MHITS - A Musical Harmony Intelligent Tutoring System

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Abstract. In this article, the MHITS Musical Harmony tutoring system will be presented. The MHITS proposes an environment of Harmony learning focusing on present learning (aiding the teacher) as well as distance learning. Its form of performance is via Internet together with all of its multimedia resources and hypertext. It is based in a multi-agent architecture of intelligent tutoring systems.

1. Introduction

This work is a continuation of the development of an Intelligent Tutoring System (ITS), focusing on the learning of Musical Harmony (Costa, Teixeira, Santos & Ferneda, 1996). In this perspective, the MHITS (*Musical Harmony Intelligent Tutoring System*) is the bond of previous works on the fields of knowledge representation (Teixeira, 97; Teixeira, Ferneda & Costa, 98; Costa, Teixeira & Ferneda, 1997) and MATHEMA environment (Costa, Perkusich & Ferneda, 1998).

The MHITS (Caminha, 2000) proposes an environment of Harmony learning focusing on present learning (aiding the teacher) as well as distance learning. Its form of performance is via Internet (WWW) together with all of its multimedia resources and hypertext.

This work is organized as follows: initially, a resumed presentation is done about the architecture of MATHEMA environment (section 2), used here to model the representation system of knowledge used (section 3) by the MHITS system. In section 4, the architecture of this system is described.

2. MATHEMA: an architecture of ITSs

MATHEMA is an environment of interactive learning, being conceived to enable adaptive teaching and the breaking down of the learning processes. The adaptive teaching is seen here as consequence of the process of cooperative interactions involving its components

(*Apprentice, Tutors*) in activities based on problem solving. In this perspective, the MATHEMA proposes to provide principles and an alternative architecture, necessary to guide the development of particular ITS (Costa, 1997).

The simplified architecture of MATHEMA consists essentially in three components:

1. *Human Apprentice*: agent interested in learning something about a given domain, working in the MATHEMA environment.
2. *Artificial Tutoring Agents Society* (ATAS): set of agents which sometimes cooperate among each other to promote the learning of a given apprentice in a learning activity. ATAS is defined, as mentioned before, as a function of a vision about domain knowledge, resulting in a series of sub-domains, obeying a certain criterion. This idea was initially inspired on the reflections of "Mind Society" of Marvin Minsky (Minsky, 1988). According to Minsky, intelligence emerges from the combination of mental agents, each one responsible for a small process.
3. *Human Specialist Society* (HSS): source of external knowledge to the computational system (something like an oracular agent) for the ATAS. From this society is expected the maintenance of the ATAS and eventual assistance to the apprentices.

The main objective, at the highest level, in an educational system like MATHEMA is to capacitate the Apprentice to acquire knowledge as a result of its interaction with the tutor. It is to be understood that this interaction is the exchange of messages between system and apprentice. It is fundamental the investment in quality related to the nature and contents of these messages, as well as the relation among its processing to, for example, choose a content adequate at the moment of interventions. For this, there is a need to define a sufficiently rich environment to perform such pretension. So, the use of multimedia interfaces is indispensable, mainly dealing with environments considering the teaching of aspects related to Music.

Some demands of desirable quality regarding the conception of a good environment for teaching/learning become necessary. For an improvement and effectiveness in the process of interaction between System and Apprentice, one should include:

(i) *the knowledge about the domain,*

(ii) *the pedagogical knowledge* (the Apprentice considered as an agent in the process of learning),

(iii) *the knowledge about the student* and

(iv) *)the capacity of interaction.*

To achieve the qualities discussed above, in the idealization of the model (Costa, 1997), a proposal which ranged and made possible, in a certain way, each one of them, was thought. Having established a model of the mentioned interaction, the demand of knowledge about the domain (quality *(i)*), was initially emphasized, culminating with a definition of a multi-dimensional model of this knowledge. This multi-dimensional vision shows the possibility of a domain that can be focused by a conceptual vision, such that this vision might be accompanied by various alternatives of variations of approaches of deepness and sideness in relation with each context chosen in the domain.

3. A knowledge base in Harmony

In (Teixeira, 1997), a representation of knowledge in Harmony aiming a construction of an intelligent tutoring system based in the MATHEMA architecture was proposed. For this, preponderant musical elements were identified in the resolution of harmonic problems. The smallest musical particles were isolated and, from them, the subsequent objects were constructed in order of complexity.

By having the definition of the *note* object as a base of musical structures, the flow chart presented in figure 1 was the result, with the dimension of the relations among the various objects of this domain. Here, the intrinsic goes from the simplest object (structurally) to the most complex one.

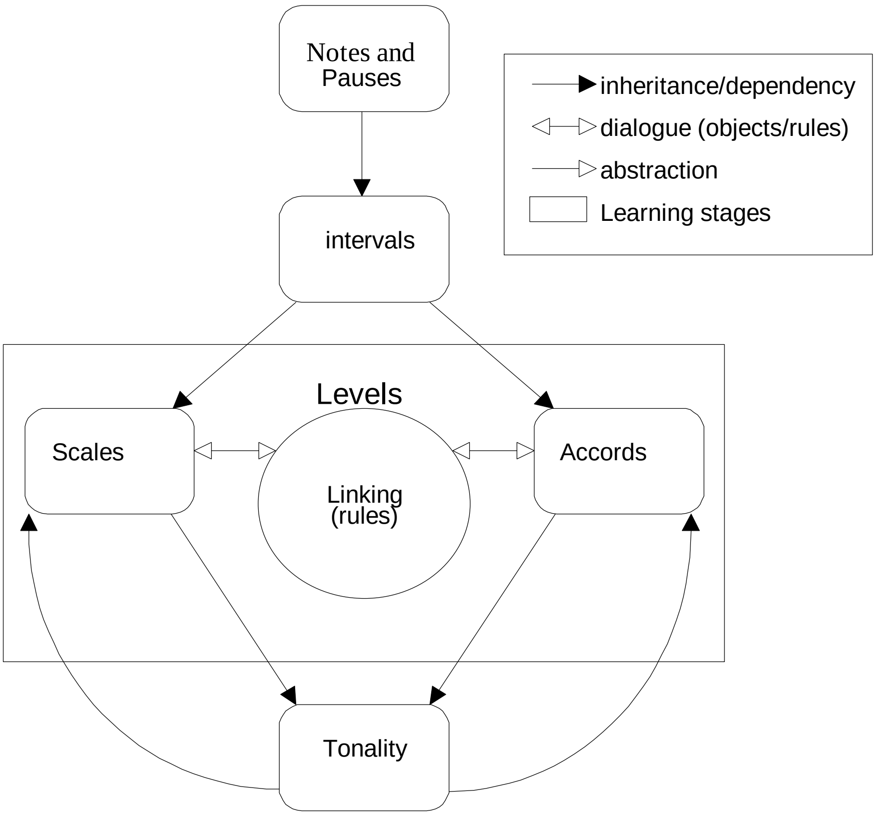

Figure 1: the structure of the musical objects relevant to Harmony

By following this order, one will find:

- that the intervals are in relation to the dependency and the horizontal inheritance* with the Notes object;
- that the Scales and Accords are related to dependency and horizontal inheritance with the Interval object and that in accordance with its layout (vertical or horizontal), one or the other will be generated,

  that some attributes and methods of Scales and Accords are defined by the
- Levels object, which represents the various learning stages,
- that the relation between Scales and Accords with the Linking object is done through

methods (rules) of manipulation and handling;

- that Scales and Accords define a Tonality object being as well an abstraction of this last one and
- that Tonality defines a set of singular Accords and only one Scale.

In a similar manner, and mainly in relation to the accords, maybe the object of most interest in Harmony, its structure should allow certain possibilities of inference, such as:

- reach the missing notes from an incomplete accord;,
- deduce a basic construction (without dissonance, etc.) from a complex accord,
- build all possibilities of inversions of an accord,
- locate, within a tonality, what is the function of a fixed accord.

About the representation of musical knowledge performed, one can catch a glimpse of its contributions and the capacity of solving some theoretical questions of Music, such as:

- unharmony in particular,
- find complete answers from incomplete musical objects,
- ability of building scale, accord and tonality objects, relevant to their domain in Harmony.

4. The MHITS

The MHITS system had as a model the MATHEMA architecture. From this architecture, the following components were saved, according to figure 2. Beyond the *Tutor Society* and the *Human Specialist Society*, the MHITS has also the following components:

- a *Multimedia Adaptive Interface*, which communicates with the user (*Human Apprentice*) promoting its interaction with the system and the Apprentice, the main part of the whole system, and the individual to which it intends to transmit knowledge;
- the *Communicator Agent*, which promotes the exchange of information between the Interface and the Tutoring Agent Society.

From this basic architecture, MHITS was implemented according to the model of objects presented in figure 3. The components of this model are described below.

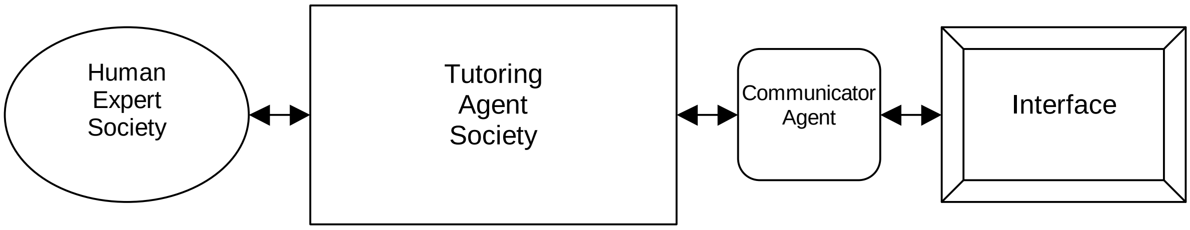

Figure 2: Initial Model of MHITS

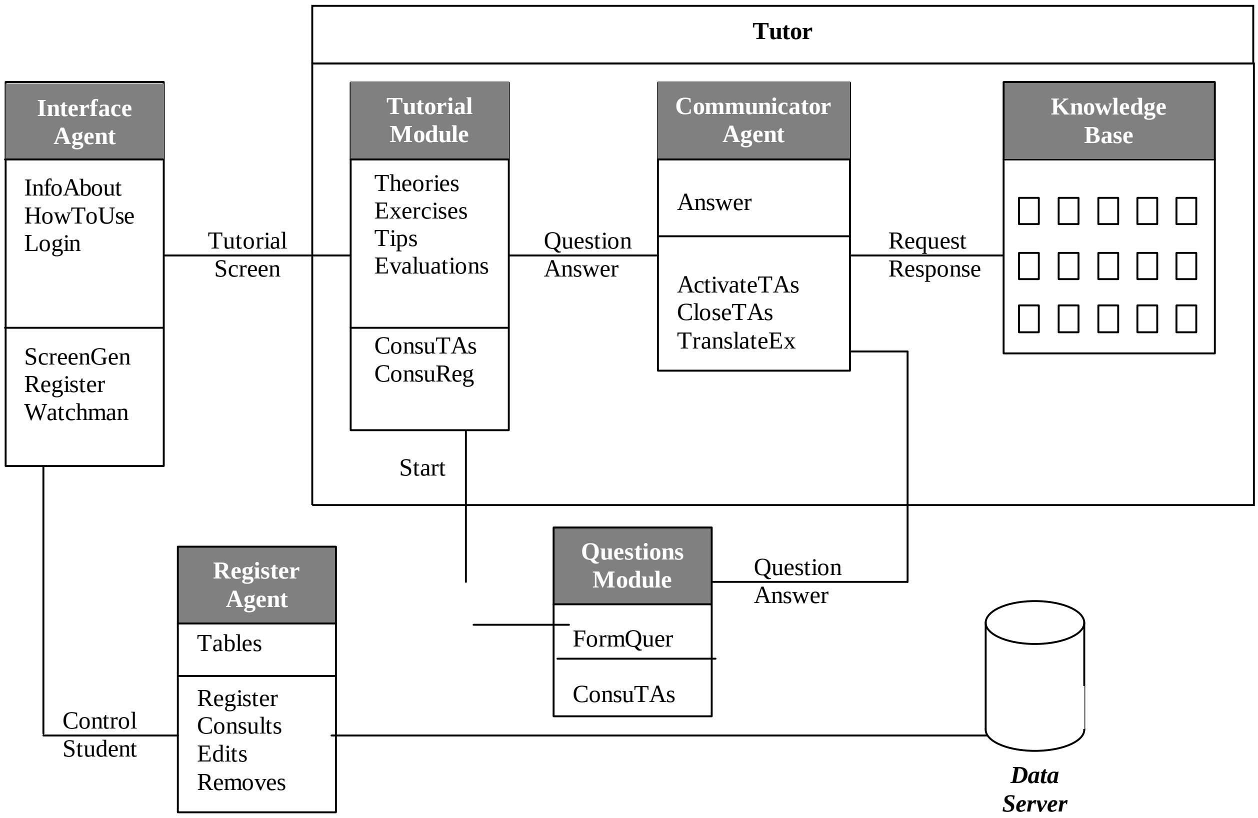

Figure 3: MHITS object diagram

4.1 Interface Agent

This is the component which allows the communication from the Apprentice with the MHITS. This agent controls what will be shown at the initial moments of navigation through the system, makes paths for the hypermedia navigation available, including for hypertext information about the system and how to use it. It also controls the entrance (login) of the user, identifying the level of access to the databases of the registers.

Objects and interaction areas are available through the Interface, from which data, responses, help calls and other interaction events with the Apprentice are captured. It can be visualized through a typical window of graphical operating systems allowing its visualization locally or remotely.

The Interface Agent activates the Tutorial Mode passing the input data of the Apprentice to the initial tutorial interactions. After the first interaction, the Tutorial Mode will interact directly with the register base to adequate the exercises with the student’s level, as well as to modify this level, in the right moment.

4.2 Tutorial Module

The Tutorial Mode controls how the tutoring material should be demonstrated, generates the screen for each session of the learning in accordance with the improvement and level of the student, presents the questions that make part of the tutoring through various medias like graphs, sounds and text, communicates with the Knowledge Base via the Communicator Agent, sends the answers of the student receiving the correct answer for this to present it for the student, beyond generating a configuration for the next screen from this evaluation..

By generating these screens, this module consults the state of the student, communicating with the Register Agent, to verify the level (beginner, intermediate or advanced). When the Apprentice completes one level, being approved to another one, the Tutorial Mode tells the Register Agent that this should be updated.

During the presentation of the theoretical content, exercises, tips, and evaluations, the Apprentice can activate, from any screen controlled by this agent, the Question Module, described ahead. This module is a new tool in this type of systems which helps in the resolution of problems, increasing the interaction with the content presented and increasing the possibility of knowledge acquisition for the Apprentice.

4.3 Communicator Agent

The Communicator Agent does the communication between the Tutorial Module and the knowledge base via TCP/IP ports (Internet file transfer protocol). This agent follows, briefly, these steps: *(i)* receives the events of the student re-passed by the Tutorial Mode or the questions generated by the Question Module and "translates" them to the Tutoring Agent (TAs) language, *(ii)* asks the TAs the correct answer, *(iii)* receives the answer from the TAs and makes it available to the agent which requested it.

The use of TCP/IP ports guarantees the remote use by various clients (Agents running remotely in user browsers) simultaneously, allowing the use of the system in training programs or in distance courses.

Figure 4 is a scheme of the communication model between the components of the system which access the knowledge base through the Communicator Agent. The standard TCP/IP port used is 4000, using also the *Queries* and *Answers* directories as temporary file deposits necessary for communication.

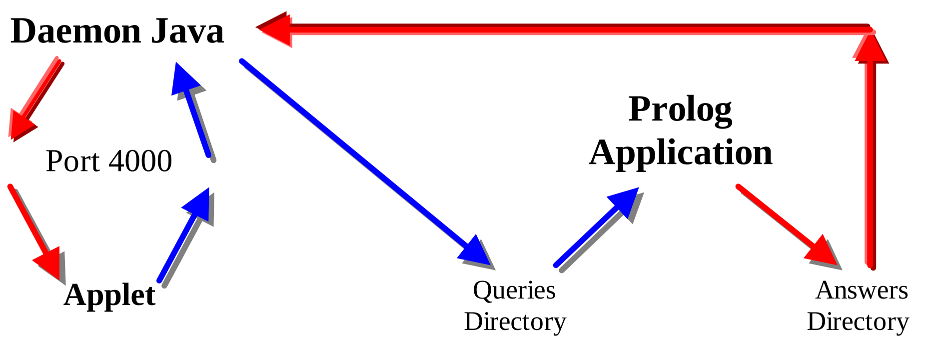

Figure 4: Scheme of the functioning of the MHITS Communicator Agent (Daemon Java)

4.4 MHITS Knowledge Base

The current version of MHITS uses a knowledge base (KB) specified and implemented by L. de M. Teixeira (Teixeira, 1997; Teixeira, Ferneda & Costa, 1998), and is presented in section 3, modified and adapted in this project for the interaction with the Communicator Agent. This KB informs the correct answer to the questions presented to the student by the Tutorial Module. It interacts with the MHITS through the Communicator Agent.

The KB is activated to evaluate the correctness of the answers of the Apprentice to questions and also when the Apprentice activates the Question Module through the Tutorial Module, to resolve some doubts or study a bit more about the theory presented in that moment by MHITS.

The functioning of this KB obeys the communication rules between agents according with MATHEMA, where each component is responsible for an aspect or sub-domain of knowledge and tries to compose the answer through consults to other agents having more specific knowledge, necessary to the solution of the question.

4.5 Register Agent

The Register Agent controls the information about the student, the level of learning and about the teachers, users of the system. It has a register system and consults the information which is modified only by the Human Specialist Society (responsible for the students and system administrator). It is consulted by the Tutorial Module to aid in the generation of the screens of each session from the level of the student.

Through this agent, it is possible to print reports about student performance for accompaniment.

4.6 Questions Module

This module is a multimedia interface which accesses a KB through the Communicator Agent to respond to user questions formatted according to the objects available on the screen. Through this module, it is possible to ask about a specific note or if a specific set of notes compose an accord or scale, or other similar questions, limited by the form available for questions. Figure 5 shows the screen for this module.

4.7 Final Considerations

The MHITS uses also an external resource base which has necessary files for formatting the Interface for interaction with the user: GIF, JPG and PNG images, HTML files having tutorials together with animations and MIDI sound files.

The Register Agent uses a base server for better efficiency in the access of information about users of the system, mainly the level of the student, being consulted in execution time by the Tutorial Module.

Figure 5: Draft of the MHITS Question Module

The Tutorial Module, Communicator Agent, and the Knowledge Base components compose the main part of the system which is really the own tutor. These components represent the Intelligent Tutoring Agents Society (TAs), which is part of the MATHEMA model, designed and implemented in this work in a simplified manner, refining the traditional model of ITSs composed of Interface, Student Model, Knowledge Base and Tutor Model.

5 Conclusions

The main contributions of this work is the directing of ITSs to be used via Internet, with the inclusion of the Communicator Module, essential for communication via TCP/IP between JAVA modules and a Prolog base. All of the modules of MHITS were developed aiming also the distance use, minimizing the file sizes and optimizing the code to gain an acceptable Apprentice/MHITS interaction. There is also the possibility of using JAVA Servlets and JSP (JAVA Server Pages) technologies to achieve a faster system in the client/server communication.

When it comes to ITS architecture, beside the project focused on the big network, we have another important contribution in this work. With the inclusion of the Question Module, a communication between Apprentice and Knowledge Base is possible through questions of limited scope by the input fields, available in the interface module. The Knowledge Base works like an Oracle for questions inside the chosen knowledge domain, which enriches the teaching-learning relation.

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