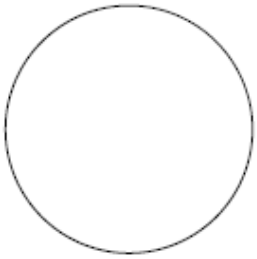

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Interview -
Creativity for Recovery from Crisis

Arrow, K.

1. How you define inventivity and creativity?

Inventivity is the ability to make new connections among the different aspects of the world. Most such perceptions are wrong; therefore, they must be subject to rigorous criticism, by the author and by others, to insure their compatibility with what we can all observe and with the principles of logical coherence.

2. What were the inventivity and creativity triggers in the case of your contribution for which you were awarded a Nobel Prize?

Like all such events, there are two conditions: the previous knowledge on which to draw and the particular question asked. In my case, I was asked to explain to non-economists what was the meaning of a value to a collectivity (e.g., a nation). I had background in economic theory and in logic which caused me to formulate the question in a way that admitted of an unexpected analytic conclusion.

3. How to induce inventivity and creativity among young people, especially in small countries, like in Montenegro or Serbia?

A necessary condition for creativity is access to a wide and diverse basis of knowledge. For any country, even the largest, this means that it must reach out to the whole world. For example, our scientific journals are open to scholars from all nations. A small country will have less diversity and therefore more need to reach out to the world. I therefore think it important that the best students be sent to larger countries for advanced study. When these students return and serve as the next generation of academics and research engineers, they will bring more knowledge and higher standards.

About the Author

Kenneth Joseph Arrow (born August 23, 1921) is an American economist and joint winner of the Nobel Memorial Prize in Economics with John Hicks in 1972. To date, he is the youngest person to have received this award, at 51. In economics, he is considered an important figure in post-World War II neo-classical economic theory. Many of his former graduate students have gone on to win the Nobel Memorial Prize themselves. Ken Arrow's impact on the economics profession has been tremendous. For more than fifty years he has been one of the most influential of all practicing economists. His most significant works are his contributions to social choice theory, notably "Arrow's impossibility theorem", and his work on general equilibrium analysis. He has also provided foundational work in many other areas of economics, including endogenous growth theory and the economics of information.

Early Year's Geometry

— Children's Conception According 'Transformation'

Motoya, Y.

Abstract - *We have examined drawings of figures drawn by children from 3 to 5 years old. We pursue the problem of the quality of learning by way of analyzing children's conception of space. We had shown them figures (using two cups) as a model. One cup was placed in ordinal way, the other in reverse. How children drew figures concerning domains. Why differences occur when children drew one and the same model? Our research to the problem of cognition of 'Transformation' by children is carried out by the standpoint of projective geometry.*

INTRODUCTION

Many teachers pay attention only to the result of teaching and educational effects, but have a few interests to the method of thinking by children. They ignore the progress and process of investigation, or the stumbling in course of their thinking before arriving at a result.

When children are confronted with difficulties, first and foremost they rush in their shelters. These shelters are their abilities to do their best. They mobilize all their abilities, they think out their own decisions. But it is difficult for children how to express the contents in their mind. Therefore we should support them by the appeal to their process of thinking. Development of learning begins from noticing their own troubles of understanding by themselves.

Our attempt by the method of drawing-analysis may offer some hints to find out the secret of their process of thinking.

TASK AND PROCEDURE

Children from 3 to 5 year old are told to draw the model (figure 1), using two cups as a model. They were set in different ways. One was in an ordinary way, the other was upside down. The color of each domain of cups was pink, yellow, red and blue. When we looked at the left cup, we couldn't see the domain of the inside bottom.

Table 1: Sam total of children and sheets

2009.2,24 – 3,18 In Sendai, KATA nursery school

numbers	plane model	cubic model	
3 years old	20	27	52
4 years old	24	23	45
5 years old	23	34	60

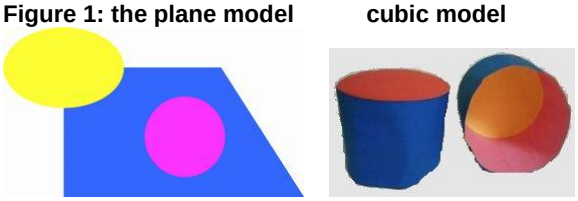
Method of this experiment

* Pretest - We asked children to draw the plane model first, and then cubic model without any suggestion.
* Game - After the drawing, they played the following game. The game was called pole asunder game.
* Posttest – After playing the game, they were asked to draw the same cubic models again.

MODEL FOR DRAWING

How children draw the model? We analyze this problem applying the method of projective geometry.

Figure 1: the plane model **cubic model**

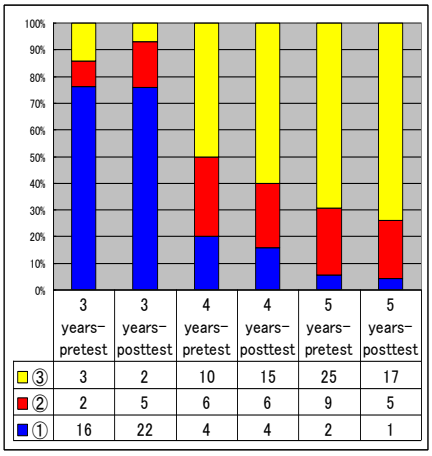


1 Characteristics of drawings of children

1.1 Distinction of the qualities in the drawing

Author is with the Pedagogy Department, Osaka Jyosi College, Japan. (e-mail: y-motoya@osakajyosi.ac.jp).

Table 2: distinction of the qualities of two cups



For the drawing of cups from different two standpoints, children felt many difficulties. By a child, we could find differences of understanding between the two models. But the quality of understanding was getting raised gradually by age. In the case of the drawing of the posttest by 4 and 5 years children, a child showed the understanding of each model heterogeneously. In case of the drawings by 3 years, children drew two cups as one cup without distinguishing them, or drew them in two circles.

1.2 How children drew differently the model of two cups?

Table 3: The way of draw differently two cups

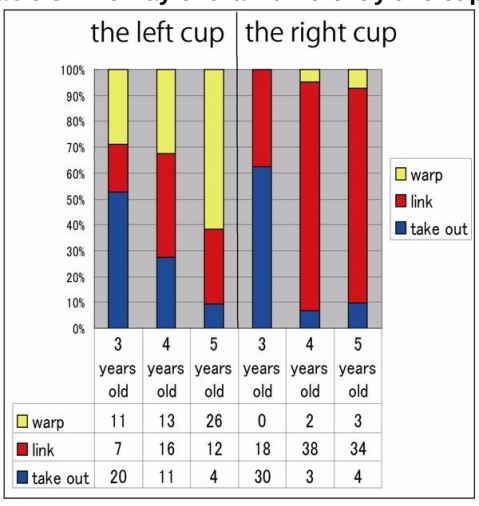
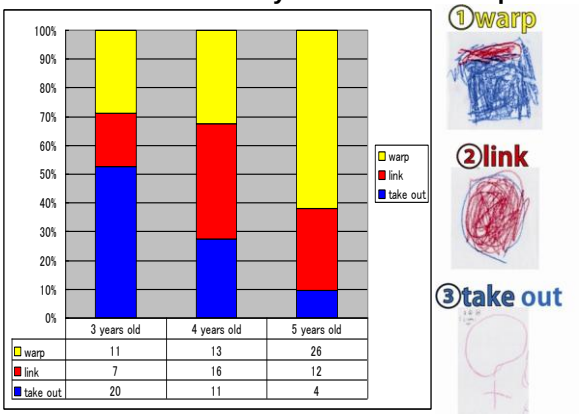


Table 3-a: The way of draw the left cup



1) take out – simple picking out of domains
2) link – connection of two or many domains
3) warp – transformation from circle to ellipse

Figure2: take out (1)

Figure3: take out (2)

Figure4: take out (3)

Figure 5: link (1)

Figure 6: link (2)

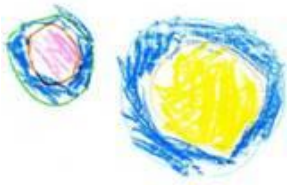


Figure 7: link (3)

Figure8: warp (1)

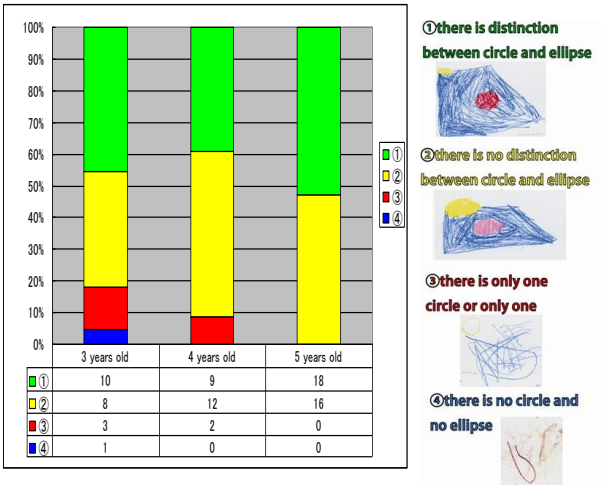
Figure9: warp (2)

Figure10: warp (3)

[Result]
Left cup: Transformation of a domain is changing one after another: 'take out'—'link'—'warp' by age (Table 3).
Right cup: Connection of three domains is derived differently by age.

1.3 How children drew the plain model in circle and ellipse?

Table 4: distinction between circle and ellipse

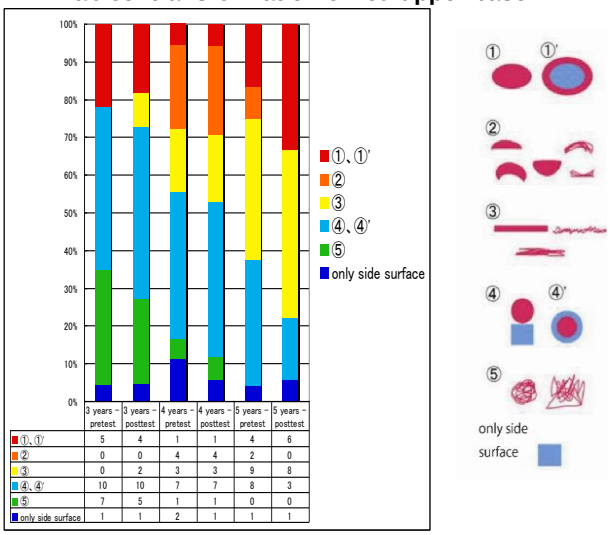


	3 years old	4 years old	5 years old
①	10	9	18
②	8	12	16
③	3	2	0
④	1	0	0

① By plain model, over 40 % children could draw the model correctly distinguishing circle and ellipse. But they couldn't distinguish circle and ellipse by cubic model.

② By cubic model, children in any years could scarcely draw the red upper base as ellipse. (Table 5) For the transformation of red upper base from circle to ellipse, they must change the standpoint from the real circle to the image of sight (ellipse). This manipulation is very difficult for them.

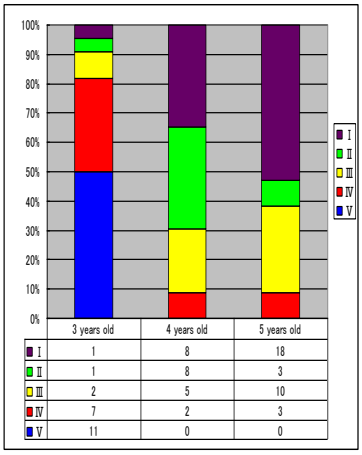
Table5: transformation of red upper base



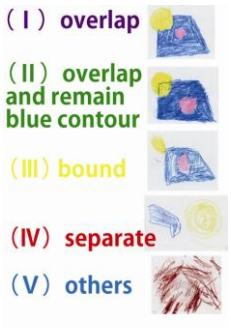
	3 years - pretest	3 years - posttest	4 years - pretest	4 years - posttest	5 years - pretest	5 years - posttest
①、①'	5	4	1	1	4	6
②	0	0	4	4	2	0
③	0	2	3	3	9	8
④、④'	10	10	7	7	8	3
⑤	7	5	1	1	0	0
only side surface	1	1	2	1	1	1

1.4 How children drew the contrary poles?

Table6: The relation of yellow and blue domains



	3 years old	4 years old	5 years old
I	1	8	18
II	1	8	3
III	2	5	10
IV	7	2	3
V	11	0	0



We take the problem, how children acquire the cognition of poles, such as near and distant, over lap and far, embrace and separate. We tried to analyze the relation of the yellow ellipse and blue pentagonal mount in case of the plain model (Figure1).

In the relation of yellow and blue, we can divide ①include – be included, ②appear – disappear, ③bound – separate. To understand the relation children should notice these divisions, especially separation. Children need distinguish overlap and apart to draw figures correctly.

Concerning to draw figures apart and outside, children need to consider the overlap relation of two domains. By means of thinking the contrary poles, they reach to the correct figures in succession (figure1). We find the quality of understanding was getting raised gradually by age. It is especially important for children to discover the contrary poles in one thing or in the relation of the two.

1.5 Interlude How children change through the play of games?

Children learn and think mechanism of space while they play an active part in games. They consider, suspect, imagine and devise from teacher's influence. Meanwhile teacher should never inculcate the solution.

[Pole asunder game]

In this group game children will think the contrary relation of things in pole asunder as follows.

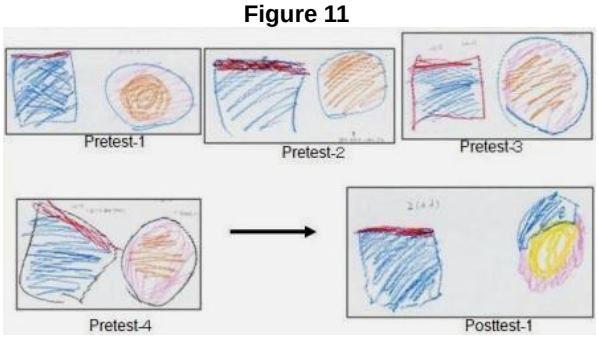
* In the game children played by the appeal of teacher as follows.

① top - bottom
② ground – sky charcoal gray - light blue
③ candy - cream puff hard - soft
④ ant – elephant small - large
⑤ long trunk - short leg Dachshund,
⑥ left hand – right hand

1.6 Change of drawing after the playing

・SIONN (5 years old) drew the model as follows.

Figure 11



SIONN imagined and expressed her asunder poles as follows.

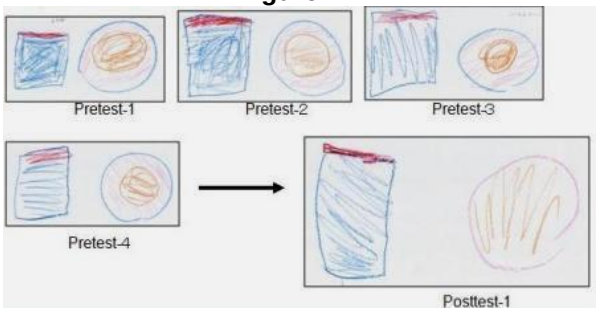
** sky – sea solid - liquid*
airplane – way unfixed air rout – fixed rout
sun – mole untouched sun – touchable mole

She starts from transforming the red upper base. She drew the contour line of the right model in blue. In the pretest 2, contour line was opened. In the next pretest 3, she drew it with red contour line. In pretest 4, she drew it in black.

In the posttest, she drew it correctly. She changed the understanding of the model from two domains connection to 3 domains connection. It was indeed a splendid change.

・NANAMI (5 years old) drew the model as follow

Figure 12



NANAMI imagined and expressed her asunder poles as follows.

** sky – sea*
ground – rainbow
ground

Her drawing showed a sort of retrogression in the posttest, ie. she changed to drew the model from three to two domains. What is the reason?

The aspects of attentions to the models differ by each child. The change of recognition through the pretest to the posttest tempts a motivation in children's studying. But this change is not one to one correspondence. The difficulty lies in the narrowness of their understanding. In case NANAMI, passwords are related only to one dimension.

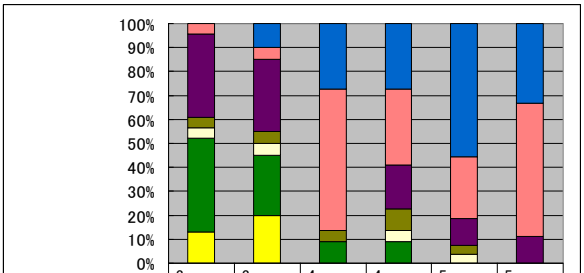
In the studying there are two points. One is child's effort and will, the other is teacher's influence.

2 Analysis of drawing of children

2.1 Domains

How many domains are there in their drawings?

Table 7: the number of domains of the right cup

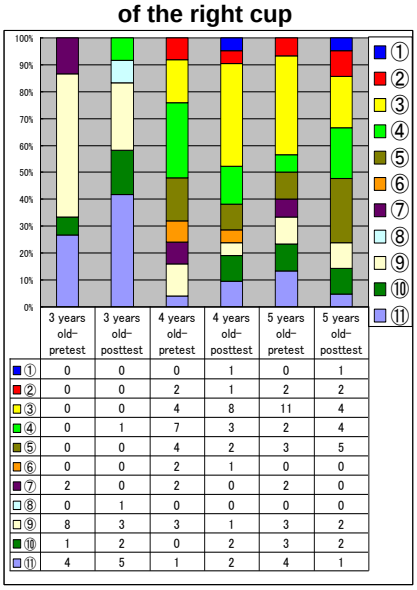


	3 years old–pretest	3 years old–posttest	4 years old–pretest	4 years old–posttest	5 years old–pretest	5 years old–posttest
3 domains	0	2	6	6	15	6
2 domains	1	1	13	7	7	10
1 domains	8	6	0	4	3	2
4 domains	1	1	1	2	1	0
5 domains	1	1	0	1	1	0
multi domains	9	5	2	2	0	0
there is not the right model in drawings	3	4	0	0	0	0

Figure 13
SATOSHI (4 year's old)

Figure 14
HIKARU(5 year's old)

Table 8: The types of the way to connect domains of the right cup



	3 years old–pretest	3 years old–posttest	4 years old–pretest	4 years old–posttest	5 years old–pretest	5 years old–posttest
①	0	0	0	1	0	1
②	0	0	2	1	2	2
③	0	0	4	8	11	4
④	0	1	7	3	2	4
⑤	0	0	4	2	3	5
⑥	0	0	2	1	0	0
⑦	2	0	2	0	2	0
⑧	0	1	0	0	0	0
⑨	8	3	3	1	3	2
⑩	1	2	0	2	3	2
⑪	4	5	1	2	4	1

The cubic model (the right model) has 3 domains. SATOSHI (4 year's old) drew the model as figure13. Though he drew three domains in figure13, it shows different level compared to figure14 (HIKARU 5 year's old) .

We will try to classify the types of the way to connect two domains. (Table 7, Right cup model). In this case, there are 3 colors and 3 domains (①-③).

In 3 year's children, there is no relationship in the two domains. In 4 and 5 year's children, there appear some connections in two domains. The quality of understanding is getting gradually by age. Besides the quality of understanding is outstanding in posttest.

In pretest, some children (4 and 5 children) drew red domain. But they showed changes of

cognition in the posttest as follows.

* a: blue domain, b: pink domain, c: yellow domain, d: red domain. For example, ac means the combination of blue domain and yellow domain.

Figure 15: SOYOGU (5 year's) From ad to ab, bc

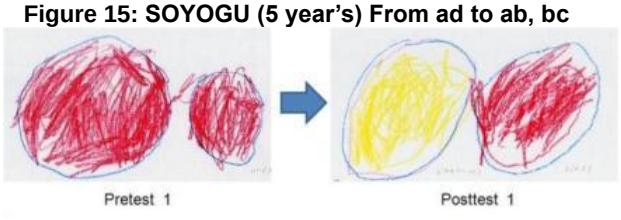


Figure 16: SEIITIROU (4 year's) From ad to ab

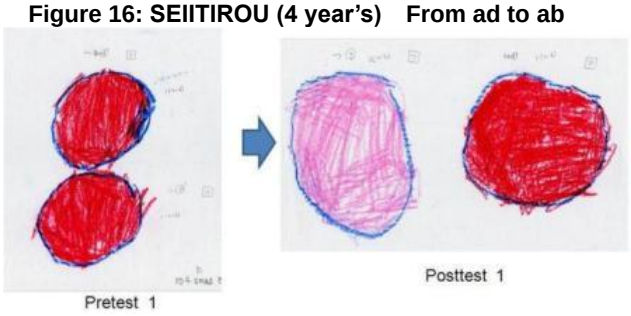
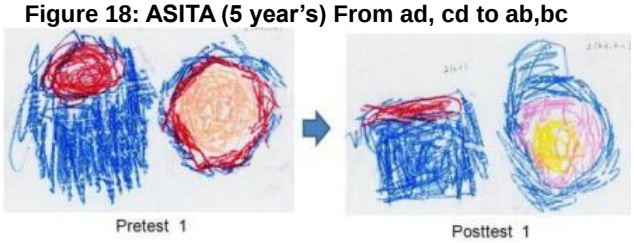


Figure 17: JYUN (4 year's) From ad to ac

Figure 18: ASITA (5 year's) From ad, cd to ab,bc



They all changed from ad (d is disappeared). Now they drew the model as ab, ac and bc. Though the connection bc is not the real connection, the drawing with bc shows a advanced level.

*cd, bd: There is no connection of domains both in the original cup and the right cubic model (d can not be seen).

ad: There is connection of domains in the original cup but no connection in the right cubic model (d can not be seen).

ab: There is connection of domains in the original cup and in the right cubic model (surface and reverse).

bc: There is connection of domains in the original cup and connection in the right cubic model.

ac: There is no connection of domains in the original cup but visual connection in the right model.

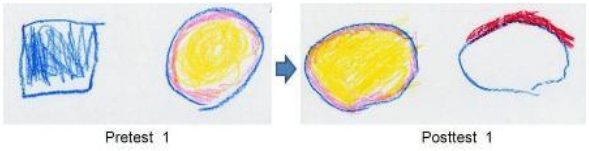
2.2 To be or Not to be

Many adults wonder why children draw the red domain, though they cannot see in their eyes. And they will think it is easy to draw the right cubic model connecting yellow and pink domains, while this connection is visible to their eyes. But in fact, children who drew the red domain, have a higher level of cognition. They drew red domain because they understood correctly that the blue domain continues to the reverse red domain. They want to draw what they have understood.

Concerning the left cubic model, a child didn't draw the connection of red and blue domain (Figure19 HONOKA Pretest). To her eyes the red bottom was certainly visible, but she maybe thought that the bottom should not appear to her eyes.

For children it is rather difficult to draw a model as it appears to their eyes. They draw by their intuition and imagination. So we must by the analysis of their drawings research the ability of sensibility and imagination in children.

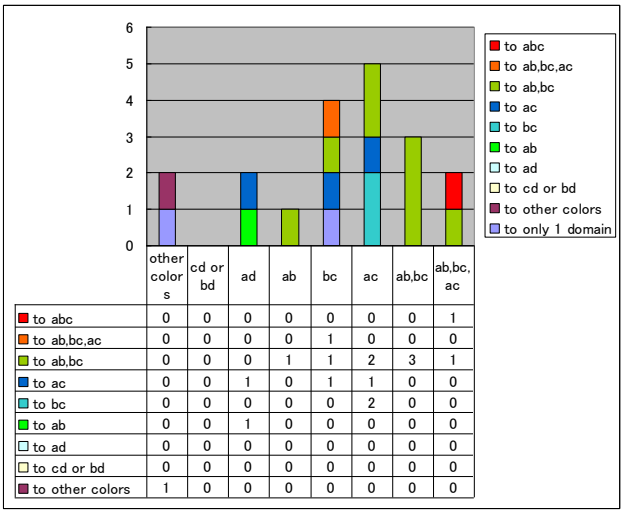
Figure19: HONOKA (4 year's)



Children draw connections, though they cannot find them under their perspective. And they often correct by themselves through some prompts (in this case, the play of contrary poles). They have since a very early year's many naïve imaginations, and they are apt to see things, not with their eyes, but with their imaginations. Imaginations read cognitions. This ability of imagination by children is very strong and plays decisive effects. They feel things not by sights of things but by images of things. Ability of cognition is characteristic and inherent to children, and as connected with the ability of thinking. They live in the world of imagination, first cognition and then correct it in course of their exercise or praxis. They have ears which can listen the conversation between crow and fox.

Children are fond of drawing what they can understand. Even to their eyes it is 'to be', to their heart it is 'not to be'. And it is 'not to be', it is 'to be'. So, if we pay attention to their process of thinking, we will have a chance to find the secret in the mind of children.

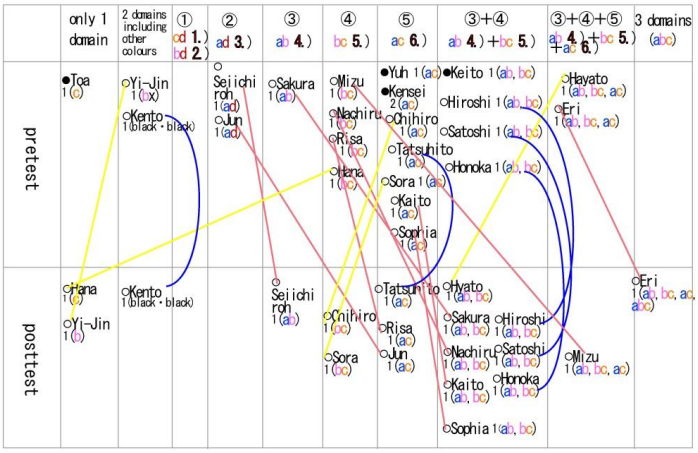
Table 9: The details of variation of connection of right cup (4 year's)



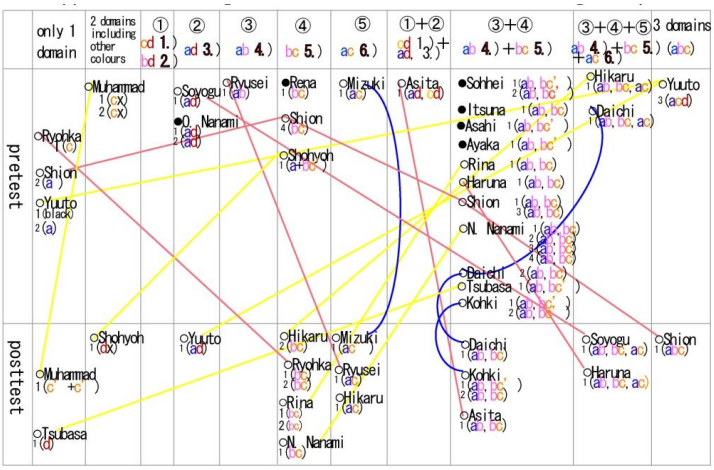
	other colors	cd or bd	ad	ab	bc	ac	ab,bc	ab,bc, ac
to abc	0	0	0	0	0	0	0	1
to ab,bc,ac	0	0	0	0	1	0	0	0
to ab,bc	0	0	0	1	1	2	3	1
to ac	0	0	1	0	1	1	0	0
to bc	0	0	0	0	0	2	0	0
to ab	0	0	1	0	0	0	0	0
to ad	0	0	0	0	0	0	0	0
to cd or bd	0	0	0	0	0	0	0	0
to other colors	1	0	0	0	0	0	0	0

Table 10:

The variation of drawings of right cup (4 year's children)



The variation of drawings of right cup (5 year's children)



Object Knowledge for Retrieval and Diagnosis

Yamasaki, S.; Sasakura, M.; and Iwata, K.

Abstract—*We analyze some ideas of objective knowledge as (1) an agent to implement content retrieval, and (2) conjectured diagnosis. We then specify the ideas by a formality so that we may interpret objective knowledge as method. Since the method contains implementable views, we can see that objective knowledge may be not only data, but also procedures. By means of a diagnostic system practice as well as content retrieval, we may acknowledge such an aspect of objective knowledge. As in application of DSM (Diagnostic and Statistical Manual of mental disorder) to decision of disorders caused by syndromes, the expert (who is not always a doctor) may take a role of interaction between the patient and the automated system based on DSM. However, the automated system does not necessarily make the expert capability useful, as long as the expert is just an auxiliary agent between them. We incorporate a significant function (role) into the whole diagnostic process for the expert (agent) to make some conjecture diagnosis against suspicious syndrome, before the query-answer mental stage for each cause syndrome with reference to conjecture diagnosis. In general, we interpret conjecture diagnosis as objective knowledge, while conjecturing is based on reasoning. This manner can be generalized to design scheme for automated diagnosis of two stages: (1) the function of an expert agent, considered as conjecturing diagnosis, and (2) the verification of conjectured diagnosis, whether it is automatic or re-examined from professional views.*

Index Terms—*Intelligent systems (ISY), Knowledge structure, Reasoning*

1. Introduction

From the ontology views with type theory (as in [4]), the object may be identified from the method of procedures. In this paper, we have an outlook on the role of objects as methods, where the task domains are taken from Web usability, object-oriented programming and diagnosis in psychology.

In the field of knowledge representation, procedural aspects in knowledge have been studied as reasonings. The keynote of [21] focused on:

- reasoning in distributed environments and its correctness as procedure, and
- diagnosis as basis of causal theory applied to a consultant system.

In the keynote, we next turned to objective knowledge, apart from procedural aspect of it in reasoning. As in object-oriented programming ([4]), the object recursively involves methods (procedures) as well as objects. Motivated by construction of e-learning system designs, we rather take sequential structure formed by objective knowledge concatenations than recursive structure of objects. With primitive rules of replacements of objects by sequences of objects, how to form structure to denote some sequential process of primitive knowledge processing is a problem.

In this paper, we deal with the problem of how to interpret the objects as methods. As typical objects, we have:

- an agent with keywords (an object) to retrieve the contents in the distributed system whose behaviours are described with a pseudo-language, and
- conjectured diagnosis with DSM ([1]) for detection of mental disorders.

We firstly show that an agent with keywords is both a communication medium and a tool (method) to acquire keywords (knowledge).

We then turn to an illustrative example of a program, where methods contained in an object are evoked. As the second problem, we focus on an object in a diagnostic automation problem:

It is not so easy how to automatically diagnose mental syndromes obtained by means of interaction between the licensed expert (who is not always a doctor) and the patient. In case that the expert may not be always the psychiatrist to possibly prescribe, he or she must contribute to rather redundant interactions with the patient to get some answers to the presented questionnaire, but diagnoses reasoned with answers may not be verified. In such a case, time complexity of interactions and insufficiency in the verified diagnosis caused by the expert frustrates the effect of interactions which it may take more time for.

We consider two stages:

1. a stage to automatically support the expert's knowledge or to implement a part of diagnosis for the expert must be of much help, such that conjectured disorders may

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be reasoned as diagnoses, and

2. another stage to verify conjectured diagnoses by means of exact question and answer interactions managed by the expert,

such that the expert can make an effective role without any loss through automated conjecturing.

The problem is how to conjecture disorders from claimed syndromes. As a solution, we elaborate a consistent reasoning with a rule for the diagnosis from syndromes and with constraints, which may be applied to a mental disorder diagnosis with formulation of DSM ([1]). If the conjectured diagnosis is reasoned, the diagnosis is interpreted as an object containing methods or methodologies. In this sense, we list up the problem of conjecturing disorders from syndromes and its solution by two stages of diagnosis.

This paper is organized as follows. In Section 2, we present an object as method, concerning the content retrieval with keywords. In Section 3, the way of conjecturing diagnosis is presented. In Section 4, concluding remarks of this paper are made to observe the views on objective knowledge as method.

2. CONTENT RETRIEVAL

We consider the content retrieval by means of key words as an Web usability, where the keywords contain both positive and negative aspects to denote a content. As an agent, we assume a case that a request containing key words searches the Web site pages which involve expected, coherent keywords. For the reliable response of a Web page to the request which can cause an enumeration (apperception) of the page and make the page included in a list (of the request data structure):

- We need an interaction between a managing process with a request as a medium, and multi-site (of a distributed system), where each page has got a recursive link structure in a site.
- Any page supposedly responds to the request as a program with knowledge content (keywords) such that if the keywords of the page are consistent with those of the request, then they are to be merged with those of the request, otherwise (that is, the keywords of the page are inconsistent with those of the request), the page cannot make a reliable response and it is rejected/neglected in the request search.

The request itself searches a consistent page in the sense that their keywords are mutually consistent, and also acquire consistent keywords from the page.

We now make a sketch on the whole system, which consists of a managing program, a request (data structure), and sites with their own pages:

(i) A managing program communicates with a site through a request (data structure) of keywords as a medium. Among communication requirements of sites, only one from a site is selected, and other requirements are excluded until the adopted communication would be over.

(ii) The request is not only a data structure, but also a function to acquire consistent keywords from reliable (acceptable) pages in a site and not to get any keyword at all from rejected pages (note: see (iv) for the ideas of reliability/acceptability and rejection). The request is unique, whether it is regarded as a medium or function, since the keywords contained by it may be amended through visits to site pages.

(iii) Each site in the system contains pages under the site environment.

(iv) Each page of a site involves both a program (to make the request data consistently revised) and keywords. If the page contains consistent keywords with those of the request, it is regarded as reliable or acceptable. Otherwise it is thought of as rejected so that the request is not to be revised.

The request data structure is defined as follows, where it contains a memory to store reliable (acceptable) pages through searching.

Format of Request (BNF)

```
<Request>  ::= Name <p-keywordList>
                   <n-keywordList> <PageList>
<p-keywordList> ::= Keyword+
<n-keywordList> ::= Keyword*
<PageList> ::= Page*
```

The above variables Name, Keyword+, Keyword* and Page* are of data type “string". The function to acquire consistent keywords but not to get inconsistent ones is performed by means of a program equipped with in each page, such that Request contains no program. It may be represented as an XML-file.

An Example of Request

```
<Request>
 <Request-name> Name </Request-name>
 <p-keywordList> <p-keyword> A </p-keyword>
          <p-keyword> B </p-keyword>
          .....
 </p-keywordList>
 <n-keywordList> <n-keyword> a </n-keyword>
          <n-keyword> b </n-keyword>
          .....
 </n-keywordList>
 <PageList>
 </PageList>
</Request>
```

The "Manager" (managing program) has an interaction with a site in a distributed multi-site system, with the data structure "Request".

Manager

```
Manager::Managing
 begin
  read Request;
  u = 0;
```

```
  while u = 0 do
   begin
    if requirement_i exists then
     begin
      select requirement_i;
      send Request (or none unless Request
                    exists)
          to Site_i
     end;
    if Request reaches then
     begin
      if "to be continued" then
       take Request
      else
       u = 1
     end
   end
 end
```

The Manager communicates with more than two sites in distributed environments, where each $Site_i$ keeps all the pages to consistently respond to Request. If Manager is interpreted as virtual, a mutual communication between sites are considered as available, where such a mutual one is later formulated.

$Site_i$

```
Site_i::Assigning
 begin
  send requirement_i to Manager;
  v = 0;
  while v = 0 do
    if Request reaches then
     begin
      take Request;
      for all pages do
       begin
        assign Request to a page;
        revise Request
       end;
       send Request to Manager;
       if "to be continued" then
        send requirement_i to Manager
       else
        v = 1
     end
 end
```

Each page takes the form consisting of a program and (a data structure of) keywords. The following Name, Keyword+, Keyword* and ProgramName are of data structure "string". The above Page can be expressed in an XML form.

Format of Page (BNF)

```
  <Page> ::= Name <p-keywords> <n-keywords>
             ProgramName
  <p-keywords> ::= Keyword+
  <n-keywords> ::= Keyword*
```

An Example of Page (XML)

```
<Page>
 <Name> PageName </Name>
 <p-keywords> <keyword> A </keyword>
  <keyword> B </keyword>
  .....
 </p-keywords>
 <n-keywords> <keyword> a </keyword>
  <keyword> b </keyword>
  .....
 </n-keywords>
 <ProgramName> Checking </ProgramName>
</Page>
```

The program of "Page" can be represented as follows. It acquires consistent keywords.

Program of Page

```
Page::Checking
 begin
  if p-keywords and Request::n-keywordList
       have some common keyword
       then return Request
  else if n-keywords and Request::p-keywordList
          have some common keyword
       then return Request
  else
   begin
    Request::p-keywordList =
          the merge of  Request::p-keywordList
                and p-keywords are merged;
    Request::n-keywordList =
          the merge of Request::n-keywordList
                and n-keywords are merged;
    add this page to Request::PageList;
    return  Request
   end
 end
```

If we regard the program "Manager" as implicit and functionally virtual in a distributed system of sites, then we can have a communication between two sites (through the program Manager). Then we interpret Request as a situation (or a state) transitive to another by means of the page: If the page is rejected, there is no transition. On the other hand, the empty transition may occur when Request is not amended through keywords of a page, that is, keywords of Request covers all the keywords of the page.

Note that a reliable (acceptable) page sequence can be kept in the data structure Request, even if the program Manager is supposedly implicit (virtual) for site communications with Request. This page sequence is required to be recognized as an object sequence in the calculus of this manuscript.

3. *Conjecturing Diagnosis*

Based on DSM ([1]), the structured clinical interview for DSM (SCID) contains the rules in questionnaire form like a flowchart [7], where the expert can be wise to interact with the patient and to draw the answers to the questionnaire for diagnosis. There may be an automated way from the answers to some diagnosis, with the aspects:

- answers to the questionnaire as objective knowledge
- diagnosis as method

In this setting, there is a problem that the expert may not be always the licensed psychiatrist to possibly prescribe. In addition, the way may be often of high computational complexity in reasoning when the interaction between even the good expert and the handicapped patient might be complex. These are to be re-considered with reference to information system designs. To cope with such problems, we must:

(i) make the expert's skill more adopted, and
(ii) make the whole diagnosis effective.

We have an suggestion to take two stages for (partially) automated diagnosis:

(a) to conjecture diagnosis by consistent reasoning from assumed syndromes and constraints, and
(b) to verify conjectured diagnosis by means of the questionnaire with the expert.

We then regard conjectured diagnosis as objective knowledge, while conjecturing is a method without inconsistency.

We construct a prototype system for assisting to make a diagnosis of a mental disorder based on DSM and SCID. The system consists of the two stages mentioned above. We call the former (a) as "the first stage" and the latter (b) as "the second stage". We describe the details of the system.

The First Stage

We pick up symptoms from the description of DSM and construct a knowledge base for the first stage. Some symptoms are effective in distinguishing a disorder from others. Other symptoms are common among disorders. Some symptoms must be seen for diagnosing some disorders, and other symptoms may be seen in some cases and may not be seen in other cases of a disorder. Therefore, we choose some characteristic symptoms and we use consistent reasoning to find suspicious disorders from them.

The form of consistent reasoning is

$$A \triangleright B_1,\ldots,B_m,C_1,\ldots,C_n$$

where:

- A is a disorder.
- $B_1,\ldots,B_m,C_1,\ldots,C_n$ are symptoms.

The manual may include descriptions among relations of disorders and symptoms. The consistent reasoning can be constructed in the manner.

On condition that

(i) there is a rule $A \triangleright B_1,\ldots,B_m,C_1,\ldots C_n$,

(ii) $not\ C_i$ fails $(1 \le i \le n)$,

(iii) there are symptoms $A_1,\ldots A_l,B_1,\ldots B_m$, and

(iv) A_1 and A_2 and $\ldots$ and A are consistent,

reason the disorder A as diagnosis.

Because $not\ C_i$ fails, we can consistently assume a symptom $C_i\,(1 \le i \le n)$ such that symptoms

$$B_1,\ldots,B_m,C_1,\ldots C_n$$

are to be listed up. On the other hand, assumed symptoms $A_1,\ldots,A_l$ would never deny the conjectured disorder A, because the conjunction of A_1 and A_2 and $\ldots$ and A_l and A is consistent.

For a list of claimed symptoms, consistent reasonings may make the expert learn more than 2 disorders such that conjectured disorders are gathered into a set as conjectured diagnosis.

In the prototype system we developed, the first stage is implemented simply:

1. The system lists up all symptoms related disorders.
2. An expert decides a threshold rate.
3. An expert checks all symptoms that a patient has.
4. If the number of checked symptoms related to a disorder goes over the threshold rate, the system picks up the disorder.
5. All disorders the system picked up are displayed on the screen for the second stage.

The Second Stage

The second stage will start for a disorder that is listed up by the first stage of the system. The expert firstly looks at the list of the suspicious disorders, such that the expert can pick up a disorder that seems to be the possibly true disorder of the patient. Then the verification stage (the second stage) starts on here.

The system asks a question that follows SCID, while the expert answers. This answer includes a thought of the expert. The expert interacts with the patient, and judges how to answer to the question from the system. This means the expert interacts with the system also, not only with the patient. The system stored the answer to the database, and shows a new question to the expert. The system also shows the process of the flow. This helps the expert to judge the disorder of the patient. The expert can think about the answer of the question from the system too.

The cycle is continued until the flow reaches the end. At the end of the flow, the system displays if the suspicious disorder of the patient would truly match to the symptoms or not.

The questions in the second stage of SCID have 3 values. The answer for the question is one of ?, -, or +. The answer is interpreted by : ? means inadequate information, - means absent or sub-threshold (negative), and + means present (positive). If the answer is +, the patient has the symptom asked by the question.

The questions of SCID can be categorized into two types following:

Type 1 The next question is decided by the answer of this question.

Type 2 The next question is decided by the answers of the previous questions including this question. In this type of questions, sometimes more than 10

previous questions are related to decision of the next question.

The system supports these two types of questions and controls flows in the second stage.

System Design

The proposed system aims to assist the psychiatrist in making a diagnosis. It is designed as a Web-based system. The architecture of the system is shown in Figure 1.

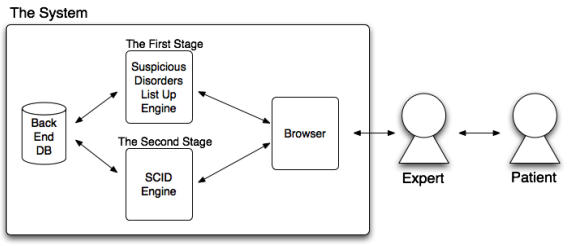

Figure 1 The system architecture of a diagnosis system.

The system consists of four parts: Back End DB, Suspicious disorders listing up engine, SCID engine and Browser. Back End DB keeps knowledge for diagnoses and records of diagnoses. Suspicious disorders listing up engine is an implementation of the first stage. SCID engine is an implementation of the second stage. Browser is an interface between the system and a psychiatrist. Any popular Web browser can be used as the Browser.

Figure 2, 3 and 4 show snapshots of the system. Figure 2 is a snapshot of the first stage. A psychiatrist asks and observes symptoms of a patient and checks in boxes of present symptoms. Figure 3 presents the result of Figure 2: a list of suspicious disorders. When the psychiatrist clicks the "go" button in Figure 3, the second stage starts. Figure 4 is a snapshot of the second stage. In the second stage, questions are displayed on the screen in sequence. The psychiatrist makes inputs of answers for the questions by checking an appropriate item, such that the result flows: the patient has the suspicious disorder or not.

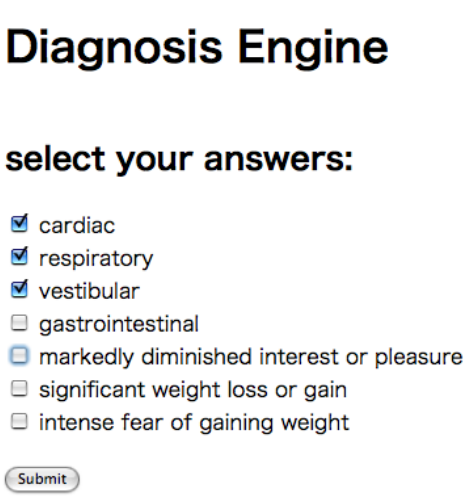

Figure 2 The first step.

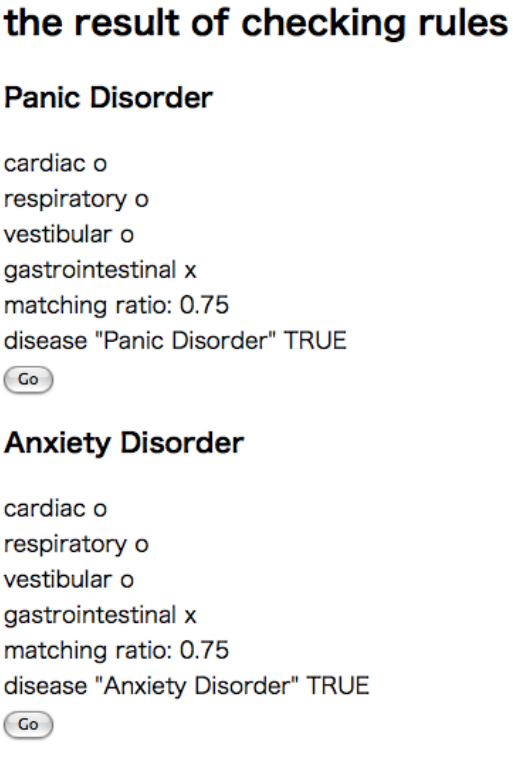

Figure 3 The suspicious disorders.

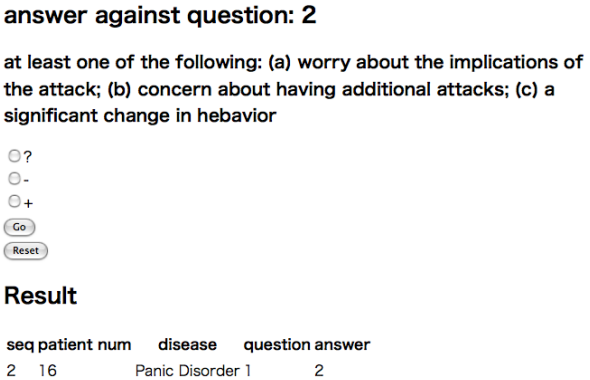

Figure 4 The second step.

4. CONCLUDING REMARKS

With reference to [21], we can mention the same ideas:

As regards the procedural aspects, we have our established results on (a) procedural correctness in distributed logic programming and (b) acquisition function in a consultant system with causal theory. These aspects are included in automation of consultant systems ([18], [19]).

For structural analysis and synthesis of objective knowledge and through the content retrieval problem, we present an abstract framework of (c) the distributed system.

Through the subjects in (a)-(c), semantic issues are the common item for formality and abstraction with applications. For semantical conditions, procedural knowledge is based on model theory in logic, and sequential knowledge is owing to the assumed rule of follower relation. As some interaction is involved in the grammatical constraint system ([20]), human machine interaction and its abstraction should be made clearer for the contributions to the social system developments and robotics, different from agent technology refinements and effects.

In a strategy scheme like the structure of Section 2, the objective knowledge may be concerned with:

- space
- time

The more expressive, the more complicated. But as in action semantics ([13]), the treatments of space and/or time are required.

As a problem left for study, we have how to organize a formal system including situations which are described by logical formulae (as in [14]).

We also deal with a practical problem of how to organize conjectured diagnosis before its verification for the mental disorder detection. The conjecturing is a method, while the conjectured is an object such that an object as method is seen when we treat conjectured disorders from syndromes.

Because objective knowledge and reasoning contain diagnoses as methodologies in artificial intelligence, the views of this paper on objective knowledge as method are thrown into significant points as well as ontology notions, compared with the frameworks:

1. The logical analysis standpoint has contained a wide range of formal systems since its organization ([8], [10], [12] [16]), including hybrid logic ([2], [3]) and event calculi ([5], [6]).
2. Action and knowledge have been in details studied ([13], [15]).
3. The agent technologies in [9], [11], [17] are formulated from functional and algebraic aspects.

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Metadata Management in Building Bridges between Software

Berati, G.

Abstract - *This article presents a novel approach for constructing converters between software environments and a proposal for a transformation methodology between different software environments, especially between databases modeling software environments. Advantages of the proposed Meta Data Modeling are evidented.*

Introduction

Issues treated in this paper concern the theoretical level efforts to resolve a concrete problem in a project to restructure the cargo system in the airline company KLM (Netherlands). The problem stood in the inability to generate the data model of this project from the program (Casetool-i), which was selected as a modeling tool for of the project. It was really a large amount of information that should be lexicalized and generated to provide the data base model by the Casetool FCO-IM (Casetool selected as standard for the modeling of information in company Atos Origin BMS, the company that should implement the project). This amount was not possible to handle from the toll.

Problem Statement

The problem was in the lexicalization process. The project of the model had been almost completed, but it couldn't be generated. It was needed to restart the project from the beginning in another modeling tool or to transform the project using a bridge to another modeling tool. The resumption of the project was practically impossible because of the high cost, so efforts should focus on the possibility of translation of the model in a format of a tool, which allows the generation of a large-amount data base project.

Being involved in the project for implementation of the converter that will enable the transformation of the model conducted in FCO-IM to a model in ERWIN tool, I suggested the idea of building an intermediate repository.

The steps followed theoretical results and general conclusions were reached, representing an important theoretical research in the field of meta modeling, which, especially in our country, is little known.

Meta Model **(Berg, J. M., Levin, O. & ROUILLARD, J. (Meta-Modeling: Performance and Information Modeling. Http://books.google.com Internet Material Volume 6: Meta-Modeling: Performance and ... System-Level Performance Model and Method))** is the core of structure of any model, i.e. it specifies the way the software maintains data of itself and of its files. Data base, which makes storage of these data, is called repository or nucleus (kernel). So, when it comes to the meta level, it is discussed at the level of data.

Problems with recognition (acceptance) or non-recognition of a file from the software of the same type are well known. Even within software, we have such problems between different versions of it. Anyone has experienced failing to open an MS-WORD file created in MsOffice 2003 in MS-WORD 97. The problem is how repositories store relevant information.

If we pay attention to the structure of the relevant repositories of some different software environments of the same type, we can build bridges to translate files (models) from one to another. Knowing very well repositories of the software environments can help also for other purposes such are

improving versions of the software or rising opportunities to use information provided by the software.

Let's focus our job within family of database analyzing and modeling software environments. Let's try to connect with a bridge two different software tools of this type.

Existing solution and their criticism

In general, conversions are done by directly converting repository data from one enverinment to another one. That might have good impact in complexity of the conversion algorithm, but this way of doing conversion can cause lossing a lot of information that is not relevant from one environment to another one.

Let us see a concrete conversion. Let us convert from **FCO-IM Casetool v4.1** to **Erwin.**

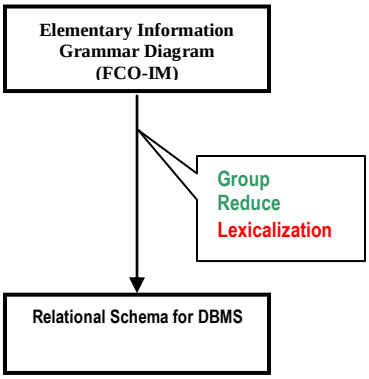

Figure 1

1 - FCO-IM Casetool v4.1
It is a tool which is based on the theory of Facts Oriented Modeling. This tool is very suitable for complex models and very flexible in implementing constraints of the model (Business Rules); it is very convenient in determining the relationship, etc.

However, practice showed that the FCO-IM Casetool has problems in managing large projects. Lexicalization procedure of the large amount of information was not covered by Version 4.1. That process, in this tool is performed by using operating memory (RAM).

The model created by this Casetool we will call Model FCO-IM. The steps that follow in the model, until the database or script is generated, is shown simplified in Figure 1. In Figure 2, is presented the information grammar (IG) and diagrams of grammatical information (IGD) for a very simple example. Also is shown the FCO-IM repository of the model. (**This commentary refers to VAN DER LEK, H., BAKEMA, G. & ZVART, J. P. 2001: Fully oriented Communication - Information Modeling FCO-IM, Page 57-90).**

All necessary information is in tables of the repository. In this paper is shown how and why information will be pumped into an intermediate repository and why an intermediate repository is the optimal solution.

2 - Erwin is a tool based on the theory of entity relationship modeling (ERM). This Software is based primarily on entities and not on facts to model and design a process.

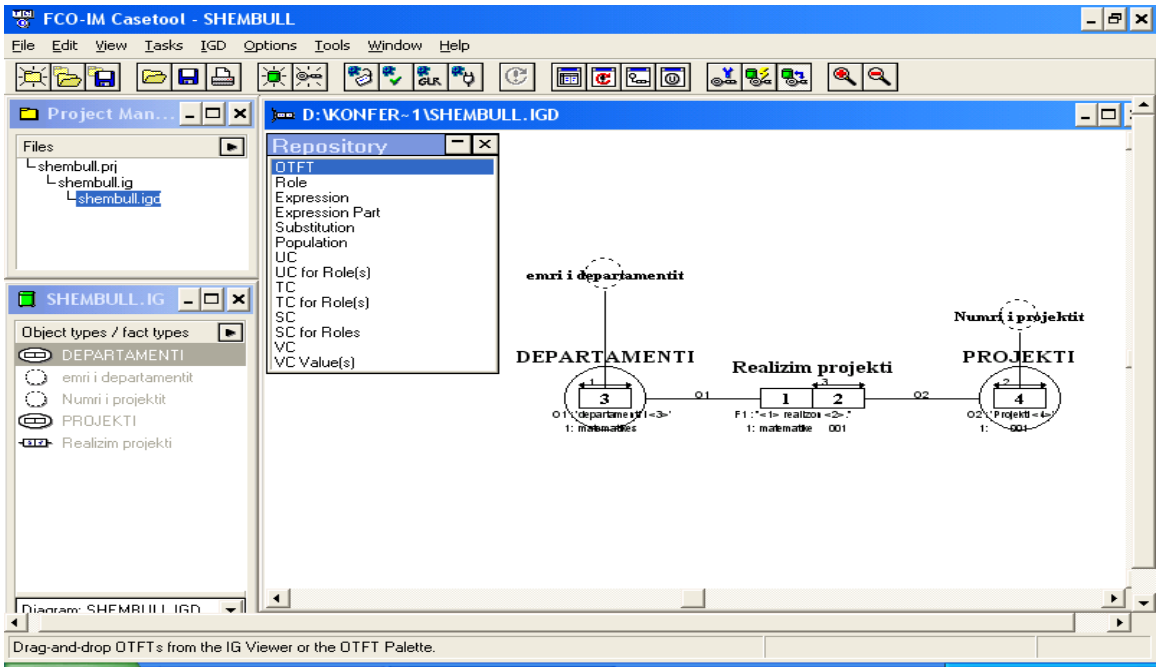

Figure 2

Besides other advantages, models built with this tool can be generated for a very large number of database management systems (DBMS). But, in our case, the most important advantage is the unlimited amount of information that could process this tool. Model constructed with this tool is referred to as the ER Model.

An FCO-IM model grouped and reduced is a masked ER model. For this reason it is theoretically possible that a grouped and reduced model is exported into an intermediate deposit and later on in an ER tools repository.

Essence of the proposed solution

The FCO-IM repository contains a lot of information which cannot be stored directly into repositories of the Entity Relational Tools. This refers to specific information of this tool, such population and some extra constraints. Of course, it would be good that this kind of information not be thrown away. We can store this information in Intermediate Repository, so it is necessary to add tables in Intermediate Repository to keep this information.

Repositories of ER tools (e.g. Erwin) have many tables which hold the tool-specific information and the model information which is automatically generated once the model is created. Therefore, intermediate repository must be a subset of the tables of the repository of the ER tool. Since we are dealing with a relatively limited number of tables, intermediate repository will not be very complicated.

Considering the fact that we have a large amount of information which is stored in different ways in the two environments mentioned above, the idea of building an intermediate deposit of the model information is more flexible then a direct conversion.

Conclusion for building an intermediate repository was reached after I have studied in depth, functioning, semantics, and the structure of the two tools mentioned above.

At the same time, I accurately identified all elements of an ER model and ways of sorting of these elements into its repository comparing to FCO-IM repository.

So, if we model a complex (full) ER model, we can perform a repository which is a wise place for the conversion of the FCO-IM model into the ER model. So, in this direction, ER is the destination of the conversation.

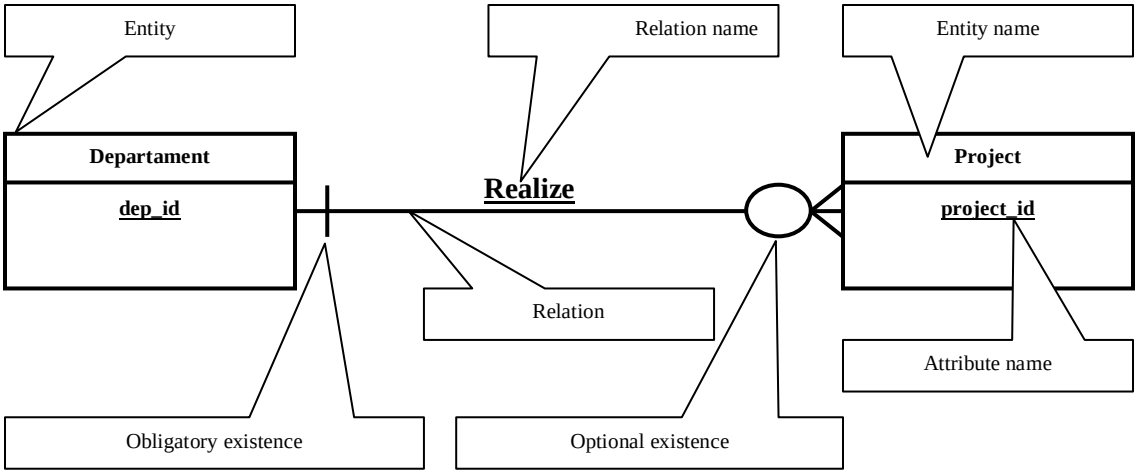

Figure 3

Analysis

Elements of a very simple model will be presented in the ER diagram, as in Figure 3. Of course, this model is not the one that is used to build intermediate repository, because this doesn't have all elements of a model. This example is taken only to show the idea of modeling in the ER and the idea of some elements of the model of the model.

Figure 3 explains what the main elements of a data model are and modeling this model is the way to create the model called data model, which in itself is Intermediate Repository which we are talking about.

Details

Data base which we are building contains a table that will hold all the elements of a model. Let us choose an ER model which is complex in the component elements, so an ER model which has as many different elements such as entities, attributes, one to one relations, one to many relations, optional attributes, mandatory attributes, many constraints, etc.

Entities and relations **(according RAMAKRISHNAN, R. & GEHRKE, J. 2002: Database Management Systems. Chapter 2. Page 25-32)** are those that we will model first, then are the attributes, which are divided into key attributes (primary key, key foreign therefore key attributes) and finally non-key columns (non key attributes).

Below are presented the steps for creating of Intermediate Repository of the model (Figure 4). Issues of importance are:

• Identificagtion of elements of a complex ER model and modeling them
• Verbalization with FCO-IM of the ER model (so we can use FCO-IM to build IR).
• Conducting a draft FCO-IM diagram of the ER model
• Completing the diagram with the relevant conditions (addition of key columns in the diagram, adding non-key columns in the diagram, etc.)
• Making the diagram of the generalization of hierarchies
• Validation of the model through nominalization
• Adding integrity rules
• Generation of the model of the model (intermediate repository).

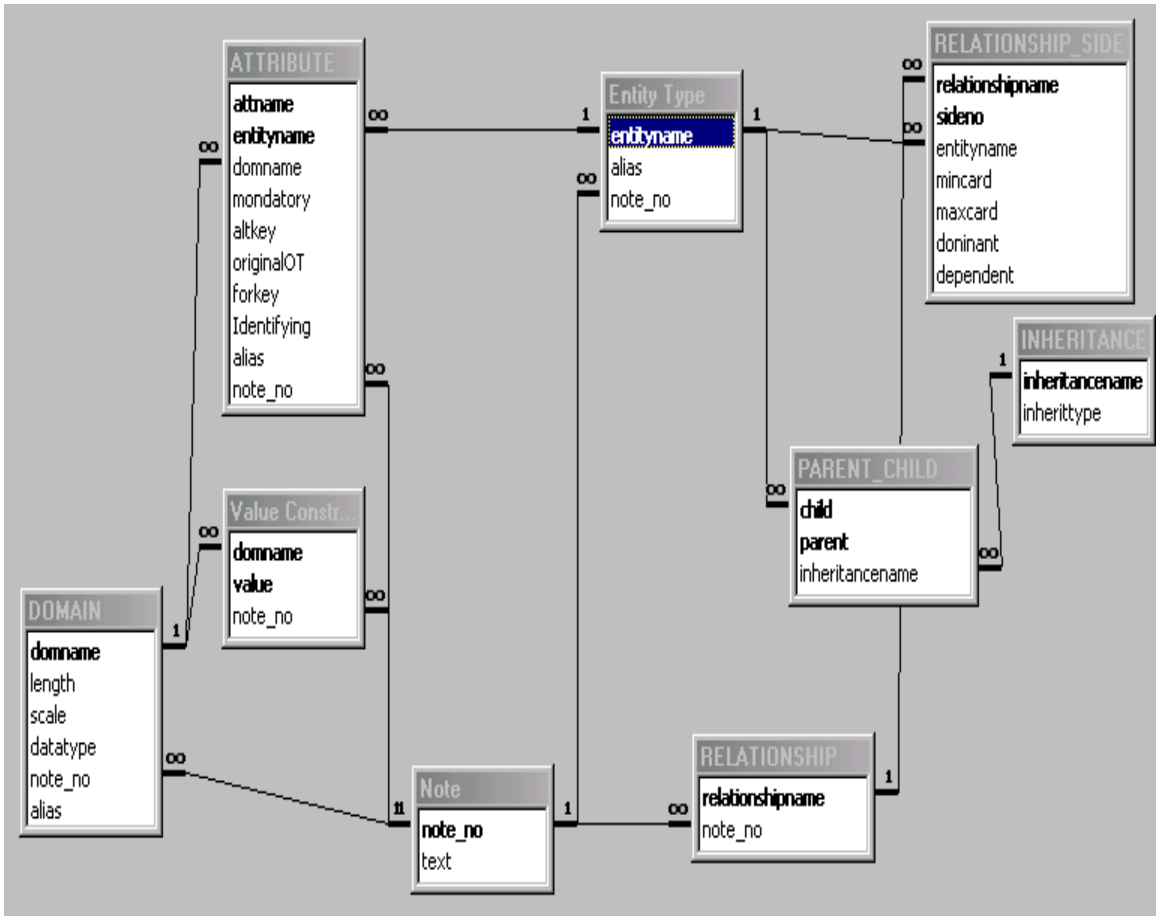

Figure 4. Intermediate Repository in MS Accsess

Environment of FCO-IM tool (Fully Communication Oriented Information Modeling) offers the possibility to explore the repository of the model in which all required information of the model are stored.

Since the semantic of FCO is very readable, we have chosen to implement the meta model of ER model complex in FCO-IM. With this we created a model which will represent in fact the structure of Meta ERM model; of course, only the essential elements of a model. In this model will be included entities, relations, attributes, rules of integration, information recurrences, subtypes, etc. Now in the role of the Entities, will be elements of the Conceptual Model which is selected (e.g. entity, relationship to example above).

The essence of this paper is precisely this model which is the intermediate repository which is an additional step to the process of conversion of the model. This intermediate repository can become an independent mechanism or a part of converter tools. So, now we have an independent environment (with model information form still unspecified), from which one can generate different ER patterns of model. Precisely that is the biggest advantage of this repository.

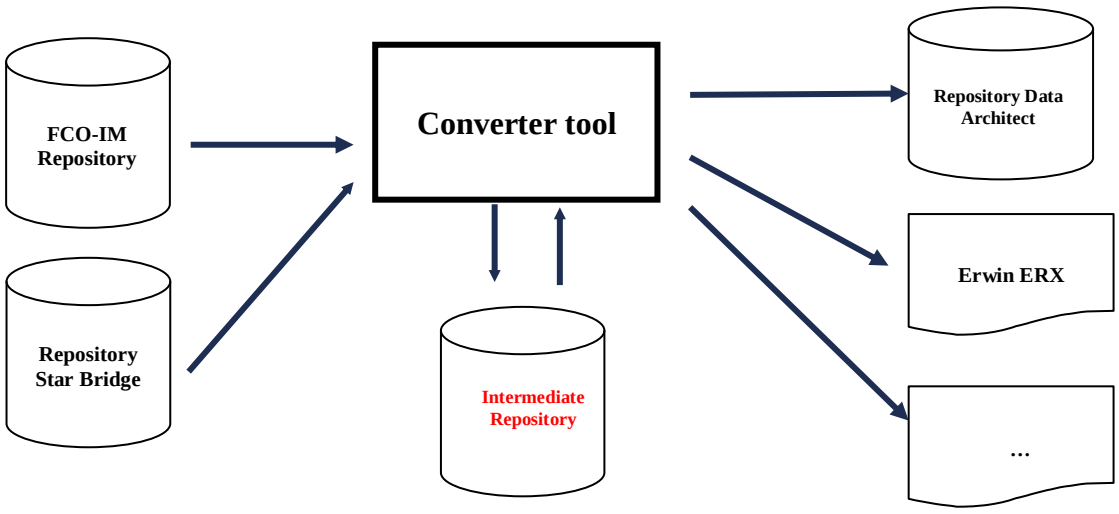

Figure 5. Transformation Schema

Conclusions

Designing intermediate repository enables the creation of easy converter tools. Concretely, we created a converter to surpass the FCO-IM Casetool Lexicalization bug. The tool can convert to a larger number of ER tools (such as: Data Architect, Power Designer, etc.).

Based on these results, one can propose a method for running authentic transformations that can be called the transformation method based on the intermediate repository (Intermediate Repository Based Transformations).

Results of this research have been used in a number of applications in the Albanian software industry, in Shkodra and Tirana.

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Modeling of the Humanoid Robot Motion

Mester, G.

Abstract—*This paper will deal with the simulation and autonomous motion of humanoid robots. Studies in the area of humanoid robotics have recently made a remarkable progress. The modeling of the humanoid robot motion is analyzed. A kinematic scheme of a a 20-DOFs biped locomotion system is used in simulation. The simulation results in the Matlab /Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method.*

Index Terms — *Humanoid robots, biped locomotion, modeling, Lagrangian dynamics, kinematic scheme, simulation.*

1. INTRODUCTION

THIS paper will deal with the humanoid robot locomotion. The modeling of the the humanoid robot motion is analyzed. The problem of bipedal motion is a very complex task. Studies in the area of humanoid robotics have recently made a remarkable progress.

The considered humanoid locomotion in this paper has 20 DOFs (18 powered and 2 unpowered). The simulation results in the Matlab/Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method. The paper is organized as follows:

Section 1: Introduction.

The modeling of the humanoid robot motion is given in Section 2.

In Section 3 the simulation results of the humanoid robot motion are illustrated.

Finally, conclusions are given in Section 4.

2. DYNAMIC MODELING OF THE HUMANOID ROBOT MOTION

Biped locomotion is the a very complex process to modeling. The bipedal walking of the robot consists of several phases that are periodically repeated:

single-support phases and

double-support phases.

The robot's body consists of a number of rigid segments interconnected with spherical or cylindrical joints. During the bipedal walking, some kinematic chains in their interaction with the unknown environment transform from open to closed type of kinematic chain.

The dynamic model of the locomotion mechanism of the robot in a vector form is:

$$\mathbf{H(q)}\ddot{\mathbf{q}} + \mathbf{h(q,\dot{q})} = \boldsymbol{\tau} + \mathbf{J}^T\mathbf{(q)F} \qquad (1)$$

where:

$\mathbf{H(q)}$ – is the inertia matrix of the mechanism,

$\mathbf{h(q, \dot{q})}$ – is the vector of centrifugal, Coriolis and gravitational moments,

$\mathbf{J(q)}$ – is the Jacobian matrix of the system,

$\mathbf{q}$ – is the vector of the internal coordinates,

$\mathbf{F}$ – is the vector of external forces and moments,

$\boldsymbol{\tau}$ – is the vector of the driving torques at the robot joints.

The dynamics of the locomotion mechanism can be expressed by the Lagrangian dynamics. Computed Torque Control method is applied for control of the humanoid robot motion.

The considered humanoid locomotion mechanism used in simulation in this paper has 20 DOFs: 18 powered and 2 unpowered DOFs. The kinematic scheme of a 20-DOFs biped locomotion system is presented in Fig. 1.

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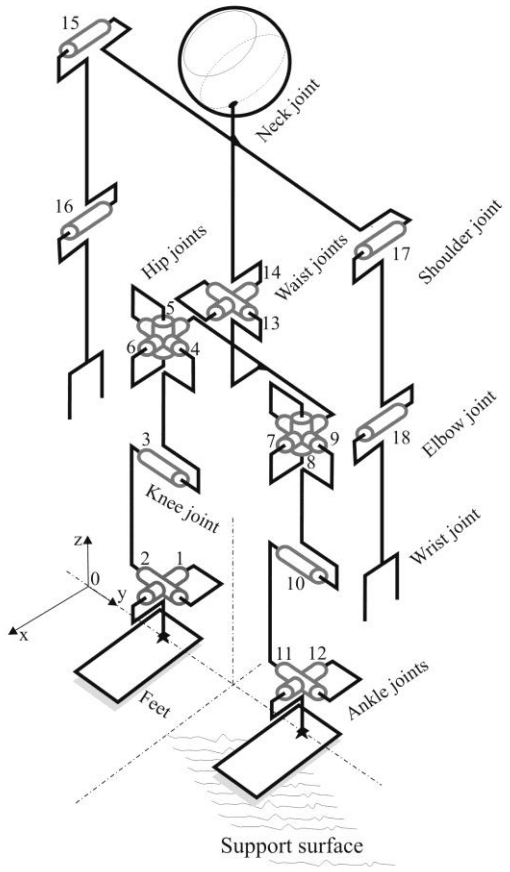

Fig. 1. Kinematic scheme of a 20-DOFs biped humanoid robot

The proposed scheme has:

- three active mechanical DOFs at each of the joints of the hip (6),
- two active mechanical DOFs at the ankle (4), waist (2), and
- one active mechanical DOF at the knee (2), shoulders (2), elbow (2).

Kinematic and dynamic parameters of the humanoid robot are presented in [2].

3. *Simulation Results of the Humanoid Robot Motion*

Simulation of the humanoid robot motion was performed using Matlab/Simulink and Robotics toolbox for Matlab/Simulink. The results of the simulation are shown in Fig. 2-14**.**

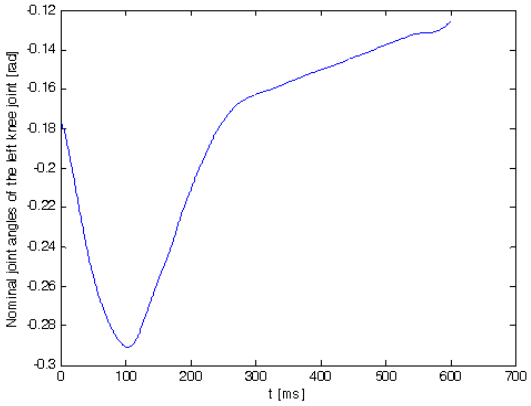

Fig. 2. Nominal joint angles of the left knee joint

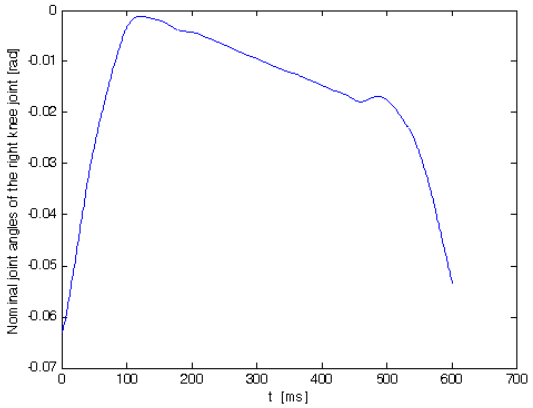

Fig. 3. Nominal joint angles of the right knee joint

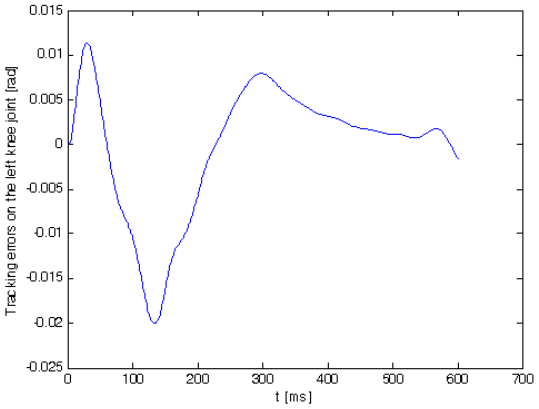

Fig. 4. Tracking errors on the left knee joint

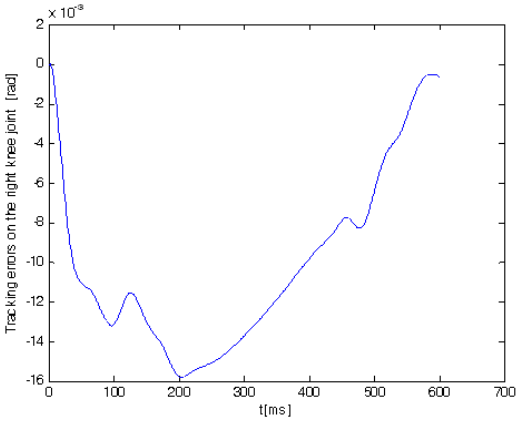

Fig. 5. Tracking errors on the right knee joint

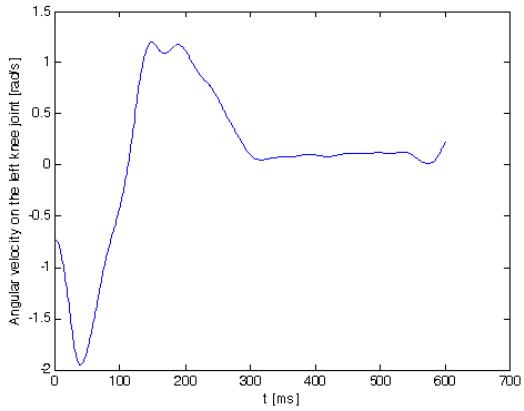

Fig. 6. Angular velocity of the left knee joint

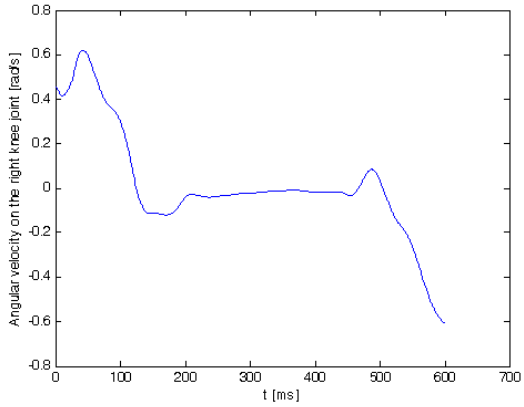

Fig. 7. Angular velocity of the right knee joint

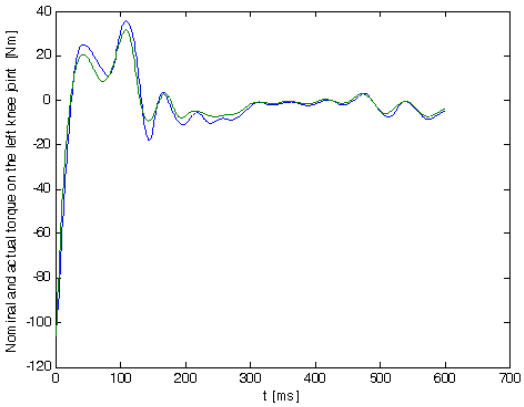

Fig. 8. Nominal and actual torque of the left knee joint

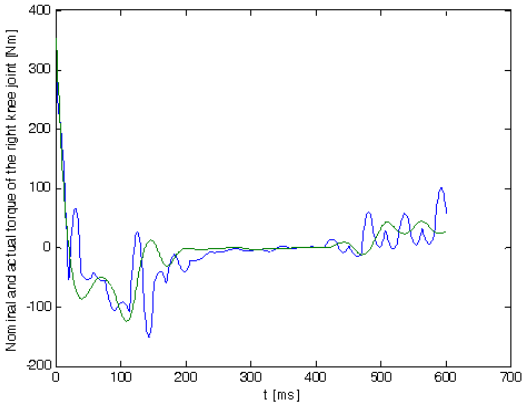

Fig. 9. Nominal and actual torque of the right knee joint

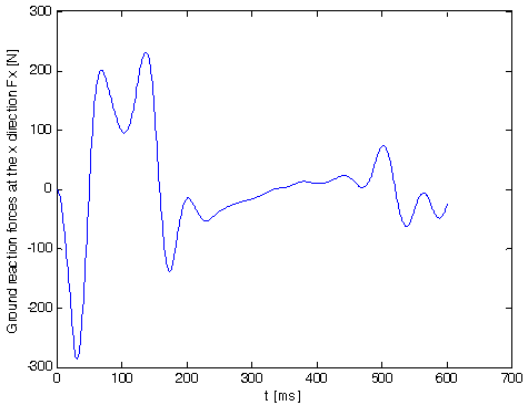

Fig. 10. Ground reaction forces at the x direction

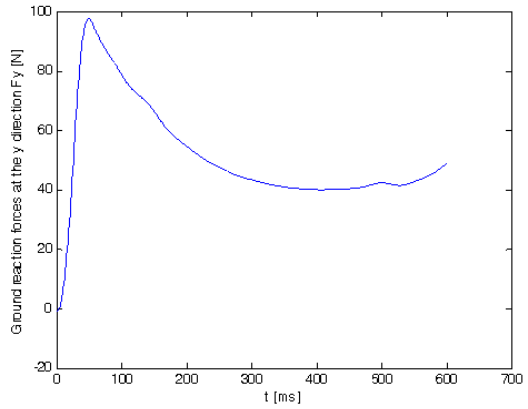

Fig. 11. Ground reaction forces at the y direction

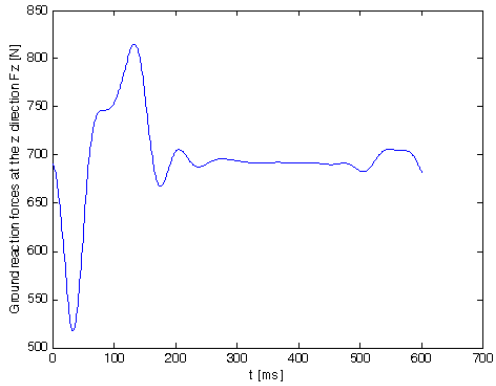

Fig. 12. Ground reaction forces at the z direction

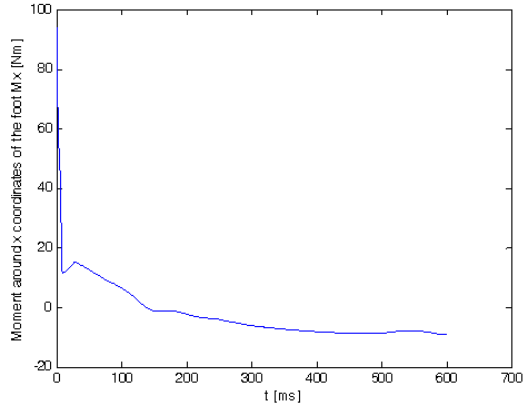

Fig. 13. Moment around x coordinates of the foot

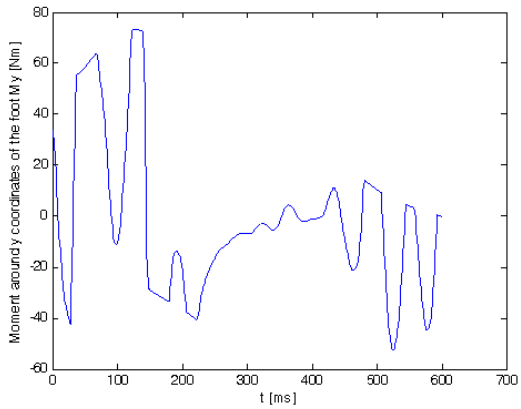

Fig. 14. Moment around y coordinates of the foot

The human body for its complex motion uses synergy of more than 600 muscles. It has more then 300 DOFs [6].

Some of these particular motions are essential for the human activities while the others give it a full mobility.

In this article, a 20 DOFs biped locomotion mechanism of the anthropomorphic structure (Fig. 1) will be considered as an appropriate model of biped locomotion mechanism.

The proposed strategy of biped robot autonomous locomotion is evaluated through the corresponding simulation experiments.

The simulation platform is Matlab/Simulink toolbox dedicated for advanced modeling and simulation of biped robots of anthropomorphic structure. The software uses Robotics toolbox for Matlab [24] to calculate basic model functions of the simple kinematical chains. This toolbox provides many functions that are useful in robotics including such things as kinematics, dynamics and trajectory generation. The Robotics toolbox is useful for simulation. Using Simulink input/output interface it is possible to store simulation results in the corresponding data-files.

The simulation results in the Matlab/Simulink and Robotics toolbox for Matlab/Simulink environment show the effectiveness and the validity of the proposed method.

4. CONCLUSION

This paper will deal with the modeling and simulation of the autonomous motion of humanoid robots.

A kinematic scheme of a a 20-DOFs biped locomotion mechanism of the anthropomorphic structure is used.

The simulation results in the Matlab/Simulink and Robotics Toolbox for Matlab/Simulink environment show the validity of the proposed method.

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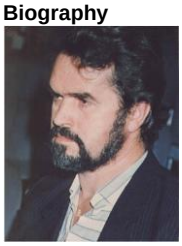
Biography



Dr. Gyula Mester received his D. Sc. degree in Engineering from the University of Novi Sad in 1977. Currently, he is a Professor at the University of Szeged, Department of Informatics, Hungary. He is the author of 168 research papers. His professional activities include R/D in different fields of robotics engineering: Intelligent Mobile Robots, Humanoid Robotics, Sensor-Based Remote Control. He is an invited reviewer of more scientific journals and the author of several books. He is the coordinator of the Robotics Laboratory from the University of Szeged, in European Robotics Research Network. His CV has been published in the Marquis “Who’s Who in the World 1997”.

Some Isotope Aspects of a Hydrogen Energy Concept

Miljanić, Š.

Abstract - A concept of energy cycling through hydrogen is considered taking into account the isotope (D/H) aspect. It is based on a two-step cycle: 1.- Storing of electrical energy into hydrogen *via* water electrolysis and 2.- Bringing a part of the stored energy back to the system at the moment of demand *via* the fuel cell plant. Both steps have an impact on the isotope compositions of working fluids at the point of transfer, due to isotope effects appearing. These effects are characterized by the D/H isotope separation factor. The model considers possibilities to improve the cycle efficiency by simultaneous improvement of energy and isotope separation efficiencies of both steps. For the first time the role of hydrogen fuel cells in a deuterium/hydrogen isotope separation process was considered.

Keywords: Hydrogen energy, Water electrolysis, Fuel cell, Deuterium, Isotope separation

1. Introduction

Hydrogen is the key energy medium for the „hydrogen-based economy" of the future, due to its unique properties, i.e., production for storage, gas-line or truck transport, and transfer back to energy on demand at the place of usage.

There are three hydrogen isotopes: light hydrogen or protium (H), heavy hydrogen or deuterium (D), and super-heavy hydrogen or tritium (T). The heavy hydrogen isotopes are of great importance in the nuclear energy technology, although nuclear energy is not a dominant energy source at present time. Its world share is about 7.5 %, but it will probably rise faster than that of other types of energy in the near future. Deuterium in the form of heavy water (D_2O) is used in natural uranium fuelled fission reactors, both as the neutron moderator and as coolant. A heavy water nuclear power reactor needs roughly one tonne of D_2O per megawatt (electric) installed [1,2]. The average abundance of deuterium in natural hydrogen all over the world is about 150 ppm (*parts per million*). Main raw material for its production is water.

Both D and T are promising fuel components for the thermonuclear fusion reactors in the future.

Briefly, we can say that the importance of hydrogen, along with its isotopes, will rapidly rise in the coming decades toward the concept of hydrogen economy [3].

The idea of this work is to base a hydrogen energy concept on an open energy cycle that includes: (i) the alkaline water electrolysis (AE) to produce hydrogen for storing electrical energy, and (ii) its transfer back to electrical energy at the moment of demand in a fuel cell power plant (FCPP). Process (i) delivers deuterium depleted hydrogen gas (along with oxygen) on one side, and deuterium enriched water remaining in the alkaline electrolyte, relative to the feed content, on the other, while process (ii) consumes hydrogen and oxygen evolved in step (i), giving electrical energy and the deuterium enriched water relative to the burning hydrogen. In this way both AE and FC play the role of *isotope separating units*[1]. In both cases isotope separation is carried out with a help of the so-called isotope separating agent. This agent divides the feed stream into two outgoing streams, the heads one (by convention it is assumed to be enriched in the desired isotope - the desired isotope here is deuterium), and the tails one (depleted). The idea of the fuel cell (FC), not considered before in such a context, was introduced into this rather old *hydrogen production—isotope separation* concept, to improve the overall energy cycling efficiency. Dependence of that efficiency on the energy efficiency of AE and FC in particular, as well as on the isotope separation efficiency of both devices, expressed through some fundamental process parameters, is discussed with an intention to point to some relevant facts rather than to make a precise calculation, although some basic relations would be developed.

An approach which also considers a combination of electrolysers and fuel cells, but with a focus on 'a novel deuterium separation system' and without taking isotope separation efficiency of FC into account, was recently discussed [4].

[1] A fundamental measure of the separation efficiency of a specified separating unit (or stage) is the *stage separation factor*, α, or simply the *separation factor*. This factor is defined by the following equation:

$$\alpha = \frac{x'}{1-x'} : \frac{x''}{1-x''} \qquad (1)$$

where x' and x'' are atom fractions of D (desired isotope) in the *heads stream* (enriched) and the *tails stream* (depleted), while $(1 - x')$ and $(1 - x'')$ are corresponding fractions of H, respectively. For details see Fig. 1.

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Electrolyzers and fuel cells are simple, efficient, clean and silent electrochemical devices, with no moving parts. The only effluents of FC are pure water, electrical energy and heat.

1. Description of the concept

The idea of the concept is schematically represented in Fig. 1. The general scheme includes:

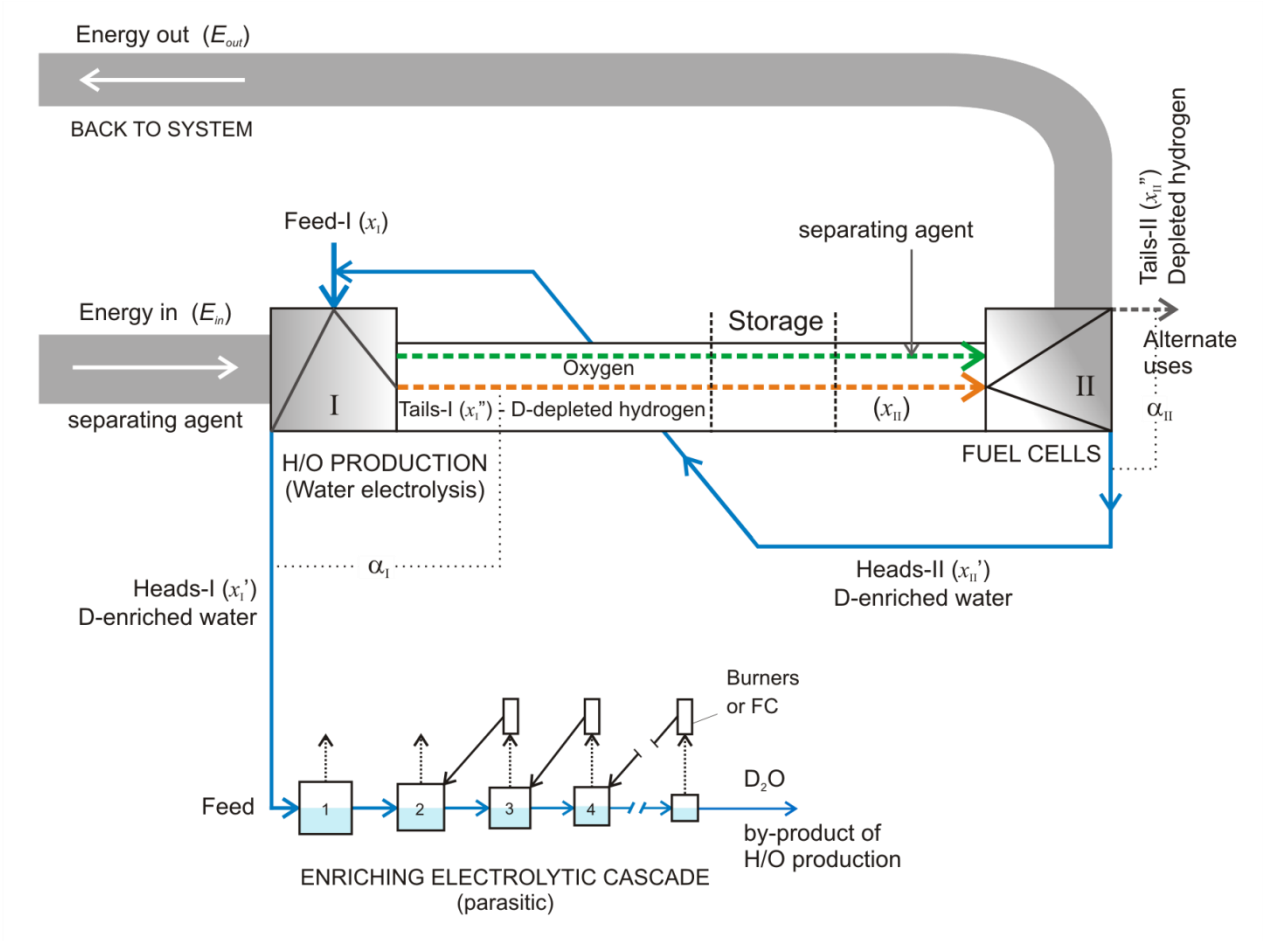

Figure 1: Schematic representation of an open *energy-hydrogen-energy* storage cycle: Reversible power plant concept with a parasitic D/H isotope enriching cascade. I – Energy-to-hydrogen transferring/separating unit; II – Hydrogen-to-energy transferring/separating unit; *x* represents the atom fraction of the desired isotope (D) in corresponding streams.

(**i**) Transfer of electrical energy into hydrogen in the Device I for storing, *via* the water electrolysis from alkaline electrolytes. This device is continuously fed with pure water. In the sense of energy terms, this is the *energy transferring* device. This step is directly characterized by the energy consumption per mass unit of hydrogen evolved, which actually means the *current density/cell voltage* characteristics of the electrolyzer under certain conditions. They can be easily measured. We did that on a laboratory scale for some electrode materials, either in the pure KOH electrolyte or in combination with some activators added *in situ* to that electrolyte to improve catalytic properties of electrodes [5]. At the same time this device is the *isotope separating* unit, where energy plays the role of the isotope separating agent. It is supposed to be an *electrolyzer with a constant level* [6]. In such a unit the deuterium concentration in both outgoing phases proportionally rises during electrolysis until so-called boundary enrichment, remaining the ratio determined by the separation factor (Eqn 1). The heads stream is water remaining in the electrolyte, while the tails stream is evolved hydrogen.

Device I is a single separating unit or stage, to which an enriching cascade can be attached as a bypass, to further process the enriched stream until needed concentration of deuterium is attained. In principal, very small part of the material processed goes to that cascade [7].

(**ii**) Bringing a part of the entire energy in the form of electricity back to the system *via* the fuel cell based power plant (Device II). In this device, hydrogen (in the presence of oxygen or air) is consumed to be transferred back to electrical energy. In this way,

deuterium from the feed material is stripped twice. Consequently, oxygen added to enable this transfer is the *isotope separating agent* of this *energy transferring* device. In terms of isotope separation, this device can also be considered as a *single unit* or *stage*, delivering water (heads stream) enriched in D relative to the incoming hydrogen gas. Due to that, the water leaving the unit II is expected to be above the natural level, which mostly depends on processes in FC. Even if there is no difference in isotope contents between this water and the feed one, the least benefit for the cycle can be found in returning it back to the device I to be used for feed, because the FC product-water is clean and needs no pre-treatment. Conclusively, water partly serves here as the working fluid. A bigger part of it moves between units I and II, while another part, taken from the electrolyzer of the unit I to feed the enriching cascade, is further processed. Of course, that part should be continuously supplemented from feed.

The hydrogen energy-storing system proposed in this work is actually the reversible power plant concept in witch hydrogen serves as the energy carrier. It assumes, by definition, storing of low-cost off-peak electrical energy, combined with simultaneous D/H isotope enrichment. The energy stored in this way can be transferred back to electricity to be used at times of high demand at a much higher price. An analogous scheme was discussed more than a decade ago [8], but with no analysis of the isotope separation possibilities.

2. Discussion

It is clear that the cycle illustrated in Fig. 1 has a negative energy balance, the degree of which is actually the net energy cost of cycling, $\Delta E = (E_{in} - E_{out})$. It substantially depends on the transferring efficiencies at the units, f_{I} and f_{II}, given as

$$f_{\mathrm{I}} = \frac{m_{\mathrm{H_2}}}{E_{in}} \text{ and } f_{\mathrm{II}} = \frac{E_{out}}{m_{\mathrm{H_2}}}, \text{ i.e. } \frac{E_{in}}{E_{out}} = \frac{1}{f_{\mathrm{I}} \cdot f_{\mathrm{II}}} \qquad (2)$$

Here m_{H2} is the total amount of hydrogen produced per cycle (mol) consuming the input energy E_{in} (at a low off-peak price $C_{el\text{-}in}$; € J^{-1}), the output energy equivalent of which is E_{out} (to be sold at a peak price $C_{el\text{-}out}$; € J^{-1}).

Since we do cycling for the purpose of storing energy, the ΔE value predominantly contributes to the total cost of the cycling (storing). That cost also includes the storage cost in particular, for the given amount of hydrogen, as well as the cost of transport (if any). In addition to that, the synergy between production of hydrogen and the heavy water 'by-production' offers an extra impact on the final price. In fact, the total cost of energy storage should be reduced for benefits derived from the isotope enrichment. Thus, the total cost of the cycle (€) is given as

$$c = E_{in} C_{el-in} - E_{out} C_{el-out} + c_{sto} + c_{tr} - c_{ise} \qquad (3)$$

where

$$c_{sto} = C_{sto} \cdot m_{\mathrm{H_2}} = C_{sto} \cdot \frac{E_{out}}{f_{\mathrm{II}}} \qquad (4)$$

is the cost (€) that should be paid to store the total amount of hydrogen (m_{H2}, mol). Here C_{sto} is the corresponding price of hydrogen storage (€ mol^{-1}).

Similarly,

$$c_{tr} = C_{tr} \cdot m_{\mathrm{H_2}} = C_{tr} \cdot \frac{E_{out}}{f_{\mathrm{II}}} \qquad (5)$$

where C_{tr} is the price of transport of that amount of hydrogen (€ mol^{-1}).

In principal, benefits expected from the isotope enrichment per one cycle, c_{ise} (€), can be estimated by taking into account the total amount of deuterium in the leaving hydrogen. It is a useful, but not the only measure of the 'isotope benefit' of an optimized cycle. Now, we can write

$$c_{ise} = C_{ise} \cdot x_{\mathrm{II}} \cdot m_{\mathrm{H_2}}, \qquad \left(x_{\mathrm{II}} = x''_{\mathrm{I}} = \frac{m_{\mathrm{D}}}{m_{\mathrm{H_2}}} \right) \qquad (6)$$

where m_{D} (mol) is the total amount of pure deuterium in evolved gas, while C_{ise} is its unit price (€ mol^{-1} D)[2]. Actually, this price accounts for all isotope contributions to the total cost reduction at a given average deuterium content in the system. Its precise estimation, although possible, is not an easy work at all.

Other relevant deuterium contents, like that in the electrolyte of unit I, or that in the product water of unit II, can also be considered in such a context, because they are all inter-related. At the same time, they are all dependant on the values of D/H isotope separation factors, see Fig. 1. We measured these factors experimentally on lab scale units and found them to be very high (up to 10) [9]. As far as we know such measurements on FC were never made before.

Finally, after introducing equations (2, 4, 5 and 6) to the equation (3), and division by the output energy, E_{out}, to obtain the unit price of cycling, C (€ J^{-1}), we now have

$$C = \frac{1}{f_{\mathrm{I}} \cdot f_{\mathrm{II}}} C_{el-in} - C_{el-out} + \frac{1}{f_{\mathrm{II}}} (C_{sto} + C_{tr} - C_{ise} x_{\mathrm{II}}) \qquad (7)$$

In the first place, this price depends on the ratio of the input and output energy in the cycle. According to the equation (2), it is inversely proportional to the $f_{\mathrm{I}} \cdot f_{\mathrm{II}}$

[2] By the way, price of heavy water varies from about 400 \$/kg D_2O to about 600 \$/kg D_2O. These data can be found in some publications [1,10] or on the Internet.

product, thus, the higher the transferring efficiencies of the units I and II, the lower the E_{in}/E_{out} ratio and lower C. These efficiencies essentially depend on the nature or processes taking place in units, as well as on the conditions a specific process is run under. One of these efficiencies has an additional impact on the final price through the second part of the equation (7).

Under input and output energy we understand electrical energy, the market price of which is expressed as $C_{el\text{-}in}$ and $C_{el\text{-}out}$, respectively. These prices can be either lower or higher than the productional one, depending on the market supply and demand at a moment. Together with the price of storage and transport they contribute to the final price. However, the storage and transport prices were not subjected to this analysis.

3. Conclusions

The unit price of energy cycling (C) is a function of the following crucial parameters:

- The input-to-output energy ratio (E_{in}/E_{out}), which directly depends on the transferring efficiencies f_{I} and f_{II}. The latter ones can essentially be improved by using advanced materials and design.
- Prices of electrical energy. For hydrogen production and simultaneous deuterium enrichment, electrical energy should be as cheap as possible. On the other hand, we estimated that the *output* energy should be at least twice more expensive than the *input* one, since it is generated and sold at times of highest demand. Accompanied with efficient simultaneous D/H isotope enrichment it makes such a cycle quite attractive.
- The average content of deuterium in the system, expressed through x_{II}. This parameter is strongly dependent on the separation factors on AE and FC.

Almost the only disadvantage of electrolyzers is the expensive energy they consume. However, fuel cells still have significant disadvantages at present time. They are expensive, since there is no large scale production. Consequently, high power stations (hundreds of megawatts) are not yet industrially developed.

The power plant system described here is a reversible one. It absorbs the excess load at times of high output and low demand, contributing at the same time to the relaxation of the system. The heavy water plant is a parasitic one. Its production cost is mainly based on using enriched water from the cycle.

Because of very low natural content of deuterium, it is necessary to process very big amounts of raw material for a reasonable quantity of heavy water produced. Therefore the above isotope concept is more appropriate for big systems, transferring huge amounts of energy to hydrogen.

High D/H isotope separation factors obtained experimentally have pointed out the need to consider the hydrogen energy concept discussed in this work quite seriously.

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