a picture cannot be satisfied by the interpretation of two rules.

4.3 Syntax Analysis

4.3.1 Element Analysis

Recognition of elements is simple. In our system, we can use a mouse/pen and a keyboard. When we use a keyboard, an input element must be a string. By a mouse/pen, an input element may be a polyline. If a polyline has only two points which are the start and end point, it may be a line. Otherwise it may be curved line. Then we do not need any button to input an element.

An arrow is a set of lines. Therefore we must analyze which set of lines forms an arrow. An arrow consists of an arrow body and an arrowhead. An arrow body is a line. An arrowhead is more than one line. The line for an arrow body must be longer than any line for the arrowhead. Then, an arrow decision algorithm when a line L is drawn is the following.

Algorithm 1

```
if here is an arrow A and the line L is
near by the start or end point of A and
the body of A is longer than L then
     L is an arrowhead of A
else if there is a line B and the line
L is near by the start or end point of
B and B is longer than L then
     A and B construct an arrow of
    which body is A and arrowhead is B
```

4.3.2 Rule Analysis

The rule analysis checks whether a set of elements satisfies any given rule. This consists of two steps.

- Step1: check the type of elements: a line, a string or an arrow, and
- Step2: check whether connections of elements satisfy a rule.

All elements (includes the result of binary operators) have the right point and the left point. The right point is the most right-up point of an element. The left point is the most left-up point.

Then, an algorithm for rule analysis is the following:

Algorithm 2

```
Put all elements into an array A in the
order of the right point.
  for all rules
   begin
   for i = 0
       to the number of elements
     begin
     for j=i to the number of
           elements of a rule
      begin
      if the types of elements from
         A[j] match the types of
         elements of the rule
      then
       begin
       if all relations between the
          elements from A[j] satisfy
          the rule
       then
          send an FTP command to the
          FTP client
      end
     end
    end
   end
```

This check algorithm is invoked whenever an element is added. In order to avoid sending the same command more than once, the system records the elements that are used to send a command.

5. Implementation of the Picture Script Interface

In this section, we mention implementation issues of the picture script interface. We design a file transfer protocol (FTP) client as an example of the interface. The FTP client is implemented as an example of the application which is indicated in Figure 1.

5.1 An FTP Client Implementation

An FTP command that is the output of the picture rule analysis should be sent to an appropriate FTP server. We design an FTP client which has an interface to the picture script interface:

- Our FTP client receives a message from the picture script interface and sends it to an appropriate FTP server. And it receives a message from an FTP server and sends back it to the picture script interface.

The feature of the picture script interface is that it needs no button and menu on the canvas. A user just draws a figure by a mouse or pen, or types a keyboard to input alphabet characters. Therefore our FTP client has no button and menu in its user interface.

The FTP client works according to the following cycle.

1. A user inputs diagram by a mouse or pen, or characters by a keyboard.

2. The system recognizes the input and checks rules.
3. If there is a proper rule, the system sends an appropriate message to the FTP client.
4. Return to 1.

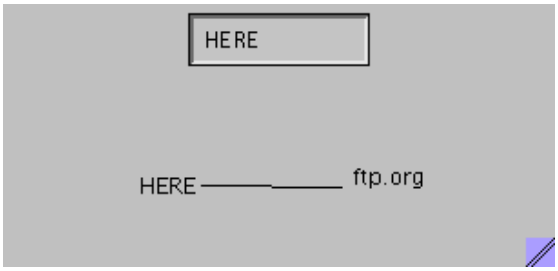


Figure 3 The "open" command. The line between "HERE" and "ftp.org" specifies to open a connection to ftp.org.

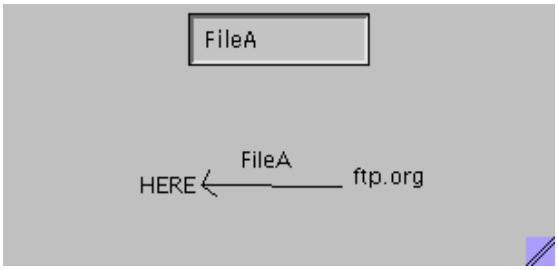


Figure 4 The "get" command. The "get" command is made by recycling the line for the "open" command.

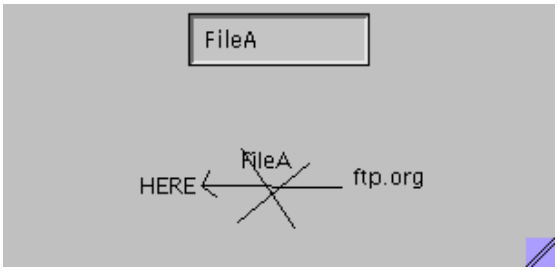


Figure 5 The "close" command. The "close" command is made by recycling the line for the "open" command.

Figures 3, 4 and 5 show the user interface of the system. In Figure 3, we can see a line and two strings which are placed in the left side and right side of the line. It means opening a connection between ftp.org and the machine what a user is using. Figure 4 shows an arrow and two strings. This figure is constructed by adding an arrowhead to Figure 3. It means getting the FileA from ftp.org. Figure 5 has the same elements with Figure 4 except two lines which are crossed on the arrow. It means cutting the connection. In these figure, we can send an FTP commands by recycling the previous elements.

An element can be deleted by drugging it to out of the canvas of the picture script interface. Copying an element and scaling an element are not implemented in this system.

By the inputs shown in Figures 3, 4 and 5, the picture script system sends (a) open (b) get file and (c) to our FTP client. Our FTP client is implemented by Perl. It can receive messages from the picture script system and send them to FTP servers. And also it can receive messages from FTP server and an appropriate message to the picture script system.

5.2 Discussion

5.2.1 Advantages and Limitations of the Picture Script Interface

The picture script is a kind of visual languages that translates a picture to any kinds of commands. Therefore, in principle, the picture script interface can be applied to any GUI application.

The advantages of the picture script interface are the following points.

- Recycling: a picture recorded in the system can be recycled. If we want to send the same command as previously, we may click the picture.
- Extendibility: if we give other set of rules to the picture script interface, it works according to the new rules.
- Convenience: the picture script interface could be implemented as a front end processor so that it interprets a picture to any application.

The interface is limited:

- We can use only lines, arrows, and characters. We cannot use a rectangle, a circle, a curved line.
- The picture script interface assumes that a figure must be analyzed in horizontal way.

To raise the limitations:

- For recognizing more elements, we can use other researches on a freehand interface [14], [24].
- We may analyze a figure by not only from the left to the right but also any direction.

5.2.2 Applications

The picture script interface can be applied to any GUI application. In this subsection, we list applications in which the picture script interface is useful.

- When we want to process many e-mails by a SPAM filter program.
- When we want to house many files into many folders.
- When we develop a program on an integrated development environment.

The picture script can visualize the history of executed commands and recycle them. This ability allows us to make a macro, in other words, a batch operation, for any GUI. Current GUIs

almost do not have the ability of defined macros by a user. The picture script can provide a convenient interface to a user.

We design the picture script for graphical user interfaces. However, it can be used for other purposes. For example, it may be useful to write a specification of a system, especially a concurrent system, with a specification language [9], [18], [29], [31], [32].

6. CONCLUDING REMARKS

We propose the picture script interface that can recycle mouse/pen operations for any application. The basic idea is that visualizing a movement of mouse/pen and remaining it on a screen. We establish the picture script as a visual language so that we show its syntax and analysis mechanism in this paper. We also show an example application that performs the file transfer protocol. The picture script interface achieves:

- Recording pictures for further recycling
- Translating from a picture to commands for any application consistently

REFERENCES

[1] Agusti, J., Puigsegur, J. and Robertson, D., "A visual syntax for logic and logic programming", *J. of Visual Languages and Computing*, vol.9. no.4, pp.399-427, 1998.

[2] Bonhomme, C., Aufaure, M.-A. and Trépied, C., "Metaphors for visual querying spatio-temporal databases", *Proc. of 4th International Conf., VISUAL 2000, (Lecture Notes in Computer Science vol.1929)*, pp.140-153, 2000.

[3] Borg, K., "IShell: a visual UNIX shell", *CHI '90*, pp.201-207, 1990.

[4] Bottoni,P., De Marsico, M., Di Tommaso, P., Levialdi, S. and Ventriglia, D., "Definition of visual processes in a language for expressing transitions", *J. of Visual Languages & Computing*, vol.15, no. 3-4, pp.211-242, 2004.

[5] Burnett, M. M. and Baker, M. J., "A classification system for visual programming languages", *J. of Visual Languages and Computing*, vol. 5, no.3, pp. 287-300, 1994.

[6] Chok, S.-S. and Marriott K., "Automatic construction of user interfaces from constraint multiset grammars", *11th IEEE International Symposium on Visual Languages*, pp.242-249, 1995.

[7] Cyper, A. and Smith, D.C., "KidSim: end user programming of simulations", *ACM Conf. companion on Human factors in computing Systems*, pp.35-36, 1995.

[8] Erwig, M. and Schneider, M., "A visual language for the evolution of spatial relationships and its translation into a spatio-temporal calculus", *J. of Visual Languages and Computing*, vol. 14, no.2, pp.181-211, 2003.

[9] Galloway, A. J. and Stoddard, W. J., "An operational semantics for ZCCS", *First IEEE International Conf. on Formal Engineering Methods*, pp.272-282, 1997.

[10] Harada, Y. and Potter, R., "Fuzzy rewriting - soft program semantics for children –", *IEEE Symposium on Human Centric Computing Languages and Environments*, pp.39-46, 2003.

[11] Helm, R., Marriott, K. and Odersky, M. "Building visual language parsers", *ACM Conf. Human Factors in Computing*, pp.105-112, 1991.

[12] Hewagamage, K. P. and Hirakawa, M., "An interactive visual language for spatiotemporal patterns", *J. of Visual Languages and Computing*, vol.12, no.3, pp.325-349, 2001.

[13] Hirakawa, M., Tanaka, M. and Ichikawa, T., "An iconic programming system, HI-VISUAL", *IEEE Trans. on Software Engineering*, vol.16, no.10, pp.1178-1184, 1990.

[14] Igarashi, T., Matsuoka, S., Kawachiya, S. and Tanaka, H., "Interactive beatification: a technique for rapid geometric design", *Proc. of the 10th annual ACM symposium on User interface software and technology*, pp.105-114, 1997.

[15] ISO,"G-LOTOS: a graphic syntax for LOTOS", *ISO/IEC JTC 1/SC 21 N 4228*, 1989.

[16] Iwata, K., Sasakura, M. and Yamasaki, S. "Visualization for management of electronics product composition", *Proc. of Ninth International Conf. on Information Visualization (IV05)*, pp.194-199, 2005.

[17] Koike, H., Takada, T. and Masui, T., "VisuaLinda: a framework for visualizing parallel Linda programs", *Proc. of the 1997 IEEE Symposium on Visual Languages*, pp.176-182, 1997.

[18] Mahony, B. and Dong, J.-S., "Timed communication Object Z", *IEEE Trans. on Software Engineering*, vol. 26, no. 2, pp.150-177, 2000.

[19] Marriott, K. and Meyer, B., *Visual language theory*, Springer, 1998.

[20] Modugno, F. and Myers, B. A., "Visual programming in a visual shell - a unified approach", *J. of Visual Languages and Computing*, vol. 8, no.5-6, pp.491-522, 1997.

[21] Myers, B.A., "Taxonomies of visual programming and program visualization", *J. of Visual Languages and Computing*, vol.1, no.1, pp.97-123, 1990.

[22] Pautasso, C. and Alonzo, G., "The JOpera visual composition language", *J. of Visual Languages and Computing*, vol. 16, no.1-2, pp.119-152, 2005.

[23] Repenning, A. and Ambach, J., "Tactile programming: a unified manipulation paradigm supporting program comprehension, composition and sharing", *1996 IEEE Symposium on Visual Languages*, p.102, 1996.

[24] Saga S.,"A freehand interface for computer aided drawing systems based on the fuzzy spline curve identifier", *Proc. of 1995 IEEE International Conf. on Systems, Man and Cybernetics*, pp.2754-2759, 1995.

[25] Sasakura, M., Joe, K., Kunieda, Y. and Araki, K., "NaraView: an interactive 3D visualization system for parallelization of programs", *International J. of Parallel Programming*, vol.27, no.2, pp.111-129, 1999.

[26] Sasakura, M. and Yamasaki, S. "A three-dimensional visualization of communications in distributed program environments", *Proc. of Seventh International Conf. on Information Visualization (IV03)*, pp.132-137, 2003.

[27] Shigesada, Y., Koshizuka, N. and Sakamura, K., "Design of VACL: a visual script language system which controls and extends applications on a graphical user interface environment", *13th TRON Project International Symposium/TEPS '96*, pp.104-14, 1996.

[28] Shimomura, T., "Visual design and programming for Web applications", *J. of Visual Languages and Computing,* vol. 16, pp.213-230, 2005.

[29] Smith, G., *The Object-Z specification language*, Kluwer Academic Publishers, 2000.

[30] Sprinkle, J. and Karsai, G., "A domain-specific visual language for domain model evolution", *J. of Visual Languages and Computing*, vol.15, no. 3-4, pp.291-307, 2004.

[31] Spivey, J.M., *The Z notation*, Prentice Hall, 1992.

[32] Taguchi, K., Dong, J.-S. and Ciobanu, G., "Relating pi-calculus to Object-Z", *Ninth IEEE International Conf. on Engineering Complex Computer Systems*, pp.97-106, 2004.

[33] TRON, http;//www.tron.org/index-e.html.

[34] Yamasaki, S., Iwata, K. and Sasakura, M., "Reasoning procedure and implementation for logic programs as managing schemes to extract demand", *IPSI Trans. on Advanced Research*, vol.1, no.1, pp.83-90, 2005.

Mariko Sasakura received Eng.D. in information science from Kyushu University in 2000. She is an assistant professor of Okayama University.

Kenichi Iwata is a Ph.D. candidate at Graduate School of Natural Science and Technology, Okayama University.

Susumu Yamasaki received Eng.D. in information science from Kyoto University in 1980. In 1985/86, he was a visiting fellow at Dept. of Computer Science, University of Warwick, U.K. In 1987, he joined Okayama University as a professor.

Interactive Distance Teaching -

Field Report of a combined Semester Course of two Universities

K. Meissner, U. H.P. Fischer, D. Wermser, U. Dettmann

Abstract — ***In the following article a project supported by the Ministry for Education and Cultural Affairs of Saxony-Anhalt is described. An interactive course in electrical engineering between the two Universities was performed by using high-speed internet connections and specialised multimedia equipment. All components will be presented in combination with an analysis of its usability. Additionally, the experiences are described using the technique in daily lectures between the two Universities: expert knowledge from the lecturer view in comparison to the experiences of the student view. Finally the collected experiences are summarized and evaluated.***

Key Words*: Distance learning, internet based learning, distance teaching, internet multimedia lecture*

1. INTRODUCTION

As the demand for high-speed digital communication such as data, video, and the broadband Internet increases, the required throughput of the modules in communications systems[1] must also increase. Ethernet is well established up to 10Gbit/s in local area networks. In combination with this high speed transmission technology[2] it seems to be possible to realize online education courses via internet over several long distance transmission routes. The distances are practically unlimited, based on the high speed of light, carrying the multi-media data[3]. In Combination with the higher obtainable bandwidth, many efforts has been taken to sent video and audio signals via IP services in combination with telecom high standard quality of service[4,5] (QoS).

On the basis of the currently prevailing space, financial and personnel situation in the universities of applied science, a project promoted by the Ministry for Education and Cultural Affairs in Saxony-Anhalt considering the general space and allocation of different courses was developed and tested using modern multimedia components. The goal is the relief and effective assignment of the teachers on the one hand and, on the other, the creation of the possibility for students to take part in courses offered by different universities. In this way, it will be possible to make lectures covering specialist fields and topics accessible to a wider audience, regardless of the physical distance. The first stage is therefore concerned with a survey of the average available capacity and the technical equipment at the universities. In the second stage, the technology required for the video-conferencing and the desktop-sharing will be introduced. Various products will be briefly compared for this. The teaching experience of this new educational concept from the perspective of the teachers and the students will form the content of the next stage. Finally, the collated experiences will be summarized and evaluated.

Manuscript received March 15th, 2006. This work was supported in part by the Department of Research and Development of the Federal Republic of Germany and the Ministry of Sachsen-Anhalt supported this work.

U.H.P. Fischer and K. Meißner are with the Informatics and Automation Department, Harz University of Wernigerode, Germany (e-mail: ufischerhirchert@hs-harz.de). D. Wermser and U. Dettmann are with the Electrical Engineering Department, University of Applied Sciences Wolfenbuettel Germany.

2. Inventory

Due to the mostly small-group, seminar-style lessons in the universities, especially in the main study course, the room situation is mostly comprised of small to medium-sized rooms with a count of 20 to 40 students per lecture. Excluded from this are introductory lectures held in lecture halls, as these are generally attended by a much higher number of students. Here, the deployment of staff is considered effective and these courses are similarly offered in all colleges.

The technical equipment in the seminar rooms normally consists of computers for the lecturers, data/video projectors and possibly also interactive whiteboards. In addition, the rooms are equipped with 100 Mbit/s IP connections. Access to the German research net[6] (DFN) is likewise available at (nearly) all universities via the university computer centre. The DFN provides various services for videoconferencing according to the H.323[7] standard, and desktop-sharing according to the T.120[8] Standard and the required bandwidth.

3. TECHNICAL EQUIPMENT OF THE LECTURE CONFERENCING ROOMS

On the basis of the described equipment of the existing seminar rooms, two different development variants for the technical equipping of video conferencing rooms, as shown in fig. 1, will be presented. In both variants, lecturers PCs with dual-headed graphic adapters are used. With this, presentations, slides and program

demonstrations can be shown using a data/video projector, and with the second projector the interactive whiteboard entries can be projected. The interactive display board[9] entries, generated through the use of an electronic whiteboard in combination with a projector, can easily be distributed via the IP network using a suitable desktop-sharing tool. The introduction of whiteboard systems with integrated back projection was not part of the scope, due to the still very high costs of these systems.

The video conferencing system[10] (VCS) with the connected audio system forms the second central component. On the basis of tests performed by the DFN and the centre of excellence for videoconferencing services (VCC) at the TU Dresden, the Polycom Viewstation SP128 was selected for the installation of the compact videoconferencing system. This offers desktop systems with integrated cameras and the possibility of an additional camera connection. The inserted camera can be both swiveled and zoomed, in order to optimally show the speaker and/or students. For communication, the systems have both a RJ45 connection for access to the IP network and an ISDN[11] connection for video conferences over the telephone network. The audio system consists of a interfacial microphone system with the option of an additional radio microphone for the lecturer. For the processing of the microphone signals, an external microphone amplifier with echo canceller and digital equalizer is interposed. The output signal of the videoconferencing system is distributed via an audio amplifier and loudspeakers appropriate to the room.

During the start-up period, the three desktop-sharing tools Microsoft NetMeeting 3.01, BrigdeIT and Netviewer, which along with the video conferencing play a central role for the distribution of the lesson content, were tested.

- Microsoft NetMeeting[12] is a free, decentralized working program, which is installed as a standard installation with Windows 2000/XP. It is principally suitable for small groups, since it enables the basic functions such as the distribution of the screen contents and also the taking-over of the write function by other users. Disadvantages, however, are that there is no support from Microsoft and the software crashed several times during a session lasting several hours. A program crash during a lecture always leads to delays and concentration loss among the students. With the use of the T.120 protocols with the corresponding ports, only a restricted operation is possible from behind a firewall.

- The BridgeIT[13] program by Smart consists of a server installation and a client installation. With this, the client software can be sent to the relevant participants, by email for example, and needs only to be started on the remote PCs, and not installed. The licensing takes place via the number of participants who log on to the server. The session administrator can thereby arrange several meetings on one server and pass on the appropriate session names and passwords to the participants. It is preferable that communication takes place via port 80. This allows a problem-free operation from behind a firewall.
  A disadvantage is that the program is designed to specifically distribute the screen contents. The invited participants can make colored entries on the screen, but have no possibility of directly entering into the presented programs. Thus the interaction wished for between lecturer and students in the shared lessons is highly restricted.

- The third tested transmission software called "one2many" from Netviewer. Like BridgeIT, Netviewer consists of a server and a client component. With the standard installation, the server is not installed in the university; the registration and the data transfer run via special servers at Netviewer. The costs of maintenance and installation can thus be lowered. Contrary to the variants specified above, however, use of the intranet is not possible in the event of the loss of the internet connection. A personal server installation is possible for a surcharge. The use from behind a firewall is unproblematic here as well, since communication with Netviewer also runs via port 80. All participants can be given remote access rights by the meeting leader, in order to make a genuine interaction between the participants possible.

For an acceptable video presentation, a bandwidth of 768 kbit/s is necessary for the video conference with audio signal. The supply of this bandwidth should be guaranteed using QoS in the IP network, since otherwise cut-outs in the audio and video stream can occur. Short disruptions in the video stream are here less critical than cut-outs in the audio stream. For the desktop-sharing, a bandwidth of 128 kbit/s proved sufficient. The adherence to these bandwidths is not critical, since short delays with the slides are not particularly disturbing. The connection to the internet is technically easy to realize and, as with both the videoconferencing system and the software, is completely menu-led. For the use with several participants, a Multi Conferencing Unit (MCU) must be used for the management and the distribution of the video and audio streams, as the Polycom Viewstation SP128 is only a Single Point (SP) version, i.e. only point-to-point connections are possible. The optional H.323 Gatekeeper is needed for the authentication of the participants. Figure 1 shows the necessary network infrastructure.

The installation of a sun-blind in the rooms is very important, in order to avoid disturbing influences by foreign light. The audio system represents the

most critical point in the videoconferencing room. Due the requirement that it should be possible for both the lecturer and the students to talk freely as in a normal lesson, a solution involving freely-hanging room microphones was designed.

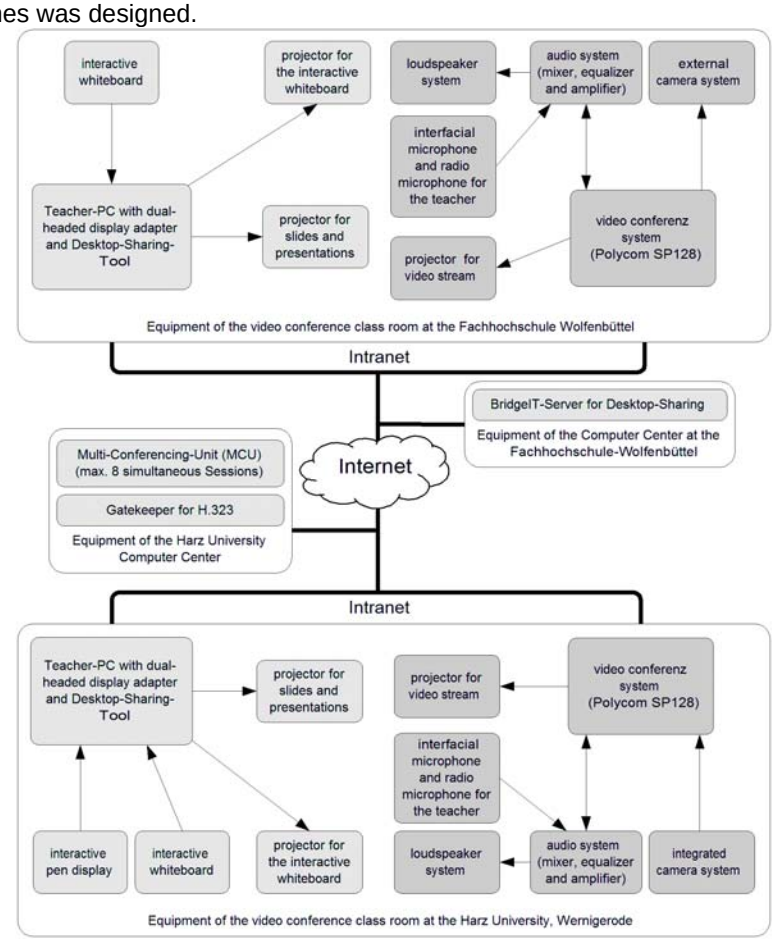


Fig. 1: Network infrastructure for long distance lecture teaching at Harz University and University Wolfenbuettel

For this, the rooms should be adapted to the acoustic requirements by structural measures, in order to reduce arising reverberation effects and echoes. A modification which would allow the audio quality of a sound studio was out of the question from a practical and financial point of view.

Fig. 2 shows as an example the schematic configuration of the hardware structure at the sites in Wernigerode and Halberstadt. Similar to this, the Braunschweig/Wolfenbuettel University of Applied Science has installed a multimedia lecture hall with darkening, appropriate micro-phone and camera equipment.

Fig. 3 shows a view of the realization of the multimedia lecture hall (VIL) at the Harz University of Applied Science. The illustration shows the electronic board (1), the two screens (2, 3) and the projectors required for them (4), one of the room microphones (5), the lecturer's seat (6) and the workstations for the students (7).

Fig. 2 : Schematic structure of the virtual informatics lab (VIL)

Fig. 3 : Insight into a seminar conference room

4. EXPERIENCES WITH THE VIL

4.1 STUDENTS VIEW

To follow the lesson actively it is important to observe directly the gestures and mimic of the lecturer. That's why it is a necessity to use a high resolution camera system in the lecturer room, a fluent video transfer without dropouts and a high resolution projection system with wide-area screen. It turned out that from view of the students single dropouts in video transmission are uncritical.

On the other hand the perception of the quality of the audio signal is really critical. Already short dropouts are highly critical and disturbing. They make it very difficult to follow the content, sometimes it is almost impossible. In progression of using the VIL it turned out to be useful for the lecturer to wear a headset. The reverberation and the low sensitivity of the room microphones worsened the signal to noise ratio strongly and the understanding of information suffered immanently.

Furthermore it is required, that the sketches on the blackboard were transmitted using a high resolution camera system. Even better would be to use a large area (1.5 x 2.5m) electronic blackboard. Negative experiences were made by simply filming the blackboard, either the contrast or the resolution of the camera was to low.

The personal contact to the lecturer was not very crucial for the students and was only small missed. After the lecture it was often observed that the students asked questions via the internet connection with a sufficient exchange with the lecturer.

4.2 LECTURERS VIEW

For the lecturer a few very advantageous aspects arise while processing the content of teaching. The unavoidable and work-filled conversion of all slides, board pictures etc. to electronic media like PDF or PowerPoint finally result in favourable working conditions. These media now can be queried at any time. Consequently it is possible to access further data during the lesson immediately.

The electronic board requires some exercise from the lecturer in handling and in the writing management. The largest drawback is that electronic boards are still strongly limited in size. By a board of 1m x 1m it is almost impossible to create a "normal" largely written board picture. Only a small part of the usual information can be placed on the board, because the persons in the lecturer's room have to discern the board from an appropriate distance as well. This deficiency can be improved only by the coming technological development. A benefit of using an electronic board is that the board history can be stored and used for following lectures.

Like mentioned before, the simple filming of the blackboard was insufficient because of problems with contrast, resolution and brightness.

Another innovation in the multimedia lecture is the use of the showing device for the PowerPoint slides (mouse etc.); this device must be usable as board display at the same time. Because of that the handling is quite difficult at the beginning, but can be improved over time.

To sum up, one can say that seen from lecturer and from students view this kind of lecture is rated to middle acceptance only. A personal lecture is preferred by both groups.

This type of internet remote teaching is only then advantageous, when other resources and persons are not available or long distances between the academies make the personal presence very difficult. The personal teachings can only be replaced conditionally.

5. SUMMARY

Based on the present room-, financial and personnel situation at the universities a project was developed, promoted by the ministry of education and the arts of the state Saxony-Anhalt, to introduce a room and location-spreading distribution of lectures by modern multimedia components and its testing in the daily teachings.

The first section dealt with a stocktaking of the average available room capacity and the technical equipment at universities. In the second section the technical configuration necessary for video conferencing and desktop sharing was represented and different products were compared briefly. The following sections contain the experiences of this new teaching concept from view of the lecturers and the students. Finally, the collected experiences were summarized and evaluated.

Acknowledgement

Thanks to the co-workers of the computing centres of the Harz University of Applied Sciences and the University of Applied Sciences Braunschweig/Wolfenbuettel for kindly support.

First A. Author
Biographies

Ulrich H. P. Fischer

U.H.P. Fischer earned a degree in physics from the Free University of Berlin, Germany in 1983. In 1988 he made his PhD in physics of condensed matter. In 1988 he joined the Heinrich-Hertz-Institute in Berlin for the development of broadband optical communication systems. He has served as head of the optical packaging group at the Institute since 1994. In April 2001 he became professor of optical packaging and optical networks at the Harz University of Applied Studies and Research, Germany.

Udo Dettmann

Udo Dettmann works as a consulting informatics engineer at the University of Applied Sciences Wolfenbuettel, Germany

Knut Meissner

Knut Meissner works as a consulting engineer and PhD student at the Harz University of Applies Studies and Research in Wernigerode/ Germany

Dietrich Wermser
Dietrich Wermser is currently Professor for electrical engineering and mobile transmission systems at the University of AppliedSciences Wolfenbuettel, Germany

REFERENCES

[1] T. Naito:" One Terabit /s Transmission over 10.000km using C-Band and L-Band", Networks and Optical Communications I, IOS Press, 2000, pp 2-9
[2]Yang, Curtis, and Freeman: "AT&T Ethernet transport services: metropolitan and long-haul transport services", JON 1150 August & September 2002 / Vol. 1, Nos. 8 & 9 / JOURNAL OF OPTICAL NETWORKING, pp 253-262
[3] U. H. P. Fischer (Member IEEE), S. Zech, K. Peters: "Transmitter modules with reusable fiber-chip coupling method for optical communications systems", TechOnline (http://www.techonline.com/community/ed_resource/tech_paper/14811) (2002)
[4] Gilardi, Pattavina, and Verticale:" Transport of Internet Protocol traffic over an Ethernet–over–wavelength-division-multiplexing architecture", JON 1021, August & September 2002 / Vol. 1, Nos. 8 & 9 / JOURNAL OF OPTICAL NETWORKING, pp 313-323
[5] Kramer and Mukherjee: "Supporting differentiated classes of service in Ethernet passive optical networks", JON 1335 August & September 2002 / Vol. 1, Nos. 8 & 9 / JOURNAL OF OPTICAL NETWORKING, pp 280-300
[6] www.dfn.de_ (last access 3.11.2004)
[7] INTERNATIONAL telecommunication union t H.323 teleconferencing protocol
[8] International Telecommunication Union T.120 set OF standard for DATA conferencing across various feed media
[9] interactive display board : http://www2.smarttech.com/st/en-US/Products/SMART+Boards/default.htm
[10] VCC authority center for video conference services: http://vcc.urz.tu dresden.de/
[11] Flanagan, A.: "ISDN. A Practical Guide to Getting Up and Running." McGraw-Hill Education, 2000, pp 134
[12] MS NetMeeting: http://www.microsoft.com/windows/netmeeting/
[13] BridgeIT software: http://www2.smarttech.com/st/en-US/Products/Bridgit/

The Effect of Demographics on Seamless Mobile Service Interface

Mattila, Anssi; and Pento, Tapio

Abstract— ***The purpose of this paper is to demonstrate the effect of demographic variables on choice of a service delivery channel and on the factors affecting the seamless user experience related in different electronic channels. Profession proved to have the most diverse effect in this study as it affects the usage of all the other channels except the option of personal service. To elaborate the relationship between demographics and dimensions of seamless use experience further, we conducted ANOVA for all the user segments – Fixed-line, Mobile and Combined users. The results are based on a large consumer survey conducted among mobile and fixed-line Internet users in Finland during summer 2003.***

Index Terms— demographical variables, seamless, service interface

1. INTRODUCTION

ADDING digital channels such as mobile and developing more and more commoditized products will clearly help to shift further tasks towards the customer through self-provisioning and thus, will help cutting additional costs [1]. For the sake of successful business models, the service providers and equipment manufacturers must observe the needs of mobile service customers and more importantly, study their willingness to pay. It has been stated that weight which individual users put on performance in relation to their perception of simplicity and acceptability, may not only be very different but may also change over tasks and situations [2].

The number of mobile Internet users is expected to grow up to 730 million to year 2005 [3]. Such a large number of users is bound to consist of a very heterogeneous mass of customers with differing demographic profiles. It has been proposed that mobile Internet services can be categorized under utilitarian services, which offer instrumental benefits, and hedonic services, which offer experiential benefits [4].

2. USAGE AND CURRENT MOBILE SERVICE USERS

Customers have been slow to adopt mobile Internet services. Users prefer fixed-line Internet for communication purposes and content application usage over mobile Internet whereas commerce applications are used via mobile Internet [5]. In Finland, for example, only 15 percent of customers with a GPRS / WAP-enabled mobile phone use mobile Internet services consistently [6]. It has been also found that only half of the customers, who have tried mobile Internet services, continue using them [7]. Continuers may regard the current mobile Internet services as more usable than discontinuers may, because they have used the services enough to overcome frequently occurring usability problems [7]. 73 percent of Web sites studied had at least one accessibility error [8]. Only 15 percent of Web sites are free of accessibility errors [9]. This research finding was based on analyses of 219 home pages.

Actual users are more susceptible to the benefits resulting from the adoption of a new information system while potential users are more vulnerable in terms of usability [10]. This finding is in line with results presented in earlier research reports on this topic [11]. Females are more likely to experience technostress in using computers compared with males [12]. It has been also reported that males are more likely than females to perceive computer usage as fun [13]. It has been examined whether there exists a gender differences between ease of use and complexity of computer usage [14]. Age was chosen as a covariate. Age has been found to be associated with unfavorable perceived usefulness and a decreased attitude towards using computers as well as adoption [15, 16].

3. METHODOLOGY AND DATA COLLECTION

The usability attributes by Nielsen were chosen as the starting point for our seamless use experience investigation as they constitute a generic model and fit in the service context too [17]. The relation between usability and seamless use experience has been described in detail in a previous research report published by the author [18]. Before the actual data collection, focus group interviews among expert users were conducted. The meaning of these interviews was to map the possible options for survey questions. The questionnaire was pre-tested on a group of 60 students and modified accordingly. A postal survey was conducted in May 2003. The sample was drawn from TeliaSonera[1] Finland's customer

[1] Based on the number of customers, TeliaSonera is the largest mobile operator in Sweden and Finland, the second largest operator

database. The sample was stratified in three active user segments of mobile users, fixed-line users and combined users equal in size depending on the main electronic service delivery channel in their use. The questionnaires were tailored respectively.

We call the customers, who did not own according to the database a private fixed-line connection at home, the Mobile users. The customers collected under this sample had the highest volume of mobile data transfers (GPRS, high-speed data) during the last six months in comparison to other customers in the database. They represented in every way the most active mobile Internet users the database had. The Combined users had a private fixed-line Internet connection in use at home. Further, their customer record showed active usage of mobile Internet (GPRS, high-speed data) connection and WAP-services during the last six months. The Fixed-line users owned a mobile phone and they were using regular mobile phone services such as SMS. There was no sign of Internet related activities during the last six months in their customer record. They had a private fixed-line Internet connection (mainly ADSL) in use at home.

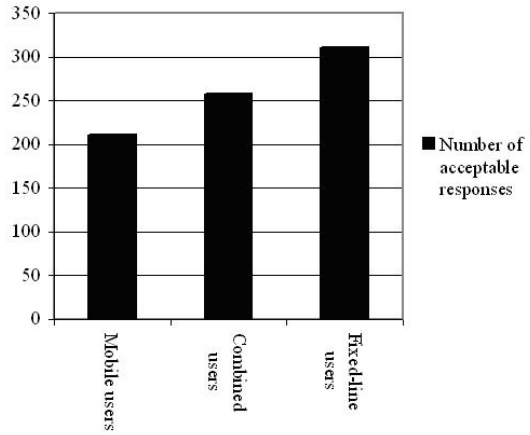


Figure 1: The division of response rate among the different user segments of customers

After a second follow-up, 778 responses were accepted under further analyses. The final response rate was 25.9%, which is acceptable according to economic science standards. The distribution of the responses in different user segments is presented in figure 1.

The respondents were asked to fill out a structured questionnaire on a 7-point Likert scale concerning their preferences, experiences and beliefs towards usage of mobile and Internet services. Literature as well as prior conducted surveys guided us in defining the scales to measure the customers' perceived seamless use experience [19, 20, 21]. There were up to 27 questions in each tailored questionnaire.

4. RESULTS

The demographic profile of the respondents is presented in table 1. One third (33.9%) of the respondents were women and two thirds (64.8%) were men. The majority (59.8%) of the respondents were 25-49 years old and their annual household income (28.1%) before taxes fell within the range of 20 000 – 30 000 euros, which matches with the average annual income of two adults family in Finland [22]. Only every fifth (18.2%) of the respondents had two or more children living at home. The majority of all the respondents were workers (40.6%). This result is compatible with the result of the educational background of the respondents, which was in most cases (29.0%) vocational school. Obviously, Internet and its services are becoming available for all the consumer segments regardless of their annual household income or educational background.

Table 1: Profile of respondents

Demographic characteristics	Mobile users		Combined users		Fixed-line users		Total	
	No	%	No	%	No	%	No	%
Total	211	100.0	257	100.0	310	100.0	778	100.0
Gender								
Male	157	74.4	192	74.7	155	50.0	504	64.8
Female	54	25.6	55	21.4	155	50.0	263	33.9
Missing	0	0	10	3.9	0	0	10	1.3
s.d	*0.437*		*0.417*		*0.501*			
Age								
Under 24 years of age	64	30.3	33	12.9	43	13.9	140	18.0
25-34 years	81	38.4	96	37.4	62	20.0	239	30.7
35-49 years	43	20.4	83	32.3	100	32.3	226	29.1
Over 50 years of age	20	9.5	41	15.9	104	24.5	129	16.6
Missing	3	1.4	4	1.6	1	0.3	8	1.0
s.d	*0.998*		*0.974*		*1.196*			
Annual household income								
Less than 10 000 euros	33	15.6	21	8.2	43	13.9	97	12.3
10 001 – 20 000 euros	54	25.6	48	18.7	82	26.5	184	23.7
20 001 – 30 000 euros	59	28.0	87	33.9	73	23.5	219	28.1
30 001 – 40 000 euros	25	11.8	37	14.4	40	12.9	102	13.1
More than 40 001 euros	29	13.8	53	20.5	60	19.3	142	18.3
Missing	11	5.2	11	4.3	12	3.9	34	4.5
s.d	*1.650*		*1.875*		*1.741*			
Marital status								
Married	27	12.8	101	39.3	128	41.3	256	33.0
Cohabitation	60	28.4	69	26.8	58	18.7	187	24.0
Single (incl. widow, divorced)	115	54.5	80	31.1	116	37.5	311	39.9
Missing	9	4.3	7	2.7	8	2.6	24	3.1
s.d	*0.940*		*1.154*		*1.397*			
Number of children living at home								
0	165	78.2	152	59.1	176	57.0	493	63.4
1	21	10.0	45	17.5	71	23.0	137	17.6
2	14	6.6	29	11.3	42	13.6	85	11.0
3 or more	8	3.8	28	10.9	20	6.5	56	7.2
Missing	3	1.4	3	1.2	1	0.3	7	0.8
s.d	*0.791*		*1.074*		*1.019*			
Education								
Elementary school	24	11.4	31	12.1	48	15.5	103	13.2
Secondary education	34	16.1	63	24.5	64	20.7	161	20.7
Vocational school	69	32.7	85	33.1	72	23.2	226	29.0
University degree	48	22.8	39	15.2	82	26.4	169	21.7
Other	33	15.6	36	14.1	41	13.2	110	14.2
Missing	3	1.4	3	1.2	3	1.0	9	1.2
s.d	*1.952*		*1.916*		*2.063*			
Profession								
Leading position	10	4.7	20	7.8	20	6.5	50	6.4
Worker	96	45.5	116	45.1	104	33.5	316	40.6
Public servant	28	13.3	31	12.1	40	12.9	99	12.7
Other	71	33.6	85	33.0	144	46.3	300	38.5
Missing	6	2.8	5	1.9	2	0.6	13	1.8
s.d	*2.367*		*2.526*		*2.547*			

Over third (37.3%) of the Mobile users use mobile services weekly and four out of five (83.8%) Fixed-line users use fixed-line electronic services weekly. The Mobile users report of using mainly five services. The Fixed-line users suppose that they needed a bundle of two

in Norway, and the fourth largest operator in Denmark. TeliaSonera is also the largest fixed voice and data provider in the region with leading positions in Sweden and Finland and a significant position in Denmark. TeliaSonera International Carrier is the leading IP wholesaler in Europe with a 10% market share. TeliaSonera is listed on the Stockholm Exchange, the Helsinki Exchange and Nasdaq Stock Market in the USA.

services, if they would be daily using mobile services. The most commonly used mobile services used are related to home and family, hobbies and leisure time, and making reservation. Over the fixed-line Internet connection customers access mostly search engine, communication and financial services. Among the customers who are not currently using mobile services, the most tempting service bundle comprises of gender specific services search engine and using mobile service for remote control purposes (e.g. activating burglar alarm).

Besides pure demographic variables, the respondents' level of innovativeness was measured using ethnographic arguments on a scale of -3 (totally disagree) to 3 (totally agree). Figure 2 shows somewhat surprisingly, the Fixed-line users (mean 1.84, s.d. 1.877) appear to value technical improvements over personal service more than the Mobile users (mean 0.53, s.d. 1.873). In overall, the Fixed-line users have more positive perceptions about technology and use of technology than the Mobile users. This might be due to the negative beliefs the Mobile users may have towards WAP-enabled services. Controversially, the Mobile users seem to be more favorable towards automated services (s.d. 1.861) and adapting to changes (s.d. 2.082) more easily than the Fixed-line users. The standard deviations were moderate or high for all arguments.

The effect of demographic variables on the choice of a service delivery channel among different user segments are presented in table 2. Only the significant correlation coefficients are visible on the table to increase its readability. The values for the Mobile users are bolded, for the Combined users on italic and for the Fixed-line users underlined. We can see from the table that all the demographics correlated with one or more service delivery channels. Gender is a significant factor for the Combined (men) and Fixed-line users (female) when choosing mobile phone as a modem via PC as their primary electronic service delivery channel. Age affects the choice of mobile (younger) and fixed-line Internet (younger) and the usage of mobile phone as a modem to connect on the Internet (older). Profession proved to have the most diverse effect in this study as it affects the usage of all the other channels except the option of personal service. There is also a correlation between personal service and marital status, which might be partially also due to the number of children married people may have and children's needs in regard with the service delivery channel choice. Line of business did not correlate with any of the distribution channels.

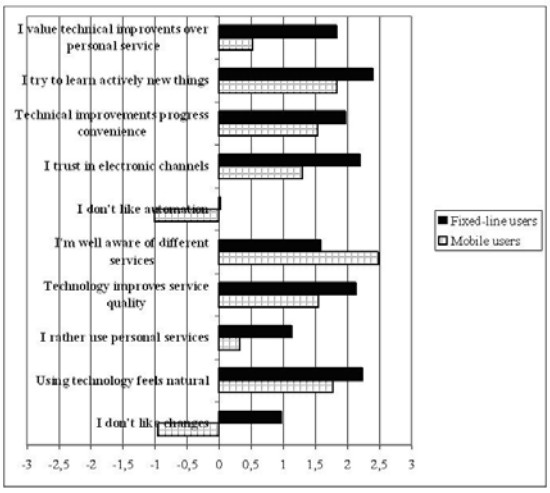


Figure 2: Innovativeness of the respondents

Table 2: Correlation matrix on the effect of demographic variables on service delivery channel choice: MOBILE USERS, COMBINED USERS AND FIXED-LINE USERS

CORRELATION MATRIX **Service delivery channel usage ⇒** **Demographic variables ⇓**	Mobile Internet services α=.68	Fixed-line Internet services α=.64	Mobile phone as a modem (via PC) α=.71	Mobile service usage via PDA α=.62	Self-service, automated services α=.78	Personal service α=.81
Gender			*-.141*, .675***			
Age	*-.170***	*-.227**, -.349***	**.282****			
Marital status		*.124**				*.274**
Education		**.236****, *.317**	**.209****, *.131**			
Income		**.147***	**.213****, *.276***	*.163**		
Profession	*.335**	*-.198***	**.224****,	*.143**	**-.165***	
Line of Business						

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

There are dependencies between all the demographic variables and factors affecting the seamless user experience (see table 3). Mobile users, who perceive mobile service delivery channel as seamless, have a lower level of education. It is usual that as the education level rises, one becomes more critical and analytical towards phenomenon. Married Fixed-line users perceive their primary electronic service delivery channel prone to errors. Females seem to be more affluent to errors than male when they are Mobile or Combined users. The younger and less educated respondents in all the user segments are the most likely to perceive electronic channels as independent from time and place.

Table 3: Correlation matrix on the effect of demographic variables on the factors affecting the seamless user experience related in different electronic channels: MOBILE USERS, COMBINED USERS AND FIXED-LINE USERS

CORRELATION MATRIX Demographic variables ⇒ To which channel you related the following statements ⇓	Gender α=.65	Age α=.75	Marital status α=.72	Education α=.68	Income A=.71	Profession α=.68	Line of Business A=.64
Seamless				-.150*			
Easy to learn		.137*			.132*		
Difficult to remember				.206*			-.181*
Inefficient	.175** -.219*	.228**		-.188**		-.231*	
Prone to errors	.186* .184**		-.234*				
Satisfies my needs	.155*	.156*					
Easy to use when traveling				-.192**			
Easy flowing when I'm busy				-.398**		-.151*	
Popular among my peers		.164*		-.201**			
Independent from time and place		-.226**		-.164* -.383*			

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

To further elaborate the relationship between demographics and dimensions of seamless use experience, we conducted an ANOVA for all the user segments. All the users were asked to visualize the mobile service customer-technology interface in use. Therefore, the results from the Mobile users and Combined users represent the actual user experience whereas the results from the Fixed-line user segment are merely their perceptions about dimensions of seamless mobile service interface. However, as the Fixed-line users may be the potential mobile service users and at least they are used to technology-based services in general, their perceptions and beliefs were thought to be valuable to map.

The variables, which during the follow up analyses showed significant correlations, were identified after close examination. As a result, we are now able to conclude that despite the results of a preliminary testing of interdependence, education does not affect how customers are positioned in the segment of the Mobile users view the memorability of mobile services as part of seamless use experience (see table 4). Line of business was also not found to affect the perceived efficiency of use in this user segment. Men find the memorability of mobile services a more important dimension than females and the more one is educated, the less meaningful the dimension memorability of mobile services becomes.

Table 4: Dimensions of seamless use experience among the Mobile users: ANOVA on demographics

Learnability	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.72			**between groups**		
1. Line of business			2.801	3.713	.002
Heavy industry	51	4.9504			
Public administration	11	4.9798			
Transportation	25	4.3450			
Services sector	48	4.7535			
Computing and Telecommunications	10	4.7444			
Commerce	16	4.6597			
Other	7	3.5397			
Total	168	4.7073			

Efficiency of use	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.72			**between groups**		
1. Line of business			1.675	1.988	.070
Heavy industry	51	4.4575			
Public administration	11	4.4621			
Transportation	24	4.3148			
Services sector	48	4.1780			
Computing and Telecommunications	10	3.7778			
Commerce	16	3.9306			
Other	7	3.5714			
Total	167	4.2286			

Memorability	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.88			**between groups**		
1. Gender			6.154	6.635	.011
Male	148	3.8790			
Female	48	4.2911			
Total	196	3.9799			
1. Education			1.549	1.665	.120
Elementary school	21	4.4101			
Business school	16	4.3194			
Vocational school	63	4.0071			
Technical school	18	4.0123			
Polytechnic institution	21	3.8803			
University degree	24	3.5451			
High school graduate	30	3.8852			
Other	2	3.8333			
Total	195	3.9855			
2. Line of business			1.891	2.177	.048
Heavy industry	51	4.0784			
Public administration	11	4.3712			
Transportation	25	3.7000			
Services sector	48	4.0463			
Computing and Telecommunications	8	3.7500			
Commerce	16	3.6484			
Other	6	3.0556			
Total	165	3.9364			

Satisfaction	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.64			**between groups**		
1. Income			5.183	4.046	.002
Less than 10.000 euros	28	4.2901			
10.001-20.000 euros	52	3.5474			
20.001-30.000 euros	57	4.0750			
30.001-40.000 euros	23	3.8614			
40.001-50.000 euros	12	2.8500			
Over 50.001 euros	14	3.5770			
Total	186	3.8170			

Errors	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.67			**between groups**		
1. Education			1.834	2.132	.042
Elementary school	21	4.9869			
Business school	16	4.9938			
Vocational school	63	4.8501			
Technical school	17	4.8235			
Polytechnic institution	21	4.3762			
University degree	26	4.5068			
High school graduate	29	4.2974			
Other	2	5.0000			
Total	195	4.6968			

Notice Scale between 0 (not at all important) … 6 (very important)

In the user segment of Combined users, the dimension of seamless use experience labeled learnability was affected by marital status, gender and age. The single people find easy learnability of mobile services more important than the married ones. The older respondents perceived

the importance of service's learnability as part of seamless use experience higher. In this user segment, females perceive efficiency of use as well as memorability of electronic service more important than males. The importance of errors lowers as the annual household income level rises. Income as a determinant of efficiency of use and memorability was not found significant. All dimensions of seamless use experience had different influence by demographics than in a segment of Mobile users although they were both asked to describe the seamless use experience of mobile services.

The Fixed-line users presented their perceptions about what they would see as important for seamless mobile service user experience and in table 6 we present the results of the demographic effect for this segment. The learnability shares partially same demographic effect than in the Combined users segment. Only gender is found having significant effect as females find the learnability of mobile services more important than males. There are no significant determinants for the efficiency of use in the Fixed-line user segment and for the memorability, only education is found having significant effect. This finding is typical only for the Fixed-line users according to the data in use. Also, both dimensions of satisfaction and errors have distinctive features compared to other user segments: the older respondents placed higher importance on the satisfaction and the younger ones seemed to be more irritated with their belief of expected errors in mobile service usage.

Table 5: Dimensions of seamless use experience among the Fixed-line users: ANOVA on demographics

Learnability	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.69			**between groups**		
1. Gender			8.497	8.901	.003
Male	138	4.4020			
Female	133	4.7562			
Total	271	4.5759			
2. Age			0.734	0.745	.562
Less than 18-24	41	4.5274			
25-34	56	4.4341			
35-49	86	4.5860			
50-64	66	4.6244			
Over 65 years of age	22	4.8414			
Total	271	4.5759			
3. Education			1.484	1.579	.142
Elementary school	38	4.7675			
Business school	25	4.6129			
Vocational school	64	4.7573			
Technical school	32	4.3635			
Polytechnic institution	26	4.3812			
University degree	46	4.5000			
High school graduate	28	4.3020			
Other	10	5.0300			
Total	269	4.5809			
Efficiency of use	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.76			**between groups**		
1. Age			0.363	0.240	.915
Less than 18-24	40	4.2333			
25-34	55	4.3962			
35-49	87	4.3286			
50-64	58	4.4582			
65 years of age	18	4.2847			
Total	258	4.3543			
Memorability	**N**	**Means**	**Mean square**	**F value**	**Sig.**
α=.74			**between groups**		
1. Marital status			2.702	2.241	.065
Married	95	3.9291			
Cohabitation	52	3.7521			
Single	60	3.7875			
Leski	7	4.2608			
Divorced	246	3.7861			
2. Education			2.857	2.414	.021
Elementary school	33	4.1344			
Business school	25	4.0210			
Vocational school	58	3.9768			
Technical school	31	3.5842			
Polytechnic institution	25	3.6639			
University degree	42	3.3862			
High school graduate	28	3.5857			
Other	8	4.4028			
Total	250	3.7927			

3. Income			1.683	1.412	.211
Less than 10.000 euros	34	3.7418			
10.001-20.000 euros	68	4.0373			
20.001-30.000 euros	57	3.7351			
30.001-40.000 euros	37	3.6843			
40.001-50.000 euros	23	3.5700			
50.001-60.000 euros	11	3.7273			
More than 60.001 euros	13	3.2201			
Total	243	3.7693			
Satisfaction	**N**	**Means**	**Mean square between groups**	**F value**	**Sig.**
α=.82					
1. Age			4.091	3.501	.008
Less than 18-24	42	3.5548			
25-34	61	4.0086			
35-49	86	3.9233			
50-64	62	4.0129			
Over 65 years of age	21	4.6159			
Total	272	3.9594			
2. Profession			1.930	1.622	.119
Leading position	17	3.4876			
Worker	95	3.8124			
Government official	20	4.1944			
Public servant	37	4.1568			
Student	27	3.7704			
Pensioner	37	4.3345			
Entrepreneur	16	3.9813			
Unemployed	14	4.1500			
Other	9	3.7580			
Total	272	3.9594			
Errors	**N**	**Means**	**Mean square between groups**	**F value**	**Sig.**
α=.68					
1. Age			3.8997	3.321	.036
Less than 18-24	47	4.8429			
25-34	60	4.4148			
35-49	66	3.2838			
50-64	63	4.0719			
Over 65 years of age	20	2.7248			
Total	256	3.8676			

Notice Scale between 0 (not at all important)… 6 (very important)

5. CONCLUSIONS

Gender seems to have significant effect as females find the learnability of mobile services more important. The older respondents place higher importance on the satisfaction and the younger ones seem to be more irritated with their belief of expected errors in mobile service usage.

Less educated Mobile users seem to perceive mobile service delivery channel as seamless, and independent from time and place. Female Mobile users seem to be more affluent to errors, and male value memorability of mobile services higher.

Females in the Combined group seem to be more affluent to errors than males. Profession proved to have the most diverse effect in this study as it affects the usage of all the other channels except the option of personal service. The older respondents perceive the importance of service's learnability as part of seamless use experience higher.

The huge mass of potential mobile service customers will need an available and reliable infrastructure to access electronic services. The expected improvements in present and future generations of mobile phones will encourage the uptake of mobile services. Marketers need some directions of future customers' perceptions and likings to be able to focus on right issues in marketing mobile services.

REFERENCES

[1] Durlacher Report, "An Investment Perspective", http://www.durlacher.com/downloads/umtsreport.pdf, 9.12.2002.

[2] Gleiss, N., "Human Factors and Usability Evaluation", European Telecommunication Standardization and the Information Society – the State of the Art 1995," *Atalink Ltd*, Stockholm, Sweden, 2001, pp. 345-356.

[3] Jüptner, O., "Wireless Web population to soar", http:// www.e-gateway.net/infoarena/news.cfm?nid=2131, 19.3.2003

[4] Lee, I., Kim, Jaesoo, Kim, Jinwoo, "Use Contexts for Mobile Services: A Longitudinal Monitoring Study on Actual Use of Mobile Internet Services," under review for publication, 2003.

[5] Kim, J., "Analyzing Mobile Internet Users: Results from a monitoring study, an experiment, and a survey study", presented at the CHI 2001 workshop on mobile communications, 2001.

[6] Accenture, "Seven Myths about Japanese mCommerce," http://www.accenture.com, 16.12.2002.

[7] Kim, H, Kim. J., Lee, Y., Lee, I**.,** "Post-Adoption Behavior of Mobile Internet Users: An Empirical Validitation with a Structural Equation Model," under review for publication, 2003.

[8] Flowers, C., Bray, M. Algozzine, R. "Accessibility of special education program home pages," Journal of Special Education Technology, 1999, pp. 112-124.

[9] Schmetzke, A., "Distance education, web-resources design, and compliance with the Americans with Disabilities Act," *Association of College and Research Libraries*, 10th National Conference of the Association of College and Research Libraries, pp. 556-574.

[10] Karahanna, E., Straub, D., Chervany, N., "Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs," MIS Quarterly, 1999, pp. 467-488.

[11] Mattila, M., Pento, T., "Modelling Internet Adoption," *Spellbound Publishers*, International Quarterly Journal of Marketing, 2002, pp. 44-65.

[12] Elder, V., Gardner, E., Ruth, S., "Gender and age in technostress: effects on white collar productivity," Government Finance Review, 1987, pp. 121-134.

[13] Kaplan, R., "The gender gap at the PC keyboard," American Demographics, 1994, pp. 223-242.

[14] Teo, T., Lim, V., "Factors influencing personal computer usage: the gender gap," Women in Management Review, 2001, pp. 11-34.

[15] Igbaria, M. & Parasuraman, S., "A path analytic study of individual characteristics, computer anxiety and attitudes toward microcomputers," Journal of Management, 1989, pp. 554-567.

[16] Igbaria, M. & Nachman, S., "Correlates of user satisfaction with end user computing: an exploratory study," Information and Management, 1990, pp. 354-365.

[17] Mattila, M. "Factors affecting the adoption of mobile banking services," *Array Development*, Ottawa, Canada, 2003, online publication.

[18] Teo, T. "Demographic and motivation variables," Internet Research: Electronic Networking Applications and Policy, 2001, pp. 134-144.

[19] Mattila, M. "Factors affecting the adoption of mobile banking services," *ICFAI Press*, The ICFAI Journal of Services Marketing, 2004, printed with a re-print permission, pp. 110-131.

[20] Järvenpää, S., Todd, P., "Is There a Future for Retailing on the Internet?" in Electronic Marketing and the Consumer, ed. Peterson, R. A., *SAGE Publications Inc.*, Thousand Oaks, US, 1997, pp. 265-278.

[21] Crisp, B., Järvenpää, S., Todd, P., "Individual differences and Internet shopping attitude and intentions," *University of Texas*, Austin, US, 1997.

[22] Statistics Finland, "Nordic information society statistics 2002," www.stat.fi, 17.6.2003.

Modeling of Non-linear Stochastic Systems

Tabrizi, H. N., Mohammad; Liu, J., Jui; and Billings, A., Steve

Abstract—***In this paper the identification of both linear and non-linear parametric models of the river-flow system are investigated. Models relating rainfall and river-flow at three stations are estimated using NARMAX (Non-linear Autoregressive Moving Average with eXogenuous input) models. The Orthogonal Least Squares (OLS) algorithm was used to estimate the parameters and detect the system structure. The identification of linear and non-linear models are described to represent the relationship between local rainfall and river-flow at stations 1 and 2 located along the two rivers (inputs) and river-flow at the third station located along the third river (output) of the river-flow system.***

Index Terms— ***Modeling, Stochastic, River-flow, Water management, Identification, NARMAX, Non-linear, Orthogonal, Least Square***

1. INTRODUCTION

The study of hydrology has a long history and is of immense importance because of its potential impact on agriculture, industry, environment, navigation, and the production of energy. Accurate predictions of river-flow (runoff) are important for the management of river-flow networks and water resources in general [1].

River-flow forecasting for a downstream catchment area is usually based on the discharge hydrography observed further upstream on the catchment. These hydrographs already reflect the integrating action of the rainfall-flow process, and their availability removes the need for further consideration of the complex processes involved on the relevant upstream subsections of the catchment.

The forecasting problem then becomes mainly one of routing either single or multiple observed flow hydrographs through the channel system, with some correction for rainfall on the intervening catchment [2]. However, the main problem in water management arises from rainfall that relates inflows to the system [3], and there exists a strong non-linear relationship between rainfall and flow in typical river catchments. These non-linearities originate from the following sources.

• The complexity of internal system behavior arising from dynamic and multidimensional interactions that is physical, and possibly chemical and biological.

• Interactions may occur in several medium, each of which is heterogeneous. These media are likely to have quite different characteristic time and space scales to others in the system.

The complexities mentioned above will lead to inaccuracy in predicting the system. To improve the quality of the models, the concept of effective rainfall is taken into account. The effective rainfall is produced by a non-linear rainfall filter (RF) which is used to provide a transformation [4]. This transformation allows linearization of the rainfall river-flow relationship by considering only that part of the rainfall available to contribute to the river-flow during the period of interest.

This study uses a totally different technique, the NARMAX method, to develop a model to describe the river-flow network system which is based on linear and nonlinear system identification methods. The model is estimated directly using input/output data only. In this way a concise mathematical description of the system can be built which can then be used as a basis for prediction and analysis. The major advantage of using the identification technique described in this study is its ability to model complex systems that are difficult to describe using conventional approaches. Once the response data are available, the model can be rapidly developed and validated, and then be used to represent the river-flow network system.

2. RAINFALL AND RIVER-FLOW MODELING AND METHODOLOGIES

Many rainfall and river-flow systems have been studied using various approaches for modeling and there now exists an extensive range of predictive models in hydrology. Most of these have evolved pragmatically in response to practical situations and consequently are difficult to apply in all of the cases. Therefore, a number of hydrological models including Physical [1], Threshold [5, 6], Data-Based Mechanistics [7], NARMAX, and Neural network models have been proposed.

2.1 NARMAX Model

A wide class of discrete time multivariable non-linear stochastic systems (e.g. water management systems) can, under mild assumptions, be represented by the NARMAX model. The output m input r system can be described as:

$$\underline{y}(k) = \underline{a} + \underline{F}^{l}[\underline{y}(k-1),...,\underline{y}(k-n_y),\underline{u}(k-d),..,$$
$$\underline{u}(k-d-n_u),.\underline{\xi}(k-1),..,\underline{\xi}(k-n_\xi)] + \underline{\xi}(k) \quad (1)$$

where *y(k), u(k), and ξ(k) represent the output, input, and noise, respectively; n_k, n_y, and n_ξ are the numbers of lags in the input, output, and noise; d, l* are the system time increment, time

Manuscript received July 10, 2005.

Tabrizi. Author is with the Computer Science Department, University of East Carolina, USA (e-mail: tabrizim@mail.ecu.edu).
Billings, is with the Control and Systems Engineering Department, Sheffield University, UK (e-mail: S.Billings@sheffield.ac.uk).

delay, and degree of nonlinearity respectively. ξ(k) is zero mean white noise sequence; $\underline{a}$ is the constant vector term to accommodate the system *F[.]* mean level, and is some vector value non-linear function.

$$\underline{y}(k)=\begin{bmatrix} y_1(k) \\ . \\ . \\ . \\ y_m(k) \end{bmatrix}, \underline{u}(k)=\begin{bmatrix} u_1(k) \\ . \\ . \\ . \\ u_r(k) \end{bmatrix}, \underline{\xi}(k)=\begin{bmatrix} \xi_1(k) \\ . \\ . \\ . \\ \xi_m(k) \end{bmatrix}$$

represent the system output, input and prediction error respectively; A typical i[th] row may be taken for equation (1) and different values of the model structure selection that is maximum lags for each output, input, and noise may be assigned so that

$$\begin{aligned} y_i(k) =& a + F_i^l[y_1(k-1),...,y_1(k-n_{y1}^i),..., \\ & y_m(k-1),...,y_m(k-n_{ym}^i),u_1(k-d),..,u_1(k- \\ & d-n_{ur}^i),...,u_m(k-d),...,u_m(k-d-n_{um}^i), \\ & \xi_1(k-1),...\xi_1(k-n_\xi),...,\xi_1(k-n_\xi^i),...,\xi_m(k \\ & -1),...,\xi_m(k-n_{\xi m}^i)]+\xi_i(k),\ k=1,...m \end{aligned} \quad (2)$$

The non-linear form of $F_l[.]$ in equation (2) can be very wide, and the Volterra, Wiener, bilinear models are subsets of this representation. In the present study only polynomial expressions will be considered.

When $m=r=1$ the model of equation (2) reduces to the single-input single-output case:

$$\begin{aligned} y(k) =& a + F^l[y(k-1),...,y(k-n_y),u(k-d), \\ & ..,u(k-d-n_u),\xi(k-1),...,\xi(k-n_\xi)]+\xi(k) \\ & k=1,...,m \end{aligned} \quad (3)$$

which is called NARMAX model (Non-linear Auto-Regressive Moving Average model with eXogenous input) [8,9]. An orthogonal least squares (OLS) algorithm [10] is then used to estimate the parameters of the model. Applications of this technique have been carried out by the authors [11-13].

Here the NARMAX model will be used to include both single-input single-output and multi-input multi-output cases. Once the significant terms have been identified and estimates of the associated parameter values have been obtained, then it is important to examine whether the model has successfully captured the system dynamics. This can be achieved using the one-step ahead predictions, model predicted output, correlation tests, and cross validation tests in order to give some ideas regarding the goodness of the fitted model. The one-step ahead prediction of the output is defined as:

$$\begin{aligned} \hat{y}(k) =& \hat{F}^l[y(k-1),...,y(k-n_y),u(k-d),..., \\ & u(k-d-n_u),\xi(k-1,\hat{\theta}),...,\xi(k-n_\xi,\hat{\theta})] \\ & k=1,...,m \end{aligned} \quad (4)$$

where $\hat{F}^l[.]$ is the estimate of $F^l[.]$ and $\xi(k,\hat{\theta})$ is the residual given by

$$\xi(k,\hat{\theta})=y(k)-\hat{y}(k) \quad (5)$$

The model predicted output is defined as

$$\begin{aligned} \hat{y}(k) =& \hat{F}^l[\hat{y}(k-1),...,\hat{y}(k-n_y),...,u(k-d) \\ & ,..,u(k-d-n_u),..,0,...,0] \quad k=1,...,m \end{aligned} \quad (6)$$

Each of these tests provides useful information on the properties and validity of the estimated model. But it is also important to check that the identified model is unbiased and does adequately describe the system. This can be achieved by noting that when the system is non-linear the residuals should be unpredictable from all linear and non-linear combinations of past inputs and outputs. This will be true if the following correlation tests are satisfied:

$$\begin{aligned} & \varphi_{\xi\xi}(\tau)=\delta(\tau) \\ & \varphi_{u\xi}(\tau)=0 \qquad \forall\tau \\ & \varphi_{u^{2'}\xi}(\tau)=0 \qquad \forall\tau \\ & \varphi_{u^{2'}\xi^{2'}}(\tau)=0 \qquad \forall\tau \\ & \varphi_{\xi^{2'}u}(\tau)=0 \qquad \forall\tau \end{aligned} \quad (7)$$

Where $\varphi_{ab}(\tau)=E[a(k-\tau)b(k)]$ and the dash indicates that the mean has been removed. Estimated models are usually validated using an independent set of data called the validation data (test set). This is usually referred to as cross validation. The output from the model and the system are compared when they are run with the same input.

The NARMAX method is designed to determine both the model structure and estimate the unknown parameters. This approach ensures that the models obtained are as simple as possible to represent the underlying system and often the models identified can be related back to the system under study. The models obtained are therefore transparent and can be readily mapped into the frequency domain or analyzed using other well known approaches. NARMAX is therefore often applied to data sets where the user wishes to relate the final model back to earlier models developed by other methods such as analytical models, or wishes to analyze the system characteristics to reveal the fundamental system behaviors. The disadvantage of the NARMAX approach is that the user needs to have skills in system identification to apply these methods. Neural networks in comparison are easy to use but they almost always produce models that are opaque and which are difficult to write down and analyze. These models therefore are excellent for prediction but cannot easily be related back and analyzed in relation to the underlying system characteristics.

3. ANALYSIS OF THE SYSTEM

3.1 System Description

The system under investigation consists of two river-flow systems merging at a point to create a third river-flow system. Three gauging stations are located along the three river Sub-basin. The drainage area between stations 1, 2 and 3 is 3.7 squares miles. The outflow at station 3 is based on the flow at station 1 and station 2 and on the rainfall on the average rain-gauging station spread over the intervening catchment areas of stations 1 and 2. The 4 inputs to the models are the flows at station 1 and 2, and local rain at station 1 and 2, and the output is the outflow at station 3. Therefore the system can be treated as a 4-input single-output system.

3.2 Data Analysis

The analysis began by investigating the characteristics of the data. The procedure for analyzing the statistical properties of time series is presented as power spectral density analysis, auto-correlation analysis, cross-correlation analysis, mean analysis, and non-stationary analysis. The monthly mean of the flows at station 1, 2, and 3, and the monthly mean of rainfall at station 1 and 2 were observed. For weakly stationary processes, the mean value is a constant and the auto-correlation function is dependent only on the time displacement τ. Inspection of the results revealed that the data sets can be considered as non-stationary since the mean varies widely over time in an arbitrary fashion [14-17].

The above statistical analysis suggested that the rainfall data sets are not well correlated and that there may be significant non-stationarity in the data. Hence, before the samples of data are used for modeling, it is essential to pre-process the data. Pre-processing involved shifting the data, removing the means, data decimation, and/or use of proper rainfall filters [4-7], [18].The data used in the modeling analysis were taken from years 1967 and 1968 and the data from 1969 was used as a test set.

4. SYSTEM IDENTIFICATION AND MODEL VALIDATION

Although the actual system is a multi-input single-output system, it is often worth fitting single-input single-output linear and nonlinear models to the data initially. The single-input single-output model fitting will provide a priori knowledge about the maximum number of lags for the multi-input single-output model.

4.1 Single-Input Single-Output Models

Single-input single-output model fitting can be divided into four cases namely, linear models between station 1 and 3 using firstly the original data and then the transformed data, a non-linear model between the flow at station 1 and 3, and an effective rainfall flow model between rainfall at station 1 and the flow at station 3. Years 1967, 1968 data sets were used as the estimation data set to build the model and 1969 data set was used as the test set to validate the estimated model.

4.2 Rainfall-flow Model

The modeling of a rainfall-flow processes is a major task for hydrologists who require such models for applications such as flood forecasting, wastewater flow rate forecasting, and water table elevation prediction and such models have received considerable attention in the hydrological literature [1], [11,12], [19-21]. However, the rainfall-flow process is clearly dynamic, with non-linear characteristics. Since the 'antecedent' rainfall conditions clearly affect the subsequent flow behavior, the physical process involved should be non-linear. In particular, if the prior rainfall has been sufficient to thoroughly wet the soil in the catchment area then river-flow will be significantly higher than the condition when the soil had been dried out due to lack of rainfall. Such 'soil moisture' nonlinearity is well known in hydrology, and various models have been proposed in the past based on the antecedent precipitation index approach [2] to construct large deterministic catchment simulation models such as the Stanford watershed model.

The non-linear rainfall filter [5] can be used to produce a rainfall excess or 'effective rainfall' which takes into account both short-term conditions, mainly the soil moisture status, and long term effects such as evapotranspiration and storage. The rainfall filter model involves three simple operations

(i) A modulation of the measured rainfall *r(k)* at time step *k* by a temperature dependent factor to compensate for evapotranspiration losses. This is given by

$$r^*(k) = t_m^{-1}(t_m - t_k)r(k) \qquad (8)$$

(ii) An adjustment which allows for antecedent precipitation effects on the soil moisture

$$s(k) = s(k-1) + \tau^{-1}(r^*(k) - s(k-1) \qquad (9)$$

iii) The effective rainfall

$$u_e(k) = Const\,.\,r^*(k)s(k) \qquad (10)$$

where *r(k)* is the rainfall, *s(k)* is a measure of soil moisture, (t_m- t_k) is the difference between the overall maximum temperature t_m, and the monthly mean temperature t_k, for the month in which the k^{th} observation is taken, *r*(k)* is a transformed measure of rainfall which allows for temperature induced evapotranspiration effects, *r* is a constant to be optimized. This is an optimum estimate of the time constant, which is introduced to exponentially weight the past effects of antecedent precipitation index, which is obtained by an interactive optimization procedure.

The success of the modeling technique of [2,5] critically depends on the information regarding the temperature and moisture of the soil. However, in certain cases due to practical limitations the possibilities of obtaining the information about the temperature and moisture

are difficult. An alternative method proposed by [8] can be used when no information concerning temperature and moisture is available.

4.2.1 Effective Rainfall flow Model

The effective rainfall $u_e(k)$ is defined as the product between the observed rainfall $r(k)$ and the delayed flow $y(k-\delta)$. The overall relationship between the effective rainfall $u_e(k)$ and the flow $y(k)$ is given by the following 'bilinear' model

$$u_e(k) = r(k)\ y(k-\delta) \qquad (8)$$

$$y_d(k) = [b_m(z^{-1}) / a_n(z^{-1})]u_e(k) \qquad (9)$$

$$y(k) = y_d(k) + \xi(k) \qquad (10)$$

Where $y_d(k)$ is the deterministic, noise-free output of the system model and $\xi(k)$ are the noise terms.

A rainfall filter technique as mentioned above was used to generate effective rainfall data. Experience with such a model suggests that the best value for the delay δ in equation (8) is 2. A model was fitted taking the effective rainfall at station 1 as input and flow at station 3 as output.

The model was estimated for an initial specification of l=1, n_u=2, n_y=6, and n_ξ=10.The input to the model is the effective rainfall which is defined as the product between the measured rainfall and the delay river-flow as emphasized in equation (8). Therefore the relationship between effective rainfall and river-flow is the bilinear non-linear model. Comparing the one-step ahead model output and system output revealed that the model output was perfectly superimposed on the data set of the system output. Inspection of the one-step ahead predicted output equation (4) suggested that this may not be a good metric to use for prediction. At each step the model is effectively reset by inserting the appropriate values of the right hand side in equation (4). Any errors in the prediction are therefore reset at each step and consequently even a poor model can produce reasonable one-step ahead predictions. In reality the generated model (the predicted output) should be used to predict the system response into the future or over different data sets. The model predicted output as defined in equation (6) which is a far better indicator of the model performance can be used in these situations. The model predicted output was shown to be reasonable except around data point 250 where the flow rapidly changes. The model validity tests are shown to be acceptable.

The model was then used to predict over the next year (1969) data set. The plots of the predicted output over the prediction data set illustrated (Figures 1 and 2) that the model was reasonable, because the basic trend was followed.

4.3 Multi-Input Single-Output Modeling

There are four inputs and a single output for this system. The first input, u_1 is the flow at station 1, the second input, u_2 is the flow station 2, the third input, u_3 is the local rain at station 1, and the fourth input, is u_4 the local rain at station 2. The flow at station 3 is defined as output y_1.

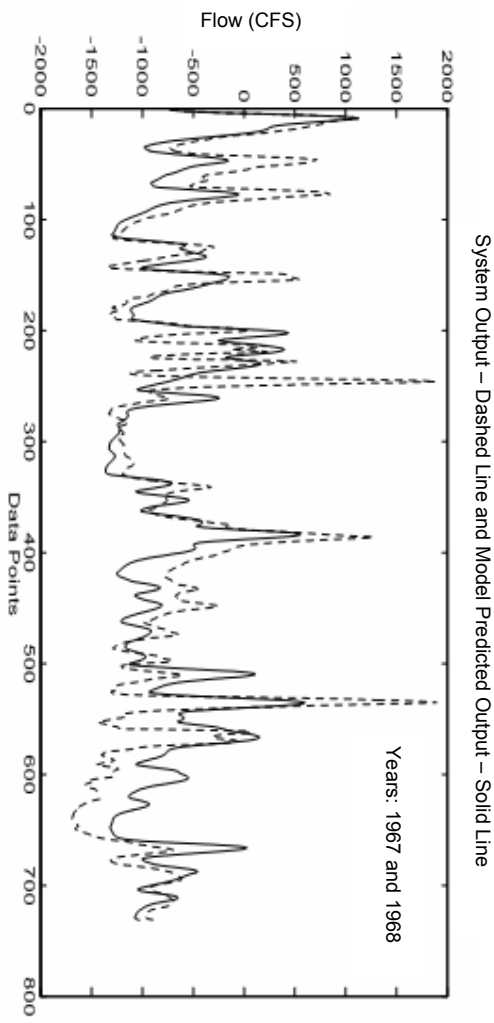


Figure 1. Plots of the Model Predicted Output of the Effective Rainfall-flow Model Superimposed over the Estimation Data Set.

4.3. 1 Linear Multi-Input Single-Output Model

The investigation of single-input single-output models presented before suggested that there may be benefits in transforming the data before fitting a model. This was investigated, and improved single-input single-output linear model were developed. The model was estimated over the data set for an initial model specification of l=1, $n_{u(t-4)}$ = n_y = n_ζ = 15.The model predicted output was in agreement with the data set of the system output. This model was then used to predict over the next years data set and the model predicted output followed the data quite well. The model validity tests illustrated some correlations outside the 95% confidence band suggesting that there are probably missing terms in the model. The next stage in the modeling process was to increase the degree of nonlinearity to obtain a second order non-linear multi-input single-output model.

4.3.2 Non-linear Multi-Input Single-Output Model

Although the model predicted output and model validation tests looked good for the linear model so far, the validity tests, on the other hand, were still outside the confidence limits indicating that the estimation may be biased. The introduction of

non-linear multi-input single-output models was therefore considered to see if there would be any improvement in the modeling.

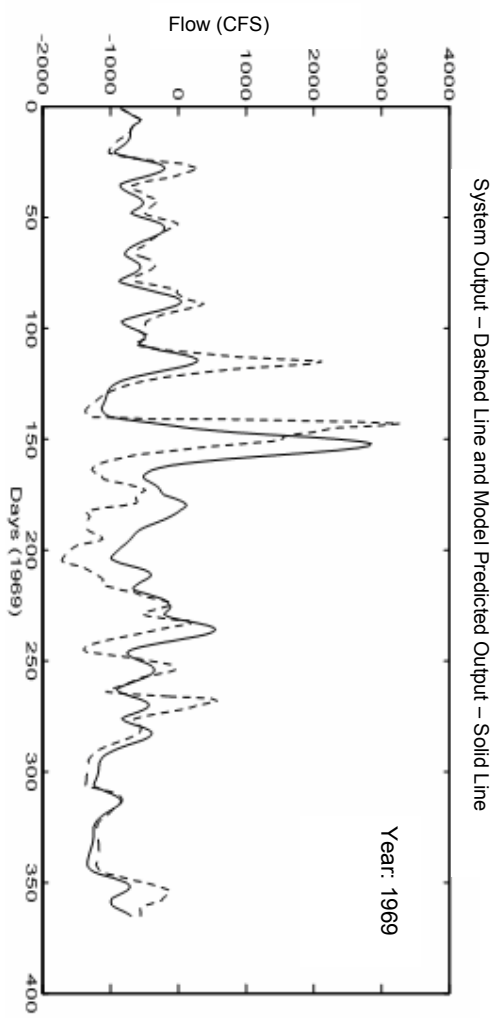


Figure 2. Plots of the Model Predicted Output of the Effective Rainfall-flow Model Superimposed over the Validation Data Set.

The estimated model was observed for an initial specification of *l=2, $n_{u(t-4)}$ = n_y = 12 and n_ζ = 17*, The model predicted output superimposed on the system output is shown in Figure 3. The model was used to predict over the test data set (1969) and this is shown in Figure 4.

The model validity tests indicate that the model is now acceptable. Although $\varphi_{u^2\xi}(k)$ and $\varphi_{u^2\xi^2}(\tau)$ are still slightly outside the confidence bands at higher lags, the contributions of these effects are perhaps insignificant as illustrated by the good model predicted output superimposed on the actual one as shown in Figure 3 and 4.

5. CONCLUSION

Models have been estimated using an orthogonal least square (OLS) algorithm. The error reduction ratio test and model validity tests which were used to construct a valid model, and comparison of the model predicted output with the actual system output over both the estimation and test data sets were employed to measure the model performance. The statistical properties of the data have been fully analyzed to get a priori knowledge of system in providing valuable information during system modeling. Several river-flow models including both linear and non-linear models have been fitted to the river-flow data and the predictive performance of the final model is quite satisfactory.

Fitting a good model using rainfall flow data is more difficult compared with river-flow data. The effective rainfall concept offers a possible solution to get a good model from the rainfall data. Models have been fitted using this concept to give some improvements to the model. However, the model validity tests suggested that there were missing model terms. This may be due to the difficulty involved in fitting models to rainfall flow data in which there are so many unknown factors, for example temperature, soil moisture, evapotranspirative parameter, etc.

Finally, a multi-input single-output system model was fitted. Although $\varphi_{u^2\xi}(\tau)$ and $\varphi_{u^2\xi^2}(\tau)$ were still just outside the confidence bands at higher lags, the contributions of these effects are perhaps insignificant. The excellent model predicted output and cross validation tests reveal that the multi-input single-output second order NARMAX model could be used to sufficiently represent the multi-input single-output river-flow system.

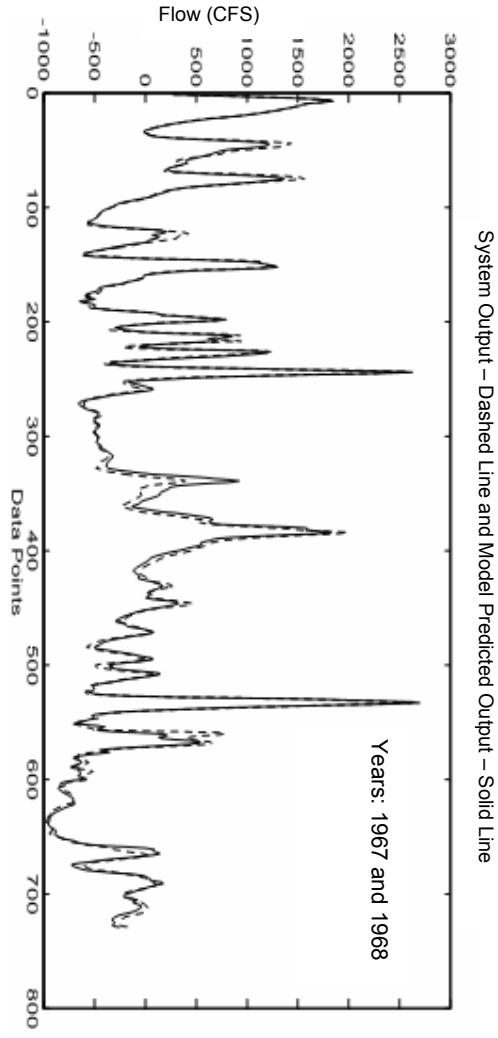


Figure 3. Plots of the Model Predicted Output of the Non-linear Multi-input Single-output Model Superimposed over the Estimation Data Set.

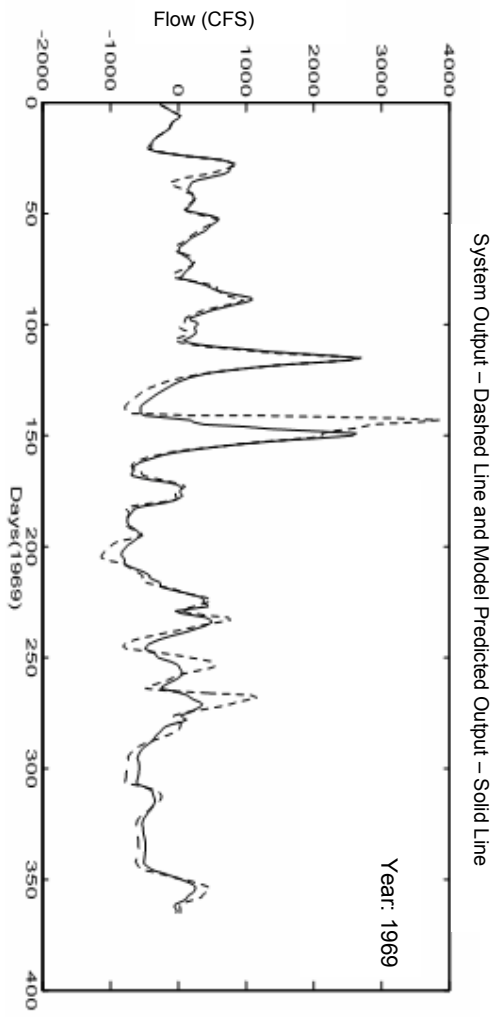


Figure 4. Plots of the Model Predicted Output of the Non-linear Multi-input Single-output Model Superimposed over the Validation Data Set.

REFERENCES

[1] Fkirln, M.A., "Fixed-point smoothing in the flow prediction of widely varying catchment dynamics", *Int. J. Syst Sci*, 21, 1990, pp. 2029-2035.

[2] Liang, G.C., O'Connor, K.M. and Kachroo, R.K., "A multiple-input singleoutput variable gain factor model", *J. Hydrol*., 1994, pp. 155-185.

[3] Tan, P.C. Berger, C.S., Dabke, K.P. and Mein, R.G., "Recursive identification and adaptive prediction of wastewater flows", *Automatica*, 27. 1991, pp. 761 - 768.

[4] Jakeman, A.J., Littlewood, I.G. and Whitehead, P.G., "Computation of the instantaneous unit hydrograph and identifiable component flows with application to two small upland catchments", *J. Hydrol*., 117, 1990, pp. 275 -300.

[5] Tong, H., "Threshold models in non-linear time series analysis", *Springer Verlag*, 1983.

[6] Tong, H., "Non-linear time series, a dynamical system approach", *Clarendon Press, Oxford,* 1990.

[7] Young, P. and Beven, K., "Computation of the instantaneous unit hydrograph and identifiable component flows with application to two small upland catchments – Comment", *J. Hydrol*, 129, 1991, pp. 389 - 396.

[8] Billings, S.A. and Tsang, K.M., "Spectral analysis for non-linear systems, part I: Parametric non-linear spectral analysis", *Mechanical Systems and Signal Processing*, 3, 1989a, pp. 319 - 339.

[9] Chen, S. and Billings, S.A., "Representation of nonlinear systems. The NARMAX model", *Int. J. Control*, 49, 1989, pp. 1013-1032.

[10] Billings, S.A. and Tsang, K.M., "Spectral analysis for non-linear systems, part II: Interpretation of non-linear frequency response functions", *Mechanical Systems and Signal Processing*, 3, 1989b, pp. 341 - 359.

[11] Tabrizi, M.H.N. Jamaluddin, H., Billings, S.A. and Skaggs, R.W., "Use of identification techniques to develop a water table prediction model", *Trans. ASAE*, 33, 1990, pp. 1913-1918.

[12] Tabrizi, M.H.N., Copperthwaite, L., Billings, S.A., "Influent flow Modeling using Identification Techniques", *Int. J. of Modeling and Simulation*, 21, 2001, pp. 1-9.

[13] Tabrizi, M.H.N., Taib, M.N., Billings, S.A., "Nonlinear Model Estimation of the Regulated Stream flow system", *Journal of Rivers,* 7, 2000, pp. 126-137.

[14] Bendat, J.S. and Piersol, A.G., "Random data, analysis and measurement procedures", *John Wiley and Sons*, 1991.

[15] Box, G.E.P., and Jenkins, G.M., "Time series analysis Forecasting and control", *Holden-day San Francisco*, 1970.

[16] Marmarells, P.Z. and Marmarells, V.Z., "Analysis of physiological systems: The white-noise approach", *Plenum Press*, 1980.

[17] Priestley, M.B., "Non-linear and non-stationary time series analysis", *Academic Press Limited,* 1988.

[18] Ozaki, T., "Statistical identification of storage models with application to stochastic hydrology", *Water Resources Bulletin*, 21, 1985, pp. 663- 675.

[19] Ashan, M. and O'Connor, K.M., "A simple non-linear Rainfall-runoff model with a variable gain factor", *J. Hydrol*, 155, 1994, pp. 151 - 183.

[20] Ikeda, S., Ochial, M. and Sawaragi, Y. "Sequential GMDH algorithm and its application to river-flow prediction", *IEEE Trans. on Syst. Man, Cybernetics, SMC*-6, 1976, pp. 473 - 479.

[21] Foss, B., Haug, J.E. and Alne, J., "User experience with on-line predictive river flow regulation", *IEEE Trans. on Power Syst*, 4, 1989, pp. 1089-1094.

Thermal Wave Propagation Phenomenon in Thin Film Subjected to Symmetrical Temperature Change

Torii, Shuichi; and Wen-Jei, Yang

Abstract— ***Numerical study is performed on thermal propagation in a very thin film subjected to a symmetrical temperature change on both sides by means of molecular dynamics method. Numerical result is compared with the other numerical one which is obtained from the non-Fourier, hyperbolic heat conduction equation using a numerical technique based on MacCormak's predictor-corrector scheme. Consideration is given to the time history of thermal wave before and after symmetrical collision of wave fronts from both sides of a film. It is disclosed that (i) in transient heat conduction, thermal wave front is transported as a wave in the film, (ii) substantial temperature amplification causes within a very short period of time, and (iii) the heat-affected and undisturbed zones are found to be caused by the atomic movement and in particular the temperature overshoot is induced by the substantial amplification of the atom movement in the film.***

Index Terms— ***molecular dynamics, thermal shock wave, thermal propagation***

1. INTRODUCTION

The classical theory of heat conduction is based on the Fourier's law. This implies that heat conduction in materials is usually treated as a diffusion process in which the effect of a thermal disturbance is transmitted throughout the materials with an infinite velocity. Although infinite transmission speeds and an instantaneous steady-state heat flux are not physically accurate, Fourier's law gives quite reliable results in most practical heat transfer applications. When the elapsed time during a transient is extremely small, the classical Fourier's heat conduction equation breaks down at temperatures near absolute zero or at moderate temperatures. This is because the wave nature of thermal propagation is dominant, that is, a thermal disturbance travels in the medium with a finite speed of propagation [1, 2, 3, 4]. Several issues of basic scientific interest arise in cases such as laser penetration and welding, explosive bonding, electrical discharge machining, and heating and cooling of micro-electronic elements. In particular, the issue of energy transfer into a lattice and resulting temperature in the lattices during such a short period of time and over such a tiny region is of fundamental importance, but remains a matter of controversy [5].

The phenomena are physically anomalous and can be remedied through the introduction of a hyperbolic equation based on a relaxation model for heat conduction which accounts for a finite thermal propagation speed. Recently, considerable interest has been generated toward the hyperbolic heat conduction (HHC) equation and its potential applications in engineering and technology. Some researchers studied wave characteristics and finite propagation speeds in transient heat transfer conduction [3, 6, 7, 8, 9, 10]. Baumeister and Hamill [1] studied thermal wave in a semi-infinite solid subjected to a suddenly applied temperature at the wall. Kao [11] investigated the temperature wave across tin-film media. Carey and Tsai [12] analyzed a one-dimensional case for a propagating heat wave reflected at a boundary. A similar study was carried out by Maurer and Thompson [4], who emphasized the importance of the wave effect in response to a high heat flux irradiation. Glass et al. [13] developed a numerical technique based on MacCormack's predictor-corrector scheme capable of predicting the wave front propagating in materials and its discontinuity. Glass et al. [14] applied the same method to the hyperbolic Stefan problem with a heat flux boundary condition and temperature dependent thermal conduction and obtained the interface position and the temperature distribution in a semi-infinite slab. Frankel et al. [15] developed a general three-dimensional constant property heat flux formulation based on the hyperbolic heat conduction approximation. Tan and Yang [16] investigated heat transfer resulting from a symmetrical collision of thermal waves induced by a step change in the wall temperature of the thin film by means of the method of separation of variables. Results were obtained for the time history of the propagation process, magnitude and shape of the thermal waves, and the range of film thickness and duration time. By using the same method, Tan and Yang [17] predicted the wave

Manuscript received February 1, 2006.

T. Shuichi is with the Department of Mechanical Engineering and Material Science, Kumamoto University, Japan (e-mail: torii@mech.kumamoto-u.ac.jp).

W.-J. Yang is with the University of Michigan, USA.

nature of heat propagation in a very thin film subjected to an asymmetrical temperature change on both sides. Furthermore, Tan and Yang [18] treated heat propagation in a very thin film subjected to an exponentially decaying temperature change on both sides. The corresponding numerical analysis is performed by Torii [19], who employ MacCormak's predictor-corrector scheme to solve the non-Fourier, hyperbolic heat conduction equation. Pulvirenti et al. [20] also investigated a numerical evaluation of the temperature field in an infinite solid medium, in which the thermal conductivity and specific heat of the solid medium are considered as temperature-dependent. The similar problem, i.e., thermal wave propagation phenomena in thin solid films with temperature-dependent thermal conductivity is also studied by Torii and Yang [21].

In general, heat conduction is one of the energy transfer mechanisms of molecules through kinetic motion and potential interaction, while the energy transfer of solid materials will be dominated by potential interaction. Even in molecular collisions, the final process of energy transfer should be controlled by potential interaction. Thus, in order to disclose the detailed physical mechanism of the thermal phenomena, the molecular dynamics method, which solves the movement of atoms or molecules directly without a relation formula between heat flux and temperature, is capable of revealing the thermal propagation phenomena. For example, Kotake and Wakui [22] investigated the process of heat conduction in solid materials by using the molecular dynamics simulation.

This paper treats wave behavior during transient heat conduction in a very thin film (solid plate) subjected to a symmetrical temperature change on both side surfaces. Numerical solutions are obtained by means of the molecular dynamics equation and hyperbolic heat conduction equation. The aim of the study is to compare results of atomistic and HHC macroscopic models. Emphasis is placed on the thermal propagation in the solid medium.

2. Formulation and Numerical Method

2-1 Molecular dynamics equation

Thermal propagation in nanoscale fcc metal (as aluminum) is analyzed. At *t=0*, the temperature within medium is uniform. For *t>0*, two opposite wall sides are suddenly heated at the same temperature. It is assumed that radiation is negligible and there is no effect of the inner heat source. The physical configuration and the coordinate system are shown in Fig. 1.

In molecular dynamics simulation, Newton's equation of motion for atoms or molecules can be written using Hamilton's mechanics relationship as:

$$m_i \frac{d^2\mathbf{r}_i}{dt^2} = \sum_{j\neq i}\mathbf{F}_{ij} = -\frac{d}{dr_{ij}}\sum_{j\neq i}\Phi(\mathbf{r}_{ij}) \ , \qquad (1)$$

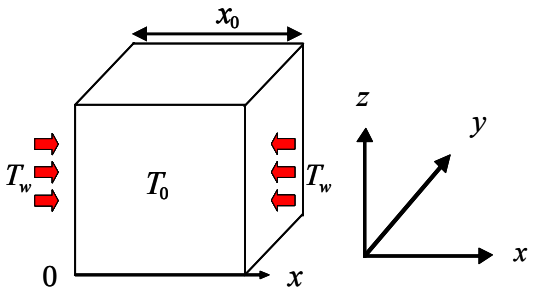


Figure 1. Physical configuration and coordinate system.

where $\mathbf{r}_i$, m_i and $\mathbf{F}_{ij}$ denote the position, mass and force between the particles *I* and *j*, respectively. *t* and $\Phi(\mathbf{r}_{ij})$ represent the time and the potential between two atoms *i* and *j*, respectively. $\mathbf{r}_{ij}$ is the distance between *i* and *j* atoms, i.e., $\mathbf{r}_{ij}=\mathbf{r}_i-\mathbf{r}_j$. In this paper, Morse potential, which is commonly useful for solid-solid metals interaction, is used as a potential function:

$$\Phi(\mathbf{r}_{ij}) = De^{-2A(r_{ij}-r_0)} - 2De^{-A(r_{ij}-r_0)} \ . \qquad (2)$$

Here, D, A, and r_0 are the physical constants. The position and velocity vector of atoms or molecules were solved by Verlet Method, in which the position is determined by a second-order accurate explicit difference equation at 0-1 step as:

$$\mathbf{r}_i(t+\Delta t) = \mathbf{r}_i(t) + \Delta t\mathbf{v}_i(t) + \Delta t^2 a_i(t)/2 \qquad (3)$$

$$\mathbf{r}_i(t+\Delta t) = 2\mathbf{r}_i(t) - \mathbf{r}_i(t-\Delta t) + (\Delta t)^2\sum_{j\neq}\frac{\mathbf{F}_{ij}(t)}{m_i} \qquad (4)$$

$$\mathbf{v}_i(t) = \frac{1}{2\Delta t}\{\mathbf{r}_i(t+\Delta t) - \mathbf{r}_i(t-\Delta t)\} \qquad (5)$$

where, $\mathbf{v}_i$ is the velocity vector in the i direction. The local temperature *T* can be obtained based on the Maxwell's velocity law as:

$$T(t) = \frac{2}{3Nk_B}\left[\frac{1}{2}\sum_{n=1}^{N} m\left\{v_x^2(t)+v_y^2(t)+v_z^2(t)\right\}\right] \qquad (6)$$

where *N* is the atomic number and k_B is the Boltzmann constant k (=1.3805×10-23 [J/K]). Here, N=1,000,000,000 is employed.

Extra spaces are added above and below the target, which allow the macro-motion of atoms in the x direction, as shown in Fig. 1. Periodic boundary conditions are implemented on boundaries in the y and z directions, and free boundary conditions on boundaries in the x direction. The first step of the calculation is to initialize the system to thermal equilibrium before heating start, which is achieved by a thermal

equilibrium calculation. In this calculation, before heating start, the target is initially constructed based on the fcc lattice structure of the aluminum. The values the parameters used in the simulation are listed in Table 1.

Table 1. Parameter of aluminum

D	0.2703	[eV]*
A	1.1646	[Å^{-1}]*
r_0	3.253	[Å]*
m	26.981539/(6.02252×10^{23})	[g]
k_B	1.38062×10^{-23}	[J/K]
s	2.6578	[Å]
r_c	6.6445	[Å]

2-2 Linearized thermal wave theory

Consider a very thin film with thickness of x_0 maintained at a uniform, initial temperature T_0, as mentioned in the above section. The walls at x=0 and x_0 are suddenly heated at a same temperature T_w. Under the conditions, the constitutive equation used in the linearized thermal wave theory [9] is expressed as

$$\tau \frac{\partial q(t,x)}{\partial t} + q(x,t) + k \frac{\partial T(t,x)}{\partial x} = 0 \tag{7}$$

Note that the relaxation time τ defined as $\tau=\alpha/C^2$ is assumed to be constant, where C is the speed of "second sound" (thermal shock wave) and α and k are thermal diffusivity and thermal conductivity, respectively. In the one-dimensional flow of heat, the energy equation in the absence of the heat generation reads:

$$\rho c_p \frac{\partial T(t,x)}{\partial t} + \frac{\partial q(t,x)}{\partial x} = 0 \tag{8}$$

Attention is focused on a film with thickness of x_0 maintained at a uniform, initial temperature T_0. The walls at x=0 and x_0 are suddenly heated with uniform wall temperature. In the present study, radiation is assumed to be negligible. The initial and boundary conditions to be imposed here are given by

$T = T_0$ at t = 0, 0 < x < x_0
$T = T_w$ at t > 0, x = 0 and x = x_0

The following dimensionless quantities are introduced: dimensionless temperature, dimensionless heat flux, and dimensionless time and space:

$$\theta(\xi,\eta) = \frac{T - T_0}{T_W - T_0} \tag{9}$$

$$Q(\xi,\eta) = \frac{\alpha_0 q}{(T_w - T_0) k_0 C_0} \tag{10}$$

$$\xi = \frac{C_0{}^2 t}{2\alpha_0} \tag{11}$$

$$\eta = \frac{C_0 x}{2\alpha_0} \tag{12}$$

Here α_o and C_o is thermal diffusivity and specific heat at initial temperature T_0, respectively. Equations (7) and (8) can be expressed in terms of the above dimensionless variables as:

$$\frac{\partial Q(\xi,\eta)}{\partial \xi} + 2Q(\xi,\eta) + \frac{\partial \theta(\xi,\eta)}{\partial \eta} = 0 \tag{13}$$

and

$$\frac{\partial Q(\xi,\eta)}{\partial \eta} + \frac{\partial \theta(\xi,\eta)}{\partial \xi} = 0 \tag{14}$$

respectively. The initial and boundary conditions become:

θ= 0, Q = 0 at ξ=0, 0<η=η_0
θ= 1.0, $\frac{\partial Q}{\partial \eta} = 0$, at ξ>0, η=0 and η=η_0

where, $\eta_0 = \frac{C_0 x_0}{2\alpha_0}$

Note that the boundary condition of Q at ξ > 0 is derived from Eqs. (7) and (8).

In general, investigators have combined the flux and energy equations (i.e., Eqs. (7) and (8)) into a single second-order partial differential equation to solve the HHC problem. For this solution method, Glass et al. [13] disclosed that MacCormack's method [23], which is a second-order accurate explicit scheme, can handle these moving discontinuities quite well and is valid for HHC problems. The hyperbolic problems considered in the present study have step discontinuities at the thermal wave front. MacCormack's prediction-correction scheme is therefore used. When the HHC problem is numerically solved through the scheme employed here, it is convenient to solve Eqs. (7) and (8) separately rather than combining them into a single second-order partial differential equation [13]. When MacCormack's method is applied to Eqs. (10) and (11), the following finite difference formulation results:

Predictor:

$$\overline{\theta_i^{n+1}} = \theta_i^n - \frac{\Delta\xi}{\Delta\eta}\left(Q_{i+1}^n - Q_i^n\right) \tag{15}$$

$$\overline{Q_i^{n+1}} = Q_i^n - \frac{\Delta\xi}{\Delta\eta}\left\{\theta_{i+1}^n - \theta_i^n\right\} - 2\Delta\xi\, Q_i^n \tag{16}$$

Corrector:

$$\theta_i^{n+1} = \frac{1}{2}\left\{\theta_i^n + \overline{\theta_i^{n+1}} - \frac{\Delta\xi}{\Delta\eta}\left(\overline{Q_i^{n+1}} - \overline{Q_{i-1}^{n+1}}\right)\right\} \quad (17)$$

$$Q_i^{n+1} = \frac{1}{2}\left[Q_i^n + \overline{Q_i^{n+1}} - \frac{\Delta\xi}{\Delta\eta}\left\{\overline{\theta_i^{n+1}} - \overline{\theta_{i-1}^{n+1}}\right\} - 2\Delta\xi\overline{Q_i^{n+1}}\right] \quad (18)$$

Here, the subscript i denotes the grid points in the space domain, superscript n denotes the time level, and $\Delta\eta$ and $\Delta\xi$are the space and time steps, respectively. The circumflex terms, i.e., $\overline{Q_i^{n+1}}$, $\overline{\theta_i^{n+1}}$, etc. are a temporary predicted value at the time level n+1.

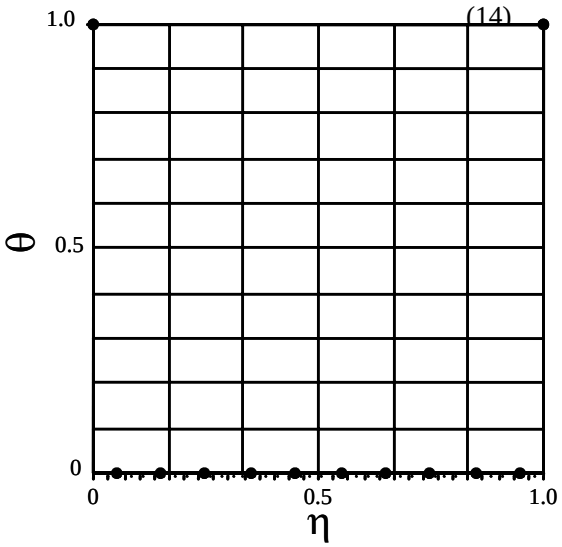
Computations are processed in the following order:

1. Specify the values of Q and θ at ξ=0, i.e., the initial values.
2. Solve Eqs. (15) and (16) for θ and Q to obtain temporary predicted value at the time level n+1.
3. Calculate new values of θ and Q at the time step n+1 using Eqs. (17) and (18).
4. Repeat steps 2-3 until n reaches a desired time level from the onset of calculation.

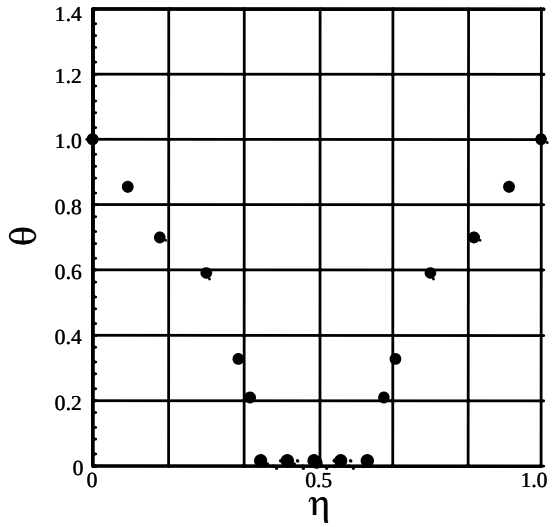
Throughout numerical calculations, the number of grids is properly selected between 1,000 and 5,000 to obtain a grid-independent solution. This results in no appreciable difference between the numerical results with different grid spacing, in which the dimensionless temperature distributions in a film are depicted with different grid size, as the parameter. In solving the governing equations employed here, i.e., the HHC problem including the nonlinear nature, the stability is affected by the ratio of $\Delta\xi$ to $\Delta\eta$, $\Delta\xi/\Delta\eta$, which is called the Courant number [24]. For example, as the Courant number becomes smaller, the effect of odd derivative truncation-error terms becomes larger, and oscillations occur in the vicinity of discontinuities in the solution. Therefore, $\Delta\xi/\Delta\eta$ is fixed at 0.98 in the present study.

3. RESULTS AND DISUCUSSION

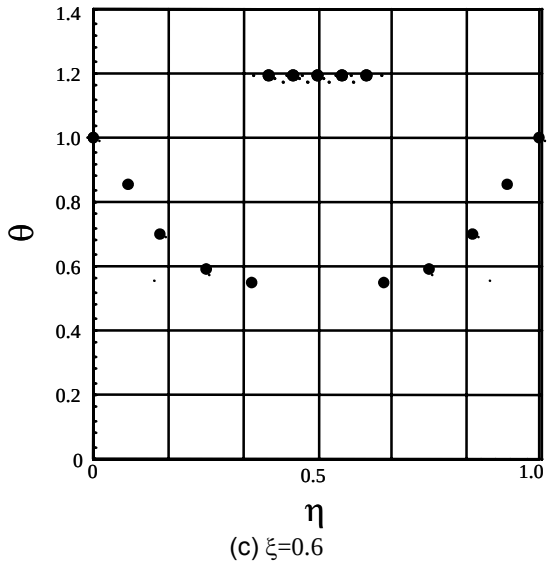
Figure 2 illustrates the temperature distribution in the film at different time. Here, the solid circle implies the temperature at the molecular location used here, but all molecular locations are not shown. One observes that after the wall temperature on two sides is suddenly raised, the film temperature is increased as time progresses and there are the area of the temperature amplification and its no effect area in the film. This implies that a thermal disturbance is transmitted throughout the film with a finite velocity, whose nature can not be predicted by the Fourier's law. In other words, the thermal propagation is in contrast to the diffusion nature, which is dominated based on the Fourier's law. It should be noticed that the film temperatures in the vicinity of both sides of strongly heated walls exceed the imposed wall temperature at ξ=0.6, as seen in Fig. 2(c). These temperature characteristics become clearer for the atomic behavior in the film.



(a) ξ=0.0

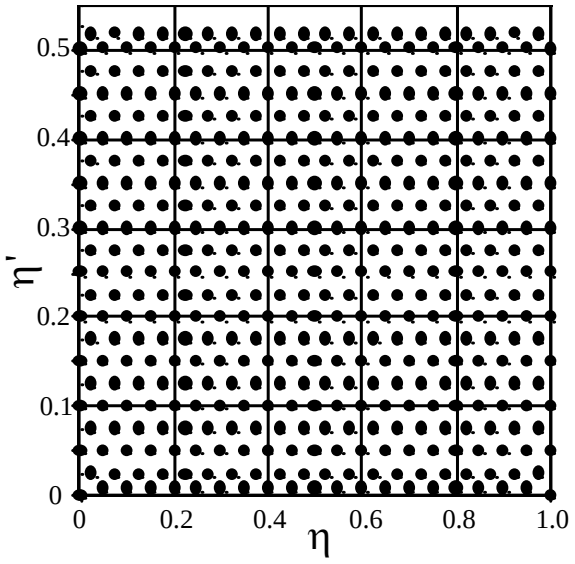


(b) ξ=0.4

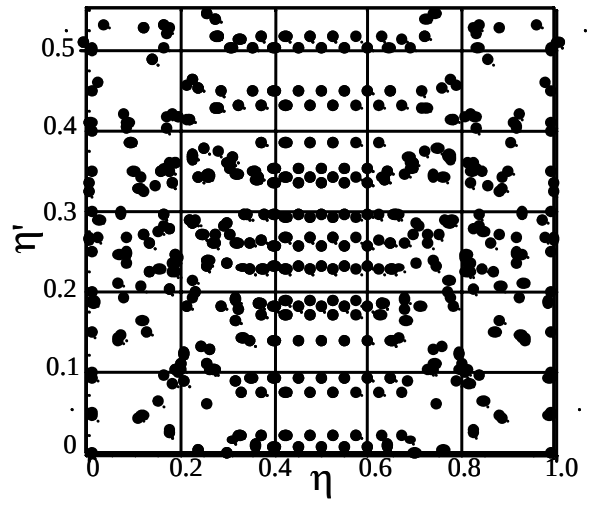


(c) ξ=0.6

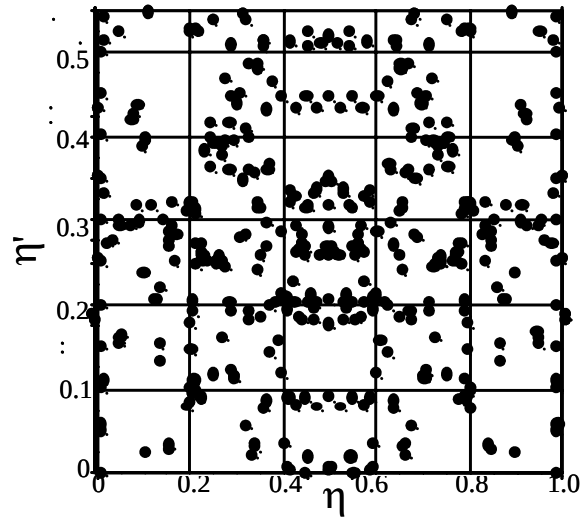
Figure 2. Temperature distribution in the thin film.



(a) ξ=0.0



(b) ξ=0.4



(c) ξ=0.6

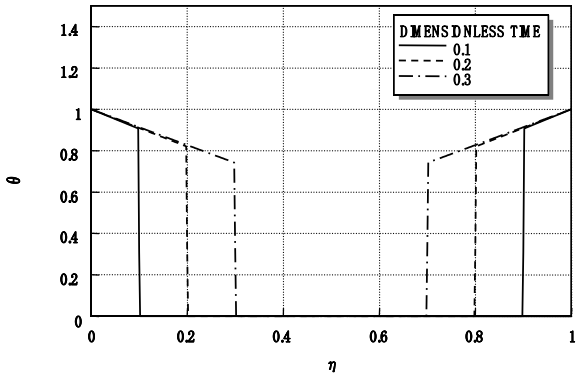
Figure 3. Atomic behaviour in thin film.

The corresponding atom distribution is depicted in Fig. 3 with the initial atomic location shown in Fig. 3(a) for reference. Notice that all atom locations are not depicted in Fig. 3, because the atom movement becomes clearer. Here, $\eta'=C_0z/2\alpha_0$ and the atomic location implies the average value along y axis at each η location. It is observed that at ξ=0.4, the atoms move near both heated side walls, while no movement of the atoms appears in the central zone of the film. At ξ=0.6, the substantial movement of the atoms yields over the whole file area, resulting in occurrence of the temperature overshoot, as seen in Fig. 2(c).

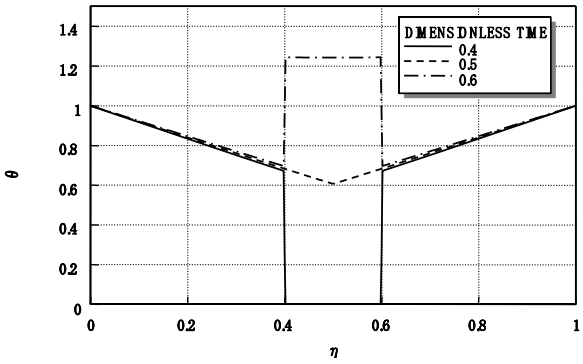
Figures 4(a) and (b) illustrate the timewise variation of the temperature distribution, θ, in a film having η=1. They are obtained by means of a numerical technique based on MacCormak's predictor-corrector scheme to solve the non-Fourier, hyperbolic heat conduction equation and correspond to numerical predictions before and after collision of thermal wave fronts, respectively. Note that Fig. 4 reproduces precisely the theoretical results of Tan and Yang [17], which show in detail the propagation process of thermal waves in a film. Figure 4(a) depicts that after the wall temperatures on both sides are suddenly raised, a set of sharp wavefronts appears in the thermal wave propagation and advances towards the center in the physical domain which separates the heat-affected zone from the thermally undisturbed zone. Here both zones are caused by the active movement and no movement of the atoms, as seen in Fig. 3(b). It is observed in Fig. 4(b) that after first collision, the center temperature in a film causes a significant amplification, resulting in much higher temperature in this region, which is induced by the substantial movement of the atoms (Fig. 3(c)). A temperature overshoot is predicted by the molecular dynamic simulation, as shown in Fig. 2(c). The numerical solution predicts the existence of thermal waves, particularly in a very thin film and presents the propagation process of thermal waves, the magnitude and shape of thermal waves.

4. SUMMARY

It is revealed that if a film is strongly heated, a temperature overshoot takes place in the film of smaller thickness within a very short period of time. The transient temperature distribution is simulated for heat conduction process in nano-scale structure using the molecular dynamics equation and hyperbolic heat conduction equation, that is by means of atomistic and HHC macroscopic models. The heat-affected and undisturbed zones are found to be caused by the atomic movement and in particular the temperature overshoot is induced by substantial amplification of the atom movement in the film.



(a) Before collision of thermal wavefronts



(b) After collision of thermal wavefronts

Figure 4. Temperature distribution predicted by non-Fourier, hyperbolic heat conduction equation.

REFERENCES

[1] Baumeister, K. J. and Hamill, T. D., "Hyperbolic Heat Conduction Equation - A Solution for the Semi-Infinite Body Problem," Journal of Heat Transfer, Vol. 91, 1969, pp. 543-548.

[2] Chan, S. H. Low, J. D. and Mueller, W. K., "Hyperbolic Heat Conduction in Catalytic Supported Crystallites," AIChE Journal, Vol. 17, 1971, pp. 1499- 1507.

[3] Kazimi, M. S. and Erdman, C. A., "On the Interface Temperature of Two Suddenly Contacting Materials," Journal of Heat Transfer, Vol. 97, 1975, pp. 615-617.

[4] Maurer, M. J. and Thompson, H. A., "Non-Fourier Effects at High Heat Flux," Journal of Heat Transfer, Vol. 95, 1973, pp. 284-286.

[5] Bloembergen, N. Kurz, H. Kiu, J. M. and Yen, R., "Fundamentals of Energy Transfer during Picosecond Irradiation of Silicon, in Laser and Electron-Beam Interactions with Solids, Elsevier Science Publishing Co., Inc., New York, 1982, pp. 3-20.

[6] Wiggert, D. C., "Analysis of Early-Time Transient Heat Conduction by Method of Characteristics," Journal of Heat Transfer, Vol. 99, 1977, pp. 35-40.

[7] Vick, B. and Ozisik, M. N., "Growth and Decay of a Thermal Pulse Predicted by the Hyperbolic Heat Conduction Equation," Journal of Heat Transfer, Vol. 105, 1983, pp. 902-907.

[8] Ozisik, M. N. and Vick, B., "Propagation and Reflection of Thermal Waves in a Finite Medium," International Journal of Heat Mass Transfer, Vol. 27, 1984, pp. 1845-1854.

[9] Ozisik, M. N. and Tzou, D. Y., "On the Wave Theory in Heat Conduction," Journal of Heat Transfer, Vol. 116, 1994, pp. 526-535.

[10] Yuen, W. W. and Lee, S. C., "Non-Fourier Heat Conduction in a Semi-Infinite Solid Subjected to Oscillatory Surface Thermal Disturbances," Journal of Heat Transfer, Vol. 111, 1989, pp. 178-181.

[11] Kao, T. T., "Non-Fourier Heat Conduction in Thin Surface Layers," Journal of Heat Transfer, Vol. 99, 1977, pp. 343-345.

[12] Carey, G. F. and Tsai, M., "Hyperbolic Heat Transfer with Reflection," Numerical Heat Transfer, Vol. 5, 1982, pp. 309-327.

[13] Glass, D. E. Ozisik, M. N. McRae, D. S. and Vick, B., "On the Numerical Solution of Hyperbolic Heat Conduction," Numerical Heat Transfer, Vol. 8, 1985, pp. 497-504.

[14] Glass, D. E. Ozisik, M. N. Kim, W. S., "On the Numerical Solution of Hyperbolic Heat Conduction," Numerical Heat Transfer, Vol. 18, 1990, pp. 503-516.

[15] Frankel, J. I., Vick, B. and Ozisik, M. N., "Flux Formulation of Hyperbolic Heat Conduction," Journal of Applied Physics, Vol. 58, 1985, pp. 3340-3345.

[16] Tan, Z. M. and Yang, W.-J., "Non-Fourier Heat Conduction in a Thin Film Subjected to a Sudden Temperature Change on Two Sides," Journal of Non-Equilibrium Thermodynamics, Vol. 22, 1997, pp. 75-87.

[17] Tan, Z. M. and Yang, W.-J., "Heat Transfer during Asymmetrical Collision of Thermal Waves in a Thin Film," Int. J. Heat Mass Transfer, Vol. 40, No. 17, 1997, pp. 3999-4006.

[18] Tan, Z. M. and Yang, W.-J., "Propagation of Thermal Waves in Transient Heat Conduction in a Thin Film," Journal of Non-Equilibrium Thermodynamics, Vol. 22, pp. 1997, pp. 1354-1365.

[19] Torii, S., "Propagation Phenomena during Symmetrical Collision of Thermal Waves in Thin Film," International Journal of Transport Phenomena, Vol. 3, 2001, pp. 357-364.

[20] Pulvirenti, B., Barletta, A., and Zanchini, E., "Finite-Difference Solution of Hyperbolic Heat Conduction with Temperature-Dependent Properties, Numerical Heat Transfer," Part A, Vol. 34, 1998, pp. 169-183.

[21] Torii, S. and Yang, W.-J., "Thermal Wave Propagation Phenomena in Thin Solid Films with Temperature-Dependent Thermal Conductivity," International Journal of Transport Phenomena, Vol. 4, 2002, pp. 133-140.

[22] Kotake, S. and Wakui,S., "Molecular Dynamics Study of Heat Conduction in Solid Materials," JSME International Journal, Series B, Vol. 37, 1994, pp. 103-1084.

[23] Anderson, D. A. Tannehill, J. C. and Pletcher, R. H., "Computational Fluid Mechanics and Heat Transfer," Hemispherer, 1983, New York.

[24] Glass, D. E. Ozisik, M. N. McRae, D. S. and Vick, B., "Hyperbolic Heat Conduction with Temperature-Dependent Thermal Conductivity," Journal of Applied Pysics, Vol. 59, 1986, pp. 1861-1865.

Shuichi Torii received Eng.D. degree in thermal science from Kyushu University, 1989. In 1990/91, He was a visiting scholar at Department of Mechanical Engineering and Applied Mechanics, the University of Michigan. In 2003, he jointed Kumamoto University as a professor.

Wen-Jei Yang received Ph.D. degree from the University of Michigan, 1960. In 1970, he became a professor.

An fMRI Study of Emotional Engagement In Decision-Making

Perez-Alvarez, Frederic; Timoneda, Carme; Reixach, Jordi

Abstract—***It has been suggested that decision making depends on sensitive feelings associated with cognitive processing rather than cognitive processing alone. From human lesions, we know the medial anterior inferior-ventral prefrontal cortex processes the sensitivity associated with cognitive processing, it being essentially responsible for decision making.***

In this fMRI (functional Magnetic Resonance Image) study 15 subjects were analyzed using moral dilemmas as probes to investigate the neural basis for painful-emotional sensitivity associated with decision making. We found that a network comprising the posterior and anterior cingulate and the medial anterior prefrontal cortex was significantly and specifically activated by painful moral dilemmas, but not by non-painful dilemmas.

These findings provide new evidence that the cingulate and medial anterior prefrontal are involved in processing painful emotional sensibility, in particular, when decision making takes place. We speculate that decision making has a cognitive component processed by cognitive brain areas and a sensitivity component processed by emotional brain areas. The structures activated suggest that decision making depends on painful emotional feeling processing rather than cognitive processing when painful feeling processing happens.

Index Terms: ***Cingulate cortex, Decision-making, Cognitive-emotional processing, Educational psychology, fMRI, Medial anterior inferior-ventral prefrontal cortex.***

1. *INTRODUCTION*

A clear distinction between emotion and cognition has not been established. The so called "appraisal" of the processed painful sensitivity has been suggested to be the primary reason for any emotional behavior, which points to sensitivity rather than cognition as a causal explanation. Additionally, this last notion is claimed to be applicable to emotional "order" and emotional "disorder" [1].

On the other hand, the cognitive phenomenon is far from being understood. A modern neurologically based concept, the PASS (Planning, Attention, Simultaneous, Successive) theory of learning, deserves very close attention [2]. Its essential principle is central processing is independent of both sensorial input and verbal or non-verbal output. This idea is crucial to understanding that decision making has to do with personal beliefs, which work more unconsciously than consciously at a neurological level.

It is well known that physical pain processing and emotional processing share, at least in part, anatomical areas and physiological functions. This allows us to suppose that both physical and emotional painful sensitivity are codified by the neurons as the same entity, in particular, as a danger signal for evolutionary reasons. Evidence from animal experiments indicates that painful-fearful sensitivity is unconsciously processed and controlled by the temporal amygdala, which sends unconscious, uncontrolled, automatic protective-defensive responses, involving even the prefrontal cortex [3]. A common unspecific processing of danger occurs in different situations like stress, fear, etc. Thirdly, from the investigations on human lesions it has been shown that two prefrontal cortices, the emotional and the cognitive, exist. The decision making seems to depend on the emotional prefrontal cortex rather than on the cognitive prefrontal cortex . How is it that patients with medial prefrontal lesions are intelligent and aware of the consequences of the acts, but they exhibit unsocial behavior without remorse or decide to play a high-risk game with unnoticed consequences [4, 5, 6, 7, 8, 9, 10]?. Fourth, evidence exists that decision making and feeling are interactive processes [2, 11].

The aim of this study was to dissociate the painful feeling processing network from the cognitive processing network and to associate the mental decision making act with the painful feeling processing network (emotional engagement). According to neural correlates of emotion [12], we predicted that the crucial difference between painful and non-painful decision making lies in the emotional engagement processing. We have attempted to develop an informed symbiosis of psychological theory and neuroscience method. The present

Manuscript submitted September 19, 2005. This work was supported in part by the University of Girona, Spain. Contact first author: Frederic, Perez-Alvarez MD. Neuro-Pediatric and Neurobehavioral Unit Dr. J Trueta Hospital. University of Girona. Girona. Spain. Phone: +34 972 940200; FAX: +34 972 940270 (e-mail: fpereza@comg.es).

Carme, Timoneda PhD. is with the Psychoeducational Department. University of Girona. Girona. Spain. (e-mail: carme.timoneda@udg.es). Jordi, Reixach PhB is with Fundacio C Vidal de NeuroPsicoPedagogia. Girona. Spain. (e-mail: h416ufpa@htrueta.scs.es).

study extends previous fMRI findings in decision making [13, 14]. These previous works compare a more painful with a less painful decision making. Indeed, painful dilemmas must be considered "personal moral dilemmas", "impersonal moral dilemmas", "difficult personal moral dilemmas", "easy personal moral dilemmas", "utilitarian difficult personal moral dilemmas" and non-utilitarian difficult personal moral dilemmas". Our study compares a painful with a non-painful decision making.

2. METHODS

We have designed an noninvasive fMRI study aimed to dissociate the painful-emotional prefrontal network from the cognitive network and to support that decision making depends on the emotional rather than on the cognitive prefrontal cortex. fMRI has no injected contrast or tracer and does not appear to have any risk with repeat exposure. Six males and nine females between 12 and 15 years of age, who (with their parents) were provided with written informed consent forms, were recruited from the local scholar community. The study was approved by the ethic committee. A medical screening was carried out to rule out any psychiatric or neurological illness or any medical condition or medication. All subjects were healthy and right-handed with average or above-average intelligence (WISC-III-R). The stimuli selected were dilemmas. These were divided into "emotional" and "non-emotional" categories according to both their nature and the responses of 30 pilot participants , according to the evaluation of two independent coders (validation). No emotional dilemma was felt emotional for one person and non-emotional for another. The emotional dilemmas involve a painful experience (blame sentiment) whatever the decision. Two options (A and B) are possible. Option A and B are painful, although one of them is the most painful. The selected non-emotional dilemmas are painless. We assume that "emotional dilemma" is emotionally engaging, which means an intensively badly felt (blame) sentiment depending on the decision making response. Blame sentiment is an experience involving painful-feeling sensitivity, although other different processes may be also operating. Testing materials were similar to those available online at www.sciencemag.org/cgi/content/full/293/5537/2105/DC1.14, September,2001. Distinguishing between cognitive and emotional tasks can be argued as somewhat arbitrary for some cognitive component is always present. For this reason we are talking in terms of more or less a predominant cognitive component. To minimize the cognitive requirement we used a quasi-passive viewing procedure, which reduces the linguistic cognitive component of the task to a minimum. This makes comparison between cognitive and emotional condition much easier. This task consists of viewing a picture (cartoon) that represents a selected emotional or non-emotional dilemma. Every dilemma had to have a "yes" / "no" response option with the minimal motion of the 1st or 2nd finger of the hand. As a previous instruction, the subjects were presented pictures similar to those used during the session. Once the task was understood, the subjects were presented a visual display with each dilemma in the form of a picture or cartoon. Alternating blocks of emotional and non-emotional dilemmas were presented in random order in a series of three blocks of ten trials each. Every participant responded to each dilemma while undergoing brain scanning by fMRI. Stimuli were projected onto a white screen located in front of the child and automatically displayed for 5 s by means of a computerized system. A previous unpublished pilot study showed that this presentation rate allowed subjects to comfortably look at the picture and respond to it. Longer time on task tends to increase the involvement of cognitive network. The intertrial interval (ITI) lasted long enough to allow the hemodynamic response to return to baseline after each trial. During the ITI, participants viewed a fixation cross.

Anatomic and functional data were obtained with a 1.5 Tesla GE Signa scanner. For anatomical localization, scan parameters were: repetition time (TR), 3100 ms; echo time (TE), 30 ms, matrix, 256 x 256; FOV (Field Of View), 22 cm; slice thickness, 6 mm; 22 axial slices. For the functional scan, parameters were: TR, 2000 ms; TE, 40 ms; flip angle (FA), 90º; matrix, 256 x 160; FOV, 24 cm; 18 axial slices, 6 mm thick, 0 mm skip. Head motion was constrained by foam padding. At the end of each scanning session a T1-weighted structural image was acquired in each subject.

Data analysis were performed with SPM 99 (Statistical Parametric Mapping. Wellcome Department of Cognitive Neurology, University College of London) and included motion correction and smoothing [Gaussian filter = 8 mm FWHM (Full Width at Half Maximum)]. Individual analysis was performed by using the general linear model [15] on normalized data (fixed effects model, high-pass filter = 108 sec, low-pass-filter = hrf, global scaling). SPGR (SPoiled GRadient echo pulse sequence) was normalized to T1 template [MNI (Montreal Neurologic Institute) stereotaxic space] in SPM 99 and then used as a template to normalize the in-plane anatomy (sinc interpolation, 2-mm voxels). Contrast images for each subject were normalized (tri-linear interpolation, 1x1x1-mm voxels) by using the parameters from the in-plane normalization. The contrast images were entered into a one-sample t-test across the 15 subjects. Activation was averaged over the 15 subjects. Group analysis was performed with a random effects analysis [16]. According to the SPM approach, statistical contrasts are performed by essentially calculating an ANOVA across all of the images under consideration. Statistical maps were thresholded for significance ($P < 0.01$) and cluster size (20 voxels). A whole

brain analysis was made to identify voxels significantly more activated during emotional dilemmas than non-emotional dilemmas.

3. RESULTS

Whole brain analysis, performed to identify brain regions that showed greater activity for emotional dilemmas, showed that emotional dilemma condition had increased activity in a number of brain regions (Table 1). The most statistically significant activation was in the posterior cingulate (BA 23/30/31). Other significantly activated regions included the anterior cingulate (BA 24/25/32) and medial anterior inferior-ventral prefrontal (BA 10/11) (Fig. 1). The locations and Z-scores of peak activation in activated regions are shown in Table 1.The number of activated voxels is defined as the area under the difference distribution having Z scores. These areas were not significantly activated in non-emotional condition. In contrast, the dorsolateral prefrontal, angular gyrus, several regions of frontal, parietal and temporal cortex were significantly more activated during non-emotional condition. This response has been shown in a number of studies across different methodologies.

Table 1. Significant activation during emotional dilemmas compared to non-emotional dilemmas

Voxelwise significance threshold $P < .01$; min cluster size 20 voxels.
Activated voxels were required to have a Z value for a claimed P.

Brain region Brodmann's Area	Talairach Coordinates X	Y	Z	Z score
Frontal lobe				
Medial prefrontal				
	-31	55	3	3.98
10				
	0	52	-12	3.86
10,11				
	7	62	-12	4.43
11				
	-10	46	-14	3.85
10,11				
Limbic structures				
Anterior cingulate gyrus				
	-10	26	-10	4.69
32,25				
	7	28	28	4.05
32,24				
	0	27	36	3.58
24,25				
	0	12	33	5.25
24,25				
	-3	24	33	4.07
24,25				
	6	3	45	4.33
24				
Posterior cingulate gyrus				
	0	-38	41	3.81
31				
	14	-38	7	4.92
30				
	-7	31	24	2.64
23				
	-12	-55	27	3.97
23				

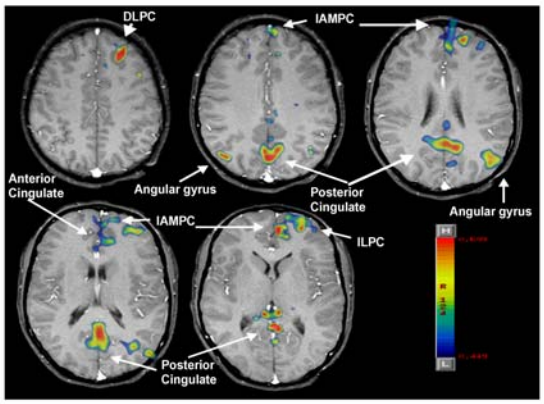


Fig. 1 DLPC: Dorso Lateral Prefrontal Cortex; IAMPC: Inferior Anterior Medial Prefrontal Cortex; ILPC: Inferior Lateral Prefrontal Cortex

4. DISCUSSION

The structures in this study are in agreement with the amygdala, anterior cingulate cortex, posterior cingulate cortex, insula, and medial anterior inferior emotional prefrontal cortex being associated with emotional condition as opposed to non-emotional condition that are supported by classically cognitive external cortical areas [12]. We count on evidences suggesting that the neural mechanism subserving both cognitive and emotional processing may be at least partially dissociated.

The thalamus, amygdala, cingulate gyrus, orbitofrontal gyrus, insula, secondary somatosensory cortex, and angular gyrus are structures that form part of the physical (somatic and visceral) and emotional-painful feeling network, [3, 12, 13, 14, 17, 18]. Although our conceptual framework suggests that physical pain and emotional pain processing share an unspecific network, it does not exclude the existence of other specific networks [18].

A substantial amount of fMRI evidence suggests a relationship between particular structures and the conscious versus unconscious nature of processing. Unconscious amygdala activation has been demonstrated. In contrast, the anterior cingulate cortex appears more frequently associated with processing the feeling related to the conscious cognitive component. The medial anterior ventral prefrontal cortex activates regardless of the conscious-

unconscious cognitive component of the task. A rule can been proposed. The more conscious component is working, the more external-dorsal structure is also working, whatever cognitive-emotional task is being processed. Conversely, the more unconscious the operation is on, the more the inferior-interior structure works. For instance, the most cognitive conscious structure is the dorsolateral prefrontal cortex responsible for working memory. However, the anterior cingulate cortex, an older internal structure, satisfies the earlier mentioned rule. The more conscious level processing is on, the more the dorsal region activates [18]. In fact, the anterior cingulate cortex seems more related to conscious processing, as concluded from recalling experiences [12]. We must remark that conscious processing is linked to both cognitive and emotional processing. Therefore, both cognitive and emotional tasks can activate it. That anterior cingulate is associated with conflict or attention-to-action processing [14] could be explained because both tasks involve stressful processing, which would be a way of painful processing, something like a arousal state related to negative affective state [19]. In general, the more conscious the activity is required, the more the functionally associated structures appear on fMRI, and vice versa. In conclusion our fMRI pattern is more compatible with unconscious processing than conscious processing.

According to the PASS conception [2, 20], the information processing stream should be analyzed in terms of sensorial-unimodal input network (primary areas), intermediate multimodal input-dependent networks (association areas) , central input-independent networks (highly distributed functional networks) , intermediate multimodal output-dependent networks, and unimodal output-dependent network (verbal and non-verbal). According to the previous reported fMRI results, the medial anterior inferior ventral prefrontal acts as an input/output independent area [12]. In regard to input-dependency, the anterior cingulate cortex, as well as the insula, has been mostly linked to recall input than to visual and auditory input [12]. Thus, it appears to be linked to language-mediated processes [12, 21], which is not consistent with our study where language component of the task is reduced to a minimum. The input-dependency condition associates the activation with the input modality (visual or auditory), which must be taken into account to interpret possible associations.

The amygdala may be considered a sensitive organ, something close to the “sensory-perceptual level” [22, 23]. The anterior cingulate cortex appears to work at a higher level of processing with input-dependency. In contrast, the non-input dependent medial anterior prefrontal cortex may be considered to process the feeling of the cognitive content, working at an even higher functioning level. In other words, the neurons of the medial anterior prefrontal cortex presumably process and integrate both sensitivity and data cognitive information. In any case, the medial prefrontal cortex works as a higher order processor with higher discriminating capacity [3]. Conversely, the neurons of the dorsolateral prefrontal cortex presumably process exclusively conscious cognitive information.

Particular attention should be given to the posterior cingulate cortex. Several fMRI results unequivocally link this structure to the non-valence dependent emotional feeling and to the painful feeling network [21, 24] in both emotional order and emotional disorder. Non-input-dependency has been observed because it was consistently activated by verbal, pictorial, and recalling stimuli [25, 26]. A relationship between this cerebral area and the ocular saccade movements, especially when an emotional-feeling task involving visual processing is occurring, has been reported [27]. Probably, the significant activation seen here is because an important quantity of information of the task is processed by the posterior brain. We suggest that the posterior cingulate is a relevant part of the painful feeling network linked to the cognitive posterior brain processor.

The reported relationship between fRMI and similar techniques with the decision making process deserves attention [9, 24, 28, 29, 30, 31]. What we are calling the emotional prefrontal, namely the medial anterior inferior ventral prefrontal, is involved in the painful decision making process. Our study on the process of decision making involving painful-feeling processing indicates that the emotional prefrontal processes painful-feeling associated with the corresponding cognitive processing and determines the emotional response associated with the thought. We are unable to state whether the medial prefrontal neurons process only painful feeling sensitivity or process both sensitivity and informative cognitive data (cognitive concept used here) in an integrated way. Our contention is that the medial prefrontal cortex processes feeling sensitivity, but the cognitive dorsolateral prefrontal does not. Something like the somatotopic differentiation between motor cortex and sensitive cortex. This conclusion is in agreement with the lesion studies that indicate the lesion in these areas brings about a failure in logical decision making [2, 4, 10]. This involves a failure in foreseeing the consequences of the acts. In fact, it must be considered a failure in feeling rather than knowing the consequences [10]. Probably, that is why these patients exhibit unsocial behavior without remorse and an indifference to playing a high-risk game with unnoticed consequences [10].

We can reasonably deduce by comparing these fMRI results with other scientific evidences that the essential concept universally agreed upon is that independent of the behavior that is put in action, both cognitive (ideas) and feeling (sensitivity) processing happen at neurological

level. That is, whether consciously or unconsciously, all action is really driven by both cognitive and affective-feeling processing. We believe our study demonstrates that painful decision making, but not non-painful decision making, activates the medial prefrontal. This can also be taken from the lesion studies. For instance, a patient with an emotional prefrontal lesion unsociably behaves because their emotional prefrontal is not processing or codifying the painful feeling associated with the corresponding cognitive processing. This is not because their cognitive dorsolateral prefrontal along with their temporal, parietal, and occipital cortices are unable to understand which consequence follows which behavior [4, 10].

The next thing to keep in mind is that painful feeling sensitivity is neurologically experienced in countless circumstances, we call countless linguistic terms, such as anxiety, depression, stress, fear, anger, and worry, as well as in unthinkable circumstances like aggression and violence. Likewise, "the empathy for pain" [18] or the experience of regret [4] and of punishment [31, 32] are painful experiences, which activate the brain areas linked to emotional painful processing. Recent neuroimaging studies continue to explore the neural correlates of decision making [17]. Our study compares painful with non-painful dilemmas, which is different from previous studies where more painful dilemmas are compared with less painful ones [13, 14]. For evolutionary reasons, it must be emphasized that neurons similarly codify as a danger what we call the countless linguistic terms, in particular blame sentiment, involved in our emotional dilemmas. More and more neurological evidence indicates that the painful sensitivity processing network counts on neurons processing and codifying sensitivity, but not cognitive informative data, even for the cognitive prefrontal, the cognitive cerebral lobe par excellence. In fact, this described functional mechanism agrees with what we now know about painful-fearful feeling processing in animals [3]).

According to our theory, many different tasks can activate the areas of our study, but also other different areas depending of the nature of the task. We postulate that the task used here allowed us to dissociate a sensitivity network from a cognitive network. We suggest that a longer time for response than that employed here involves the engagement of brain areas commonly associated with deliberative thought processes, which means a confound factor to dissociate the cognitive from the emotional (sensitivity) network. Moreover, we postulate that the deliberative thought associated with longer times for response reflects the engagement of conscious abstract reasoning processes, which happens later than the unconscious reasoning-feeling associated with the unconscious personal beliefs processing responsible for the response (decision making) when painful feeling processing takes place. It would be a reasoning process occurring after the point of decision [14]. The response would be in accordance with "unconscious" judgement of the personal beliefs. In support of this, we can mention the cognitive-psychological evidence that demonstrates the dissociation between verbal report and action. That is, a child is solving a task and we can verify that the verbally reported ("a posteriori" abstract reasoning) strategy is not that really being used, which we can deduce by observing the eye movements. That is, the unconscious strategy may be opaque to introspection. For example, the child is solving a task of searching for a number embedded in a field of other numbers. When asked how the target was located , we can see that screening eye movements tell us a different action than that verbally reported. [2]. Likewise, in an experiment [33], adult subjects were asked to do decision making tasks and a dissociation between verbal report and action was noticed frequently.

Guilty feeling processing is involved in the resolution (decision making) of the emotional dilemmas. Decision making involves the processing of personal beliefs. Personal beliefs influence decision making. Personal beliefs work basically at a central subconscious level beyond what we externally can see or hear between the input of information (dilemma presented) and the output of information (behavioral response). In pure PASS cognitive terms, for example, a child is presented with single separated letters, such as u, b, and s. He/she is asked to pronounce the successive combination [b u s], and he/she answers correctly. Later, he/she is asked to pronounce the sequence [q u s], and the answer is the same as before; this is obviously the incorrect answer. However, if the knowledge mentally processed is the symbol “b” is pronounced “/b/” independently of placing it right side up or not, then good logical reasoning has happened, because “a chair remains a chair whether its feet are on the floor or pointing toward the ceiling”. The response may be considered the consequence of a mental decision making act. What matters in decision making is the central mental processing in terms of beliefs [2]. This act involves both cognitive and feeling processing. In the case of painful feeling processing, according to animal experimentation, the neurons at the amygdala are inferred to be codifying danger, which determines that the medial prefrontal becomes active [3].We suggest that this central cognitive-sensitive processing is supported by the medial prefrontal according to our results.

5. CONCLUSION

The results of this study suggest that we can identify an emotional-painful processing network different from a cognitive processing network. The structures we observed are those being activated when painful feelings (in the form of

blame sentiment in our study) are being processed. The structures activated, on the other hand, suggest that the decision making process depends on painful emotional feeling processing rather than cognitive processing when painful feeling processing happens. Future studies to further elucidate the functional significance of this fMRI activation, which allows us to establish not only diagnostic patterns but also the patterns in response to various treatments, will be needed.

ACKNOWLEDGMENT

We are indebted to J Baus, J Alabau, J Hernández, S Mayoral, and to the children, and their parents for their invaluable collaboration. Thanks to Dr. J Pujol, Dr. Vilanova and Dr. Barceló for his assistance, and to Dr. Paul Kretchmer (kretchmer@sfedit.net) at San Francisco Edit for his assistance in editing this manuscript.

REFERENCES

[1] Power, M., and Dalgleish, T."Cognition and emotion. From order to disorder". UK:Psychology Press, Publishers. 1997.

[2] Das, J.P., Kar, R.,and Parrila, R.K."Cognitive planning. The psychological basis of intelligent behavior"**.** London: Sage Publications Ltd. 1996.

[3] LeDoux, J.E."Emotional brain".New York: Simon Schuster.1996.

[4] Camille, N.,Coricelli, G.,Sallet, J.,Pradat-Diehl, P.,Duhamel, J.R., and Sirigu, A. "The involvement of the orbitofrontal cortex in the experience of regret". Science 2004; *304:* 1167 - 1170.

[5] Adolphs, R.H., Damasio, D., Tranel, G., Cooper, A., and Damasio, A.R. "A role for somatosensory cortices in the visual recognition of emotion as revealed by 3 – 0 lesion mapping". J Neurosci. 2000; *20*: 2683-2690.

[6] Bechara, A., Tranel, D., and Damasio, H. "Characterization of the decision-making effect of patients with ventromedial prefrontal cortex lesions". Brain 2000;*123*: 2189-2202.

[7] Anderson, S.W., Bechara, A., Damasio, H., Tranel, D., and Damasio, A.R. "Impairment of social and moral behavior related to early damage in human prefrontal cortex". Nature Neurosci.1999; *2*: 1032-1037.

[8] Grafman, J., Schwab, K., Warden, D., Pridgen, A., Brown, H.R., and Salazar, A.M. " Frontal lobe injuries, violence, and aggression:A report of the Vietnam Head Injury Study". Neurology 1996; *46*:1231-1738.

[9] Rolls, E.T., Hornak, J., Wade, D.,and McGrath, J."Emotion- related learning in patients with social and emotional change associated with frontal lobe damage". J Neurol. Neurosurg Psychiatry 1994*; 57*: 1518-1524.

[10] Damasio, A.R. "Descartes'Error: Emotion, Reason, and the Human Brain" New York: G.P. Putnam. 1994.

[11] Goldberg, E. "The executive brain: frontal lobes and the civilized mind." Oxford: Oxford Unversity Press. 2001.

[12] Phan, K.L., Wager, T., Taylor, S.F., and Liberzon, I. "Functional neuroanatomy of emotion: A meta-analysis of emotion activation studies in PET and fMRI". Neuroimage 2002; *16:* 331-348.

[13] Greene, J.D., Sommerville, R.B., Nystrom, L.E., Darley, J.M., and Cohen, J.D. "An fMRI investigation of emotional engagement in moral judgment". Science 2001;*293*:2105-2108.

[14] Greene, J.D., Nystrom, L.E., Engell, A.D., Darley, J.M., and Cohen, J.D. "The neural bases of cognitive conflict and control in moral judgement". Neuron 2004; *44*: 389-400.

[15] Friston, K.J., Holmes, A.P., Poline, J.P., Grasby, P.J., Williams, S.C., Frackowiak RS, and Turner, R. "Analysis of fMRI time-series revisited". Neuroimage 1995; *2*: 45-53.

[16] Friston, K.J., Holmes, A.P., Price, C.J., Buchel, C., and Worsley, K.J. "Multisubject fMRI studies and conjunction analyses". Neuroimage 1999; *10*:385-96.

[17] Pessoa, L., and Padmala, S. "Quantitative prediction of perceptual decisions during near-thresholded fear detection". Proc. Natl. Acad. Sci. USA. 2005. www.pnas.org./cgi/doi/.10.1073/pnas.0500566102. 2005

[18] Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J., and Frith, C.D."Empathy for pain involves the affective but not sensory components of pain". Science 2004; *303:* 1157-1162

[19] Critchley, H.D., Mathias, C.J., Josephs, O., O'Doherty, J., Zanini, S., Dewar, B.K., Cipolotti, L., Shallice, T.,and Dolan, R.J. " Human cingulate cortex and autonomic control: Converging neuroimaging and clinical evidence". Brain 2003; *126,* 2139-2152.

[20] Mesulam, M.M. "From sensation to cognition". Brain 1998;*121*: 1013-1052.

[21] Maddock, R.J. "Retrosplenial cortex and emotion: New insights from functional imaging studies of the human brain". TINS 1999; *22*: 310-316.

[22] Teasdale, J.D., Howard, R.J., Cox, S.G., Ha, Y., Brammer, M.J., Williams, S.C.R., and Checkley, S.A. "Functional MRI study of the cognitive generation of affect". Am. J Psychiatry 1999; *156*: 209-215.

[23] Reiman,E."The application of positron emission tomography to the study of normal and pathologic emotions". J Clin. Psychiatry 1997; *58* (Suppl 16): 4-12.

[24] Maddock, R.J., Garrett, A.S., and Buonocore, M.H. "Posterior cingulate cortex activation by emotional words: Fmri evidence from a valence decision task". Hum. Brain Mapping 2003; *18*:30-41.

[25] Maddock, R.J., Garret, A.S., and Buonocore, M.H. "Remembering familiar people: the posterior cingulate cortex and autobiographical memory retrieval". Neurosci. 2001; *104*: 667-676.

[26] Maddock, R.J., and Buonocore, M.H. "Activation of left posterior cingulate gyrus by the auditory presentation of threat-related words: an FMRI study". Psychiatry Res. Neuroimaging 1997; *75*:1-14.

[27] McCoy, A.N., Crowley, J.C., Haghighian, G., Dean, H.L., and Platt, M.L. "Saccade reward signals in posterior cingulate cortex"**.** Neuron 2003; *40*:1031-40.

[28] Heekeren, H.R., Wartenburger, I., Schmidt, H., Schwintowski, H.P., and Willringer, A. "An fMRI study of simple ethical decision-making". Neuroreport 2003;*14:* 1215-9.

[29] Moll, J., de Oliveira-Souza, R., Bramati, I.E., and Grafman, J. "Functional networks in emotional moral and nonmoral social judgments". Neuroimage 2002; *16*:696-703.

[30] Cabeza, R.and Nyberg, L."Imaging cognition II: an empirical review of 275 PET and fMRI studies". J Cogn. Neurosci. 2000; *12*: 1-47.

[31] DeQuervain, D.J., Fischbacher, U., Treyer, V., Schellhammer, M., Schnyder, U., Buck, A., and Fehr, E. "The neural basis of altruistic punishment". Science 2004; *305*: 1246-7.

[32] Rogers, R.D., Ramnani, N., Mackay, C., Wilson, J.L., Jezzard, P., Carter, C.S., and Smith, S.M. "Distinct portions of anterior cingulate cortex and medial prefrontal cortex are activated by reward processing in separable phases of decision-making cognition". Biol. Psychiatry 2004; *55*: 594-602.

[33] Broadbent, D.,Fitzgerald, P., and Broadbent,M. Implicit and explicit knowledge in the control of complex systems. British J Psychology 1986; *77*, 33-50.

Frederic, Perez-Alvarez has a doctorate in Medicine from the University of Barcelona, Spain. His clinical specialty is Pediatric Neurology and his research is on Behavioral Neurology. Carme, Timoneda has a doctorate in Educational Psychology from the Girona University. Both of them hold a Master of "NeuroPsicoPedagogia" from the University of Girona, Spain.

Do Takeovers Downgrade the Contents of Human Rights and Freedoms in EU?

KORŽE, BRANKO

Abstract - In this paper I closely examine how the contents of market competition and human rights in the social state are changing under the influence of economic globalization and because of the states' integration into European Union (EU). With the help of content analysis of the competition and its functions in a social state I endeavour to prove that, as a result of economic globalization, the social functions of the competition are downgraded and, accordingly, so too are the human rights and fundamental freedoms that are asserted through those functions. Because the nature of many human rights and freedoms is such that can be enforced only on the national level, the integration of states into EU in some areas causes similar negative consequences for protection of human rights and freedoms as it is happening in the world market, the only difference being that those member states which have transferred their sovereign rights to regulate the market onto EU institutions do not have the means to prevent such negative consequences. On the basis of an analysis of the reasons which are causing a loss of balance between the economic and social functions, I have studied the ways in which the mentioned trends are appearing. I also draw up proposals as to how, in the area of takeovers of business undertakings within the EU, the negative consequences of globalization could be prevented or reduced.

Key words: human rights, social state, free competition, competition function, economic function, social function, competition policy, competition protection, economic globalization, community legislation, undertakings takeover, social standards, EU single market

I. HUMAN RIGHTS AND THE SOCIAL STATE

I. 1. DEFINING THE ORIGIN AND OUTLINING THE SIGNIFICANCE OF HUMAN RIGHTS AND FUNDAMENTAL FREEDOMS

Philosophical, legal and political doctrines consider human rights that developed in the first half of the previous century as being: fundamental (i.e. human rights represent the foundation for other rights), universal (i.e. it is generally viewed that human rights are everyone's inalienable rights), moral (i.e. human rights originate from human morality) and alike. Since human rights are inseparably linked to human beings, they are inalienable, absolute, political and have to be on certain level equaly protected by law. In must not be overlooked that some aspects of human rights are at the same time manifestation of a particular philosophic, moral, cultural, political and social development as such, and of its respective heritage of traditional values,[1] therefore in the part that exceeds altogether denominator, they are in different social states dispersed in content.[2]

Multiple interpretations of human rights, which surfaced during the debate about their content[3] in the United Nations (UN) after WWII, made it impossible to adopt only the Universal Declaration of Human Rights, therefore the UN adopted two conventions: International Covenant on Economic, Social and Cultural Rights and International Covenant on Civic and Political Rights (December 10, 1948). Universal standards and observance of human rights could not be declared. That situation resulted in establishing the Council of Europe in 1949 as a non-governmental organisation, whose aims were directed towards securing human rights and fundamental freedoms in Europe. The Council of Europe prepared a draft of the European Convention on Human Rights and Fundamental Freedoms and succeeded in having it adopted on November 3, 1950 in Rome.

I. 2. HUMAN RIGHTS AS THE FOUNDATION OF THE SOCIAL STATE

Human rights in their anthropological, moral, legal, political and broader social conditions represent the starting point for a person's individual and collective (i.e. social) nature, hence they are one of the fundamental presumptions for comprehending contemporary economic, political and legal systems and processes. After WWII, the countries of Western Europe, based on human rights and fundamental

[1] See Cerar M., Narava in pomen človekovih pravic (The Nature and Meaning of Human Right), In: Dokumenti človekovih pravic z uvodnimi pojasnili, Društvo Amnesty International in Mirovni inštitut, Ljubljana 2002, p. 17.

[2] See also Cerar M., Večrazsežnost človekovih pravic in dolžnosti (Wide-ranging Meaning of Human Rights and Duties), 2nd edition, Znanstveno in publicistično središče, Ljubljana 1996, p. 65 to p. 98 and p. 122 to p. 132.

[3] See Perenič A., Svet Evrope in človekove pravice, In: Dokumenti človekovih pravic z uvodnimi pojasnili, already quoted, p. 49.

freedoms, enacted in the European Convention on Human Rights and on the basis of conclusions of Keynes' theory[4] on the role of the state in regulating economy, have established a new economic model – the social state. This model, which since the fall of the Berlin Wall has been adopted by the newly constituted European countries and by those who have reformed their political and economic systems, is defined differently within the framework of legal systems. Some regulate it directly and some indirectly through substantive deduction of individual human political, economic and social rights and fundamental freedoms.[5] The model of social state is legally and politically based on human rights and fundamental freedoms, and granted to all legal subjects, and subject only to such limitations as the rights of others and the matter of realisation of other public interests[6]. According to this model, every national state is obliged to organise the market and facilitate and monitor its operations, to create and implement policies for ensuring macroeconomic (e.g. monetary) stability, to generate conditions for optimum allocation of production factors, and to define the optimum set of public goods (cost benefit analysis), with the help of which the greatest possible support for implementation of free economic initiative of competitors on the market (i.e. production of private goods) will be ensured.[7] Furthermore, the state shall set up socially best-possible reallocation of generated income and mechanisms for prevention of market irregularities (e.g. market failure). To implement the above mentioned functions, which are intertwined in many elements and are co-dependant,[8] the state must strive to achieve optimal social welfare. Optimum social welfare is not only defined through economic efficiency but also by the level of market relations stability, by just and equal distribution, or by balanced redistribution of income, by the freedom of choice and by the development possibilities of society as an entity.[9] Social welfare and social development are optimal when human rights and fundamental freedoms of legal subjects are reciprocally balanced and when economic rights are in convergence.

II. SOCIAL STATE AND FREE COMPETITION

Free competition in social state systems is the expression of economic freedoms, deriving from fundamental human rights and freedoms, which are not absolute but are limited by other social goals, by which we pursue the implementation of other human rights and fundamental freedoms (the right of ownership and the right to work)[10]. There is a correlation between the individual goals of social state (i.e. welfare, freedom, justice), which makes the economic principle of competition relative. The contents of free competition in the term of fundamental freedoms therefore depend on the individual state, in time and space; the legislator, when regulating the competition and its protection, determines[11] which competitive actions are not admissible for social and political reasons. The legislator also defines the areas where the economic goals of competition have to be limited because of the possibility of implementing certain social goals.

The right of economic undertakings to demand from the state that it guarantee free competition on the market derives from the human right to liberty and dignity, and therefore it cannot be exercised only as an economic freedom irrespectively of other rights and fundamental freedoms, but only in correlation and interdependence with them.

Free competition as an economic right enables business undertakings to carry out their free business initiative, which, in convergence with social and other rights and freedoms, constitutes the right to free competition and it is the state's duty to ensure this as a long-term public interest.[12]

II.1. THE GOALS AND FUNCTIONS OF COMPETITION IN THE SOCIAL STATE

The establishment of free competition and its protection are the most important goals of competition law and competition policy in a social state, but are far from being the only goals, because there are numerous minor, supplementary goals, among which we need to mention the protection of competitors, consumers, environments and encouraging technological progress. The minor supplementary

[4] For more on this see: Oveerbeek J., Free Trade versus Protectionism, Edward Elgar Publishing Limited, UK, Cheltenham 1999, p. 392 to p. 404.

[5] See Korže B., Ustavni temelji podjetništva (Constitutional Bases of Enterprise), Podjetje in delo, No. 5-6/1993, Ljubljana 1993, p. 462.

[6] See Bailey J. S., See Bailey J. S., Public Sector economics – Theory, Policy and Practices, Macmillan Press Ltd, London 1995, p. 10.

[7] See Musgrave A. R./Musgrave B. P., Public Finance in Theory and Practices, 5. international issue, McGraw Hill book Company, Singapore 1989, p. 131.

[8] See Kranjec M., Davki in proračun (Taxes and Budget), University of Ljubljana, Faculty of Public Administration, Ljubljana 2003, p. 24.

[9] Along the context: Herzog R., Sozialstaatklausul als zukunftsorientirten Rechtsbegriff – Commentary to Grundgesetz – Maunz Duering, p. 19.

[10] Zabel B., Tržno pravo, Gospodarski vestnik, Ljubljana 1999, pg. 91-99.

[11] Similar see: Pretnar B., Intelektualna lastnina v sodobni konkurenci in poslovanju (Intellectual property in modern competition and business), Gospodarski vestnik, Ljubljana 2002, p. 107.

[12] See Šturm L., Komentar Ustave Republike Slovenije (Commentary to Constitution of the Republic of Slovenia), Fakulteta za podiplomske, državne in evropske študije, Ljubljana 2002, p. 719.

goals also reflect various public interests of particular social communities and the need for implementation of the principles of liberty, equality and other democratic principles.[13] The major and the minor goals of competition are carried out through competition's many functions. Through the structural function of competition the control over the actions of individual participants is established,[14] and with the distributive function the income is justly allocated according to market assessment. With the selective function the weak undertakings are eliminated, whilst the efficient ones develop further. Competition goals are also exercised through a number of other functions, such as the function of directing, the motivation function, the dynamic function etc.

A basic classification of competition functions is the division into economic and social ones, while the other forms actually relate to its particular aspects (e.g. selective function relates to economic aspect, distributive function relates to social aspects). Listed among the economic functions the theory considers mainly the following:

- Ensuring payment (i.e. Vergütung) to all participants in the market, which correlates with their economic performance;
- Confrontation of consumer notions and desires with producers or providers of particular goods on the market;
- Constant adjustment of production factors and their redirection into production of new products (i.e. industrial reallocation) and thus optimisation of production factors;
- Flexible adjustment and balancing production and supply among different industries;
- Constant efforts by particular providers on the market to improve their market starting point (market innovations, new products and production procedures – gaining advantages).[15]

Listed among social functions, which according to Kantzenbach have "higher" social objectives[16] in comparison to economic functions, the theory considers mainly the following social functions:

- Ensuring free participation of business undertakings in the market;
- Equal rules regarding market rivalry and equal opportunities for undertakings to enter and exit the market;
- Preventing the formation of excessive unsupervised power of individual undertakings, prevention of political influences in the society;
- Influence on profit distribution;[17]
- Ensuring democracy, division of powers and political freedom;
- Implementation of social goals.[18]

The competition has economic and non-economic goals, and there is a cyclical link between them. Alongside this, it has to be stated that free competition cannot be established as a "self-maintaining" system, because that would lead to self-destruction of the competition.[19] It is the task of the state to establish and maintain a balance between different functions of the competition.

II. 2. COMPETITION POLICY AND COMPETITION LAW IN THE SOCIAL STATE

The economic and social functions of competition that help achieve competitive goals in social states are regulated with the aid of competition policy and competition law. By doing so, competition needs to be defined as a long-term public interest that does not yield to general and daily economic and political interests.[20]

Competition policy cannot be formed independently of economic policies but only as its integral part.[21] With the aid of competition policy, a social state must set its social goals, which are often not in accordance with the economic goals of competition,[22] but pursue other social values. These goals are often not in accord with business interests of undertakings in the market, but they are of great importance for implementation of other social values, such as health, life, cultural values or values in the interest of public safety.[23]

Economic policy is not complete if not complemented by competition policy and if implementation in the long-run is doubtful. The grounds for normative (i.e. legal) competition regulation are the guidelines set by long-term economic or competition policy. Furthermore, competition policy has to be viewed dynamically in the short-term, and defined as a support in the implementation of economic policy because of

[13] See Grilc P. and others, Zakon o preprečevanju omejevanja konkurence s komentarjem (Law on Prevention of Limitation of Competition with Commentary), Gospodarski Vestnik, Ljubljana 2000, p. 113.

[14] Similar See: Grilc P., Boundaries of Competition, Competition Policies and Competion Law, Pravnik No. 9/10, Ljubljana 1996, p. 474.

[15] See Hösch U., Grundlagen des Wettbewerbsrechts, Richard Boorberg Verlag, Stuttgart 1996, p. 25.

[16] See Kantzenbach E., Die Funktionsfähigkeit des Wettbewerbs, 2. durchges. Auflage, Vandenhoek u. Ruprecht, Göttingen 1967, p. 16.

[17] See Bartling H., Leitbilder der Wettbewerbspolitik, Munchen 1980, p. 45.

[18] See Kantzenbach E., (note 16), p. 15.

[19] See Schmidt I./Binder S., Wettbewerbspolitik im internationalen Vergleich, Verlag Recht und Wirtschaft GmbH, Heidelberg 1996, p. 15.

[20] See Zabel B., (note 10), p. 131.

[21] See Herbert G., Allgemein Wirtschaftspolitik, Wiesbaden 1996, p. 73.

[22] See Hösch U., (note 15), p. 29.

[23] See Möschel W., Schutzziele eines Wettbewerbsrechts, Festschrift Pittner, p. 405.

the dictate of a number of external influences, which cannot always be foreseen.[24]

Free business initiative (economic freedom) is implemented through the economic functions of competition, but this initiative is limited by other social goals, pursued through the social functions of competition. Free competition is the result of the economic and social goals o the social state. The social state is obliged to ensure the balance between the functions with the help of competition instruments, so that it prevents all actions which could limit or distort free competition.[25]

III. ECONOMIC GLOBALIZATION AND NATIONAL PROTECTION OF COMPETITION

Robert Cox considers globalization as a growing world economy, whose factors (i.e. agents) are multinational corporations and banks and whose goals are exclusively of an economic nature.[26] Edward Herman views globalization as a path of selfish multinational corporations worrying about their development and gaining market advantages. Multinational corporations, in his view, act under pretences of internationalism and solidarity between countries as an opposition to nationalism and protectionism.[27] David Bederman thinks of globalization as a set of interrelated conditions that influence international relations not only in the field of economy and trade but also in other fields, such as communications, transport, culture, politics and security.[28] David M. Trubek denotes globalization as a demonic force that is destroying authentic culture, weakening the strength of national governments and subduing social and environmental problems to its economic goals. He sees the solution in legal regulation and in establishing discipline in the market and in founding an international institution that would exercise the implementation of market discipline. He concludes that in the past the "investment" liberalism (i.e. free investment) induced development, because national states through their legislation were able to provide defence of social interests against developed capitalist countries. National states were sovereign in regulating economic policies and development, and they insured themselves against economic risks by regulating the distribution of public incomes. With economic globalization the state lost its role and power in defending social and other national goals. Connor states that global markets lead to business behaviour which is in complete contradiction with national markets' behaviour.[29]

Generally speaking, we can conclude that present-day economic globalization is the consequence of technological, economic and trade development. The information technology development, which began its speedy advance in the 1990s, has changed into an unstoppable and uncontrollable process. It caused an influx of changes, which open up a whole new series of questions.[30] Present-day globalization cannot be denied its positive economic impacts and possibilities for economic progress (i.e. especially for the financially stronger undertakings and states); on the other hand globalization seriously endangers other goods, particularly because it is based solely on economic functions of competition and pursues only the highest possible profit. By placing governance into the hands of the transnational companies, as initiators of globalization, the power of national companies is weakened and the power of transnational companies prevails over the political power of national states. By this the social states in particular lose the possibilities of implementing the environmental and social functions of competition, through which the human rights and fundamental freedoms are performed. Economic globalization has caused a series of new conflicts, and it has an influence on international organizations, media, on the scope of social rights and on human rights in general.[31] The corporations of economically stronger states prevail over national legislators. The conflicts between the economically strong multinational companies and national authorities also have influence on the change of standards in defining and implementing national competition policy.[32]

Globalization will become just a new form of imperialism, which will enable rich owners of capital to become even richer at the expense of estrangement of workers' excess labour value and thereby also encroaching upon workers' human rights and fundamental freedoms.[33]

Founded in 1994, the World Trade Organization (WTO) promoted the liberalization of world trade. National states should therefore continue to be the makers of the competition policy, and in this

[24] See Grilc P., Pravo EU (EU Law), 2nd volume, Cankarjeva založba, Ljubljana 2001, p. 563.

[25] See Heße M., Wettbewerbsrecht, Verlag Sanerländer, Wien 1998, p. 10.

[26] See Cox R., A Perspective on globalization, in Globalization, Critical reflections, No. 21,23 J. Mittelman edition, 1997.

[27] See Herman E., The Threat of Globalization, New Policy, 1999, No. 40, p. 40.

[28] See Bederman D., Globalization, International Law and United States Foreign Policy, Emory L.J., 2001, p. 717.

[29] See Martin S., Globalization and the Natural Limits of Competition, The International Handbook of Competition, Chetlenham, UK, Northampton, MA, USA, 2004, p. 47.

[30] See Gamble J. K./Allen E. A./Dirling L. N., International Law and globalization: allies, antagonists or irrelevance?, In Globalization, Critical reflections, already quoted, p. 115.

[31] See Bennet J., Multinational corporations, social responsibility and conflict, Journal of International Affairs, March 2002, p. 186.

[32] See Martin S., (note 29), p. 50.

[33] See Šali F., Globalizacija – zaton kapitalizma in vzpon človekovih pravic (Globalization – Decline of Capitalism and Rise of Human Rights), Anthropos, No. 5-6, Ljubljana 2001, p. 170.

way they would protect the national interests. According to Basedow,[34] alongside other activities of national states, the competition law should also be harmonized, which in my opinion could not nullify the existing state because it is not possible to ensure the protection of the social function of competition on a transnational level. Extraterritorial application of national laws, advocated by certain theorists, is a utopia.

IV. EUROPEAN UNION AND ITS COMPETITION GOALS

IV.1. INTEGRATION STARTING POINTS IN THE EU AND HUMAN RIGHTS AND FUNDAMENTAL FREEDOMS

The EU evolved from three communities (i.e. international organizations) that were at first formed solely to pursue economic goals. The Treaty establishing the European Economic Community (Rome, March 23, 1957), alongside common rules on competition, taxes, conjunctural policy and balance of payments, also included individual provisions on social policy, but all those provisions were intended solely to support economic association and integration of member states national markets.[35] European economic integrations and the Council of Europe are based on common foundations of legal civilization and legal culture, but the first integrations were established solely because of economic interests, whereas the Council of Europe was founded with the intention of protecting human rights. This conclusion derives from analyzing the decisions made by the Court of European Communities, which at first rejected reference to human rights and fundamental freedoms because there was no legal basis in EU legislation. It also refused to offer protection based on constitutional law of member states or based on the European Convention on Human Rights. In 1969, the EC Court in the Stauder[36] case changed its position, and in its decision referred to human rights, claiming that human rights are a part of general principles of the Community legislation. Thereafter, the EC Court expressly referred to provisions of international treaties and acknowledged property, freedom to work, freedom to perform commercial and other vocational activities as object of protection (decision Nold, Rs 4/73).[37] The EU first mentioned human rights in formal sources of law in the Single European Act in 1986, and in 2000 EU created an informal act – The Charter of Fundamental Rights of the European Union (Charter). The act itself has the characteristics of a political declaration, but in spite of this, it is of great importance to the citizens of the EU in the field of protection of human rights. The legal bases for the Charter were the Convention and partly the European Social Charter[38]. Apart from the above mentioned, the EU gradually indirectly incorporated individual human rights into the EC Treaty. In articles 17 to 22, the EC Treaty (Maastricht Treaty) introduces citizenship of the EU, in articles 174 to 176 it regulates the protection of the environment, in articles 158 to 162 economic and social cohesion is regulated, and in articles 177 to 181 economic and social development in developing countries, or else, it refers to current and gradual integration of developing countries into the world economy and the campaign against poverty. From a broader perspective, it also regulates the issue of social politics. Relating to abolition of border control under the Schengen Agreement, human rights are dealt with from a broader perspective, especially regarding campaigns against drugs, money laundering, cooperation in the field of civil and criminal legal matters, customs services, police and asylum seekers.[39]

The Treaty establishing the Constitution for Europe (Act Ratifying the Treaty establishing the Constitution for Europe with the Final Act, Official Journal of the Republic of Slovenia, International Treaties, No 1/05) in its preamble and in Article I-2 refers to the cultural, religious and humanistic heritage of Europe and, on the basis of this heritage, developed universal values of inviolability and inalienability of human rights, freedom, democracy, equality and the rule of law. Article I-9 states that the Charter is its integral part, and that the EU becomes party to the European Convention on Human Rights, and that the rights noted down in this Convention are part of general legal principles of the EU. But the real content of the mentioned articles is revealed in Article A. The declaration on provisions of the Constitution, at point 2 of the Annex to the EU Treaty (its integral part) states that the Conference agrees that the accession of the EU to the Convention is regulated in such a manner as to preserve special characteristics of EU law. It is possible to conclude from the statement that

[34] Basedow J., Competition Policy in a Globalized Economy: from Extraterritorial Application to Harmonisation, The International Handbook of Competition, UK, Northampton, MA, USA, 2004, p. 321.

[35] See Lalić G., Temeljni akti evropskih skupnosti (Founding treaties of European Community), Official Journal RS, Ljubljana 2002, p. 12.

[36] See Grilc P., Podobnik K., Accetto M., Pravna ureditev EU in človekove pravice (Legislative Regulation of the EU and Human Rights), Dokumenti človekovih pravic z uvodnimi pojasnili, Društvo Amnesty International in Mirovni inštitut, Ljubljana 2002, p. 73.

[37] See Logar A., Varovanje človekovih pravic in temeljnih svoboščin v pravu EU (Protection of Human Rights and Fundamental Freedoms in Eu Law), Dignitas, Revija za človekove pravice, Nova revija, Ljubljana 2003, No. 17-18, p. 220 and p. 221.

[38] See Ribičič C., Evropska ustavna pogodba in človekove pravice (The EU Charter and Human Rights), Pravna praksa, p. 25/2003, Ljubljana 2003, p. 19.

[39] See supra, note 36, p. 59 and the following.

by adopting the Constitution the EU does not extend the jurisdiction to the general protection of all human rights and fundamental freedoms, but it remains within the earlier scope. This means that human rights and fundamental freedoms will continue to be protected only to the extent necessary for the implementation of essential objectives, including free movement of persons, services, goods and capital and free establishment of undertakings[40].

Such a conclusion is logical and in accordance with the finding that individual human rights and freedoms cannot be implemented at the transnational level because of their nature.

IV.2. ECONOMIC AND SOCIAL FUNCTIONS OF THE COMPETITION IN COMPETITION POLICY AND COMPETITION LAW OF THE EU

By becoming full members of the EU, the member states transferred part of their sovereign jurisdictions to the EU bodies. By doing so, they referred the matter of regulating the single European market to the EU authorities, which can influence market relations in member states through regulation.[41] Hence the question is raised as to what extent the EU implements specific social goals of competition through competition functions, with goals varying from one member state to another. As noted previously, the primary goal of the EU is the protection of economic rights and fundamental freedoms, whereas other human rights and freedoms are protected only to the extent that is useful for implementation of economic goals, in other words, to sustain competition on the single European market. These measures are directed towards individual member states which – prior to becoming members of the EU – have taken care of the protection of human rights and freedoms an such a way that, through the functions of competition, they have also tried to attain economic and social goals and to coordinate them, yet have lost the power to continue doing so. With transferal of jurisdiction in the area of regulating the single market to EU bodies, the latter by legal means and competition policy pursue competition goals on the single market, which predominantly do not overlap sufficiently with the social goals of competition in individual member states. The gap can be seen in the EU competition functions, among EU social goals and social goals in the individual member states, and this deficiency is consequently especially unfavourable for economically weaker member states and for economically weaker undertakings, which are as competitors economically successful.

IV.3. ECONOMIC GLOBALIZATION WITHIN THE EU

The competition goals of the EU, which primarily try to pursue the economic effects, are substantially closer to the interests of the economically stronger undertakings that as a rule have headquarters in more developed member states. Primary business goals of those undertakings are predominantly in accord with the economic interests of multinational companies as initiators of world economic globalization. The only difference is that the former attempt to implement those business interests in the EU market and the latter in the global, but both tend to pursue primarily economic goals of competition and not the social ones. The practical consequence of this is that their activities are not aimed at developing new programs or at establishing new undertakings, but are aimed at attaining a dominant position and taking over the economically successful smaller undertakings. Their superiority, manifesting itself in acquisitions, is executed in compliance with EU legal standards protecting only the single market, but in fact they result in equal consequences for economically weaker undertakings as do the effects of economic globalization, already mentioned. The acquirers in most cases close down research departments in the acquired undertakings claiming that it is in the "interest" of economic rationalization of business operations. After a certain period of time, having established themselves in the markets of the acquired undertakings, the next step is to centralize the sales departments, so that the acquired undertakings become a mere executor of production programs created by the acquirer. The reason why the acquirers as capital investors are only interested in implementing the economic and not the social function of the competition lies in the fact that their interest is directed at generating as much profit as possible and for economic functions to be limited as little as possible by social functions of competition. Apart from the earlier mentioned, for the acquirers as capital investors these undertakings operate in a foreign business environment, so their only interest is to produce as much surplus value as possible at lowest possible costs. Through the acquirers' pricing policy the generated excess value of the acquired undertaking is in most cases redistributed to the most advantageous place, and they can do so because of the free movement of capital principle. Consequently, it is the state and its budget that are at a loss, because such undertaking does not show its actual profit and there is nothing left for the state to tax. Individual member states otherwise are striving to obstruct such appearances by supervising transfer prices

[40] See Ribičič, Ciril, Vpliv sodišča ES na varstvo človekovih pravic v domačem ustavnem sistemu, Podjetje in delo, No. 6 – 7/2005, p. 968

[41] See Oppermann T., Europarecht, 3. Auflage, Verlag C.H.Beck, München 2005, p. 139.

with tax regulations, which is very hard to obtain in the processes of tax supervision.

By transferring competition regulation on to the market jurisdiction, the national states have given up the possibility of preventing the above mentioned trends by using social functions of the competition. Negative consequences of free competition within the EU can also be seen in the fact that competitive prices have both the negative and positive effects of competitive prices. Economically stronger undertakings, which as a rule have headquarters in economically stronger member states, and undertakings holding cutting-edge technology with more favourable competition conditions preclude the survival of smaller, technologically less advanced undertakings. The latter generally come from less developed member states. By transferring jurisdiction for market and competition regulation onto EU bodies, empowered state authorities of member states were precluded from preventing such interference as they must comply with EU legislation, which is formulated on a far broader scale than to meet the particular needs of individual member states.

Generally, it can be noted that European regionalism, coming into effect with integration into the EU, is an effective defence against negative impacts of worldwide globalization and against the economic superiority of multinational companies in markets of individual member states and from the economic policy (competition policy) of those countries. At the same time, it is also possible to come to a conclusion that the impact of EU competition functions in the EU market on the realization of member states' goals is insufficient and in many cases inadequate. Generally speaking, we cannot oppose the widely accepted views that integration into the EU is useful, and that it represents a form of protection of undertakings against worldwide economic globalization processes. But a similar trend which has numerous negative consequences particularly for less developed states[42] is also taking place within the EU. At the same time, the social functions of the competition that should be formed according to specific circumstances in individual member states are being lost. The EU does pay a certain amount of attention to the realization of social functions, environmental, cultural and other programs. These efforts take place in isolation of competition and competition policy in the form of financial incentives, whereas in EU competition economic functions prevail and the social functions are supported only to the extent of allowing and stimulating economic functions.

V. WHAT WERE THE REASONS FOR ESTABLISHMENT OF THE EU?

The beginnings of the EU as we know it today, based on the Single European Act, are the result of the newly formed centres of economic power in the 1980s, especially Japan, South East Asia and the Arab Gulf. It was the time when the world made a transition from an industrial to an information technology society. Given the new circumstances, the goods produced in Western European countries with the social state model became uncompetitive in the world market. The grounds for such a situation were in the growing social standard, which resulted in higher costs of workforce; in addition, Keynes' anti-cyclical fiscal policy became inadequate, therefore the ability of undertakings to take economic incentives and react to new technological industrial changes was lessened.[43] In order to maintain the social state model and for Western European countries to protect themselves against the ever-growing competition on the world market, the further development of integration processes in Europe was favoured. The foundation of integration processes is free movement of goods, services, workforce and capital. This is how the more developed member states expanded their markets and lessened their dependency on the world market, and at the same time they secured for themselvescheaper production factors from less developed environments.

For the EU not to be merely a transitional integration aimed at overcoming the problems that have arisen because of the relatively high social standards in developed Western European states, and have resulted in their goods being no longer competitive on the global market, the EU has without delay to create mechanisms that would for the benefit of less developed member states limit the economic functions of competition and enable the protection of its social functions and, by so doing, secure human rights and fundamental freedoms, realized through the competition in the market.

Legal theory favours the stand according to which the case-law of the European Court of Justice would be accepted as the minimum level of protection of human rights and fundamental freedoms, and it would be left for the national legislator that the implementation of human rights and fundemental freedoms is in content defined according to their specific cultural, historical, social and political values. The protection of national member states that provide higher level of protection should have an advantage over the

[42] Similar doubt is expressed by Oppermann T., Vom Niza Vertrag, 2001, Zum Europäischen Verfassungkonvent, 2002-2003, Pravni život, No. 12/2003, Beograd 2003, p. 529.

[43] See Kranjec M., (note 8), p. 22.

EU protection, and the minimum level of protection under EU law should take effect also for the members in which the level of protection is lower.[44] Nevertheless, such efforts can be successful only in the areas implementing classic human rights and fundamental freedoms, whereas their implementation in the areas relating to free and single economic space are much more subordinate to the EU standards and law, which have on its basis been set up in case-law of European Court of Justice. The level of protection of social functions of competition is displayed in the employment of fundamental freedoms such as free movement of goods, services, capital and persons. Human rights and fundamental freedoms are guaranteed by the EU and protected only as far as preservation of the specifics of EU law are concerned, but even from the aspect of formality of law the protection of each undertaking is not guaranteed to a sufficient level. Given the primarity of EU law, EU law always has an advantage over member states' legislation, the member states therefore cannot offer protection that would supplement EU law to the legal subject in the area of regulating the single market.

PROPOSALS:

1. EU should change the criteria (under 250 million Euros of joint turnover) of control over takeovers, so as to prevent takeovers which result in objectively reducing competition on the single EU market (reducing the number of competitors under the critical number due to takeovers);
2. The legal order of EU should enable member states in the area of takeovers to protect those human rights and freedoms that are implemented through social functions of competition, so that on the national level they could prevent individual takeovers by limiting economic functions of competition, which are enforced by economically stronger subjects through takeovers and with which they prevent the protection of non-economic rights and freedoms of the competition in national states.
3. To implement the two above mentioned proposals, the EU law should define EU institutions' jurisdictions anew and part of the jurisdictions should be transferred back to national institutions of member states; it should also regulate the cooperation among competent bodies of control over undertakes of EU and national states.

CONCLUSION

Human rights and fundamental freedoms, legally regulated in the Convention for the Protection of Human Rights and Fundamental Freedoms (signed at Rome on 4 November 1950, entered into force on 3 September 1953) are in social states (Sozial Staat) predominantly manifested through economic and social functions of competition. Social welfare as an expression of implementing human rights and fundamental freedoms is optimum in the above mentioned systems, once we have established a balance between economic and social functions of competition. The contents of human rights and fundamental freedoms are conditioned by philosophy, morals, culture, political tradition, level of social development and the heritage of traditional values of the social community in particular time and space. Full implementation of these rights can therefore be guaranteed only on the national level, and it is only possible to transfer the implementation of certain rights to the transnational institutions. Only those rights which are socially neutral can be transferred (the exception is of course European Court for Protection of Human Rights and Fundamental Freedoms) e.g. economic freedoms under the condition of retaining the power of the national state, with which it can despite the transference implement its social goals.

When becoming members of the EU, the member states, whose political systems were based on social states, have transferred jurisdictions for regulating macro economic policy to the EU organs, and by doing so yielded the main part of tasks to implement economic freedoms of legal entities to the EU. By transferring those rights they gave up the right, which entitled them - because of pursuit of broader national social goals (other rights and freedoms) - to limit economic freedoms. The EU can implement only the economic rights, while other rights and freedoms can because of their nature only be implemented to the extent that serves as a support for full implementation of economic freedoms. These are manifested as free economic initiative or free competition in the EU market, supplemented with certain social rights such as the right to equality and the right to environmental protection (Art. 2 of Treaty establishing the European Economic Community (1957).

Thus EU protects free competition in single European market and declares those actions of participants on the market which threaten or suppress free competition in the EU market or its relevant market as anti-competition ones. EU does not ensure protection from anti-competition actions of participants, which are carried out in national markets of member states, and member states having transferred the jurisdictions over market regulation no longer have jurisdiction to implement the protection by exercising their right to limit economic functions of competition with social functions, even if such actions are in direct contradiction with their economic and social

[44] See Ribičič C., (note 38), p. 19.

goals, and even if they are in contradiction of declared goals of free competition of the EU. The consequences of the above statements are seen especially in the area of takeovers, where economically stronger business undertakings abolish or overpower economically weaker competitors. EU legislation regulates the control over mergers (Commission Decision of 27/09/2002 declaring a concentration to be compatible with the common market, Official Journal 248 , 15/10/2002 P. 0027 – 0027) in those cases when total turnover of a business undertaking about to merge exceeds 250 million Euros in the EU market or 5 billion Euros in the world market. EU does not ensure protection against takeovers in cases when the mentioned suppositions are not met. This enables economically stronger subjects to take over the economically weaker subjects and the integration of the latter into their "economic community" or even the abolishment of the weaker. Thus the competition on the EU single market is being objectively reduced, and the economic inferiority not only of the economic subjects but as a rule also of the member states (i.e. budget), in which are the headquarters of those weaker subjects that were taken over, is increased. Typical examples in Slovenia, which confirm my thesis, are the takeover of Julon d.d., Ljubljana, Saturnus, d.d., Ljubljana, Zlatorog, d.d, Maribor, etc.

ABBREVIATIONS

EU – European Union
EU Court – EU Court of Justice Luxembourg
EU Treaty – Treaty establishing the European Community
UN – United Nations
WTO – World Trade Organisation
WWII – Second World War

REFERENCES

[1] Banič, Ivo, »Globalizacija gospodarstva in potencial tujih investicij v Sloveniji (Globalization of Economy and Potential of Foreign Investment in Slovenia)«, *Slovenska ekonomska revija, No. 3*, Ljubljana, 1992.

[2] Bailey, Stephen J., »Public Sector Economics – Theory, Policy and Practices«, *Macmillan Press Ltd*, London, 1995, p. 10.

[3] Bartling, Hartwig, Leitbilder der Wettbewerbspolitik, München, 1980, p. 45.

[4] Basedow, Jürgen, »Competition Policy in a Globalized Economy: from Extraterritorial Application to Harmonization«, *The International Handbook of Competition*, UK, Northampton, MA, USA, 2004, p. 321.

[5] Bederman, David, »Globalization, International Law and United States Foreign Policy«, *Emory*, L.J., 2001, p. 717.

[6] Bennet Juliette, Multinational corporations, social responsibility and conflict, Journal of International Affairs, March 2002, p. 186.

[7] Cerar, Miro, »Narava in pomen človekovih pravic (The Nature and Meaning of Human Rights)«, In: *Dokumenti človekovih pravic z uvodnimi pojasnili, društvo Amnesty International in Mirovni inštitut*, Ljubljana, 2002, p. 17.

[8] Cerar, Miro, »Večrazsežnost človekovih pravic in dolžnosti (Wide-ranging Meaning of Human Rights and Duties)«, 2nd edition, *Znanstveno in publicistično središče*, Ljubljana, 1996, p. 65-98, p.122-132.

[9] Cox, Robert, »A Perspective on Globalization«, *In globalization, Critical reflections, No. 21,23*, J Mittelman edition, 1997.

[10] Dupuy, Pierre-Marie, »International LAW, Thorn between Coexistence, cooperation and globalization«, *International law*, 1998.

[11] Falk, Richard, »Global civil society and the democratic prospect, in global Democracy«, *Key debates*, edited by Barry Holden, Routledge, London, 2000.

[12] Gamble, John, King/Allen, Emily A.,Dirling, Nicole L., »International law and globalization: allies, antagonists or irrelevance?« *In Globalization, Critical reflections, No. 21,23,* J Mittelman edition, 1997, p. 115.

[13] Grilc, Peter, »Boundaries of Competition, Competititon Policies and Competition Law«, *Pravnik No. 9/10*, Ljubljana, 1996, p. 73, p. 474.

[14] Grilc, Peter, Podobnik, Klemen, Accetto, Matej, »Pravna ureditev EU in človekove pravice (Legislative Regulation of the EU and Human Rights)«, *Dokumenti človekovih pravic z uvodnimi pojasnili, Društvo Amnesty International in Mirovni inštitut*, Ljubljana, 2002.

[15] Grilc, Peter et al., »Zakon o preprečevanju omejevanja konkurence s komentarjem (Law on Prevention of Limitation of Competition with Commentary)«, *Gospodarski Vestnik*, Ljubljana, 2000, p. 113.

[16] Grilc, Peter, »Pravo EU (EU Law)«, 2nd volume, *Cankarjeva založba*, Ljubljana, 2001, p. 563.

[17] Held, David, McGrew, Anthony, »The end of the old order?«, *Globalization and the prospects for World order*, International Law Studies, 1998.

[18] Herman, Edward, »The Threat of globalization«, *New policy*, No. 40, 1999, p. 40.

[19] Herbert, Giersch, »Allgemein Wirtschaftspolitik«, Wiesbaden, 1996, p. 73.

[20] Herzog, Roman, Sozialstaatklausul als zukunftsorientirten Rechtsbegriff – Commentary to Grundgesetz, Maunz Duering, p. 19.

[21] Heße, Manfred, Wettbewerbsrecht, Verlag Sanerländer, Wien, 1998, p. 10.

[22] Hösch, Ulrich, »Grundlagen des Wettbewerbsrechts«, *Richrd Boorberg Verlag*, Stuttgart, 1996, p.25, p. 29.

[23] Kantzenbach, Erhard, »Die Funktionsfähtigkeit des Wettbewerbs«, 2. durches. *Auflage, Vandhoek u. Ruprecht*, Göttingen, 1967, p. 15-16.

[24] Korže, Branko, »Ustavni temeljni podjetništva (Constitutional Bases of Enterprise)«, *Podjetje in delo, No. 5-6, Gospodarski Vestnik*, Ljubljana, 1993, p. 462.

[25] Kranjec, Marko, »Davki in proračun (Taxes and Budget)«, *University of Ljubljana, Faculty of Public Administration,* Ljubljana, 2003, p. 24.

[26] Lalić, Gordana, »Temeljni akti evropskih skupnosti (Founding Treaties of European Community)«, *Official Journal RS*, Ljubljana, 2002, p. 12.

[27] Logar, Anže, »Varovanje človekovih pravic in temeljnih svoboščin v pravu EU«, *Dignitas, Revija za človekove pravice, No. 17-18, Nova revija*, Ljubljana, 2003, p.220-221.

[28] Martin, Stephen, »Globalization and the Natural Limits of Competition«, *The International Handbook of Competition*, Chetlenham, UK, Northampton, Ma, USA, 2004, p. 47, p. 50.

[29] Musgrave, Richard A., Musgrave, Peggy B., »Public Finance in Theory and Practices«, 5th international issue, *McGraw Hill boook company*, Singapore, 1989, p. 131.

[30] Möscher, Wernhard, Schutzziele eines Wettbewerbsrechts, Festschrift Pittner, p. 405

[31] Opperman, Thomas, »Vom Niza Vertrag 2001, Zum Europäischen Verfasssungkonvent, 2002-2003«, *Pravni život, No. 12*, Beograd, 2003, p. 529.

[32] Opperman, Thomas, »Europarecht«, 3. Auflage, *Verlag C.H. Beck*, München, 2005, p. 139.

[33] Oveerbeek, Johannes, »Free Trade versus Protectionism«, *Edward Elgar Publishing, Limited*, UK, Cheltenham, 1999, p. 392-404.

[34] Perenič, Anton, »Svet Evrope in človekove pravice«, In: *Dokumenti človekovih pravic z uvodnimi pojasnili*, Društvo Amnesty International in Mirovni inštitut, Ljubljana, 2002, p.49.

[35] Pretnar, Bojan, »Intelektualna lastnina v sodobni konkurenci in poslovanju (Intellectual Property in modern

competition and business)«, *Gospodarski Vestnik*, Ljubljana, 2002, p.107.
[36] Ribičič, Ciril, »Evropska ustavna pogodba in človekove pravice (The EU Charter and Human Rights)«, *Pravna praksa*, No. 25, Ljubljana, 2003, p. 19.
[37] Ribičič, Ciril, »Vpliv sodišča ES na varstvo človekovih pravic v domačem ustavnem sistemu«, *Podjetje in delo*, No. 6-7/2005, Ljubljana, 2005, p. 968.
[38] Schmidt, Ingo, Binder, Steffen, »Wettbewerbspolitik im internationalen Vergleicht«, *Verlag Recht und Wirtschaft GmbH*, Heidelberg, 1996, p. 15.
[39] Šali, Franc, »Globalizacija – zaton kapitalizma in vzpon človekovih pravic (Globalization – Decline of Capitalism and Rise of Human Rights)«, *Anthropos*, No. 5-6, Ljubljana, 2001, p. 719, p. 170.
[40] Šturm, Lovro, »Komentar Ustave Republike Slovenije (Commentary to Constitution of the Republic of Slovenia)«, *Fakulteta za podiplomske državne in evropske študije, Uradni list RS*, Ljubljana, 2002.
[41] Zabel, Bojan, »Tržno pravo (Commercial Law)«, *Gospodarski Vestnik*, Ljubljana, 1999, p. 91-99, p. 131.

Determinants of structural adjustments: A Case of Slovenian companies

Rant, Melita

Abstract— ***In frequently changing environments firms need to operate like living organism. It is important to be adaptive in order to ensure scarce resources. Adaptiveness is effectively facilitated by organic organizational structure. Besides that control over scarce resources can be increased also by introduction of proper structure of external relationships. Structure of external relationships is better known as a network structure of firms. Networks improve stability of firms' environment. Therefore networks improve stability of firm's operations. Because of greater stability firms are more likely to operate like machines. Therefore we can talk about mechanistic network structure on one hand and organic organizational structure on the other. Link both structural concepts into one implies that in uncertain environment firm need to develop organic organizational structure on one hand, and mechanistic network structure on the other. The question is, if this is true? Are firms that facilitate these two kinds of structural adaptations more successful? How are organic organizational structure adaptations and mechanist network adaptations related to specific environmental changes? Which environmental changes cause which structural adaptations? What are other factors that affect organizational and network structure adaptations? In this paper I am addressing these questions. In order to answer them, I have developed some hypotheses about studies questions by examining different organizational theories. These hypotheses have been tested on a sample of 237 medium and large Slovenian firms. Besides highlightening of upper questions, empirical research uncovered also three things: (1) which particular environmental changes have dominated in Slovenia economy in period 2000-2005; (2) what significant organizational and network structural adjustments have been made by Slovenian firms; and (3) can we detect some partial misfits in organizational and network structure changes, that might facilitate some future business problems.***

Key words: environmental developments, network structure adaptations, organizational structure adaptations.

1. INTRODUCTION

In frequently changing environments firms need to operate like living organism. It is important to be adaptive in order to ensure scarce resources. Adaptiveness is effectively facilitated by organic organizational structure. Besides that control over scarce resources can be increased also by introduction of proper structure of external relationships. Structure of external relationships is better known as a network structure of firms. Networks improve stability of firms' environment. Therefore networks improve stability of firm's operations. Because of greater stability firms are more likely to operate like machines. Therefore we can talk about mechanistic network structure on one hand and organic organizational structure on the other. Link both structural concepts into one implies that in uncertain environment firm need to develop organic organizational structure on one hand, and mechanistic network structure on the other. The question is, if this is true? Are firms that facilitate these two kinds of structural adaptations more successful? How are organic organizational structure adaptations and mechanist network adaptations related to specific environmental changes? Which environmental changes cause which structural adaptations? What are other factors that affect organizational and network structure adaptations? In this paper I am addressing these questions. In order to answer them, I have developed some hypotheses about studies questions by examining different organizational theories. These hypotheses have been tested on a sample of 237 medium and large Slovenian firms. Besides highlightening of upper questions, empirical research uncovered also three things: (1) which particular environmental changes have dominated in Slovenia economy in period 2000-2005; (2) what significant organizational and network structural adjustments have been made by Slovenian firms; and (3) can we detect some partial misfits in organizational and network structure changes, that might facilitate some future business problems.

2. STRUCTURAL RESPONSE TO ENVIRONMENTAL SHIFTS

Relationships between organizational and network structure adaptations have become special interests of study in organizational as well as in economic field. This object of study has been addressed by contingency theory, population ecology, institutional theory, learning theories, punctuated equilibrium theory, resource based theory, system theory of the organization, strategic choice theory, transaction cost theory, evolutionary economic, artificial economies,

Manuscript received January 15, 2006.
Melita Rant, University of Ljubljana, Faculty of Economics
E-mail: melita.rant@uni-lj.si

evolutionary games (Dosi, Winter, 2000). I will study organizational and network structure changes in the context of environmental changes. Organizational structure adaptations reflect changes in the structure of relationships between employees; networks structure adaptations reflect changes in the structure of relationships between firms. Therefore, organization and network structure changes represent two kinds of structural adjustments.

Applying to the concept of structure mechanistic and organic terms are frequently used. Term mechanistic brings to mind a machinelike system designed for efficient operation (Robey, 1991). Characteristics of mechanistic (or mechanic) organizational structure are following: jobs narrow in scope; rules and procedures; clear responsibilities; hierarchy; objective reward system; objective selection criteria; official and impersonal. In mechanistic network structure relationships between partners are well defined and focused on long-term cooperation.

Organic organizational structures have properties of living organisms and therefore better facilitate adaptiveness (on account of efficiency). Organic systems adapt more readily to changes in environment. Characteristics of organic organizational structure are following: broadly defined jobs, few rules or procedures, ambiguous responsibilities; diffuse channels; subjective reward system; subjective selection criteria; informal and personal. In organic network structure relationships between partners are loosely defined and quite fluid.

Static contingency theory mainly studies organizational structure. This theory postulates that mechanistic organizational solutions better fit stable environment, routine technology, differentiation strategy, large enterprises and extrinsically motivated people (Burns, Stalker 1961; Burton, Obel 1998; Donaldson, 1999). On the other hand organic organizational solutions better fit unstable environment, non-routine technology, cost driven strategy, small and medium enterprises with intrinsically motivated people.

Institutional theory (Kondra, Hinings 1998; Knoke, 2000) introduces the concept of homogeneity and isomorphism of organizational solutions. There are many forces that stimulate homogeneity. Among most powerful ones are coercive rules, mimetic learning and professional isomorphism. These three mechanisms, especially professionalism, nowadays forces organic organizational structure and mechanistic network structure solutions.

Organizational ecology (Baum, Oliver, 1991, 1992; Singh, 1991; Baum, 1999) on the other hand says that introduction of appropriate organizational and network structure solutions is a result of luck and coincidence. Organizational ecologists see environment very unstable and unpredictable. In such circumstances it is really hard to properly respond to its emerging developments. Organizational ecology view is contrary to organizational learning theory vies. The latter assumes that firms are able to learn form past mistakes and based on developed knowledge properly predict and react to environmental development. March's (1991) organizational learning theory points out that exploitation organizational adaptations, which are based on single loop learning, are better implemented within mechanistic organizational context, and exploration adaptations, which are based on double loop learning, are better implemented within organic organizational context.

Tushman and Romanelli (1985, 1994) related learning theories ideas with organizational theory and developed so called punctuated-equilibrium theory. This theory outlines that companies that operate in a radically transforming environment, need to radically transform themselves as well. On the other hand companies that operate in a stable environment, need to perform only incremental organizational adaptations. Radical transformations is better implemented in the organic organizational context, incremental improvements are better implemented under mechanistic organizational context.

System theory (Levinthal, Warglien, 1999; Raak, Paulus, 2001) is general theory and therefore studies different kinds of systems. One of the systems are social systems and one of the social systems are firms. In relation to them complexity system theory explains how firms need to behave (that is adapt their structure and processes) in order to reach local peaks (that is possible effectiveness add efficiency levels) in their specific landscape design (that is in theirs environment).

Resource dependence theory (Mezias, Lant, 1994) studies groups of related companies, better known as networks. It is interested in their characteristics and incentives for change. In the context of increased resource scarcity, which stimulates competitive fights between firms, firms form enclaves. Enclaves facilitate better control over scarce resources (Meyer et al., 1995). Transaction cost theory (Jones, 1998; Roberts, Greenwood, 1997) on the other hand studies transactions. In the context of transaction analysis indirectly studies network structures as well. In that relation increasing environmental uncertainty raises costs of transactions conducted between different business partners. Transactions are important for firm's operations. In order to secure their operations and lower their transaction costs firms try to introduce greater controllability over uncertain transaction. They are trying to establish more formalized (mechanistic) relationships between partners.

When transactions uncertainty and therefore transactions costs exceed certain limit, transactions are internalized. Internalization is expensive and rational only when transactions costs are really high.

Child's (1972, 1997) strategic choice theory focuses on a management decision making process. It postulates management autonomy. Managers have a free choice to decide how to react to environmental developments. They have a free choice to decide, whether do adapt to environment or to try to change it. The first is mainly done by organization structure and contingency adaptations (Burton, Obel, 2004), the latter by network structure adaptations. When they have strong market position, like is the case of a monopoly or oligopoly (Donaldson, 1999), they should decide for second choice. They can try to change their environment usually by facilitating certain networking mechanisms like coopting, lobbying, forming strategic and negotiation partnerships, mergering and acquiring etc.

Lewin's and Volberda's (1999) are initiators of new line of organizational theory development, known as coevolution theory. The basic assumption of coevolution theory is that organizations, industries (populations), and environments (institutional and extra-institutional) coevolve (Lewin et al., 1999). The goal of coevolutionary inquiry is to understand how the structure of direct interactions and feedback loops within organization-environment systems gives rise to their dynamic behavior (Baum, Singh, 1994). Coevolution implies nonlinearities, which can substantially complicate attempts to understand evolutionary change on different levels. In order to study nonlinear effects feedback loops should be studied. Longitudinal coevolutionary research requires a richer arsenal or research methods and techniques beyond traditional time series methods and hazard or rate function models. (Lewin, Volberda, 1999).

To summarize, different organizational theories point out different views on firm's structural adaptations. In some aspects they complement each other or say same things differently. Majority of them (Volberda, 1999; Donaldson 1999; Lewin et al. 1999; Lewin, Volberda, 1999; Baum, Singh, 1994 and others) points out that "environmental conditions are regarded as a direct source of variations in organizational and network structures…" (Volberda, 1998, pp. 44-46).

Hypothesis 1: Environmental changes are the key drivers of organizational and network structure adaptations.

Changes in environment are a key determinant of firms' structural adjustments. For that hypothesis testing I have used a network analysis. In this analysis network is composed of changes in the environment and organization and network structure changes that have correlation higher than 0,3. Network analysis have given me important information about centrality indices and feedback loops. Centrality indices are indicators of power and influence of a specific change (Knoke, 2000). Feedback loops are indicators of lagged, nonlinear, and multilevel effects of environment-structure coevolution (Lewin et a., 1999). In relation to centrality indices I expect that environmental changes have the highest centrality indices. In relation to feedback loops, I expect that most prominent feedback loops have high knowledge incorporation potential. Most important feedback loops are loops that consist of changes that incorporate high levels of new knowledge.

Dynamic contingency (Volberda, 1999) and (co)evolutionary theories ideas (Lewin et al., 1999; Lewin, Volberda, 1999) point out that (1) substantial unpredictable changes in business environment form environmental uncertainty; and (2) that to environmental uncertainty firms should adapt by organic organizational and mechanistic network structure adaptations. Environment changes are substantial when a firm perceives many extensive changes in short time period. For instance when firms perceive raising price and quality competition, narrowing of product life cycles, raising market power of competitors, fast development of substitutes, greater takeover threats by competitors, decreasing customers' purchasing power, takeover threats by clients/suppliers, fast technology developments, significant regulations changes etc. Key environmental changes that construct environmental uncertainty are presented in Table 1.

Table 1: Environmental changes indicators

Segments	Changes	Extent of change	Theoretical and/or empirical background
Competitors	Raising numbers of competitors (VO1)	1 2 3 4 5 6 7	Porter (1983); Daft (1986;
	Product life cycle narrowing (VO2)	1 2 3 4 5 6 7	1998); D'Aveni (1995);
	Price cutting wars (VO3)	1 2 3 4 5 6 7	Volberda (1999)
	Fast quality improvements (VO4)	1 2 3 4 5 6 7	
	Raising market power of competitors (VO5)	1 2 3 4 5 6 7	
	Development of substitutes (VO6)	1 2 3 4 5 6 7	
	Takeover threats by competitors (VO7)	1 2 3 4 5 6 7	
Clients	Decreasing purchasing power (VO8)	1 2 3 4 5 6 7	Porter (1983); Daft (1986;
	Raising negotiation power of clients (VO9)	1 2 3 4 5 6 7	1998); Volberda (1999)
	Takeover threats by clients (VO10)	1 2 3 4 5 6 7	
Suppliers	Decreasing variety of suppliers (VO11)	1 2 3 4 5 6 7	Porter (1983); Daft (1986;
	Raising negotiation power of suppliers (VO12)	1 2 3 4 5 6 7	1998); Volberda (1999)
	Takeover threats by suppliers (VO13)	1 2 3 4 5 6 7	
Work force	Moving production and other operations to countries with lower cost work force (VO14)	1 2 3 4 5 6 7	Rifkin (1995);
	Importing (immigration) low cost work force from less developed countries (VO15)	1 2 3 4 5 6 7	
Technology	Automation of production activities (VO16)	1 2 3 4 5 6 7	Daft (1986; 1998); Scott
	Fast development of information technology(VO17)	1 2 3 4 5 6 7	(1987); Dean (1992); Slocum,
	Shortening of technology life cycles (VO18)	1 2 3 4 5 6 7	Lei (1995); Fulk, DeSanctis (1995); Jones (1998); Volberda (1999); Sucu, Demiral (2003)
Institutional environment	High expectation for social responsibility (VO19)	1 2 3 4 5 6 7	Scott (1987); Daft (1986;
	Transparency of firm's market values (VO20)	1 2 3 4 5 6 7	1998); Bartlett, Ghoshal (1991);
	Globalization of business environment (VO21)	1 2 3 4 5 6 7	March (1994); Jones (1998);
	Significant legislation changes (VO22)	1 2 3 4 5 6 7	Volberda (1999); Knoke (2000); Sucu, Demiral (2003); Voelpel et al. (2004)

To environmental uncertainty firm should respond by organizational structure adaptations that improve adaptiveness of the firm. Burns and Stalker (1961) called that organic structural changes. Cases of such changes are automation of work processes, information technology updating, decentralization of decision-making, professionalization of employees, downsizing and delayering hierarchy, job enlargement and rotation, cooperation and team work, outsourcing, job descriptions and work flow adaptations, customization and so on. These so adaptations have been a part of my empirical

research. They are presented in Table 2.

Table 2: Organizational (internal) structure adaptations indicators

Indicators	Prod.	Sales	Purch.	Finan.	Staff	Stats	Theoretical and/or empirical background
Work process automation (SP1)							Rifkin (1995); Volberda (1999); Hammer, Champy (1993);
Updating information technology (SP2)							Rifkin (1995); Sanchez, Mahoney (1996); Hinds, Kiesler (1995); Volberda (1999); Hammer, Champy (1993); Child, McGarth (2001)
Decision-making decentralization (SP3)							Ashkenas et al. (1995); Volberda (1999); Hammer, Champy (1993);
Professionalization of employees (SP4)							Rifkin (1995); Hinds, Kiesler (1995); Sucu, Demiral (2003); Hammer, Champy (1993);
Downsizing (SP5)							Rifkin (1995); DeWitt (1993); Cameron et al. (1995); Volberda (1999); Hammer, Champy (1993);
Delayering (SP6)							Rifkin (1995); Ashkenas et al. (1995); DeWitt (1993); Cameron et al. (1995); Volberda (1999); Smith (2003); Hammer, Champy (1993);
Job enlargement and rotation (SP7)							Rifkin (1995); Adler et al. (1999); Hammer, Champy (1993);
Team work (SP8)							Rifkin (1995); Ashkenas et al. (1995); Sanchez, Mahoney (1996); Volberda (1999); Smith (2003); Sucu, Demiral (2003); Hammer, Champy (1993); Galbraith (1993);
Cooperation between different business functions and professional fields within firm (SP9)							Rifkin (1995); Ashkenas et al. (1995); Hinds, Kiesler (1995); Sanchez, Mahoney (1996); Volberda (1999); Hammer, Champy (1993); Galbraith (1993); Lovelace et al. (2001);
Products/services customization (SP10)							Ashkenas et al. (1995); Volberda (1999); Hammer, Champy (1993);
Outsourcing (SP11)							Ashkenas et al. (1995); Volberda (1999); Smith (2003); Sucu, Demiral (2003); Hammer, Champy (1993);
Binding rewards on individual/collective outcomes (SP12)							Cameron et al. (1995); Hammer, Champy (1993);
Decentralization of planning activities (SP13)							Sucu, Demiral (2003); Chen (2001);
Adaptation of work descriptions (SP14)							Ashkenas et al. (1995); Hammer, Champy (1993);
Reorganizations of departments (SP15)							Ashkenas et al. (1995); Hammer, Champy (1993);
Project work (SP16)							Volberda (1999); Hammer, Champy (1993);
Business process reengineering (SP17)							Ashkenas et al. (1995); Al-Mashari (2001) Cao et al. (2001); Hammer, Champy (1993);

To environmental uncertainty firm should respond by mechanistic network structure adaptations (Pfeffer, Salancik, 1978). The latter include informal agreements making with business partners, clustering, joint venturing, minor or major ownerships swapping, and mergering and acquisition activities etc. Mechanistic network structure changes are presented in Table 3.

Table 3: Network (external) structure adaptations indicators

Indicators	Suppl.	Clients	Compe.	Finan. instit.	Resear. instit.	Others	Theoretical and/or empirical background
Making informal agreements (RS1)							Pfeffer, Salancik (1978); Pfeffer (1982); Jones (1998); Scott (1998);
Clustering and strategic partnering (RS2)							Pfeffer, Salancik (1978); Pfeffer (1982); Hagedoorn (1993); Jones (1998); Khan, Ghani (2004); Elmuti et al. (2005); Osborn et al. (1998)
Minority (25%) share ownerships purchasing (RS3)							Pfeffer, Salancik (1978); Pfeffer (1982); Jones (1998); Scott (1998)
Joint venturing (RS4)							Jones (1998); Scott (1998); Elmuti et al. (2005); Osborn et al. (1998)
Majority (75%) share ownerships purchasing (RS5)							Pfeffer, Salancik (1978); Pfeffer (1982); Jones (1998), Scott (1998)
Acquiring and mergering (RS6)							Pfeffer, Salancik (1978); Pfeffer (1982); Jones (1998); Scott (1998)

According to dynamic contingency theory (Burton, Obel, 2004) in environmental uncertainty firms should introduce organic organizational and/ mechanistic network structure solutions at the same time. When these two kinds of adaptations are done properly, firms should temporary reach organizational fit (Donaldson, 1999). Dynamic organizational fit is defined as a convergence between environmental, organizational and network structure change processes. Purpose of a organizational structure is to assure rational execution of operations (Lipovec, 1987). Rationality of operations is most successfully measured by value added per employee and ration between output and input. If structural adaptations improve organizational fit, these two measures should indicate this improvement.

In order to study dynamic organizational fit, I have distributed firms into four groups.

- First group consists of firms that perceived above average environmental uncertainty and conducted above average organic organizational structure adaptations and mechanistic network structure adaptations. These firms should be nearest to the organizational fit and, therefore, should have highest efficiency improvements or et least lowest decreases in efficiency rates.
- Second group consists of firms that perceived below average environmental uncertainty and didn't perform organization and network structure adaptations. These firms operate in stable circumstances and have stable organizational fit. Their efficiency levels should not change significantly.
- Third group consists of firms that perceived above average environmental uncertainty and conducted only one type of adaptation, either internal or external. These firms are not as successful in sustaining organizational fit as the first group of firms. Thex should have modest long-term efficiency improvements.
- Forth group consists of firms that perceived above average environmental uncertainty and didn't conduct organizational and network structure changes. According to dynamic contingency theory these firms are moving away from organizational fit situation. They should have highest levels of efficiency decreases.

Hypothesis 2: First group of firms is expected to be most efficient in the long-run and have the highest efficiency improvement rates. Second group of firms is in a same-state position; it should have modest long-term efficiency levels and no changes in efficiency levels. Third group of firms is expected to experience modest improvements in efficiency levels. Fourth group of firms is expected to be the least efficient in the long run. It experiences the lowest improvements or the highest decreases in efficiency levels.

On the other hand processes of organizational and network structure adaptations are substantially affected by other determinants. Different organizational theories point out different influential variables. For instance punctuated equilibrium theory (Tushman, O'Reilly 1996) points out environmental instabilities. Resource dependence theory (Mezias, Lant 1994) points out instabilities in relationships with customers. Transactions cost theory (Williamson 1994) points out uncertainties in transactions conducted between different business partners, especially clients. Globalization is an important determinant of environmental instabilities. I have measured these variables indirectly through percentage of export in whole sale. I have hypothesized that greater firm's globalization measured by firm's export percentage enforces more organization and network structure adaptations. Regular customers present another important motivation for adaptations. Firms are usually more prone to adapt to regular than

irregular customers requests. Therefore, I have hypothesized that regular clients enforce motivation for organizational and network structure adaptations.

On the other hand Argyris (1978), March (1991) and others organizational learning theorists stress that (1) firms need to learn in order to successfully adapt and (2) that education is an important determinant of firm's learning potential. Learning potential has been measured indirectly by years of formal education of employees. I have hypothesized that more educated employees improve learning potential o and, therefore, increase chance of organization and network structure adaptations.

Institutional theory (Scott 1987, 1992, 1995) says that firms introduce organizational and network structure changes that are well accepted in a specific institutional environment. DiMaggio and Powell (1983) talk about institutionalizing processes that produce greater homogeneity of firms. Special kind of isomorphism is facilitated by consulting firms. They replicate same advices to different firm and thus diffuse specific organizational and network structure solutions between them. The extent of professional isomorphism has been measured indirectly by hours of collaboration with external management counsellors. I hypothesized that more counseling enforces organic organizational structure and mechanistic network structure adaptations.

Hypothesis 3: Higher percentage of sales on foreign markets, higher percentage of regular clients, better education of employees, more hours of management counseling enforce organic organizational structure adaptations and mechanistic network structure adaptations.

These hypotheses have been tested on empirical data gathered in Slovenian economy in period January 2001-January 2005.

3. FINDINGS

3.1 Research Design

Study of environmental developments and organization and network structure adaptations was conducted in period December 1999-January 2004 on sample of 237 medium and large Slovenian companies. I was studying 22 environmental changes, 17 organizational structure changes and 6 network structure changes. These changes are presented in Table 1, 2 and 3. The level (extent) of each change has been assessed on 1 to 7 Likert scale.

Extend of the organizational structure changes I have assessed indirectly. I have used 6 different business fields, where a specific organizational change might be conducted: sales, production, purchasing, finance, staffing, and support function (information processing, planning and control etc). The extent of a specific organizational structure change has been assessed in relevance on how many fields it had been introduced. If a specific organizational structure change wasn't executed, it has been assessed with 1. If it was performed on only one field (i.e. production), it has been assessed with 2, and so on. If it was performed in all six functional fields, it has been assessed with 7.

Extent of the network structure changes I have assessed indirectly as well. I have studied six different groups of business partners: suppliers, clients, competitors, finance institutions (banks, investing funds), research institutions, and others (unions, government etc.). The extent of a specific network structure change has been assessed according to how many groups of business partners was introduced to. For instance, if a specific network structure change like strategic partnering was introduced only to suppliers, that an extent of strategic partnering for this firm in period 2000-2005 has been assessed with 2. If it was introduced to suppliers and clients, than it has been assessed with 3. If strategic partnerships were developed with all six groups of business partners, than it has been assessed with 7.

Long-term efficiency was assessed by two indicators: (1) five year average value-added per employee, and (2) five year average ratio between revenue and expenditures.

Questionnaire has been made in a form of Table 1, Table 2 and Table 3. The study was conducted retroactively. It was focused in period from January 2000 to January 2005. Questionnaires were sent to management of all medium and large Slovenian companies. Criterion was more than 50 employees at the 31st of December 2004. At those point of time there was 1370 of companies that fitted 50 employees criterion. 262 questionnaires had returned, and 237 of them had no missing data. So the sample size presents 17.3 % of all the whole population.

3.2 Sample Profile

Charts 1-4 present sample profile according to assets, product/service sales, foreign/domestic sales and state ownership of the sampled firms. Distributions of firms according to each of four criterions are relatively close to population distributions. I can conclude that this sample is a good representative of a population.

Chart 1: Distribution of companies according to assets

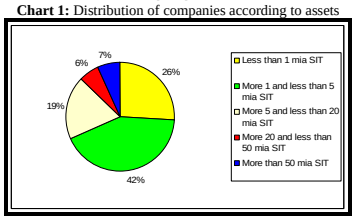


Chart 2: Distribution of companies according to services/products sales

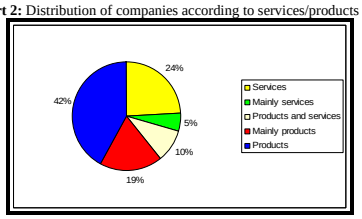


Chart 3: Distribution of companies according to portion of sales on foreign markets

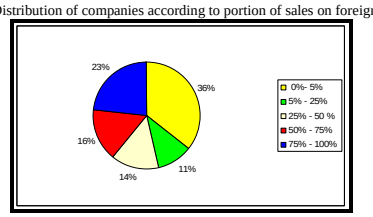
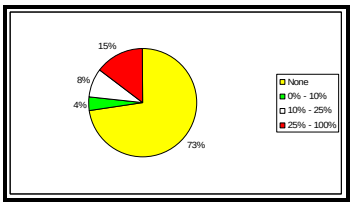


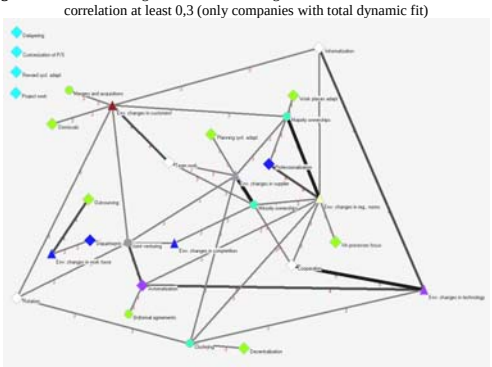
Chart 4: Distribution of companies according to state ownership



3.3 Results

Network analysis confirmed that environmental changes have the highest centrality indices. These indices tell us that these changes have the highest power and greatest influence on other changes. In Figure 1 we can see that changes of regulation and norms have directly influence 8 other organizational and network structure changes. Then follow changes of customer segment. They have 7 direct influences on organizational and network structure changes. Environmental changes of supplier segment have 6 direct effects on organizational and network structure changes. And the forth place goes to four network structure changes: joint venturing, clustering, minority and majority ownerships purchasing. These network adaptations have four directs effects on other changes and many indirect effects.

Figure: Networks of changes in environment, organizational and network structure with correlation at least 0,3 (only companies with total dynamic fit)



In the next step of network analysis I have studied simplest feedback loops. Simplest feedback loops are most powerful feedback loops. They are uncovering non-linear lagged effects between different changes. I have focused on three and four point feedback loops. They are presented in Table 4. We can see that there exists four three point feedback loops. Changes in customers' segment stimulate job rotation, which further stimulates joint venturing, which stimulates changes in customer segment in return. Changes in supplier's segment stimulate team work, which further stimulates ownership purchasing, which stimulates changes in supplier segment in return. Changes in regulation and norms stimulate professionalization and cooperation, which stimulate ownership purchasing, which stimulates changes in regulation and norms in return. Technology developments stimulate informatization and automation, which further stimulate changes in regulation and norms, which stimulates cooperation within firms, which stimulates technology developments in return. Network analysis has confirmed that environmental changes are the key drivers of organizational and network structure adaptations. Most powerful environmental changes are: technology developments, changes in regulation and norms, changes in customer expectations and changes in suppliers segments. Results of analysis of feedback loops are in congruence with hypothesis 1.

Table 4: Three and four point feedback loops

Environmental change	Organizational adaptation	Network adaptation
Changes in customers	Rotation, job enlargement	Joint ventures
Changes in suppliers	Team work	Minority ownerships
Changes in regul., norms	Professionalization	Majority ownerships
Changes in regul., norms	Cooperation	Minority ownerships
Environmental change	**Organizational adaptation**	**Environmental change**	**Organizational adaptation**
Changes in technol.	Informatization	Chng. in regul., norms	Cooperation
Changes in technol.	Cooperation	Chng. in regul., norms	Automation

Hypothesis 2 has been tested by analysis of variance. Results from this analysis are shown in Table 5. There we can see that firms from unstable environment that adopted extensive organizational and network structure changes have statistically significantly the highest value added per employee. Besides, they have the highest efficiency growth rates.

Table 5: Structural adaptations and long-term efficiency

Groups	Number; percent.	Average value-added per employee	Aver. output/input	Aver. growth rate of value-added/empl.	Average output/input growth rate
2. group: No environmental changes	13; 5,4%	7195,8	1,031	2,3077	-0,0077
Above average environmental changes:					
4. group: No structural adaptations	81; 34,7%	5511,1	1,0497	3,0127	0,0388
3. group: One type of structural adaptation	131; 55,3%	6921,51	1,0162	3,2672	-0,0097
1. group: Both types of structural adaptations	11; 4.6%	10929,81	1,0579	3,4545	0,0107

In the last step of analysis the companies have been grouped into three subgroups according four different criterions: (1) percentage of sales on foreign markets, (2) percentage of regular clients, (3) years of education of employees, and (4) hours of management counselling. For each of four different distributions I have conducted ANOVA tests of average environment, organizational and network structure changes. These tests are shown in the first part of Tables 6-9. Cells are coloured grey where ANOVA test didn't confirm statistical significant differences between groups. Second part of Tables 6-9 show which particular organizational and network structure changes are statistically significant

different between groups. Results in great extent support hypothesis 3.

In Table 6 we can see that firms with higher percentage of export perceive greater environmental uncertainty. But on the other hand we cannot say that they conduct more organizational and networks structure adaptations. Firms with more than 25 and less than 75% percent of foreign sales in whole sale have the highest internal and external structural adaptations. These firms outsource most extensively their non-core activities.

Table 6: Organizational and network structure adaptations differences according to portion of foreign/domestic sales

Grouping criterion: % of sales abroad	Number of firms	Percentage of firms	Average envir. change	Average inter. adapt. asses.	Averag. exter. adapt. asses.
0 % - 25 %	106	44,70%	3,7436	3,9928	1,9481
25% - 75 %	76	32,10%	3,9868	4,1432	2,0548
75 % -100%	55	23,20%	4,0118	4,0257	2,0212

Grouping criterion: % of sales abroad	Profesionaliz.	Outsourcing
0 % - 25 %	5,31	2,76
25% - 75 %	4,64	3,87
75 % -100%	4,55	3,53

Table 7 shows us that firms with high percentage of regular customers don't perceive environment as more certain. But on the other hand they conduct above average internal and external structural adaptations. They conduct statistically significant more IT upgrading and more job rotation, job enlargements and enrichments. They adapt production field more extensively. And generally companies with greater percentage of regular clients try to establish more mechanistic (controllable) relationships with all groups of business partners.

Table 7: Organizational and network structure adaptations differences according to portion of regular clients

Grouping criterion: % of regular clients	Number of firms	Percentage of firms	Average envir. change	Average inter. adapt. asses.	Averag. exter. adapt. asses.
0 % - 25 %	13	5,50%	3,9755	3,8507	1,5128
25% - 75 %	98	41,40%	3,8627	3,8956	2,1037
75 % -100%	126	53,20%	3,8898	4,1881	1,9683

Grouping criterion: % of regular clients	Updating infor. techno.	Enlargement and rotation	Work place changes	Production	Clients	Finance institutions
0 % - 25 %	4	2,85	4,46	0,5294	0,1026	0,0385
25% - 75 %	5,6	2,76	4,37	0,5414	0,2262	0,1514
75 % -100%	5,23	3,6	5,22	0,6116	0,2077	0,1124

Results in Table 8 show us that employee education is quite important determinant of extensity of organizational and network structure adaptations. Firms with more educated employees conduct most extensive organizational structure adaptations. Besides they invest more money and time into employee education; they introduce more flexible reward and planning systems, they conduct more extensive reengineering. They conduct internal adaptations in all business fields concurrently.

Table 8: Organizational and network structure adaptations differences according to years of employee education

Grouping criterion: years of education	Number of firms	Percentage of firms	Average envir. change	Average inter. adapt. asses.	Averag. exter. adapt. asses.
Less than 10 years	25	10,50%	3,7855	3,68	1,8933
10-13 years	186	78,50%	3,901	4,0417	1,9749
More than 13 years	26	11,00%	3,8514	4,4525	2,2756

Grouping criterion: years of education	Profesionaliz.	Reward system adapt.	Planning system adapt.	Reengineering	Sales
Less than 10 years	4,08	3	2,2	3,72	0,4753
10-13 years	4,87	4,18	3,82	4,23	0,5639
More than 13 years	6,12	4,58	4,62	5,27	0,6267

Grouping criterion: years of education	Procurement	Finance	Staffing	Support functions	Initiation of inter. changes
Less than 10 years	0,4141	0,4165	0,3835	0,4235	3,24
10-13 years	0,4873	0,4867	0,4586	0,4804	3,55
More than 13 years	0,5656	0,5543	0,5339	0,5724	4,04

In Table 9 we can see that management counselling is quite important determinant of organization structure adaptations as well. Counsellors influence all organizational structure adaptations. Besides they significantly influence network structure adaptations related to mergers and acquisitions. Even though all analyzed influential variables are important, we can see that managements counselling somehow most significantly affects both types of structural adaptations.

Table 9: Organizational and network structure adaptations differences according to hours of management counselling

Grouping criterion: hours of counselling	Number of firms	Percentage of firms	Average envir. change	Average inter. Adapt. asses.	Averag. exter. adapt. asses.
Less than 50 hours	96	40,50%	3,6856	3,6881	1,8802
50-300 hours	90	38,00%	4,0126	4,2052	2,0852
More than 300 hours	51	21,50%	4,0232	4,451	2,0719

Grouping criterion: hours of counselling	Decentraliz.	Profesionaliz.	Cooperation between fields	Planning system adapt.	Work place changes
Less than 50 hours	2,99	4,4	4,32	2,98	4,55
50-300 hours	3,93	5,31	5,27	4,08	4,52
More than 300 hours	3,75	5,22	5,18	4,57	5,88

Grouping criterion: hours of counselling	Reorganiz.	Reengineering	Sales	Production	Procurement
Less than 50 hours	3,44	3,81	0,4982	0,5251	0,4314
50-300 hours	4,2	4,54	0,6007	0,6013	0,5111
More than 300 hours	4,65	4,73	0,6113	0,6367	0,5548

Grouping criterion: hours of counselling	Finance	Staffing	Support functions	Mergers and acquisitions	Competitors
Less than 50 hours	0,4246	0,3989	0,421	1,34	0,1441
50-300 hours	0,5124	0,4837	0,5046	1,84	0,2111
More than 300 hours	0,5582	0,5283	0,5686	1,84	0,2288

3.4 Discussion

In this last section I will discuss findings from Tables 6-9 and based on them develop some speculations on what future can we expect for Slovenian economy in next four year period.

Slovenian companies have high percentage of regular clients and customization practices. Firms with higher portion of regular clients have conducted more organization structure adaptations. Among them adaptations that enforce adaptiveness (like team work, collaboration, decentralization etc.) dominate. Firms with smaller portion of regular client have conducted only organizational adaptations that lead to lower costs of business operations (delayering, downsizing etc.).

On the other hand we can see that Slovenian firms perceive increasing environmental uncertainty, but they do not try to systematically reduce it by establishing more controllable external relationships. Slovenian firms are mainly using only two kinds of network adaptations, that is (in)formal agreement making and clustering. They should consider joint venturing and ownership swaps as well. These two types of external adaptations incorporate lower levels of long-term risks.

Analysis confirmed that employees are still relatively uneducated, especially if we compare education levels to other EU countries. More than 10% of sampled firms have employees which on average have less than 10 years of formal education and there are 80% of all sampled firms, which employees have less than 13 years of formal education. Besides, analysis confirmed that poorly professionalized firms have below average investments into education of their people. In future these trend might cause huge survival problems not only form firms but also for people. These problems are indirectly indicated also by a next trend, that analysis illuminated,

which is that poorly professionalized companies much more extensively downsize, delayer, outsource and perform other cost reduction activities. This trend confirms that in Slovenia uneducated work force is very expensive and can be bought elsewhere for less money (e.g. Poland, Hungary, India, China…).

Slovenian firms with extensive management counselling more extensively change their organization and network structures. By these adaptations they are trying to fit popular management feds and ideas that are not always best solutions for specific firms. Many of them would be better off if they wouldn't be so mimetic and would allocate more of their resources into exploration of new solutions.

Relationships with research institutions and competitors seemed to be much more undeveloped as community would wish. This implies that Slovenian doesn't produce gains from clustering yet. Behind this might be a problem of trust and scare financial resources.

Slovenian companies invest a lot of time and resources in information system improvements on one hand, but on the other they lack investments into automation of work processes and professionalization of employees. Because of expensive work force, population ageing and expanding social system instability such misfits might endanger not only their but also national competitiveness.

Finally, 10% of Slovenian firms create less than 12.500 EUR of value-added per employee per year, 52% of companies create less than 25.000 EUR and only 40% of them create more than 25.000 EUR. Analysis showed that low value-added companies haven't conducted many internal and external adaptations. They lack investments into automation of work processes, substitution of work force for machines, professionalization of workforce, customization of products and services, flexible production systems, cooperation with suppliers, research institutions, competitors and other competitiveness's improving activities. For them we can predict some great turbulences and extinction chances.

4. CONCLUSION

Organizational and network structure adaptations are important balancing mechanisms to environmental trends. Firms that operate in business environment where competition is raising, clients preferences are changing, suppliers negotiating power is strengthening, technology is developing intensively and in significant leaps, regulations are changing general business conditions etc., need to automate their business processes, update their IT, introduce more collaboration and team work, outsource low value-adding activities, delayer and decentralize decision making and so on.; besides they need to establish joint ventures, clusters, research consortia and other forms of collaboration with strategic partners and so on. Analysis of variance confirmed these adaptations as appropriate reactions to emerging environmental trends. Firm that have conducted these adaptations are on average more efficient in their operations and have greater survival chances.

Network analysis uncovered that some environmental changes are more important than others. Most important emerging environmental trends are huge technological developments and changes in regulations and norms. These leaps have most powerful influence on organizational and network structure changes.

REFERENCES

[1] Baum, Joel A. C., Singh, Jitendra V., "Organization-Environment Coevolution," Evolutionary Dynamics of Organizations (Baum, A.C. Joel, Singh, V. Jitendra, eds.), New York, Oxford University Press, 1994, pp. 379-402.

[2] Baum, Joel A.C., Oliver, Christine, "Institutional embeddedness and the dynamics of organizational populations," American Sociological Review, 1992, Vol. 57, pp. 540-559.

[3] Burns, Tom, Stalker, G.M., "The Management of Innovation", 3. edt., Tavistock, Oxford University Press. 1994.

[4] Burton, Richard M., Obel, Borge, "Strategic Organizational Diagnosis and Design: The Dynamics of Fit," 3.edt. Boston, Kluwer Academic Publishers, 2004, 445 p.

[5] Child, John, "Strategic Choice in the Analysis of Action, Structure, Organizations and Environment: Retrospect and Prospect," Organization Studies, 1997, Vol. 18, No. 1, pp. 43-76.

[6] Child, John, »Organizational structure, environment and performance: The role of strategic choice,« Sociology, 1972, Vol. 6, pp. 1-22.

[7] Donaldson, Lex, "The Normal Science of Structural Contingency Theory," Studying Organization: Theory & Method (Clegg, Stewart R., Hardy, Cynthia, eds.), London, SAGE Publications, 1999, pp. 51-70.

[8] Dosi, Giovanni, Winter, Sid G., "Interpreting economic change: evolution, structures and games", in M. Augier and J. March (Eds.) The Economics of Choice, Change and Organizations: Essays in Memory of Richard M. Cyert, M. Cheltenham, UK, Edward Elgar, 2002

[9] Jones, Gareth R., "Organizational Theory: Text and Cases," 2. edt., Reading (Massachusetts): Addison-Wesley Publishing Company, 1998. 746 p.

[10] Knoke, David, "Changing Organizations: Business Netoworks in the New Political Economy," Boulder, Colorado: Westview Press, 2000. 474 p.

[11] Kondra, Alex Z., Hinings, C. R., "Organizational Diversity and Change in Institutional Theory," Organization Studies, 1998, Vol. 19, No. 5, pp. 743-767.

[12] Levinthal, Daniel A., Warglien, Massimo, "Landscape Design: Designing for Local Action in Complex Worlds," Organization Science, 1999, Vol. 10, No. 3, pp. 342-357.

[13] Lewin, Arie Y. et al., "The Coevolution of New Organizational Forms," Organization Science, 1999, Vol. 10, No. 5, pp. 535-550.

[14] Lewin, Arie Y., Volberda, Henk W., "Prolegomena on Coevolution: A Framework for Research on Strategy and New Organizational Forms," Organization Science, 1999, Vol. 10, No. 5, pp. 519-534.

[15] Lipovec, Filip, "Razvita teorija organizacije," Maribor, Založba Obzorja, 1987. 367 p.

[16] Meyer, Alan D. et al., "Organizations Reacting to Hyperturbulence, " Organizational Change and Redesign (Huber, George P., Glick, William H., eds), New York, Oxford University Press, 1995, pp. 66-111.

[17] Mezias, Stephen J., Lant, Theresa K., “Mimetic Learning and the Evolution of Organizational Populations,” Evolutionary Dynamics of Organizations (Baum, Joel A. C., Singh, Jitendra V., eds), Oxford, Oxford University Press, 1994, pp. 179-198.
[18] Pfeffer, Jeffrey, Salancik, Gerald R., “The External Control of Organizations: A Resource Dependence Perspective” New York, Harper & Row, 1978.
[19] Robey, Daniel, “Designing Organizations,” 3. edt., Homewood, Irwin, 1991. 586 p.
[20] Romanelli, Elaine, Tushman, Michael L., “Organizational transformation as punctuated equilibrium: An empirical test,” Academy of Management Journal, 1994, Vol. 37, No. 5, pp. 1141-1167.
[21] Van Raak, Arno, Paulus, Aggie, “A Social Systems Theory of Interorganizational Network Development in Health and Social Care,” Systems Research and Behavioral Science, 2001, Vol. 18, pp. 207-224.

Lab System for Higher Education in Wavelength Division Multiplex Techniques for Photonic Systems

U. H. P. Fischer (member IEEE), M. Schmidt, T. Volmer, B. Weigl, J.-U. Just

Abstract— ***The demand for high-speed digital communication such as data, video, and the broadband Internet increases, the required throughput of the modules in communications systems will also increase. In this paper we present an instruction system, which works on the basis of a wavelength division multiplex (WDM) system in the visible spectrum. It is specialised for the academic training at universities to demonstrate the principles of the WDM techniques. It works platform independent in combination with active modules in the training description, short inline videos and interactive diagrams. The system consists of LEDs in different wavelengths using analogue and digital signals.***

Index Terms***: Wavelength division multiplex, education in optical communications systems, WDM over POF, POF communications systems, polymeric fiber systems***

1. *Introduction*

The demand for high-speed digital communication such as data, video, and the broadband Internet increases, the required throughput of the modules in communications systems will also increase[1]. Fast transmitter and receiver modules are basic elements of these systems, which should be able to transmit terabits/s of information via the fiber. Such technologies in turn rely strongly on advanced opto-electronically technologies, and the progress made in optical multiplexing current transmission systems. Time division multiplex[2,3,4] (TDM) and wavelength division multiplex[5,6] (WDM) have shown to be the most powerful transmission extension techniques for long-haul in the last decade. The challenge for Universities and technical colleges is to educate technicians and engineers in this new optical communications technique, especially in WDM applications. In the last time transmission via polymeric fibers (POF) became standard in the automotive industry[7,8] and in local indoor networks. The combination of WDM with POF will broaden the horizon of low cost optical customer premises networks[9].

Manuscript received March 15th, 2006. This work was supported in part by the Department of Research and Development of the Federal Republic of Germany and the Ministry of Sachsen-Anhalt supported this work.

U.H.P. Fischer, T. Volmer, M. Schmidt, J. Just and B. Weigl are with the Informatics and Automation Department, Harz University of Wernigerode, Germany (e-mail: ufischerhirchert@hs-harz.de). D. Wermser and U. Dettmann are with the Electrical Engineering Department, University of Applied Sciences Wolfenbuettel Germany.

In this paper we present an instruction system, which works on the basis of an WDM system in the visible spectrum. It is specialised in the training of technicians in the further education to demonstrate the fundamental principles of data communication via optical fibres. Further on, we extended the basic system for using in academic training at Universities. Herein, the most important issues of the WDM optical communication techniques are implemented into an instructional system, which works PC platform independent in combination with active modules in the training description, short inline videos and interactive diagrams.

2. *Didactical concept and technological design*

In this paper we want to introduce a new training WDM system in the visible optical range. It has the intention to be used as an instructional system for in two training stages with ascending complexity. The system is focused on training technicians and students in the 1st *Basic* level and furthermore for higher students at Universities in the 2nd *Advanced* level. For both systems it is planned to develop interactive education software. With this software it is possible to aid the learning process. At experiment begin the basic knowledge of the students/technicians will be inquired. Therefore it is planned to create a database with questions for the experiment with variations. Furthermore the experiment and the preparation of the protocol can be performed fully electronically. Besides it is with the help of the software possible to create interactive diagrams to visualize and control the measurement results. Thus, the technicians/students get an overview over the topics and have several tasks to solve, depending to the system outline.

2.1. *Basic system: training of skilled employees and technicians*

The *Basic* system is focused on technicians in the further education. Its structure is most simply, because it uses WDM structure with very inexpensive equipment. As transmitters simple LED´s in the visible optical domain are used. This simple technology guarantees an inexpensive structure and promotes an intuitive understanding of the WDM technology by the use of signal sources in the visible range, because humans can recognize wavelengths within the range from 450nm - 700nm directly by the eye. Modulating the transmitters is performed by

varying the current of the LEDs directly by amplitude modulation (AM). During the lab only three LED sources (red/660nm, green/550nm, blue/470nm) are used, which are supplemented with a fourth LED which acts as an interference source. A general sketch of the planned structure of the Basic/Extended instructional system is depicted in fig.1.

The optical signals are combined by a star coupler and directly modulated via the bias current with a video signal by approx. 10MHz. The bias offset and the signal strength are the parameters which can be varied at the LEDs at the driver circuit. The individual transmitters must be levelled for the WDM transmission in their transmitting power within 1dB, which is to be realized with by an optical power meter. The three video pictures are sampled with video cameras and represented on video monitors. At the receiver Si photodiodes are used with bandwidths of 10MHz in combination with a transimpedance amplifier. The electrical signals can be varied in offset and strength. The degradation in signal to noise ratio can be evaluated with a scope by varying the length of the POF cable (1-100m).

Additionally, loss measurements and coupling efficiency of POF fibres (cut and polish, plug connection) in combination with lateral, longitudinal and angle misalignment can be performed by implementing a micrometer stage.

Tasks for the Basic system:

- PI-curve of several transmitters
- attenuation of different fiber lengths and wavelength
- bandwidth and S-parameter
- influence of EM-fields
- influences of misalignments with the help of a micrometer stage
- signal quality of a video transmission over several fiber lengths and the influence of offset and amplification

WDM TRANSMISSION WITH VIDEO SIGNALS

2.2. ADVANCED SYSTEM: TRAINING OF UNIVERSITY STUDENTS

The *Advanced* system is focused on student's education at universities. In this module the digital transmission is added to the analog part. Because of the low modulation bandwidth of LEDs, Fabry-Perot diode lasers (LD) are used. The optical signals of the three LDs are combined by a star coupler and directly modulated via the bias current by a bit error tester (BERT) to 155Mbit/s and digital amplitude modulation (NRZ, ASK/PCM). With this set-up all laboratory exercises for optical WDM-transmission can be performed as influence of attenuation, dispersion, optical bandwidth, and wavelength shift to any type of transmitted data. In combination with the self developed BERT the eye diagram measurement and bit error rate tests can be performed. In POF the mode dispersion is the relevant dispersion type which limits the transmission length. The influence of the mode dispersion must be analysed both by experiment and by simulation using standard software PHOTOSS[10]. Spectroscopic detection of the emission of the LDs, their thermal drift behaviour and the filter characteristics of the MUX/DEMUX can be performed using simple spectrometers with a resolution of 1nm (e.g. Newport model OSM-400).

Tasks for the advanced system:

- PI-curve of several transmitters
- attenuation of different fiber lengths
- bandwidth and S-parameter
- influence of electro-magnetic-fields (EM-fields)
- influences of misalignments by a micrometer stage
- digital transmission
    - o bit error rate in dependency on fiber lengths
    - o testing the signal quality with an oscilloscope
- WDM transmission with digital signals

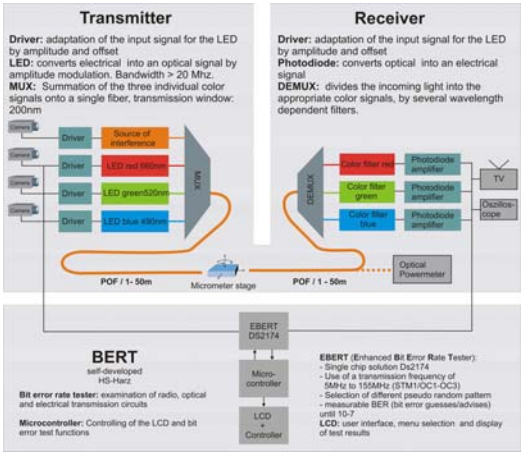


Fig.1 BASIC WDM-lab-training system on the basis of transmission via polymer optical fibers in the visible spectrum

3. THE TRANSMITTER

To convert the electrical into optical signals, which are needed for the transmission, three LEDs (blue@470nm, green@530nm, red@660nm) are used. This represents a cheap solution for the transmitter, because LEDs in this wavelength range are broad available. For analog transmission LEDs with a high linearity are required, to avoid nonlinear distortions.

The input signal will be adapted by a high-impedance operational amplifier circuit. This voltage amplification is adjustable to adapt different signals to the following circuit. Thus the students/technicians have the possibility to test these influences on the transmission.

A DC offset voltage can be applied, which is also adjustable by a high resolution potentiometer. Another part of the transmitter circuit is a voltage-current-converter, which is applied for the modulation of the LED current. The principle is

depicted in fig 2. The data to be transmitted is modulating the optical signal.
This driver circuit is especially adapted to transmit video signals. To generate corresponding input signals there are different possibilities, e.g. a video camera or a test pattern generator can be used. The transmission results can be displayed and judged qualitatively by a monitor on the receiver site.

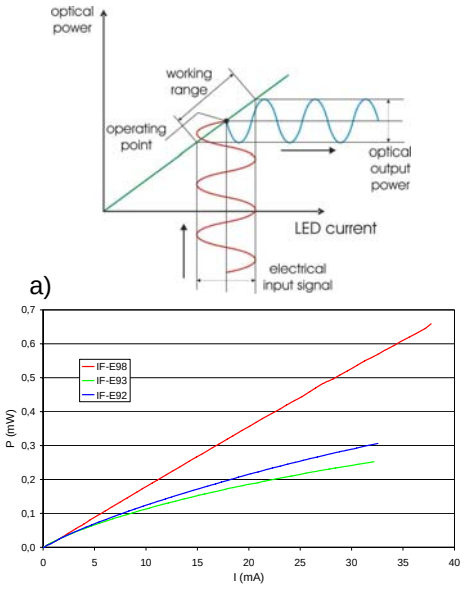


Fig.2 a) modulation of the LEDs b) PI curves of the used LEDs

Of course, other types of signals can be transmitted by this system, e.g. a signal generator can be connected and used for transmission of sinus signals. The bandwidth of the transmitter is more than 40MHz for a distance of 20m. With a transmission length of 50m a bandwidth of 35MHz was measured. These results fairly agree with the simulation of the transmission circuit. The bandwidth limitation is resulted by the used operational amplifiers.

Presently transmitters for a digital transmission are tested. These modules will also be integrated in the instruction system.

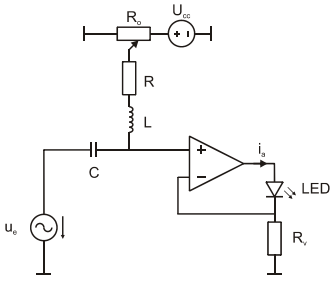


Fig. 3 LED driver circuit

The transmitter offers a variety of adjustable settings. By working with different parameters the students/technicians can see the influence on the transmission very vivid.

4. THE RECEIVER

Receivers are responsible in the teaching system for the transformation of optical signals into electrical signals. The three receivers the multiplexed signals will be separated into individual signals and adapted to the original signal form. The signal separation into the three original signals red, green and blue takes place via demultiplexing. The DEMUX consist of splitter and chromatic filter. The light is splitted into three rays by two cascading one-to-two toslink[12] splitters. The signal separation takes place via three different chromatic filters, which are directly attached in front of the photodiodes. The receiver technology within the visible range consists of Si pin photodiodes.

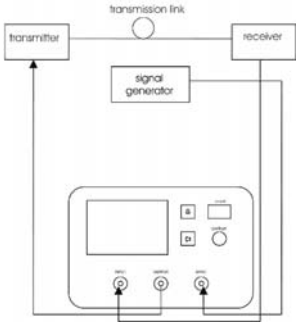


Fig.4 block diagram bit error rate measurement

This kind of photodiode consists of p-type, intrinsic type and n-type semiconductors. The photodiode converts the optical signals by photon-induced pair production into a current. The current is typically in the range of some milli amperes and is transferred into voltage by the following circuit. The appropriate circuit is a two-stage amplifier circuit. The first level is an inverting transimpedance, which is dissipating the current into a voltage. The second level is an inverting amplifier, where amplification and offset are adjustable. Thus the students can change the output signals within certain ranges. The gain can be changed up to 13dB and the offset can be changed from negative and positive voltage. By those changes of the system parameters the students are able to obtain the educational objectives because of changing the signal strength and position by themselves. The receivers are developed for analog or digital transmission. For the evaluation of the transmitted signals different devices can be used e.g. network analyzers, oscilloscopes or even television sets or monitors

5. BIT ERROR RATE MEASURING SYSTEM

Bit error rate testers (BERTs) are predominantly complete units, which can perform a high number of operations. For teaching systems, where the attention is on instructional contents, such devices are only utilizable with difficulties and very high initial costs. The BERT developed for the teaching system is customized for that use and is the low-budget version of a conventional error rate tester. The developed error rate tester consists of three major

components, an error rate tester for error rate measurement, a microcontroller for controlling the measuring device and a display for manual control by the operator. In order to examine a digital transmission circuit, the exit of the error rate measuring device is connected with the transmitter and the entrance is connected with the receiver of the transmission circuit, depicted in fig.4.

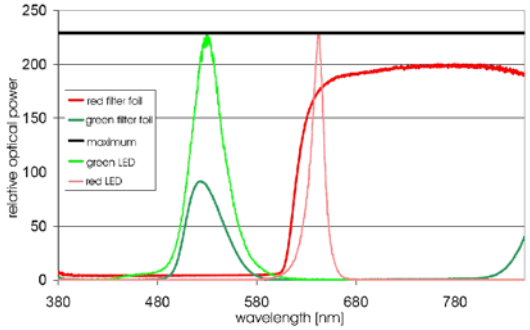


Fig.5 Absorption spectra of the red and green filter foil in comparison with the emitted LED power

The transmission frequency used can be either external (max. 155MHz) or internal (40MHz). In order to use an external transmission frequency, a frequency generator has to be attached to the entrance "transmission frequency". The measuring device is controlled via a microcontroller from the 8051 series, the 80C552. This µ-controller also calculates the error rate after the measurement by the DS2174. The measurement device is operated via a menu on the display. The selection in this menu takes place via a scroll key and an enter key. Before the measuring process can be started, the pattern and the transmission frequency (external/internal) must be selected. The error rate tester (DS2174)[12] allows the selection of coincidental bit-patterns up to a length of 2^{32}-1 and self-programmed repetitive patterns up to a length of 512 bytes. In the error rate measuring position, only three patterns can be selected via the display. In the next step, the selected pattern is transferred by means of transmitters on the transmission circuit and can be evaluated at the receiver by the error rate tester. During this evaluation, the sent and received patterns are compared and the bit errors are counted. With this data, the error rate can be calculated by the microcontroller computer 80C552 using Equ. (1)

$$\mathrm{BER} = \frac{\text{number of faulty bits}}{\text{number of received bits}} \qquad (1)$$

An important prerequisite for a meaningful measurement is the synchronization of the output and input port. At the end of each measurement, the result with the pertinent pattern, the number off errors and the BER (Bit error rate) is shown on the display. Bit error rates up to 10^{-7} can be measured with this system.

6. INSTRUCTION SYSTEM

The first prototype consists of three transmitters and receivers. This system, depicted in fig 3, is able to transmit three analog FBAS[11]-video signals or digital signals up to 10MBit/s. The light of the three transmitters are combined via three conventional mechanically fabricated star couplers 4:1 (DieMount).
To simulate a connector link or a splice, the light is guided via a micrometer stage. Thus, the technicians/students are able to test the influence of lateral, longitudinal and angle misalignments. To separate the signals TOSLINK[11] couplers are used. The insertion loss of these couplers is relatively high.

Coupler/insertion loss(dB)	1:2	1:4
TOSLINK	10,5 ± 0,9	17,8 ± 0,8
DieMount	5,5 ± 1	9,2 ± 0,6

Table 1: insertion loss of the used couplers

The signal separation is performed by red, green and blue colour filters. The absorption of this filters is relatively high, the absorption spectra of the green and red filters is depicted in fig.5. The values are shown in table 2.

Filter foil /insertion loss(dB)	green LED	red LED
red filter	25,4	0,7
green filter	3,5	26,8

Table 2 Attenuation of red and green filters

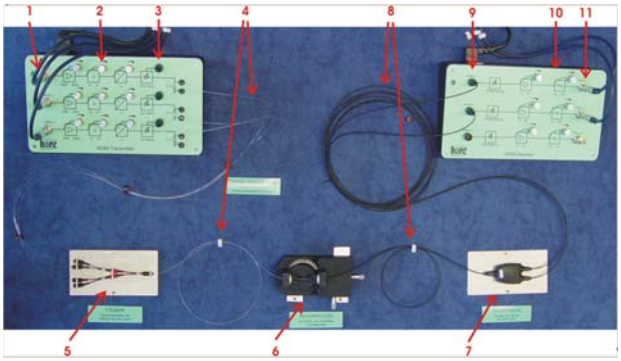


Fig.6 Photograph of the prototype

This training system prototype was first presented at a University campus exhibition in Magdeburg/Germany in July 2005 (fig.6).
It consists of following parts:

1. Video inputs (BNC)
2. regulators for signal amplification, offset and modulation
3. Optical outputs (TOSLINK connectors)
4. 1mm SI-POF, pure fiber core without any cladding to make the colours visible
5. DieMount star couplers
6. Micrometer stage (x, z and angle)
7. TOSLINK star coupler

8. 1mm SI-POF
9. Optical inputs (TOSLINK connectors) with colour filters
10. Regulators for amplification and offset
11. Electrical outputs (BNC)

The bandwidth of the complete system (transmitter, transmission link over 20m and receiver) is about 8MHz, depicted in fig.7. This value is only limited by the receiver. The total attenuation of the system is approximately 38dB.

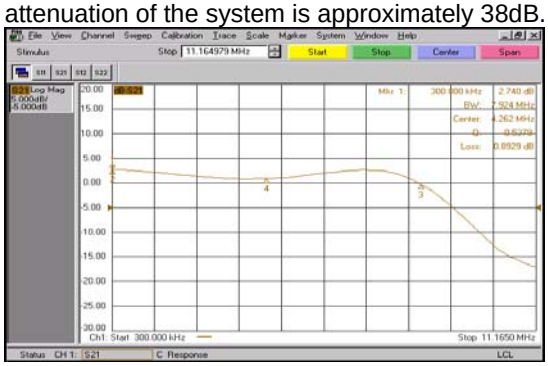
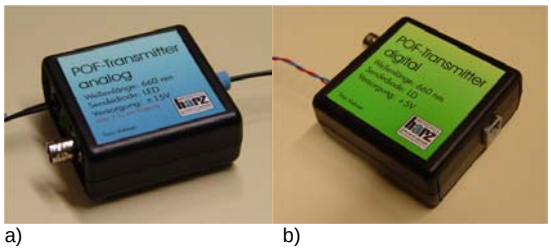


Fig.7 S21 with 20m POF

A further development of single modules for higher modulation frequencies / bit rates is shown in fig.8. For these modules, the circuit and its layout are optimized, respectively. By the use of this set-up it is possible to create a modular system for individual applications. The basic system will also consist of three transmitters and receivers with red, green and blue WDM-signals.



a) b)

Fig.8 Transmitter modules a) analog, b) digital

Right now a module is developed and tested for transmitting digital signals. It will have the same design like the analog module shown in fig.8. With these new analog transmitter modules bandwidths up to 65MHz are obtained. Thus, it will be possible to combine the transmissions of analog and digital signals via one fiber simultaneously.

To reduce the high system attenuation, the next development step will be the design of integrated optical devices for the multiplexing and demultiplexing of the WDM signals. The most important challenge is the development of simple integrated optical MUX/DEMUX (de/multiplexer) for combining/separating the wavelengths using the WDM technology. These devices are designed to transmit up to eight WDM channels simultaneously. These components are presently patent pending.

7. SUMMARY

In this work we present a new WDM training system for technicians and students at universities. The system consists of three LED transmitters in red, blue and green colour wavelength. The system can transmit and test either analogue video signals or digital signals which are AM or ASK modulated as well as PCM data. With this setup all laboratory exercises for optical WDM-transmission can be performed as influence of attenuation, dispersion, optical bandwidth, and wavelength shift to any type of transmitted data. In combination with the self developed BERT the eye diagram measurement and bit error rate tests can be performed. Spectroscopic detection of the emission of the LEDs and the filter characteristics of the MUX/DEMUX can be performed using simple spectrometers. Additionally, loss measurements of POF fibres (cut and polish, plug connection) in combination with lateral, longitudinal and angle misalignment can be performed.

The education system here presented opens easily the new world of the optical transmission to students/technicians, especially for the WDM technology. The context between emitted power, attenuation etc. can be demonstrated. One of the outstanding advantages of this system is the operation with visible light. In combination with the education software this system is a superb tool for agile teaching.

ACKNOWLEDGEMENT

We want to thank H. Kragl from DieMount GmbH. for the delivering of the optical couplers and the chromatic filters for the realization of the MUX/DEMUX functionality.

References

1. T. Naito, ”One Terabit /s Transmission over 10.000km using C-Band and L-Band”, Networks and Optical Communications I,IOS Press, pp 2-9, (2000)
2. A. Umbach, D. Trommer, A. Siefke, and G. Unterbörsch,“50GHz Operation of Waveguide Integrated Photodiode at 1.55µm“, Proc. of the 21st ECOC, Brussels, Belgien, 17.-21. Sept. 1995, p. 1075 ff., (1995)
3. A. Umbach, D. Trommer,, and G. Unterbörsch,“High-speed, high power 1.55µm Photodetectors “, Optical and Quantum Electronics, No 33, pp 1101-1112 (2001)
4. A. Umbach, D. Trommer, D. Steingrüber, R. Seeger, A. Ebert and G. Unterbörsch,“Ultrafast, high power 1.55µm side illuminated photo detector with integrated spot size converter“, Proc. ECOC 2000,FG2-1,p 117-119, (2000)
5. U. Krüger, K. Krüger, R. Batchelor, U. H. P. Fischer, C. v. Helmolt, and U. Nagengast ,”Wavelength manager covering the EDFA band and capable of controlling hundreds of transmitters”,Proc. ECOC, Vol. 1, pp 483-486 (1994)
6. U.H.P. Fischer, "Optoelectronic Packaging”, VDE-Verlag, ISBN 380072572X (2002)
7. MOST,” Media orientated system transport”, http://www.mostcooperation.com/
8. N. Weber, “Low cost optical transmission solutions for short distances”, http://www.iis.fraunhofer.de/ec/oc/index.html
9. J.-U. Just, U. H. P. Fischer, and H. Kragl, ”Development of fiber-chip coupling methods for use with polymeric fibers) ”2005 International Students and Young Scientists Workshop „Photonics and Microsystems”, Dresden, Germany July, (2005)
10. PHOTOSS: http:// www.photoss.de/
11. Krisch.: „Fernsehtechnik: Grundlagen, Verfahren, Systeme“, Verlag Vieweg, Braunschweig/Wiesbaden (1993)
12. TOSLINK: http://www.semicon.toshiba.co.jp/eng/prd/opto/topics_totx147-totx177_200407.html
13. www.maxim-ic.com

First A. Author
Biographies

Ulrich H. P. Fischer

U.H.P. Fischer earned a degree in physics from the Free University of Berlin, Germany in 1983. In 1988 he made his PhD in physics of condensed matter. In 1988 he joined the Heinrich-Hertz-Institute in Berlin for the development of broadband optical communication systems. He has served as head of the optical packaging group at the Institute since 1994. In April 2001 he became professor of optical packaging and optical networks at the Harz University of Applied Studies and Research, Germany.

Jens-Uwe Just

Jens-Uwe Just earned a degree in electrical engineering from the Harz University of Applied Sciences Berlin, Germany in 2004. Since 2005 he works as a consulting engineer in Wernigerode/ Germany

Björn Weigl

Björn Weigl earned a degree in electrical engineering from the Harz University of Applied Sciences Berlin, Germany in 2005. Since 2005 he works as a consulting engineer in Wernigerode/ Germany

Michael Schmidt

Michael Schmidt earned a degree in electrical engineering from the Harz University of Applied Sciences Berlin, Germany in 2005. Since 2005 he works as a consulting engineer in Halle/ Germany

Tino Volmer

Tino Volmer earned a degree in electrical engineering from the Harz University of Applied Sciences Berlin, Germany in 2005. Since 2006 he works as a consulting engineer in Berlin/ Germany

The evaluation of a political system, using the Markov model, with sustainability and safety as reverse processes.

Lepage, A.

Abstract: ***Which evaluation model could measure political conditions, as a real state describing the immediate future, with the combined effect of a sustainable advance process and a safety reverse one?***

The research is based on the assumption that the global evaluation of a political project follows the model which we largely validated on complex systems, such as energy production plants and customer services, for the respective measurement of availability and global satisfaction. In fact, the Markov model, as validated by our laboratory's practical application of it in commercial companies, enables us to calculate the state of availability (or global satisfaction) as the effect of two cross reverse processes: failure development (punctual dissatisfaction) and improving team performance (service quality improvement team). In extension, a validation framework, of political system efficiency measurement, is proposed, with aggregation of micro-processs measurements and a multi-criteria approach, combined with a measurement of safety abstracted from the United Nations Conference of Environment and Development.

Index Terms: ***global evaluation, political system, sustainability, safety, reverse processes, Markov model, political efficiency***

1. THE EVALUATION OF A COMPLEX SYSTEM

Many examples of discordance between politicians and the electorate can be found. The development of policy involves ambitious projects, which are able to motivate citizens and suggest a pleasant and more economically secure future, but politicians have to question themselves about the possibility of proposing projects which take into account people's perceptions of their daily lives within the many processes which constitute a complex social structure.

The political system, consisting of the citizens and politicians within it and the institutions and committees who drive the organisation of it, is a complex one. We understand that it has to be evaluated as an entity which is able to preview the immediate future, with sustainability for people and, conversely, safety in the necessary, difficult actions which assure its progression.

Our laboratory validated Markov-based models to describe such complex systems with a minimum of two reverse processes in two distinct cases: first, in power plants (which is not discussed here) and, secondly, in the measurement of global satisfaction of customers participating in the activities at a Leisure Park.

Citizens' perception of political policy is a global satisfaction which allows us to exploit the similarities between the evaluation of a political system and that of global customer satisfaction, basing our research on the assumption that the evaluation of a political system follows the Markov model, with two reverse processes: one orientated towards safety and control, which makes for citizen dissatisfaction, and a second one for sustainability which makes for citizen satisfaction.

Our purpose is, first, to present the elaboration of the complex global evaluation from two reverse processes and, secondly, to discuss the relevance of the approach, with separate examples of the perception of a detailed failure, producing punctual dissatisfaction, and the global perception of satisfaction, made up of many adjustments to punctual satisfactions and dissatisfactions.

2. PREVIOUS EXPERIENCE OF THE MEASUREMENT OF CUSTOMER SATISFACTION, ENHANCED BY THE USE OF MARKOV SYSTEMS.

2.1. Introduction to complex system dynamics

Customer Service managers need a model for the dynamic evolution of customer satisfaction (discussed in the conference report of the "National Conference of Quality Research", France, and by Cronin and Taylor (1). It has been undertaken by many companies using an empirical method which applies the same short questionnaire, of a maximum of ten questions, during a period of time, to customers who are using a service which is in slow evolution. The

detailed comparison of the results is made qualitatively by reading the customers' answers and the dynamic analysis is carried out by confronting the total result of customer satisfaction calculated at the time of measurement. The qualitative analysis is established, by discussion between managers of the customer service, experts in statistics and quality managers, without any attempt at modelling. The follow-up of the evolution remains problematical, and an innovation is needed, such as, for example, the dynamic Chronem method, which was proposed by P. Maillard of the French Institute for Research and Development of Quality. The method compares, during a period of time, the various states of customer satisfaction, by using 'snap-shots' of Factorial Analysis of Correspondences or Analyses in Principal Components, as described in the work of Herman Aguinis (2) and Cohen (3). Some authors came to consider communication and marketing approaches in customer satisfaction, such as Eiglier and Leangeard (4), and Parasuman, Zeithaml and Berry (5). However, these interesting proposals did not enable us to take into account the intensity of human effort, employed in the improvement of products and services, in order to improve customer satisfaction.

Therefore, we evolved the dynamic Qualisat method, which we deposited at INPI (6). The method proposes that, during a period of time, a comparison of customer satisfaction be made, measured with the usual tools that are available in the software for data analysis, with the level of effort and improvement of products and services as coefficients. We implemented this method at a large French leisure park and it allowed us to examine, every evening, the results of questioning a hundred people. The beginning of this theoretical approach, made on the site, was used to take concrete actions of correction when a drift in the level of customer satisfaction appeared. Indeed, at each sudden degradation of satisfaction, we deployed a 'rapid reaction force' of specialised teams, the very next morning. Conversely, if a gradual drift in degradation was observed, a steering committee, chaired by the person responsible for quality, was convened. This committee was charged with proposing solutions for the improvement in quality to the main board of management.

We were able to use, at the Leisure Park, the considerable body of data available to make a more scientific further study of the total satisfaction of the customers, as an up-to-date indicator of the efficacy of the management's strategy. We were also able to use the returns of 130 daily questionnaires, each containing 24 questions, which were applied by the hostesses at reception. One of the questions related to their personal perception of overall satisfaction which produced very varied and unreliable responses from the customers. It allowed us to make a comparison with the empirical calculation of this total satisfaction. It was easy to carry this out, using the large number of answers returned from the detailed, factual questions. This proved to be a consistent, reliable result, as was confirmed by later experiment. Analysing these statements, we postulated two hypothesises (H1 and H2) relating to the global satisfaction of customers:

H1) The perception of satisfaction does not follow a linear model.

H2) The quality of the products or services offered, as perceived by the customers, is not linear in relation to the efforts for improvement made by the teams involved in finding solutions (or service-maintenance).

Indeed, satisfaction is measured personally by the customer, at a linear level, by ticking his selection on a 1 to 5 supposed linear scale, for example. This drift appears even if a hostess poses the questions verbally and herself completes the questionnaire form for the customer. Incidentally, we cannot know if the perceived level 4, for example, is really the perception of level 2, in the mind of the customer. Some criticism can be levelled at the efforts made by the teams charged with finding solutions for the improvement of customer satisfaction with products and services. In particular, as the professional members work in a project design team, it is almost impossible for them to produce a linear result to their work -effectiveness, aptitude for collaboration, capacity for work, etc. – in relation to the number of team members. The difficulty in producing a linear result is related to their capacity for co-operation and the sharing of their own specialist knowledge, skills, and perceptions.

We can justify this assumption from the studies of Kano (7) which shows, for all products or services, that only 20% of the products and services, classified as "explicit expectations", that only 20% give a linear result. Therefore, our first hypothesis is already validated at 80%, on first examination. On second examination, the services configuration at the leisure park shows that the product or service functions do not figure in the 20% of the Kano study, in relation to the impact of the efforts to improve the services, made by the specialist teams. Indeed, we know from daily statistical data that the perception of service quality depends more on external, environmental factors than directly from the service improvement. However, later, the quality depends quasi directly on cumulative efforts of the improvement teams to offer better outcomes. So this validates to 100% our two hypothesises.

Customer satisfaction is directly linked with to how memorable the service received is

(Edvardson, Gustafsson, Enquist, (8)). Edvardson also demonstrates that the service empowers the customers to become part–time employees and to co–create functions of the product and services which give value. He also shows that customers form a favorable perception of their overall satisfaction with the product or service if they have had a particularly good experience in the small part of it. By the same token, poor experience in only a small part of the product or service has a great bearing on the formation of the overall perception of satisfaction of the customer.

An important conclusion from the “Assises Nationales de la Recherche en Qualité”, Versailles, France, In 1998 (11), was that the measurement of service quality is reliable in relative results comparing similar events, or in measuring small detailed topics of the same event, in the same conditions, and repeated many times. However, the absolute measurement of a global service at one given time is not reliable.

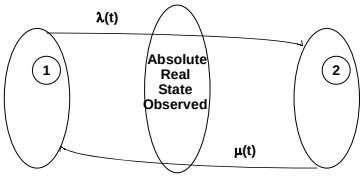
Even if these complementary conclusions from other researchers’ work confirms the validation of our two hypotheses, the measurement of global satisfaction has to be carried out by partial measurement of the simple, detailed elements which make up the complex global service.

The data obtained, and the observations made, at the leisure park, enabled us easily to elaborate two discoveries: 1 - We found that the evolution laws of the loss of total satisfaction generated by increasing levels of failure, revealed an decreasing exponential function curve; 2 - We found also that the return of satisfaction, that followed increasing levels of effort of re-design / re-organisation, revealed a logarithmic function curve.

Moreover, our analysis of the satisfaction measurements, using the criteria of the presence or absence of failure and the effort to re-design/re-organise, revealed the existence of two opposite processes acting simultaneously on total satisfaction: the first process Is the degradation of satisfaction arising from default and the second is the re-building of satisfaction by the improvement of re-design. The existence on the site of an engineering culture created conditions in which there was an incentive scheme to learn about reliability and availability of technical equipment. We should mention that one member of our research team, who had a education in engineering, had experience of working at a power plant. His specialty had been the improvement in reliability of technical plant and in the continuous measurement of the availability of this plant. Even though he had personal experience of the measurement of availability, using the Markov models, we were not concerned with Mechanics and preferred to present, directly, its application to the reliability and availability of services. The previous research supported our validation of our two hypotheses H1 and H2, and the establishment of our calculation of global satisfaction, using the measurement of discrete parts of the complex system of service, based on the Markov mathematical systems.

2.2. The two reverse processes of the Markov model, default and improvement

The Markov models were chosen to describe complex global satisfaction phenomena because of their ability to synthesise cross reverse dynamic processes. They have been tested, over a long period of time, in maintenance and technology, as described by R.D. Mauldin and M. Urbanski (9), V. Gupta, R.M. Murray and B. Hassibi (10). Here, they allow us to take into account the non-linearity of the failure of a product or service and the performance of re-design for their improvement, as well as the opposite and interactive nature of the two processes. That is, the degradation of a product or service and, conversely, their improvement, which make up the global satisfaction. It is based on the probable position in the time of a real situation between two extreme, ideal, theoretical situations relative to the number of basic team repairer-originators (elementary team members, carrying out routine re–design or repair). The principle of this model is shown in the following figure 1:



- **Global and theoretical initial state which could be ideal (1) :**
  - 100% satisfied equipment at reception test, qualification test
  - 100% satisfied general state at test,
  - Etc...
- **Global final theoretical state (2) :**
  - **Bad functionning situation**
  - **Equipment just at the rejected limit**
  - **Etc...**

Figure 1 general Markov model

The interest of the Markov Models is that they make the framework scientifically irreproachable by adopting the following definition of “satisfaction” (using the definition of “reliability” seen in Markov’s method) : "the probability of offering good responses to formulated needs of customers between the delivery time and the measurement time, noted R(t)". It should be remarked that the definition also means: "zero dissatisfaction of the customer, between the moment 0 and the moment T of analysis", which supposes a measuring instrument, from time 0,

and that we have the problem of a previously-established linearity. It should also be remarked that the definition of availability, which is included in Markov's method, is more accessible and could be written as follows: "The probability of being able to offer a solution to formulated needs of customers at the moment T, noted A(t)". This definition makes it possible to use a measuring instrument, conceived at the time of the wish to take a "snap-shot" of the situation, without being concerned with the existence of previous, or later, measurements. We will adopt this approach of "availability of satisfaction", A(t), because it is applicable even if the state of customer satisfaction, is not known before the "snap-shot" taken at the moment of measurement. It is especially applicable because it corresponds to the operational and practical methods of instinctively measurement of customer satisfaction, adopted by companies. However, while employing this method; most quality managers forget to establish questions about the existing states of satisfaction.

2.3. Approximation Method in satisfaction measurement

A simple and scientifically acceptable method of measurement consists in admitting that the natural degradation of satisfaction, $\lambda(t)$, in the absence of repair, follows a mathematical law close to "decreasing exponential", which offers approximate values. The same approximation can be made for the improvement ratio, $\mu(t)$:

- *$\lambda(t)$ = 1/Mean Time of Correct Operation (Between Failures), where MTBF is the commutative duration in hours of opening (service) or use (produced) between the delivery, after successful re-design, given 100% satisfaction, and the appearance of the first dissatisfied customer, that is, an objection to a failure in a clear and precise way.*
- *$\mu(t)$ = 1/Mean Time to Repair where MTR is the duration, in hours, between the beginning of the work of the re-design team and the moment of successful delivery of the solution for the product or service.*

It should be remarked that this approach is completely coherent with the results of the work of the National Conference of Research in Quality, Versailles, December 1997 (11), that is, the absolute total satisfaction of customers is not directly measurable, but is possibly calculable. Degradations or improvements in satisfaction can be measured effectively as a relative measurement. It is this approximative approach which will be used as often as possible, for its simplicity and ease of use the calculation of the availability of the solutions offered to the needs of customers, between two theoretical states, during the time A(t). It should be noted that there must be degradation/improvement histories in the companies because, if there is not, another calculation method based on zero initial information, must be employed. It is like making an "anticipated calculation" about the probable and total satisfaction of the customers, relative to the time passed in re-design which is allowed, under the conditions of the degradation of the product or service, as in the following mathematical model, shown in Figure 2 :

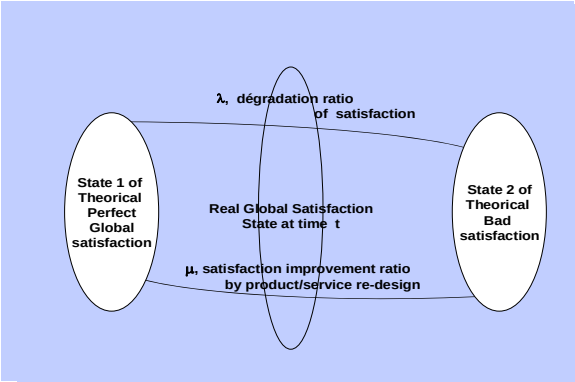


Figure 2: global satisfaction Markov model

The Laplace transformation method is used in the subsequent calculations, but they are not continued here. Significant curves, of the availability of satisfaction of customers obtained, can be seen in Figure 3.

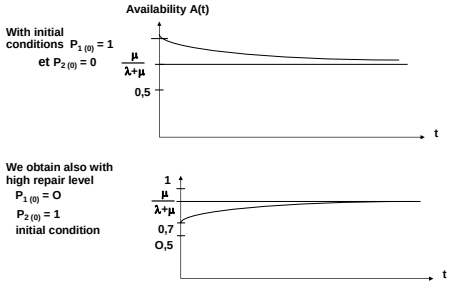


Figure 3: Satisfaction asymptotic curve at equilibrium

2.4. Validation of the model in companies

We compared the results of this method, based on the Markov Model, with the classical method, based on large-scale questionnaires, because it was easy to employ the two methods, concurrently, at the Leisure Park. The model was tested in two further companies, a Bank and a French Car manufacturer (not discussed here). In each case, the Markov Model had more consistency and reliability than in large-scale

classical questioning (A. Lepage, 2000 (12)). In conclusion, we can suggest the possible applications of these validations.

2.5. Conclusion of the validation

The application of the Markov Model at the Leisure Park, λ in % of failures, per hour of service (event) opening to customers (analysing histories of maintenance or instantaneous observation) and μ in % of cases making a successful repair per hour (a number of times where there was success divided per some times where one tried in less than one hour). It should be noted that, in this case, a successful repair achieved in 1h30, counts as zero. This model was employed on this site to improve the reliability of the measurements of satisfaction. The application of the Markov Model achieved a level of reliability of 98% in the measurement of global satisfaction whereas the use of the large-scale questionnaire method achieved around 62% reliability. The most important conclusion indicated by the validation is that the direct measurement of global satisfaction is complex and not reliable. It is better to calculate global satisfaction by using Markov systems on detailed failures and improvements (from small, reliable perceived parts of the processes, which are easily measured). On the other hand, the applications we have described in other companies showed that the effectiveness in the relation we described theoretically, between measured and perceived failure, the effort employed in improvement or repair and the calculation of global satisfaction with perceived global satisfaction. The application described here, was selected for the case of its experimental use, together with the large number of possible checks in the speed and ease of the analyses of degradation and repair. We should mention especially the speed of the effects of improvement by increasing the teams responsible for improving service, the "repair" teams. The measurements of λ and μ was very easy to carry out. They can be made on an impromptu basis, spontaneously, by the analyst, even when he does not have any history of the customer requirements, nor of repairs, which give a snap-shot of recent events. Thus the Markov Model is very adaptable because it can be appropriately employed in companies where there are relatively poorly developed methodologies in the statistical analysis of quality. The very satisfactory outcomes of the application of the model in the Bank and car manufacturing company can be consulted in the doctoral thesis of Alain Lepage (12), which shows the possibility of solving, in the car manufacture, the distortion between the lack of increase in customer's satisfaction and the delivery of a consequent, and expensive, improvement in the performance of the vehicle.

3. THE PROPOSITION OF THE USE OF THE MARKOV MODEL FOR THE EVALUATION OF POLITICAL SYSTEMS

3.1. Introduction of the Markov model

The application of the Markov system to the calculation of customer satisfaction explains the non-linearity of the perception of satisfaction, from the detailed default observation by faults, by the customer, which perhaps generates dissatisfaction, to the perception of global satisfaction with the service. This is itself combined with a complex series of particular dissatisfactions and satisfactions with the micro–processes of the daily ground. We propose to consider that, in the same way, citizens' satisfaction with a political system is not directly generated by particular points of satisfactions in the daily life of the people, but made relative to particular satisfactions and dissatisfactions with the daily political reality. From this, we have to elaborate the Markov system with its two reverse processes. We think that the process which comes immediately to mind, when we consider political development towards giving a better quality of life, is sustainability. In the same way, we think that the process which leads to the degradation of quality of life, is safety. This proposition is shown in the preview, Figure 4:

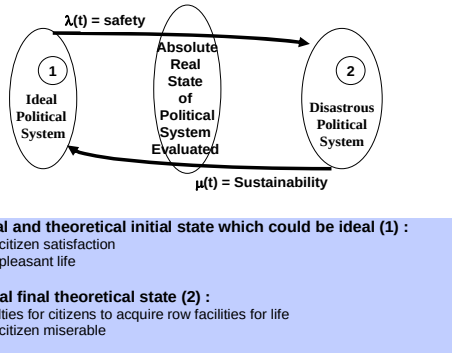


Figure 4: Markov model for political system's evaluation

3.2. The two reverse processes of sustainability and safety

The first process, of sustainability, is made up of many resources, supports and actions which offer citizens a better quality of life. However it has to be designed by the beneficiaries themselves, who are also the participants in the process in which the overall view of the shape of the future is proposed by the politicians. What we define as sustainability is the measure of the quality of the political system, as mentioned in the report on the United Nations Conference on Environment and Development (13 and 14). A

more detailed definition is postulated by H.N. Afgan and G.M. Carvalho (15): “the measure of the quality of our society is its ability to secure, and not compromise, the right of future generations to have a quality of life, at least equal to that of its own generation”. Sustainability is seen here as people’s self organisation driven by the desire to obtain the best quality of life, under constraints of financial feasibility and individual and collective safety. However, some authors view sustainability as a measure of quality (Gianpiero, Mayuari, Postar (16)) and others underline the high level of complexity in the measurement of sustainability (Heylighen (17)). We have concluded from this that the process of sustainability is itself made up of many elements which must be taken into consideration when measuring its efficiency.

The second process, of safety, concerns the natural effect of self degradation, particularly in the case of complex systems. Safety is the rate of change for any process which leads to the degradation of the system, as commented on by M. Leveson (18). The natural degradation of the environment and its systems is continuously measured worldwide and is the subject of the “World Disaster Report”. The measurement of system degradation is also complex, as is safety, but we are well-versed in the use of this well-known measure. As the two processes are evaluated with the same approach as the measurement of quality, we can consider that they hold a similar place in the conception of life. However, we can precise that the measurement of sustainability is a measure of the ability of the society, and thus the political system, to secure, and not compromise, at least the same quality of life for future generations. Conversely, the measurement of safety is the measure of the ability to facilitate the control of the steady-state of those systems which assure, at least, the minimum quality of life. Therefore, sustainability is linked to the ability to offer the best quality of life in the future, whereas safety is linked to the ability to measure change in the systems which assure the quality of life.

3.3. Multi-criteria examination of sustainability and safety

The measurement of sustainability and safety is a measurement of the quality of complex systems. The global political system is a complex one which contains the two principal processes of sustainability and safety. It is easy to understand that it is impossible to determine the quality of a political system from the daily detailed perceptions of the citizens. This is because, between the global complexity of the political system and the simple, perceptions of individual people, we have to measure the intermediate complexity of the processes of sustainability and safety. If we do not describe the evolution of the global system, using the Markov Model, we fail to measure the quality of these two intermediate processes. The principal mathematical criteria of the Markov Model is the use of a calculation of the evolution of these two processes, with the aggregation of the daily detailed perceptions and facts, and to be able to remain relatively stable during the time of evolution of the system, as opposed to detailed events which are not stable in the same period.

As the two processes are themselves complex, we have to find possible approaches for their measurement.

The evaluation of complex processes requires particular methodology which is always based on multi–criteria procedures. These are well-known as “The multi–criteria evaluation and assessment of complex systems”. An example of this can be found in economics (Hovanov, Fedotov, Kornokov (19)). Our purpose is not to design the relevant criteria for the measurement of sustainability and safety, ourselves. Our interest lies in the use of some of the criteria-elaboration methods which are available in the economic, organisational and systemic areas in order to include them in the Markov calculation. Therefore, we can now conclude that the final value of sustainability should be considered as the $\mu(t)$, repair ratio, and that the final value of safety should be considered as the $\lambda(t)$, degradation ratio, as described in our previous Markov calculation. It should be noted that the mathematical definition of safety is exactly the same as the direct one for the default ratio, that is zero default between 0 to T, or the approximated one, that is 1/ Mean Time To Degradation. Again, it should be noted that the same calculation can be applied to sustainability.

Also, sustainability offers some tools for its own measurement. Afgan and Carvalho (15) made a synthesis of sustainability with its four components, resource quality, environmental quality, technological quality and social quality. The first is measured with an integral thermodynamic approach (Prigogine,(20)), and internal parameters of change as “entropy production in the system” (Prigogine,(21)). The second can be measured with mutual interaction assessment between the complex system and its surrounding life system, and here there are many tools available. The third is measured with a very large array of tools for the measurement of quality performance in design and production systems. Finally, the fourth is measured with tools concerning social efforts towards improving quality in social systems. An example of this can be seen in Hacker and Roberts, (22).

We consider, now, that we have a method for the aggregation of elements, measured with the tools available, to make a measurement of sustainability, with significant reliability. This measurement can be made at any stage of the evolution of the complex system. If we obtain the results of sustainability measurement, over a given time, we can measure the change ratio

during this period and thus make a measurement of safety. Therefore, It is not necessary to have specific tools for the measurement of safety, because we can use the data obtained from the measurement of sustainability and apply it directly to the measurement of safety.

3.4. The use of the evaluation of a political system for its improvement

The global evaluation of a political system should not be made with a simple questionnaire on citizen satisfaction. As we learned from the multi–criteria evaluation, a political system is a second order complex system consisting of, at least, the two reverse processes of sustainability and safety. These, themselves, are first order complex systems, consisting of a multitude of micro–processes, which are themselves simple systems. It is only in these simple systems that we can find many direct, linear links between individual perception, emotions, attitudes and global satisfaction on the micro–process. In the first order and second order complex systems, it is necessary to make the calculation as follows:

- first, aggregate all the micro-measurements of the micro–processes, obtained with the multi–criteria approach, to calculate the value of sustainability and safety (the first complex level);

- secondly, calculate the global state of the evaluation of the political system using the Markov Model. This is a second complex level giving the percentage of position of the state between ideal state and disastrous state.

The theoretical definition of the ideal state is that one which gives 100% of the maximally-possible ideal life, the best quality of life for the immediate future that can be imagined, without any constraint. The disastrous state can be described from contemporary or historical examples. Therefore, if the actual state is evaluated at 61%, for example, it follows that the reality is at 61% of the imaginary state.

However, the Markov Model does not prescribe the use of that state 1 as 100%. A very simple use of the system is to take political promise as desirable future described by the politicians. It is not important to know what the percentage rating of this state is. We can use the same method to choose the state 2 from among the bad ones of which we know. In this case, the Markov Model is used to calculate the position of the real state, between a determined state 1, at X%, and a state 2, at Y%. A second measurement, made several months or years later, will be very reliable, for comparing the second real state with the first, under the condition that we keep the states, 1 and 2, at the same value, X% and Y%. It is only important to keep the same theoretical states 1 and 2, even if we do not know the exact values of X and Y. Therefore, we have a global measurement of the political system, giving reliable results of relative and comparative measurement in a given period of time, without being obliged to make real, absolute measurements of what would be the best imaginable level of quality of life or that which would be the most disastrous.

4. CONCLUSION

The direct measurement of global satisfaction of both customers and citizens, is impossible to carry out with a reliability greater than 62%, if it is based on direct questionnaires of people's snap perceptions. This accuracy rises to 97%, if the global quality, that is the global satisfaction, of a complex system like the political one (global customer satisfaction) is evaluated with a calculation of global satisfaction. This phenomenon was validated by the application of the Markov model, firstly in an energy power-plant system, which is not discussed here, and, secondly, to measure customer satisfaction at a Leisure Park, which was confirmed by further applications in Car Manufacturing and Banking, and which are also not discussed here. This calculation is made from people's detailed perceptions of the multiple-row processes of daily life activity, like those experienced by a citizen or a customer in contact with a Customer-Service Department. These perceptions are always composed of very simple elements of satisfaction or dissatisfaction, which can be measured easily, with a high level of reliability and feasibility, from the daily tasks, events and actions, which are carried out or observed by people. An important point of this research is the understanding that the global satisfaction of customers, and by the same token, the global evaluation of a political system, is not directly linked with the individual perceptions, and does not follow a simple, linear relationship between partial perceptions of the processes which make up the system, and the global perception of the total system.

The similarity, between global customer satisfaction with the service received and the perception of political systems, allows us to propose the use of the same Markov Model for the evaluation of the political system. Therefore, the description of the two principal processes, which comprises the system, has been made using sustainability and safety, followed by their definition and the elaboration of their measurement criteria.

However, one of the most important observations, arising from this research is that of a common mistake made by politicians. They confuse the desired outcome of the political system, which is an imagined state of the ideal,

'pleasant life', with the means of achieving it. These are two reverse processes: one, of propositions for sustainability and heavy control and the other, of safety actions of the people concerned. Politicians make the same confusion, in their analysis of results of soundings of Public Opinion, between the false evaluation of citizen's global satisfaction with their policies and the true measurement of satisfaction with their individual, detailed, daily life, which really affects the possibility of achieving a new-evaluated calculation of global satisfaction.

REFERENCES

[1] Cronin J.J., Taylor S.A., Servperf versus servqual : reconciling performance-based and perception-minus-expectations measurement of service quality, Journal of Marketing N° 58, 1994

[2] Aguinis H., (University of Colorado) "Crossing frontiers in quantitative and qualitative research methods", First international co-sponsored conference research methods division, Academy of Management, Lyon, France , March 2004

[3] Cohen J., Statistical power analysis for behavioral sciences, Hilsdale, NJ, Lawrence Erlbaum, 1988

[4] Eiglier P., Langeard E., Servuction, Marketing Services, Mc Graw Hill, 1987

[5] Parasuman A., Zeithaml V., Berry L., Communication and control process in the delivery of service quality, Journal of Marketing, April 1988

[6] Lepage A, « Qualisat », deposit of the method at INPI, France,1995

[7] Kano N., Nobuhiko S., Fumio T., Shinichi T, "Attractive quality and must be quality", Japan Society for Quality Control, Tokyo,1984

[8] Edvardson B., Gustafsson A., Enquist B., "Quality in new service development. Criterial success factors", QMOD, Italy, 2005

[9] Mauldin R. D.,Urbanski M., «Graph Directed Markov Systems Geometry and Dynamics of Limit Sets", Cambridge tracks in mathematics, Serie N° 148

[10] Gupta V., Murray R.M., Hassibi B., "On the control of jump linear Markov systems with Markov state estimation", American Control Conference, 2003

[11] Assises Nationales de le Recherche en Qualité, Palais des Congrès de Versailles, 12 /1997.

[12] Lepage A., « Le rôle de la compréhension des perceptions dans la qualité des projets de conception industrielle », Thèse de doctorat, Paris, 2000

[13] Report of United Nations Conference on Environment and Development, Rio de Janeiro, 1992

[14] Agenda 21, Chapter 35, Science for Sustainable Development , United Nations Conference on Environment and Development , 1992

[15] Afgan N.H., Carvalho M.G., Hovanov A.N., Energy System Assessment with Sustainability Indicators, Energy Policy 28, 2000

[16] Gianpiero M., Mayuari K., Postar G., Energy Analysis as a tool for sustainability: Lessons for complex system theory. Annals of the New York Academy of Science, 1999

[17] Heylighen F., The science of self – organization and adaptively , Free University of Brussels

[18] Leveson M., Demonstration of a safety analysis on a complex system, report of safeware, Engineering Comp., Seatle,1996

[19] Hovanov N. V., Fedotov Y. V., Kornikov V. V., General aggregation problem in economics, 4th international workshop In multiple criteria and game problems under uncertainty, Orehovo – Zuevo, 1996

[20] Prigogine I., Evaluation criteria, variational properties and fluctuations, non – equilibrium thermodynamics variational techniques and stabiblity, University of Chicago Press, 1996

[21] Prigogine I., Kondepudi D., Modern thermodynamics: from heat engine to dissipative processes, John Wiley, Chichester, 1998

[22] Hacker S., Roberts T., Transformational leadership: creating organizations of meaning, Quality Press, 2004

Reviewers by Countries

Australia
O'Dwyer, Mark F.; University of Wollongong
Brown, Simon; University of Tasmania
Currie, Carolyn V.; University of Technology Sydney
Pereloma, Elena; Monash University
Pinto, Dale; Curtin University
Soar, Jeffrey; University of Southern Queensland
Sweller, John; University of New South Wales
Unnithan, Chandana R.; Deakin University

Austria
Geser, Guntram; Salzburg Research
Mulrenin, Andrea M.; Salzburg Research
Wöß, Wolfram; Johannes Kepler University Linz

Belgium
Daele, Peter Van; IMEC-Ghent University
Tianrui, Li; The Belgium Nuclear Research Centre

Brazil
Fernandes, Marcia Aparecida; University of Uberlandia
Wazlawick, Raul Sidnei; UFSC

Canada
Bokhari, Asghar; McMaster University
Feng, Franc; University of British Columbia
Hansebout, Robert R.; McMaster University
Holroyd, Carin; Asia Pacific Foundation of Canada
Jirgens, Karl E.; University of Windsor
Jung, Benjamin; University of Victoria
L'Ecuyer, Pierre; Université de Montréal
McLeod, Bob
Peters, Dennis K.; University of Newfoundland
Vaillancourt, Remi; University of Ottawa
Wesolowsky, George O.; McMaster University
Wolfe, Dalton L.; Lawson Health Research Institute

Chile
Bedini, Alejandro; Practia

China
Cao, Bing-Yang; Tsinghua University
Chung, Walter W.C; Hong Kong Polytechnic University
Guo, Zeng-Yuan; Tsinghua University
Lau, Henry C. W.; Hong Kong Polytechnic University
Li, Lemin; University of Electronic Science
Luo, Yingwei; Peking University
Tsang, Albert H.C.; Hong Kong Polytechnic University
Yin, TANG Chak; Hong Kong Polytechnic University
Zhuoqun, Xu; Peking University

Croatia
Jovic, Franjo; University of J.J. Strossmayer

Czech Republic
Brandejsky, Tomas; Czech Technical University
Kaluza, Jindrich; Technical University of Ostrava
Merunka, Vojtech; Czech University of Agriculture

Finland
Mattila, Minna Marita; Tampere Technical University
Repo, Petteri; National Consumer Research Centre
Tico, Marius; Nokia Research Center

France
Lepage, Alain; University of Technology of Compiègne
Rossi, Fabrice; INRIA Rocquencourt

Germany
Baum, Dieter; University of Trier
Brunkhorst, Hauke; Flensburg University
Buss, Claudia; University of Trier
Hirzinger, Gerd; Institute of Robotics and Mechatronics
Köhler, Stefan; Infosim GmbH & Co. KG
Morschett, Dirk; Saarland University
Nordmann, Alfred; Darmstadt Technical University
Ragia, Lemonia; Technische Hochschule Aachen
Rennings, Klaus; ZEW Mannheim
Tschofenig, Hannes; SIEMENS Corporate Technology
Unland, Rainer; University of Duisburg-Essen
Weiß, Christian; University of Würzburg

Greece
Kosmidis, Mary H.; Aristotle University of Thessaloniki
Moulianitis, Vassilis C.; University of Patras

Hungary
Jakabfi, Anna; Eötvös Loránd University
Lorincz, Andras; Eötvös Loránd University

India
Chatterjee, Arnab; Saha Institute of Nuclear Physics
Maheshwari, Neeru; Birla Insititute of Technology
Roy, Debanik; Bhabha Atomic Research Centre
Sreeram, Pazynur Agneswaran; Bose National Centre

Israel
Levine, Adina; Bar-Ilan University
Fund, Zvia; Bar-Ilan University
Haberman, Bruria; Holon Institute of Technology
Koren, Shira; Bar Ilan University

Italy
Appice, Annalisa; University of Bari
Chella, Antonio; University of Palermo
Chella, Antonio; University of Palermo
Ferraresi, Pier Marco; CERP
Fogli, Daniela; University of Brescia
Furcolo, Pierluigi; University of Salerno
Jacobsen, Eric; Università degli Studi di Bologna
Kenett, Ron S.; University of Torino
Mello, Paola; University of Bologna
Papini, Pier Luigi; Università di Bologna
Robustelli, Anton Luca; University of Salerno
Salomoni, Paola; Universita' di Bologna
Santucci, Fortunato; Università de L'Aquila

Japan
Sasakura, Mariko; Okayama University
De Marco, Giuseppe; Fukuoka Institute of Technology
Fujimoto, Isao; Toyota Technological Institute
Okamoto,Toshio;University of Electro-Communications
Matsuo, Hiroshi; Nagoya Institute of Technology
Robb, Thomas N.; Kyoto Sangyo University
Tada, Yasunori; Osaka University

Jordan
Salhieh, Sa'Ed M.; The University of Jordan

Malaysia
Lee, Goi Chai; Curtin University of Technology
Yeap, Boon Han; Monash University

México
Domínguez, Humberto Ochoa; Universidad Autónoma
Mortera-Gutierrez, Fernando; ITESM-CCM

Netherlands
Bregt, Arnold; Wageningen University
Eldin, Amr Ali; Delft University of Technology
Leemans, Rik; Wageningen University and Research
Vermetten, Eric; University Medical Center

New Zealand
Elley, Raina; University of Otago
Huff, Sid; Victoria University of Wellington
Scornavacca, Eusebio;Victoria University of Wellington

Norway
Hoogensen, Gunhild; University of Tromsø

Pakistan
Khan Sial, Sultan Muhammad; Lahore University

Poland
Pakszys, Elzbieta; Adam Mickiewicz University
Pakienkiewicz, Julek; Warsaw University
Qatar
Kassim, Norizan Mohd; University of Qatar
South Korea
Kim, Cheol-Han; Daejon University
Singapore
Bressan, Stephane; National University of Singapore
Yau, Wei-Yun; Institute for Infocomm Research
South Africa
Blignaut, Pieter; University of the Free State
Sweden
Barse, Emilie Lundin; AerotechTelub AB
Stenfors-Hayes, Terese; Karolinska Institutet
Switzerland
Camponovo, Giovanni; University of Lausanne,
FISCHBACH, Nicolas; COLT Telecom
Goyette, Stéphane; University of Fribourg
Mutti, Carlo; Datamars SA
Papadimitratos, Panagiotis; EPFL
Spaccapietra, Stefano; EPFL
Studer, Thomas; University of Bern
Taiwan
Chang, Yang-Lang; National Taipei University
Chen, Hengsheng; Chinese Culture University
Hsieh, Ching-Tang; Tamkang University
United Kingdom
Emes, Michael; Mullard Space Science Laboratory
Rees, Philip Howell; University of Leeds
Walker, Stuart D.; University of Essex
Ali, Maaruf; Oxford Brookes University
Bailey, Stephen J.; Glasgow Caledonian University
Barnes, Stuart J.; University of East Anglia
Brewster, Stephen; University of Glasgow
Coolen, Frank; Durham University
Coolen-Schrijner, Pauline; Durham University
Jiang, Jianmin; University of Bradford
Kelbert, Mark; University of Wales-Swansea
MacDonald, Theodore; London University
Wright, Patricia; Cardiff University
USA
Assavapokee, Tiravat; University of Houston
Backer, Larry Catá; Pennsylvania State University
Beck, Kent; Three Rivers Institute
Benotsch, Eric G.; University of Colorado
Bloomfield, Peter; North Carolina State University
Champion, Jane Dimmitt; The University of Texas
Christie, William G.; Vanderbilt University
Chun, Mark W.S.; Pepperdine University
Cole, David N.; Leopold Wilderness Research Institute
Conn, Cynthia Anne; Northern Arizona University
Coppola, Jean F.; Pace University
Dai, Qizhi; Drexel University
Derzon, Jim; Econometrica Inc.
Dholakia, Nikhilesh; University of Rhode Island
Dunn, Mary; University of Texas
Dunn, Phillip C.; University of South Carolina
Embley, David W.; Brigham Young University
Erdogan, Sevki; University of Hawaii
Eskicioglu, Ahmet; CUNY Brooklyn College
Freedman, Immanuel
Gefen, David; Drexel University
Goldstone, Jack A.; George Mason University
Han, Ju; Lawrence Berkeley National Lab
Hansen, Bill;
Hasselmo, Michael Erik; Boston University
Hunt, Anthony; University of California
Kitts, Christopher; Santa Clara University
Lazarevic, Aleksandar; United Tech. Research Center
Lee, Chin C.; University of California
Lee, James; The George Washington University
Lin, Zhibin; University of Virginia
Lindner, James R.; Texas A&M University
Lorenzi, Nancy M.; Vanderbilt University
Loyall, Joseph P.; BBN Technologies
Luo, Xin; Mississippi State University
MacLachlan, Douglas L.; University of Washington
Maher, Julie; Oregon Department of Human Services
Mazumdar, Subhasish; New Mexico Tech
Melody, Alexander W.; Ball State University
Matthews, Harry R.; University of California
McKenney, Paul E.; IBM Linux Technology Center
Middleton, Blackford; Harvard Medical School
Miller, Robin Lin; Michigan State University
Moore, Michael Grahame; Pennsylvania University
Morell, Jonathan A.; The Altarum Institute
Motter, Adilson E.; Northwestern University
Neuberger, John W.; University of North Texas
Newman, Peter ; Colorado State University
Niemi, Richard; University of Rochester
Nolle, Daniel E.; Comptroller of the Currency
North, Michael J.; Argonne National Laboratory
Osterman, Karen F.; Hofstra University
Othayoth, Raghunath; Hewlett-Packard Company
Ott, Margaret G.; Tyler Junior College
Peha, Jon M.; Carnegie Mellon University
Plass, Jan L.; New York University
Podichetty, Vinod; Cleveland Clinic Florida
Poltrock, Steven; The Boeing Company
Prabhakar, Salil; Digital Persona Inc.
Prato, Tony; University of Missouri-Columbia
Raje, Rajeev; Indiana University
Reeve, Trevor; Federal Reserve System
Reynard, Ruth; Trevecca Nazarene University
Roiger, Richard J.; Minnesota State University,
Roozendaal, Benno; University of California
Rosen, Lauren; University of Wisconsin
Salovey, Peter; Yale University
Sands, Daniel Z.; Harvard Medical School
Schott, Marshall; University of Houston
Schwabacher, Mark; NASA Ames Research Center
Sears, Andrew; UMBC
Shah, Biren N.; University of Louisiana
Sittig, Dean F.; Kaiser Permanente, Northwest
Smith, Daniel T.; Purdue University
Takayama, Leila; Stanford University
Tang, Yuchun; Georgia State University
Tarjan, Robert E.; Princeton University
Thompson, Dale R.; University of Arkansas
Troutt, Marvin D.; Kent State University
Usher, John M.; Mississippi State University
Wagstaff, Samuel S.; Purdue University
Wang, Ke; Columbia University
Wang, Xinwei; The University of Nebraska-Lincoln
Weeks, Michael; Georgia State University
Xie, Qing; University of Maryland

IPSI Team

Advisor for Mathematics-Related Problems:
Jelena Miletic and Maja Etinski
Advisors for IPSI Tutorials:
Tanja Kovacevic and Tanja Petrovic
Advisors for IPSI Research:
Milos Kovacevic and Milos Milovanovic
Advisors for IPSI Developments:
Zoran Babovic and Darko Jovic

Welcome to IPSI BgD Conferences and Journals!

http://www.internetconferences.net
http://www.internetjournals.net

IPSI-2006 MONTREAL
Montreal, Quebec, Canada
June 30 to July 3, 2006
With Visits to Jazz and Laughs Festivals

IPS-USA-2006 NEW YORK
Harvard Club of New York,
27 West 44 Street,
New York, USA
July 3 to 6, 2006

IPS-USA-2006 BOSTON
Hotel@MIT, Cambridge, Boston
Massachusetts, USA
July 6 to 9, 2006

IPSI-2006 ITALY
Rome and Hotel Castello Chiola,
Loreto Aprutino in Abruzzo,
relatively near Rome, Italy
August 19 to 26, 2006

IPSI-2006 BELGRADE
Belgrade, Serbia
August 28 to 31, 2006
With Visits to Famous Serbian Monasteries

IPSI-2006 LONDON
Hotel Beaufort, Knightsbridge,
London, England
Aug 31 to Sep 3, 2006

IPSI-2006 MONTENEGRO
Hotel Sveti Stefan, Montenegro
Sep 23 to Sep 30, 2006

IPSI-2006 VENICE
Venice, Italy
October 12 to 15, 2006

IPSI-2006 SLOVENIA
Hotel Toplice,
Bled Slovenia
Nov 30 to Dec 3, 2006

IPS-USA-2007 HAWAII
Hilton Waikoloa
Big Island, Hawaii, USA
January 6 to 9, 2007

IPS-USA-2007 CALIFORNIA
Palo Alto in Silicon Valley,
near San Francisco,
Hotel Stanford Terrace,
California, USA
January 9 to 12, 2007

IPSI-2007 MARBELLA
Hotel Puente Romano
Marbella, Spain
February 22 to 25, 2007

IPSI-2007 AMALFI
Hotel Santa Caterina
Amalfi, Italy
March 22 to 25, 2007

IPSI-2007 LAPLAND
Rovaniemi,
Santa Claus World Capital,
Finland
March 29 to April 1, 2007

IPSI-2007 FRANCE
Hotel de la Cite,
Carcassonne, France,
UNESCO Heritage,
April 26 to 29, 2007

IPSI-2007 SPAIN
Hostal de la Gavina,
S'Agaro, Costa Brava
near Gaudi Barcelona, Spain
May 3 to 6, 2007

IPSI-2007 TOKYO
M.I.T., Tokyo, Japan
May 31 to June 3, 2007

IPS-USA-2007 NEW YORK
Harvard Club of New York,
27 West 44 Street,
New York, USA
July 2 to 5, 2007

IPS-USA-2007 BOSTON
Hotel@MIT, Cambridge, Boston
Massachusetts, USA
July 5 to 8, 2007

IPSI-2007 ITALY
Rome and Hotel Castello Chiola,
Loreto Aprutino in Abruzzo,
relatively near Rome, Italy
August 18 to 25, 2007

IPSI-2007 FIRENCE
Firence, Italy
Aug 25 to Aug 28, 2007

IPSI-2007 BELGRADE
Belgrade, Serbia
September 19 to 22, 2007
With Visits to Famous Serbian Monasteries

IPSI-2007 MONTENEGRO
Hotel Sveti Stefan
Sep 22 to Sep 29, 2007

IPSI-2007 VENICE
Venice, Italy
October 11 to 14, 2007

IPSI-2007 SLOVENIA
Lake Bled in Alps,
Slovenia
Nov 29 to Dec 2, 2007

The publication of this journal
is supported in part by
the Ministry of Science of Serbia

CIP – Katalogizacija u publikaciji Narodna biblioteka Srbije, Beograd

ISSN 1820 – 4511 =
The IPSI BGD Transactions on Advanced Research
COBISS.SR - ID 119128844