Telemedicine intelligent learning. Ontology for agent technology

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Abstract— ***Telemedicine (TM) is an ever-evolving multidisciplinary subject where knowledge is acquired by continuous training rather than as part of a curriculum. The current challenge is to create an intelligent tool that delivers personalized training to professionals with different backgrounds, making use of scientific innovations from any source, even the Internet.***

We present an innovative metadata packaging and rule-building tool to achieve an adaptive retrieval system that may draw on all available resources. For this purpose we used vocabulary and ontologies founded on the telemedicine body of knowledge (TM-BoK) hierarchy and Medical Sub-headings (MeSH).

The packaging tool creates a modified XML-manifest that contains a Navigable Knowledge Map and a separate Rule-extension executed by Agents during the process of navigation. Agent systems also handle personalization, selecting packages by reading metadata tags. The result is an adaptive and adaptable TM knowledge delivery tool used by the students to reduce the time on searching information.

Index Terms— ***E-Learning, Ontologies, Standardization, Telemedicine.***

1. INTRODUCTION

TELEMEDICINE (TM) is a multidisciplinary field undergoing permanent evolution as it adapts to modern trends and innovations. Professionals with very different educational backgrounds (e.g. doctors, engineers, computer scientists, etc.) use it. Its training becomes a continuous process not acquired as part of a curriculum. Furthermore, it is difficult to find experts in every key subject. In these circumstances, it is a challenge to build an intelligent tool that provides personalized distance training with up-to-date information from any source, including the Internet.

Until now, medical information retrieval has been based on keyword matches of resource descriptions or metadata. Thus syntax and semantics, used to tag contents, have been incorporated into professional indexes. Those specific taxonomies or vocabularies to describe contents, such as Medical Sub Headings (MeSH) [1], provide a certain level of standardization.

Nowadays an effective search tool in Medicine will require a standardized content, preferably with metadata headings using eXtensive Markup Language (XML), accepted taxonomies, and MeSH vocabulary.

In addition, for teaching/training purposes some means are needed to handle educational content and user profiles (e.g. IEEE-Learning Object Metadata (LOM) paradigm [2], and IMS-Learning Information Profile (LIP)[3]) incorporated into the SCORM (Sharable content object reference model)[1] standard. It allows re-usability, interoperativity and extensibility. Its Content aggregation model and the Run-time environment specifications aggregate and display the same pool of learning objects in different orders or with different views.

Further improvements include an intelligent Learning Management System (LMS) able to deliver *adaptive* and *adaptable* data.

Interactive-adaptabliliy is the goal of DILE (Distributed Intelligent Learning environment) based on a Multiagent Technology with JADE (Java Agent Development Framework) [4]. This architecture implements an agent framework in order to set rule-building strategies for learning delivery actions; it takes into consideration Student Cognitive State, Teaching strategies and Knowledge acquisition assessment.

Interactive-adaptive data delivery implies a step further, since it represents a run-time learning delivery strategy based on detected skill management during the e-learning time [5]. In this case the platform dynamically re-adapts, exchanges, re-uses and shares learning objects (assets) according to user feedback, thus optimising skill acquisition.

To integrate these and future innovations the IMS organization [3] describes Learning Objects using XML capable of being understood by most e-learning tools.

The present paper presents a tool capable of managing students' interests and skills applied to TM e-learning. The objective was to build and test an intelligent tool capable of handling specific TM ontologies and at the same time electronically deliver personalized TM content depending on user knowledge and learning process.

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2. DESIGN

Our starting point was the IST-1999-12503-Knowledge on Demand (KOD) project[2]. Based on Agent technology, it builds an e-learning tool with the following properties: automation, adaptability,

[1] www.adlnet.org

[2] http://sharon.cselt.it/projects/jade/whoIsUsing/KODAgentsandeLearning.doc

intelligent management and re-usable learning objects.

2.1 System Description- TM Agent architecture.

We modified the above-mentioned e-learning system, specifically for telemedicine knowledge delivery. In this paper we detail the TM modifications. The final system, adjusted to current standards [2-5] contains *Authoring Components* ready to interact with a *Multi-Agent System* compliant with the Foundation for Intelligent Agents (FIPA) [6]. See **Figure 1**.

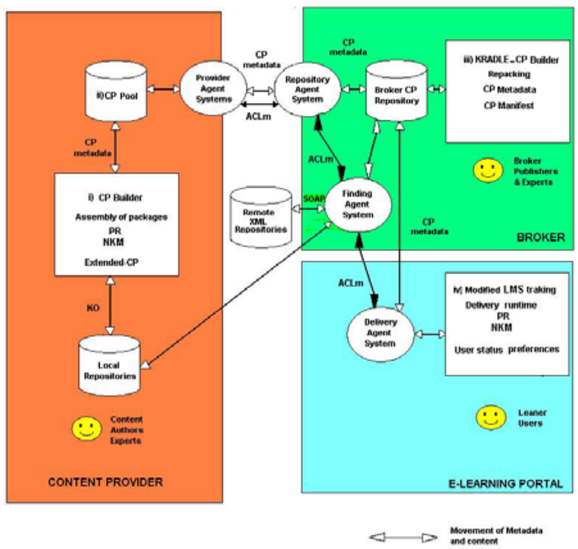


Figure 1. KOD system Description. Interaction between *Authoring components* and *Multi-Agent system*.

ACL= Agent Communication Language; AS= Agent System; CP= Content Package; KO= Knowledge Object; KRADLE= KOD Reusable Adaptive Learning Content Exchange; LMS= Learning management system; NKM= Navigable Knowledge Map; PR= Prescriptive rules; SOAP= Simple Object Access Protocol.

The *Authoring Components* are: i- a Content Package builder, ii-a Package Pool, iii-a KOD Reusable ADaptive LEarning Content Exchange Broker (KRADLE), iv- a Learning Environment, and v- an Educational Metadata Editor Manager.

i- The Content Package builder packs the information into an "extended" IMS-CP[3] standard. **Figure 2** shows the *knowledge rules* and *navigable knowledge map* extensions. Rules are packaged separately in order to be re-used. The knowledge map is a domain map representation (see below II.B.3)) built with items connected by attributes, concepts and available resources.

ii- The Package Pool collects and publishes packages and is able to detect new packages using Agents.

[3] According to the IMS-CP (Instructional Management System-Content Packager) specifications of 2001, the learning packages are collections of different "organizations", each one including a number of "items" (learning paths); every item refers to one resource, which can include a number of learning objects.

iii- The KRADLE is the broker of the remote repository of packaged metadata, whose Content Package Manifest is available for Agent interaction.

iv- The Learning Environment is the vertical learning portal for publishing, accessed via WWW. It includes a "modified" Learning Management System (LMS) that keeps learner performance and profile updated for Agent handling together with the usual LMS activities. These are student registration, sequencing instructions, content administration, assignment and recording performance, collection and data management.

v- The Educational Metadata Editor Manager is a tool to define, generate, export, and validate extra metadata. This is a Java applet editor suitable for modifying the document where the XML tag definitions are stored (Document Type Definition -DTD).

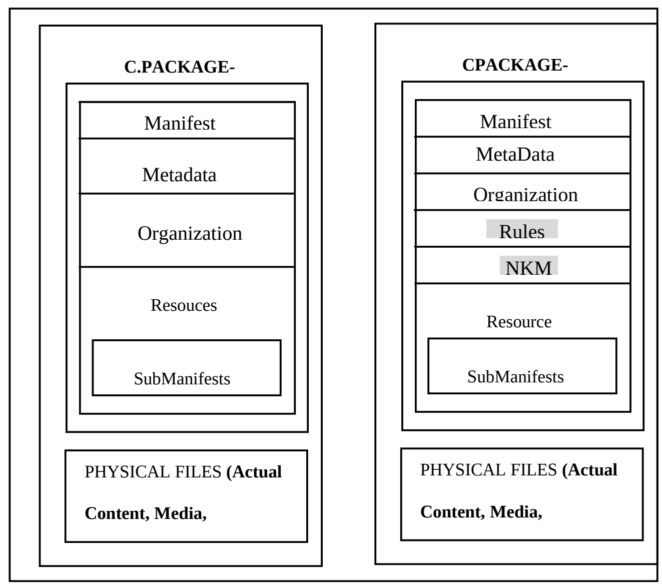


Figure. 2.- XML Content Package structure. The standard IMS CP on the left, versus IMS KOD CP on the right.
NKM = Navigable Knowledge Map

With respect to the *Multi-agent System* (**Figure 1**), messages between Agents are passed via Agent Communication Language (ACL) in *custom ontologies* (see below II.B.3. Managing attributes and enhanced data) based on adaptation rules, ontology, language and content. The Agent Architecture contains three functional layers: publication, brokerage and delivery. Each layer has agent systems as listed below; agents are named in brackets.

1. Knowledge Package publication layer. This has a Provider Agent System (Knowledge Package Publication monitor; Publisher Contact agent)
2. Knowledge package broker: 2.1. Repository Agent System, responsible for receiving and

managing incoming packages. (Knowledge Package receiver, Upstream Informer, ACT-ACL translator); 2.2 Finding agent systems. (Broker Package Finding, SOAP[4] Client Agent),

3. Knowledge package delivery layer, which is the e-learning service provider containing a Delivery agent system (e-Learning Service Provider Package Finder agent)

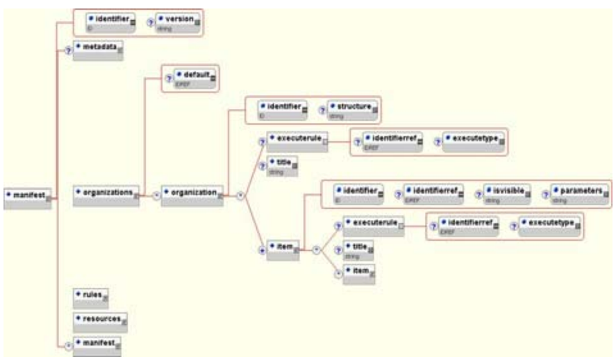
Except for the SOAP Client agent, none of the above can be duplicated in a platform

2.2 TM System Design

The system is designed to meet telemedicine learning demands and individual user requirements. It consists of:

1) An *Extended-Content Package:* Composed of TM knowledge learning objects packed in XML and tagged with metadata (e.g. IMS-LOM metadata). In addition to this, several navigation descriptions are included such as the *Table of Contents*, *Prescriptive Rules or Knowledge Maps* (see **Fig 3**).

Figure 3(a). - IMS-CP version 1.1 with the Prescriptive rule extension. Rules and execute rule.



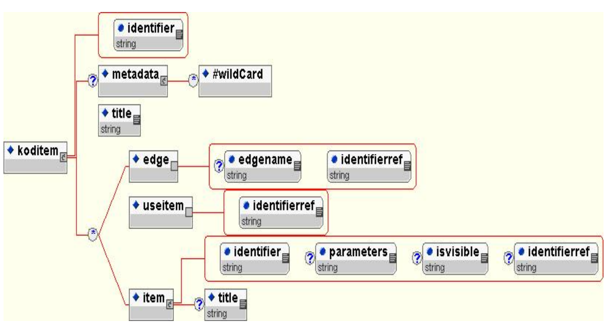


Figure 3(b). - Extended IMS-CP for the Navigable Knowledge Map

Figure 3(a&b)- The extended content package.

The default Table of Contents (TOC) hierarchy is extended into three levels allowing user adaptive navigation through telemedicine items. These levels are:

1. Conditional branching (ADL-SCORM[1]) with Boolean conditions on lesson status.

2. Prescriptive sequencing Rules that control content activation based on the Learning Management System (LMS) tracking, taking into account user status and/or preferences. (See **Table III**).

3. Knowledge maps capable of changing the domain organizational views, depending on the Prescriptive Rules.

2) An ontology adapted to Telemedicine: For this learning environment we established specific vocabularies and domain ontologies capable of being used by metadata handling Agents.

a) Telemedicine classification: This contains categories whose entities are assigned according to one or more established criteria. There are twelve main categories in the Telemedicine Body of Knowledge (TM-BoK) [7]: *[1]* History of Telemedicine, *[2]* Minimal Technical Requirements, *[3]* Main Telemedicine Applications, *[4]* Basic Knowledge of Multimedia Communications, *[5]* Quality Control and Quality Assurance, *[6]* Internet in Telemedicine, *[7]* Distant Training Tele-Working and Tele-Teaching, *[8]* Data Security and Privacy, *[9]* Liability and Legal Aspects, *[10]* Economics and Management in Telemedicine, *[11]* Social Aspects and Technology Transfer, and *[12]* Emerging Issues.

The less common/significant entities are included in "other categories" and cover: *[i]* Standardization Bodies, *[ii]* Statistics, *[iii]* Colour Theory, *[iv]* Networking & TCP/IP[5], and *[v]* Informed Consent.

b) Coding schemes: The code-dependent hierarchy structures the major categories content into subheadings. For example, the Major Category-*[3]* entitled "Main Telemedicine Applications", has the following subheadings: *[3.1]* Tele-radiology, *[3.2]* Tele-pathology, *[3.3]* Tele-cardiology, *[3.4]* Tele-home Care, *[3.5]* Tele-oncology, *[3.6]* Tele-surgery, *[3.7]* Tele-psychiatry, *[3.8]* Tele-dermatology, *[3.9]* Primary Care, and *[3.10]* Phone medicine.

c) Medical sub-heading for indexing medical procedures: Considering that TM is a medical subject, Medical SubHeading (MeSH) qualifiers can be used to refer to headings when applied to specific medical delivery procedures.

3) Managing Attributes and Enhanced Data: The extended content package (**Fig 2**) selects vocabularies twice; once for the metadata fields and once again for the Data Model and Navigation Knowledge Map.

Metadata fields are associated with the provided vocabulary including TM (**Table I**). In the case of the Data Model (**Table II**) and Navigation Knowledge Map, the *domain* is selected first, because it determines the specific vocabulary. In our case MeSH and TM domains were chosen, meaning: main categories II.B.2.a) supplemented with II.B.2.b.) and II.B.2.c.). Nevertheless, in some specific main categories different

[4] SOAP= Simple Object Access Protocol

[5] TCP/IP= Transmission control protocol/ Internet Protocol

vocabularies are required (i.e. *[9]* Liability and legal aspects require a Legal domain vocabulary)

Table I- Metadata vocabularies Association

Language	English / Spanish
Key-words	TM-BoK ; MeSH
Version	No vocabulary
Status	Lifecycle.status
Format	Mpeg/doc/html/ppt/pdf/xls
Learning resource type	Exercise/figure/table/problem/questionnaire/index/exam/test/simulation/graph/narrativetect/selfassess/diagram/slide/experiment/URL
Interactivity level	
Semantic density	
IntendedEndUserRole	Doctor/nurse/managerial/technical
Difficulty	Veryeasy/easy/medium/difficult/verydifficult
Context	Univ1cycle/Univ2cycle/Univ3cycle/ContEd/CovT
Relation.kind	Ispartof/isversionof/isformat/isreferencedby/haspart/hasformat/isbasedon
CopyrightAndOtherRestrictions	Yes/no
Subject	MeSH; Telemedicine; Legal; etc…

In the TM-BoK ontology, the attribute values or qualifiers of the main categories (i.e. nodes) are capable of building the dependency maps specific to the TM learning system. This would not be possible if MeSH qualifiers were chosen since they are not adapted to telemedicine categories and subcategories. This is regardless of the fact that both TM-BoK and MeSH hierarchies allow broader (parents or ancestors and siblings) and narrower (children or successors) concept relationships; and, that within a given hierarchy, a single concept may appear either as a narrower one or as more-than-one broader concept, thus being capable of creating dependencies and Knowledge Maps.

Table II- KOD Data Model for learner profile characteristics according to LIP model

KOD Data Model	**Learners Characteristics**
Kod.learner.demopersonal.language	Language
Kod.learner.ld.learnstyle	Learning Style (ILS-Index learning stile Felder & Silberman)[6]
Kod.learner.objective.[]	Goal (MeSH vocabulary)
Kod.learner.objective.[goal].interest_level	Competency
Kod.learner.objective.[goal].classification	Interest

In **Fig. 4** the Tele-radiology knowledge map *[3.1]* is shown to contain: Basic parts *[3.1.1]*[7] as well as Fundamental nodes (The term fundamental refers to main categories in the TM-BoK).

Defined *custom ontologies* allow complex data structures to pass among agents within Agent Communication Language messages. Our ontology implementation for communication purposes was deliberately simplistic. It was basically a rule container since attributes were considered beyond its scope particularly because actions are not read in the ontology but implemented through the behaviour of agents.

Adaptive package delivery was under the control of the *modified*-LMS, which was capable of interacting with agents (delivery agents) and of executing the run-time rules encoded in the Content Packages. The modified-LMS was also responsible for storing and checking user profiles and complementary information such as: elements already visited, performed rules and updated user knowledge. All the above is essential for personalized adaptive delivery.

3. Application Deployment-TM demonstrator

Two innovations have been implemented: A) Personalization and B) Re-using.

3.1 Personalization

This starts with the system *dimension* followed by prescriptive or adaptation rules to deliver customized contents.
The dimension definition enables the system to select *determinants* or parameters that help to decide whether the content (constituent) must be presented to a particular user. The *constituents* are divided into learning paths (collections of learning assets) and learning assets.

The dimension of the TM demonstrator takes into account user backgrounds, learning styles and goals:

- **Individuals**: The TM introductory courses reach a wide range of professionals, who were classified into three main groups: Medical Informatics Experts, Health Care Personnel, and Managerial people. The main determinant for the first group was technical issues, for the second medical items, and for managers economic and legal aspects.
- **Learning styles**: Regarding the format of available documents, half of the material had optional (textual or visual) presentation formats.
- **Topics**: Telemedicine being a new discipline, most material is *introductory* with a reduced number of *advanced* items. For that reason, we rejected so-called "dimension-levels", because no critical mass of contents is to be located in the advanced content set, in this initial demonstrator.

Table III shows a pseudo-code example of an "*adaptation rule*". When a particular user meets both conditions (being a doctor and interested in visual material), then the element addressed in the "table of contents" with the number 234 - corresponding to medicalvisualpresentation.ppt item- will be activated. In **Figure 5b** the final result is displayed.

[6] Learning and Teaching Styles in College Science Education (http://www2.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Secondtier.html)
[7] *[3.1.1.1.]* Communications, *[3.1.1.2.]* Display systems, *[3.1.1.3.]* Image acquisition & management, and *[3.1.1.4.]* Interpretation

Table III- Pseudo-code of a prescriptive/ adaptation rule that controls content activation to deliver customized content.

Initialise an element as "disable".
IF determinant=true THEN constituent=enable, AND
IF (kod.user.occupation=medical AND kod.user.learningstyle=visual) THEN (kod.behavior.seqnav(man1_ToC_234_(medicalvisualpresentation.ppt)=enable)"

3.2 Re-Using

The authoring tool imports raw learning assets located anywhere (e.g. Internet) into the Resource-window (**Fig 5)**. Once in the Knowledge-Object-window of the application, they are re-packed, re-used or modified according to the adaptive Knowledge Rules. As a result of the number of permutations (n-objects per j-dimensions), learning data delivery become individually adapted and highly personalized.

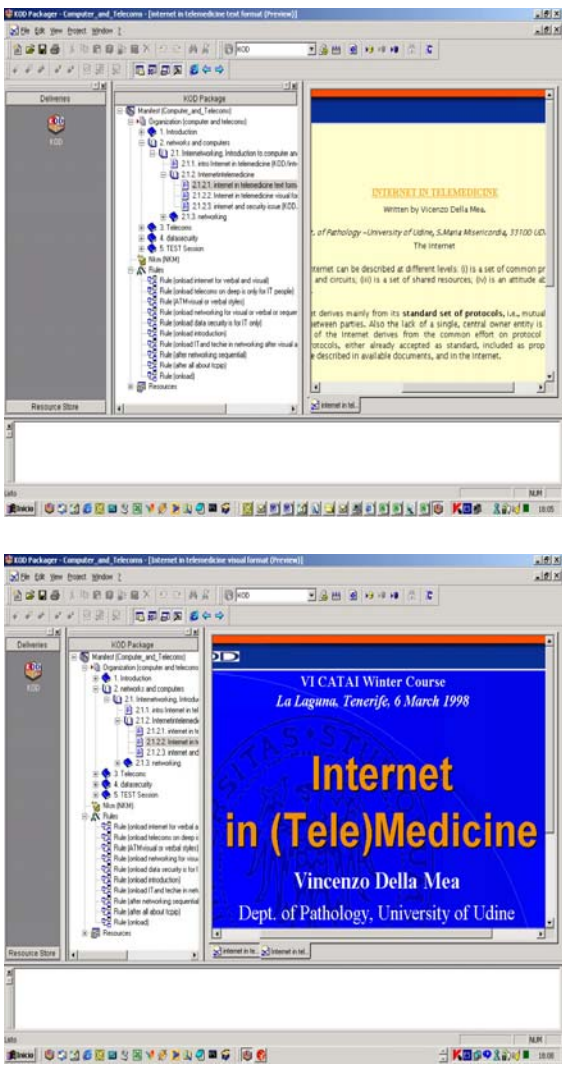


Figure. 5. – Knowledge personalization according to learning style.(a) textual; (b) visual.

The personalized packaged course (re-packable in each session or by the author) is just an aggregation, in the Knowledge Object window, of raw assets.

The system is permanently updated. For that purpose the "user-Agent" (who identifies each learner) of the Finding agent system (see **Fig 1**), looks into the available repositories for any material or complete package suiting user demands. Besides, it communicates with other agents in order to search in different repositories, including the Internet. The returned packages can be incorporated interactively into the course.

4. SYSTEM VALIDATION

For system validation a TM course integrated by a number of packages (cluster of contents organized by subject, topic, taxonomy…) to teach tele-radiology were build (**Figure 6**).

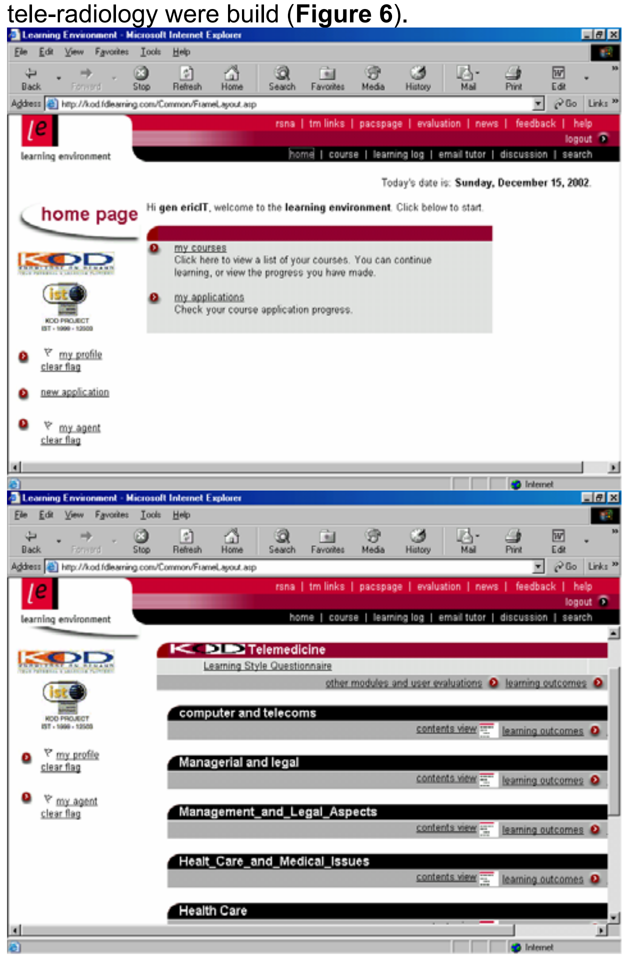


Figure 6. User portal interface for Telemedicine training. (a) Entrance to the portal. (b) Learning session for the specific student.

After checking student profile, the system decides which of those contents are suitable. The purpose is to deliver to each learner category exclusively the required information that fits his interest (doctors/ engineers/ managerial), learning style (visual or verbal) and goal (teleradiology/ quality control).

The adaptive course and package builder was provided to 96 students and 33 teachers. Their opinions were evaluated using questionnaires

(**Table IV & V**).

Table IV. User interest-difficulties to Telemedicine students.

1.	**How did you find the Tele-radiology learning usability?**
2.	**In your opinion the Telemedicine application and learning assets are…**
3.	**Has learning and time searching for contents improved?.**
4.	**Was tool familiarization time short and adequate?**
5.	**Were you able to track and bookmark your progress?.**
6.	**How did you find the telemedicine demonstrator?**
7.	**What is your opinion of the course building packager?**
8.	**Was the package builder easy to use:**
9.	**Is it easy to built a Telemedicine course?**
10.	**Is the TM demonstrator effective for learning:**

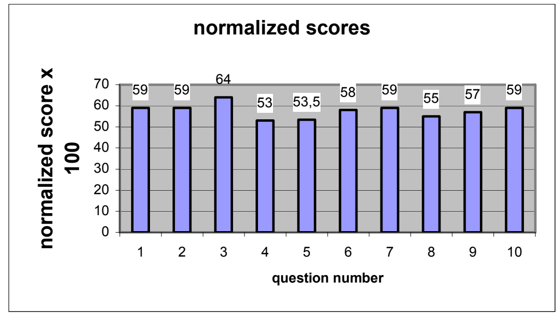
Table V. Teachers to analyse the authoring tool.

1.	**Opinion on Authoring usability?**
2.	**Opinion on Functionality for learners**
3.	**Opinion on the capability to create adaptive learning material.**
4.	**Opinion of the terminology used in the author interface**
5.	**Opinion on completeness of questions and test capabilities of the system?**
6.	**Opinion on the use of resources.**
7.	**Is the tool easier or as good as other e-learning tool?**
8.	**Is the Telemedicine demonstrator an effective learning tool?**
9.	**Opinion of the author user interface.**
10.	**Are steps to build a Telemedicine course simple enough?**
11.	**Is the terminology of the interface adequate?**
12.	**Does it support all expected functionalities for authors, publishers and brokers?**
13.	**Is the time spending to get acquainted with the use of the software reasonable?**
14.	**Do you consider that the test capabilities in the current version are sufficient?**
15.	**Opinion on the Rules interface?**

Answers were weighted from 0 to 3, with 3 being the maximum positive evaluation and 0 a negative or "do not know" answer . The global score was obtained summing the weight of each answer. The result was normalized dividing it by the maximum weighted score per answer (3x96=288 for students and 3x33=99 for the teachers).

Students of Telemedicine (University optional subject), evaluating the course, gave the results seen in **Figure 7a**. The average normalized weighted value was 57.65 per 100 with a standard deviation of 3.23. The best score was for time reduction in learning TM or searching for updated information (student question 3). The lowest score (53) was the time spent in becoming familiar with the tool.

Teachers were professionals familiar or not with e-learning tools. Results (**Figure 7b**) showed a 53.3% average weighted score with 10.03 standard deviation. The best score was for the capability to build adaptive courses (score 68; teacher question 3) followed by user interface, learner functionality (61) or rule-interface (60). The lower scores were for test-building facilities incorporated in the tool (33) and the time required to learn its use (38). A medium score (51) was given to the simplicity of building Telemedicine courses.



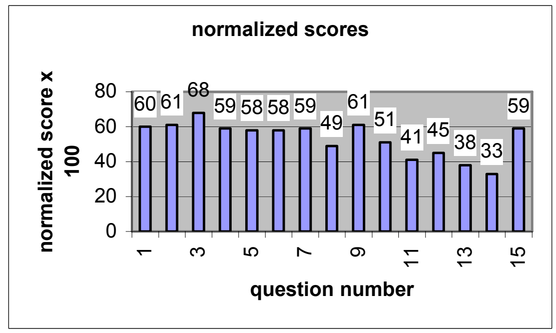


Figure 7. 7A-Students´ normalized score evaluation of the Tele-radiology course. 7B-Teachers´ normalized score evaluation of the Telemedicine authoring system.

5. DISCUSSION

The present TM Open and Distance Learning structure based on agent technology proved capable of personalized data retrieval according to user profile and goals. For that purpose we developed local and remote XML repositories, tagged with TM metadata vocabulary following TM ontology capable of being used by metadata handling Agents.

As shown in the design and deployment section this results in a multi-role personalised learning platform with a modular architecture that uses collaborative software Agents capable of reading the information located in the *modified*-XML-Manifest. Other Agents are devoted to representing the various user categories and to gather knowledge about a particular learner's profile, in order to adapt the delivery to this profile.

The platform proved to be very efficient in personalization issues, because it created only one package able to handle *n* objects per *j* dimensions, displaying only the suitable material and allowing re-use/re-pack learning objects. One of the major drawbacks was that it required tedious metadata filling sessions. The reason was that the tool does not contain automatic generation of metadata derived from relevant ontologies and resource description formats [8]; nor does it contain editing tools to add structured metadata, such as the eXtensible Authoring and

Publishing (XAP) Adobe metadata initiative for PDF formats.

Being a distributed platform for continuous learning it aims at using the Internet as an effective learning environment. Although medical researchers are often reluctant to trust Internet information mainly because it does not fulfil long-established verification criteria, the number of *on-line* Medical and Biology journals is increasing. Furthermore the availability of new techniques, lead us to consider the Internet as a future source of updated medical information. On the Internet, scientific papers can use handles [9] describing the physical location of the file (Universal Resource Names (URN) as part of the Universal Resource Identifiers) facilitating the search tasks. Moreover, the National Library of Medicine supported the Internet Engineering Task Force (IETF), in designing a quasi-permanent naming of web-based information objects. The Archival Resource Key draft entitled *The ARK Persistent Identifier Scheme* [10] defines three ARK services to access: i) the object, ii) the description of the object (metadata), and iii) the commitment description, made by the Name Mapping Authority (NMA) regarding the persistence of the object (policy).

Semantic webs are going in similar direction using: i) software Agents able to negotiate and collect information, ii) Markup Languages to tag many types of information and iii) Knowledge Systems enabling machines to read web pages and determine their reliability [5].

In the medical field, Internet discovery tool innovations go from web Ontology Agents capable of retrieving information in an intelligent manner [11] to Medical Core Metadata (MCM) standardizing attributes and enhanced data to be used by agents [12]. Finally, to support free text queries, terms should be compared with established vocabularies; the free web resource HSTAT (Health Services/Technology Assessment Text) [13] accesses full-text document title, checking users spelling queries by means of software Agents based on Unified Medical Language System (UMLS) meta-thesaurus.

The success of any of these tools relies on the use of common ontologies. Medical terminologies are long-established foundational ontologies, allowing the retrieval of related and synonymous concepts, querying and cross-mapping multiple terminologies/ classifications at the same time. They culminate in the meta-thesaurus, which is a foundation product of the National Library of Medicine UMLS initiative[14], of which MeSH-2001 forms an essential part. It is a machine-readable knowledge source that represents multiple biomedical vocabularies organized as concepts in a standard format. Although it provides an immensely rich terminology in which terms and vocabularies become linked by a meaning, it does not include most telemedicine classifications, subheadings and qualifiers that require a new set of concepts. For that reason, the TM-BoK hierarchy [7] is essential.

Until now the above mentioned tools, could assist users in the process of cataloguing hierarchic content relationships for a set of documents, but did not address personalization issues, which are vital for multidisciplinary topics such as telemedicine.

The present e-learning platform that retrieves personalized medical information according to users profile and goals is an example. Furthermore, since agent technology is fundamental for intelligent queries and data retrieval, it becomes necessary to build health care agents specialized in the various health services using specific taxonomies and adapted markup languages. In this respect, AgentCities started a Health Care Working Group [15] in 2002; actively working in 2003 [16] and 2004 [17], their work apparent among agent specialists is not yet fully implemented by the medical community in the everyday medical applications[18].

In conclusion, the structure presented in this paper could create an Internet based distributed learning platform, with repositories placed anywhere. The system will keep the information on available learning objects/packages to access and retrieve information. Once loaded, the set of rules placed in the *modified*-XML-manifests stored anywhere, will be executed, presenting only data suited to users demands.

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Have published 111 scientific articles and 7 books on image analysis and technology; including the first and only existing text-book of Telemedicine: "Handbook of Telemedicine". IOSpress. Amsterdam 1998, ISBN 90-5199-413-3, translated in two more languages as in Spanish "Telemedicina" Ed. Medica Panamericana ISBN 84-7903-600-0 and in Greek: ΤΗΛΕΪΑΤΡΙΚΗ Ed Αναστασία Κασтανιά - O Ferrer Roca. ISBN: 960-02- Papazhsh Publ. Athens 2004. Since 2003 the proceedings of the Winter Courses are published and used as a textbook for the students. The previous editions were: CATAI 2004-Quality and Security in e-Health ISBN 84-609-0493-8; and CATAI 2005-Ambient intelligence in Medicine. ISBN 84-609-4000-4.

Founded the CATAI (Centre of Advanced Technology in Image Analysis) in 1994 being the president. Established at regional and national level, undertake international activities related with promotion of the information society and fight against technology transfer problems having the role of an "intermediate body". The association deals with information society developments being specialized and recognized abroad by its telemedicine work.

The innovation has been the prime motivation since 1968: Innovation in Tissue Culture and tumor cariotyping. First to introduce tissue culture of solid tumors in Spain in 1968 to demonstrate clonal evolution of tumours and the role of virus in their chromosomal anomalies in 1972, before the demonstration of oncogenes. (Estudio Etiopatogénico del Cáncer y su importancia Clínica I. Teorías Actuales de la Carcinogénesis. Teoría Vírica. *Med Clin 65*: 212-214,1975; *65*:256-259,1975; 65: 302-306,1997; *65*: 356-358,1975; Correlación Somático-Viral. Correlación cariotipo-tumoral *Med Clin 65*: 428-432, 1975 ; Consideraciones practicas de los cultivos tisulares. *Med.Clin. 65*: 528-534,1975; Clonal Evolution of Goiters. Pathologica, Pacini, Ed Pisa 145-151,1981)

First to introduce training and examinations with real cases and patients clinical records in Pathology, since 1972.

In artificial intelligence. Developped the program of automatic identification of cells in pathology (TEXCAN) to distinguish the chromatin texture of cells and their classification, used to teach cytology of thyroid and breast tumours.(Editor and author of the book : Análisis de Imagen I. Principios básicos de Tratamiento y Evaluación Estadística. Ed. Caja de Ahorros S/C Tenerife 1986 with 370 pages)

In image analysis. Developped the program of automatic identification of the immune-scores and DNA (TEXCAN) to evaluate the prognosis and treatment of the malignant breast tumors. Used to on line teaching of the importance of prognostic factors in breast tumors in pathology. Faculty of Medicine. (Author of the book Analysis de Imagen II. Aplicaciones. University of La Laguna 1990. 218 pages)

In the field of Telemedicine. First to develop a health care network of Videophones use for real tele-consultation and distant long-life learning for the doctors located in the small islands of Tenerife. The network called REVISA started in 1990. Since then, telemedicine was introduced to the students of the Faculty of Medicine.

Spread the use of information society tool and telecommunications tools in medicine since 1982 with international courses every year in the University of La Laguna. Courses starting with technical aspects moving big systems and devices for real training in the workshop area as well as distance training if available. Those courses were entitle since 1985 Image Analisis courses and in 2005 the 18th edition was programmed. Since 1993 started the International Winter Courses in Tenerife and the International Summer Courses in different European countries (Genova, Innsbruch, Udine, Berkshire,..) in 2005 the XIII edition of the Winter and Summer course have been developed. Those courses bring the most advanced techniques in the field of information society and telecommunication in Medicine. In 1992 we were the first in Spain to do distant tele-teaching by videoconferencing through ISDN. The ISDN was the first settle in Canary Islands and is still active. Training at distance was initially done with Norway and since 1992 distant training with videoconferencing to bring the expertise of people in different countries to our student in done every year. In 1999 a permanent 3-ISDN line for medical purposes was settle.

The use of distant image analysis evaluation for training purposes at distance was done with distant DNA evaluation in 1990 (first in the world) (Videoteléfono en Anatomía Patológica. Medición de DNA y Receptores inumunohistoquímicos a distancia. *Patología* 24:225-229,1991) Start distant teaching in Internet since 1993 with pathology and Image Analysis Courses. Since 1998 Winter Courses

were provided on-line in Internet for teaching purposes by means of real-player streaming video.
First in Spain and one of the first in the world to start Telemedicine teaching in the Faculty of Medicine. University of La Laguna. Spain. The topic is recognized in the new study Plan in Medicine since 1996 and in Informatics since 1998 as an optional matter. Telemedicine was introduced as free configuration matter since 1995.

FIGURE 4. Knowledge map nodes of Tele-radiology