Integrating Intelligent Tutoring Systems and Health Information Systems *

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Abstract

The importance of integrating information about patients in Intelligent Tutoring Systems (ITS) is the opportunity given to the students to direct their own learning. We propose an integration-architecture for sharing patient's clinical data among tutoring and Health Information Systems (HISs). HL7 is used as a standard messaging protocol for collecting the clinical patient data distributed over Health Information Systems.

1. Introduction

Health care professionals frequently have a lack of knowledge about the possibilities and limitations of systematically processing data, information and knowledge and of the resulting impact on quality decision-making. They often have to use brand new information technologies in order to enhance their practices through a better use of information resources.

However, through an increase in the provision of high quality education, well-educated health care professionals world-wide are expected to raise the quality and efficiency of health care [1].

Intelligent Tutoring Systems (ITSs) has been developed for health education [2]. The purpose of these systems is to provide rich environments for maximizing learning while minimizing risks to the patients, until sufficient competency is established [3].

In order to provide good quality in health education, the International Medical Informatics Association (IMIA, [4]) has proposed a set of recommendations. These recommendations shall help to establish education in the medical field, to further develop existing educational activities in the various nations and to support international initiatives concerning education in health.

One of the key principles of IMIA is the need to provide the required theoretical knowledge, the practical skills and to achieve mature attitudes. In addition to traditional classroom-based models, there are many different teaching strategies that must be considered. In this sense, we consider the importance of integrating Health Information Systems and ITSs for providing sensible feedback, demonstrations and/or explanations to the student. Feeding the ITSs knowledge base with real cases, the student would acquire the practical skills to interact with real cases reaching the necessary abilities for improving the decision-making process.

In this paper, we propose an integrated architecture for ITSs in the health domain for sharing a patient's clinical data among ITSs and heterogeneous Health Information Systems (HISs). In this work, HL7 is used as a standard messaging protocol for collecting the clinical patient data distributed over HISs.

The main contribution is to provide to the ITSs real information about patients for training about real problems. This teaching strategy is beneficial for educating future clinicians in the patient's treatment and for improving the decision- making process.

The paper is organized as follows: Section II introduces the methods used in our approach. Section III describes ITSs and HISs. Section IV explains the HL7 Standard. In Section V the system architecture is showed. Section VI describes a case study. Finally, section VII is devoted to present the conclusions.

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2. Background

We have been working on the development of Intelligent Tutoring Systems (ITSs) for several years. In the earlier stages an ITS was developed for health education in the frame of the project SINCO [5]. However, the ITS design process was very complex due to the need for including domain characteristics, student behavior and personalized teaching strategies adapted to the students requirements. For the purpose of personalizing the teaching process and facilitate the ITS design, we developed a new ITS project (ITS-CBR) [6]. In this project, we proposed a framework for designing ITS using Case-based Reasoning methodology [7] and Multi-Agent Systems [8].

The ITS-CBR reconstructs the essential characteristics of cognitive tutoring systems and utilizes CBR as an approach to diagnosis the student's knowledge, the adaptive generation of problems and the acquisition of new knowledge. With CBR the designer can construct the desired solution through solved cases and previous experience with students. The use of agents to automate the CBR stages is also considered significant in our approach, because the multi-agent system distributes the case base and the CBR cycle among several agents. The presented framework was used to create STIM-Tutor, an ITS for training the Health Education domain. However, ITS-CBR did not consider data sharing among different HIS. Data integration is an important aspect in medical education. The integration of patient's clinical data in ITSs improves the clinician's learning process and the decision-making process.

For the purpose of sharing a patient's clinical data among ITS and heterogeneous health systems, we add a new component to the ITS-CBR project and specializes an architecture for ITS in the health domain. In this project, HL7 [9] was used as a standard messaging protocol for collecting the clinical patient data distributed over health systems. The main objective was provide to the ITS real information about patients for training about real problems.

3. Intelligent Tutoring Systems (ITSs) and Health Information Systems (HISs)

In our work the ITSs in medical domain are developed for driving the learning based in "real-life" cases that require defining the problem, creating hypothesis, gathering and analyzing data, and evaluating or justifying solutions. Each patient is a new problem designed to challenge students to develop reasoning, problem solving and team skills. The students are actively involved in the creation of solutions for the problem. They integrate and organize learned information as they encounter the problem. The problem becomes a stimulus for learning and for the recall and application of their knowledge. When a problem is presented, the students must come up with possible hypothesis to explain the patient's characteristic, symptoms and diagnosis when it is necessary.

HISs are heterogeneous and geographical distributed so the clinical information they contain is usually scattered. The importance of integrating information about patients in ITSs provides to the students the opportunity to control their own learning while they explore real complex situations. Students work collaboratively to identify issues, to frame questions, and to identify additional information to answer those questions. Besides, the students analyze a socially relevant case and gather more information, but they also engage in developing and testing their hypotheses.

Several ITSs has been developed in medical domain but no one takes care of integration with Health Information Systems during the learning process [2].

4. Health Level 7 (HL7)

Health-care records are widely distributed and have strong local autonomy. Frequently, patient information is not available when and where it is needed. The recognition of the need for interconnection led to the development and enforcement of data-interchange standards. The primary goal of HL7 is to provide a standard for the exchange of data among medical-computer applications.

The HL7 standard is message based and uses an event trigger model that causes the sending system to transmit a specified message to the receiving unit with a subsequent response by the receiving unit. Messages are defined for various trigger events. Version 1.0 was published in September 1987, and on February 1996, it was approved by ANSI as the first health care data-interchange standard.

The HL7 organization is also developing standards for the representation of clinical documents. These documents standards make up the HL7 Clinical Document Architecture (CDA). The CDA is a document markup standard that specifies the structure and semantics of clinical documents. For efficient clinical information management and system integration, clinical data, patient data and integration of records need to be well organized and conform to relevant standards. For consistency, we adopt HL7 standard in the present project.

5. System Architecture

A component has been added to the ITS-CBR framework. Figure 1 shows each one of the components and details the HL7 Message Server as the new integration component composed by the next elements.

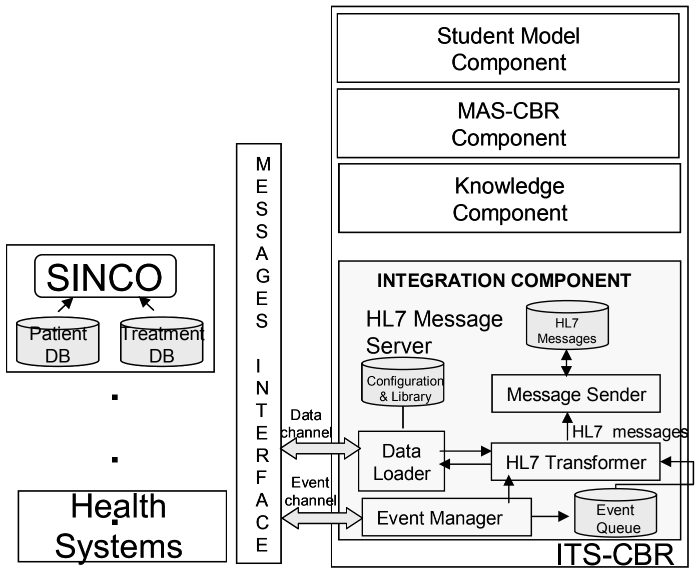

Figure 1. ITS-CBR Components

HL7 Message Server

Event manager: permits the message parsing and construction, and also sends control management message to the system. The most important functions are as follows: (a) message queue, (b) message mapping, (c) message parsing, (d) message building and (e) message control.

HL7 transformer: automatically assembles HL7 messages. Upon notification of a new HL7 trigger event, the HL7 transformer requests the data loader to fetch relevant data from the message view.

Message sender: transfers HL7 messages to the external systems. It receives acknowledgments messages for verification purposes. These acknowledgments messages guarantee a successful communication.

Student Model Component

This component models the knowledge that the student has about the domain he/she is trying to learn and how it evolves. The student module is composed of the *student model* and the *diagnostic process*. On the one hand, the student model describes the knowledge that the student has acquired in the domain to be learnt. On the other hand, the diagnostic process is in charge of updating the student model based on the current student model and the student performance during the learning process, according to diverse variables previously defined (problem evaluation, answers to questions, time spent in studying each explanation, etc.).

MAS-CBR Component

This component follows the steps of the case-based reasoning methodology. This is to say that the system goes in 4 cycles that are: Retrieval, Reuse, Revise and Retain.

In *retrieval phase* a task agent searches for a similar solved case by comparing new cases with the existing case base.

In *reuse phase* the solutions obtained in retrieval stage are adapted so that, a fine grained personalized solution is derived and expose to the active student.

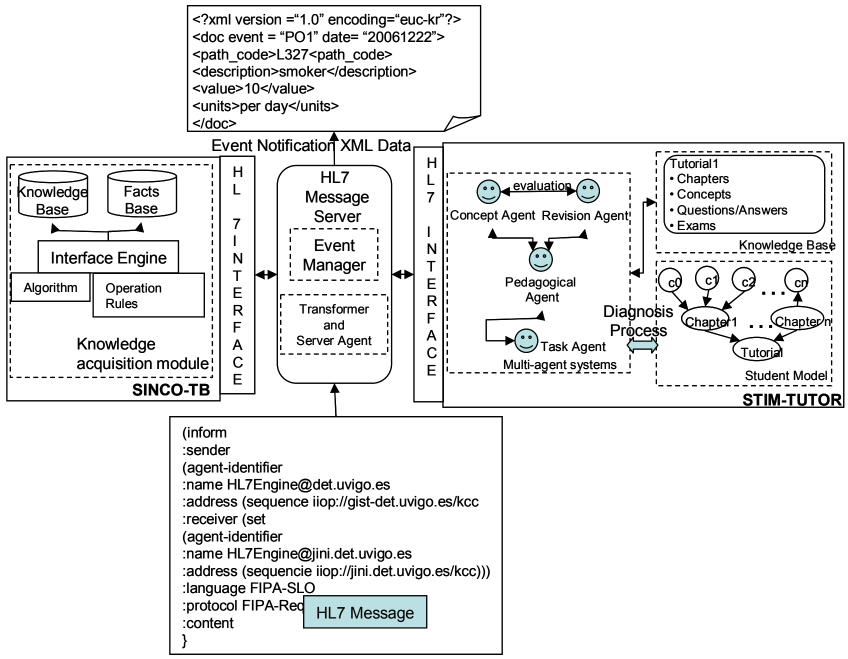

Figure 2. Inter-system communication using HL7

Knowledge Component

The elements that represent all the knowledge to be acquired by a student in a determined tutorial are stored in the system knowledge database. These elements are introduced into the system by an expert in the tutorial domain or through of the integration process with other systems.

6. Case Study: SINCO-TB integrated with STIM-Tutor

The SINCO-TB system is a specialization of SINCO project. It stores information about patients with a tuberculosis disease. The patient's information is sharing to feed the case base of the tutor system. The HL7 standard is used for sharing information among the systems. Figure 2 shows inter-system communication using the HL7 interface engine. In the internal structure of the system each entity of HL7 is implemented as an agent, which is delegated a specific function. Each agent is on a multiagent platform, where individual and heterogeneous systems can communicate and share the patient's information. The agents in the HL7 message server behave as follows:

The HL7 Management Event: receives an HL7 event notification encoded in XML from the messages interface. According to the event type, it classifies the incoming events into an appropriate event queue.

HL7 Transformer: It automatically generates appropriate HL7 messages using predefined mapping functions and it communicates with the different health systems.

HL7 messages in HL7 Agents

Traditionally HL7 messaging has been limited to ASCII text messages and has only recently been extended to XML. These messages are passed from one system to another using TCP/IP. In our agent based approach the information in each message is embedded in the agent properties. Depending on the HL7 trigger event that initiated the creation of the agents, the HL7 agents contain all the information that would have been part of a corresponding HL7 message, i.e., all the information related to the event, for example information about the person acting in the role of patient such as name, age, marital status, sex, diagnosis, treatment, etc.

In the agent communication process, the Agent Communication Language (ACL) can be encoded with XML. With it, agents send ACL messages that contain the HL7 message in the content tag.

HL7 message specification

A good part of the development time with HL7 is spent creating use cases and the information model using common modeling tools. The HL7 Version 3 can be broken down into two main phases: the requirement analysis and the solution design and implementation phase. In the first phase the trigger events are defined using use cases. The secondary phase produce means of specifying responsibilities of the senders and the receivers, i.e., the interaction model.

Each interaction consists of a trigger event which initiates the interactions. In each interaction one particular message is sent using a message ID. Besides, the application roles that send and receive the message type are defined. The message specification is based in the domains of Patient Administration and Care Provision, defined according to the HL7 specification. In Figure 3 a scenario is presented.

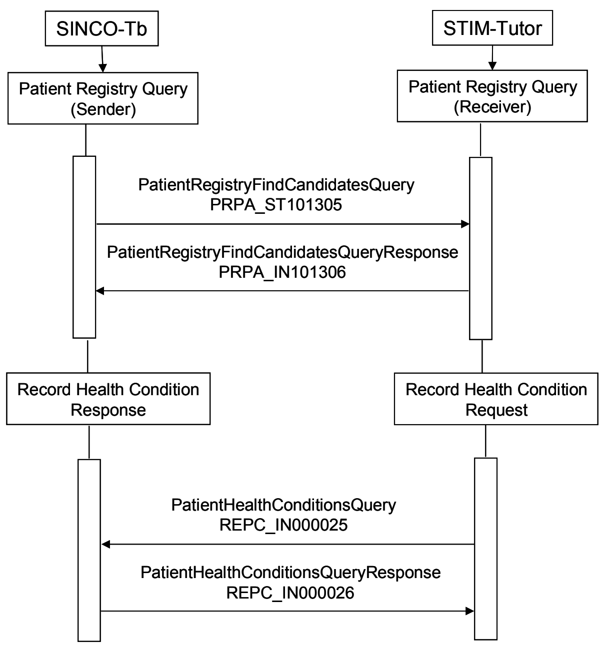

Figure 3. View interactions in the domain

Initially, this scenario demonstrates querying a person registry for a list of persons matching a set of demographic information. A user initiates a query to a person registry requesting all records that match a particular set of parameters. In our case, the STIM-Tutor search patients with multi-drug resistant tuberculosis and contraindications. The system with receiver role (SINCO-TB) responds to a query with demographic information for the persons specified in the query. This interaction corresponds to the *Get Demographics Query*.

Then, to obtain the patient's medical conditions and intolerances, the interaction *Health Condition Event Record* is used. The message requests the list of recorded patient health conditions (symptoms, health problems, diagnosis).

7. Conclusions

The use of the HL7 established health care standard, to share domain information among systems, is particularly significant for healthcare organizations that were assessed towards its adoption.

With the use of HL7 it is possible to have access to the information of each health information system only using the HL7 interface, i.e., hiding and encapsulating the internal structure of the systems' database.

In this paper we present an approach to share patients' information among Intelligent Tutoring Systems (ITSs) and Health Systems using HL7. To achieve this objective, software agents cooperate to solve mappings between local database applications and the HL7 message templates. This approach simplifies the exchange of patients' information and the training of new students in complex and real situations using ITSs.

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