Adaptive Multimedia Interface for Users with Intellectual and Cognitive Handicaps

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Abstract. This paper presents an Adaptive Multimedia Interface embedded in an Intelligent Tutorial System (ITS) for intellectual and cognitive handicapped children. There are many educational programs specifically designed for helping students but in general they do not consider the adaptation of the performed tasks to the individual characteristics of each one of the children. The aim of this work is designing a computer-based environment for supporting a teaching strategy where both the pedagogic aspects and the learning goals were adapted according to the particularities of the pupil. The two fundamental problems that are approached in this paper are: designing the interface that is embedded in an Intelligent Tutorial System and implementing an efficient communication of knowledge.

1 Introduction

This paper describes the implementation of a multimedia interface that takes part in an ITS. The goal of this interface is to adapt the presentation of the contents to the individual needs of the students with intellectual and cognitive handicaps.

Most of the software packages available today do not take into account the individual features of the final receptors of these contents. They do not change the teaching strategies according to the requirements of each user. Another drawback is that the proposed tasks are presented following a repetitive sequence. This fact limits its application to students with learning problems: the motivation of the student along the automatic tutoring is affected negatively and the uncertainty about what the student is learning: the concept or the repetitive pattern showed by the software.

The first goal of this work is to implement a multimedia interface where the presentation of the educational contents is adapted to the individual characteristics and preferences of the children. The second goal is to provide the teachers with a tool that helps them in checking the benefits of different strategies to approach the teaching task of a particular concept. Finally, the multimedia interface gives an important feedback to the ITS where the results of the presented tasks are included.

The benefits of using a tool as this one come from the individualised teaching of the students. The system goes through the concepts of the domain according to the

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framework given by the Spanish Scholar Curriculum, but the teaching strategy changes, following the particular features of each student (cognitive age, chronological age, attention level, ...).

We have based our system in the frame of the General Law for the Spanish Educational System. However, this study has been restricted to the Childhood Educational Period (3 chronological years) in the subject of Physical and Social Environment, more particularly to the theme “Objects from the Near World” and to basic concepts (Inside-Outside, Up-Down, Big-Small). This restriction makes the analysis of the teaching strategies easier, allowing us to recognise common criteria in these strategies. In this way, we can generalise the decision processes making possible their application in other similar situations. It is important to remark that the teaching strategies are used to build the logic flow of the activities presented to children, and they are provided by domain experts.

The two most important problems approached in this paper are:

- The design of an interface that is embedded in an ITS.
- The design of an efficient strategy for knowledge transmission.

This paper has been organised as follows. Firstly, we described the design of an interface embedded in an ITS. Then, we presented a methodology to build an efficient way to transmit knowledge. This methodology takes into consideration the specific contents, how they are taught and the applied instruction model.

2 The Problem of Designing the Interface of an Intelligent Tutorial System

The design of an ITS is closely related to how the ITS presents the domain knowledge to the student. These strategies are given by a type of expert knowledge that considers how the teaching process should be, and how the specific problems that could arise are diagnosed.

Following these goals, the fundamental parts of the ITS are [1]:

- A Knowledge Based System (KBS) where the knowledge of the Student Model, Pedagogical Model and Didactic Model is represented.
- A Multimedia Interface, that is used to present and communicate the concepts to the student. This communication process must be dynamic and fluent.

2.1 The Knowledge Based System

We have followed the KADS methodology for knowledge structuring [2]. This allows us to build the KBS in a comprehensive and systematic way: the Pedagogic, the Didactic and the Student Model are represented in the KBS.

One of the types of knowledge that has to be isolated is the domain knowledge (static knowledge, composed of concepts, relation and facts that are necessary for reasoning in a particular application).

The student model is composed of the student profile and the student record. The profile contains those personal characteristics that are related to motor, cognitive and psychosocial development. Variables considered in the profile are: chronological age, cognitive age, physical capacities (motor functions, ocular contact, auditory capacity), cognitive development (short time memory, attention, capacity to form concepts, capacity to group objects in significant categories, development of language and vocabulary, word understanding, capacity of reaction and initiative), relation with the environment (connection with the environment, level of adaptation, participation in group activities, getting of information from the environment), personality (fear to failure, dynamic - hyperactive or passive), patterns of behaviour (repetitive behaviour, restricted behaviour, stereotyped activities), preferences (colours, personal interests). The student profile will influence the learning style.

The pupil's record comprises: the variables related to concepts already learned by the pupil and the tendencies followed in the learning process (repetition of the exercises, tasks that have not been completed, rhythm of evolution between activities, learning style, cognitive and motivational processes). The student record is parametrised by a set of variables and a function. The *vp* variables describe progress in learning a concept. The *fls* functions(f: (*vp. Style-Learning*)=>R) measure how well the student achieved the learning goal for a particular learning style.

The concepts that have to be learned by the pupil are determined taking into consideration the cognitive age. Each concept is related to a set of learning goals.

In addition, it is necessary to provide the KBS with the pedagogic strategies followed by the teachers in the teaching process. Another fundamental part is the pedagogic model, where both the learning goals and the way they are taught are included. That is, for each student, the activities that are proposed to teach a particular concept are specified taking into account the records of student.

In contrast with the domain knowledge, the control knowledge includes the reasoning processes that are followed in solving specific problems. This control knowledge is divided into knowledge about activities (activities that are carried out to reach the learning goals), and inference knowledge (elemental steps in the general problem solving activity).

Therefore, the Problem Solving Method used by teachers consists of following a planning process. In this process, the nodes of the tree search are the situations at which the student can arrive during learning (they represent the level of achievement of the objectives). Branches between nodes represent the change from a situation to another. A plan is the set of exercises that a pupil has to complete. The goal of this sequence of exercises is to reach a final node as near as possible to the objective node.

At each moment, the student situation can be derived from his record. As was explained above, the learner record is parameterised by a set of progress variables *vp* and by a function that measures the learning carried out with different sequences of tasks. This sequence of tasks give us the learning style used. We have different types of tasks: explanation, evaluation, motivation and reinforcement task.

Subsequently, one specific sequence of task give us the learning style used. E.g.

Mot-Exp-Eval-Re, Mot-Exp-Mot- Re-Eval, Exp-Eval, Mot

The elements to take into account for designing the sequence of activities (plan) are: characteristics of the pupil, objectives of learning and resources available.

2.2 The Multimedia Interface

The interaction with the student is carried out through three different types of activities: motivation, teaching explanation, evaluation and reinforcement [3]. These activities are related to the previously introduced operation modes.

For instance, if the goal is “To identify an object from the near setting”, the general features of the different activities are:

- *Motivation activity*: At the beginning and at the end of each session the system presents a motivation task. The system selects a particular activity because it is already known that the user can solve the task without great difficulties. Other kind of motivations are also considered: feedbacks for the student that are presented both previously to the task and when the task has been completed.
- *Explanation activity*: The physical attributes of the object (shape, dimension, colour, etc ...) and another complements determined by its situation are presented.
- *Evaluation activity:* The object has to be recognised when it is embedded in different scenarios. The object appears together with other related objects. In this activity, recording the interaction of the student with the application is a fundamental operation.
- *Reinforcement activity:* The same object is presented with variations of the physical attributes and complements. Learning the concept under study can be reinforced through describing other related concepts by its functionality or physical appearance.

The individualised teaching process consists on determining, from the characteristics of each pupil, which the learning objectives are. Then the sequence of activities that a pupil will have to do to acquire the contents set by the objectives must be determined. Adapting means in many occasions, to eliminate the contents, and in others to sequence. Sequencing means divide the objectives in smaller sub-objectives. The activities are designed according to the characteristics of the student, the learning goals and the available teaching resources.

3 Knowledge Transmission

The problem of finding an efficient way to transmit the knowledge by means of presentations adapted to the particular requirements of each subject is treated here.

The multimedia interface integrates both the verbal language and the visual and sound language. We consider the multimedia communication as a particular type of communication where several media and languages or symbolic systems are taking part. In this type of communication, the message is codified in different ways and requires from the student perceiving through several senses.

In our case, knowledge transmission is carried out through different interactions between the student and a system composed of a computer and all the necessary complements that make possible the interactions. The complex task of achieving an efficient knowledge communication using an intelligent system can be summarised in the following sub-problems.

- Which concepts are going to be taught and how are they going to be represented?
- Which kind of interaction between the student and the computer is necessary and how are these interactions going to be included in the system?
- Using the previously determined interactions, which strategy is going to be followed to reach the proposed pedagogic goals?

3.1 Definition of the Specific Knowledge That Is Going to Be Transmitted

The contents that this kind of children must learn are defined in the Spanish curriculum, the difference with the other children is that these learn slower, it takes longer to pass from one state to another to them, they have more regressions and they need more individualization in teaching.

We have based our system in the General Law for the Spanish Educational System. This study has been restricted to the Childhood Educational Period (3 chronological years) in the subject of Physical and Social World, more particularly to the theme “Objects from the Near World” and to basic concepts (Inside-Outside, Up-Down, Big-Small).

We start with concepts related with objects with the following characteristics. They can be natural or artificial objects. They are common objects from the most immediate world. They are involved in common and daily activities. The specific goals are: 1-To identify the object ; 2-To learn the characteristics and functionality of the object.

The analysis has been focused on the particular problem of teaching these concepts. Experts provided us with the teaching strategies, in other words, they gave us the logical flow of the tasks. Then, our work consisted extracting common features in these strategies (norms of didactic intervention). This generalisation process makes possible designing systems where a larger number of similar situations could be approached.

Several common objects from the “near world” where chosen. In an early age, the proximity of the object is in general related with activities involved in feeding. Therefore, all the objects where chosen from this area.

From these objects, we extracted the relations with other more basic concepts. These related concepts can be grouped showing a distribution in areas, blocks, subjects and concepts.

3.2 Design of Interactions and Dynamics.

3.2.1 Interaction

We considered some previous studies of the diversity of human abilities, backgrounds, motivations, personalities, and workstyles that affect the interactive-system’s design. Understanding the physical, intellectual and personality differences among users is vital [4].

It is important for designers of interactive systems a good understanding of the cognitive and perceptual abilities of the users [5,6]. The Journal of Ergonomics proposed this classification of human cognitive processes: short-term memory, long-term memory and learning, problem solving, decision making, attention and set (scope of concern), search and scanning and finally time perception. They also suggest a set of factors affecting perceptual and motor performance: perceptual (mental) load, knowledge of results, monotony and boredom, sensory deprivation, ...

On the order hand, personality differences affect the design of systems. People may have very different preferences for interaction styles, pace of interaction, graphics versus tabular presentations, and so on. There is not a simple taxonomy of user personality types. A popular technique is to use the Myers-Briggs Type Indicator (MBTI), which is based on Carl Jung's theories of personality types [7].

The learning-disabled children education can be positively influenced by designing a special courseware that avoids lengthy textual instructions, confusing graphics, extensive typing, and difficult presentation formats [8]. Neuman's advice to designers of courseware for learning-disabled students is applicable to all users:

- Present procedures, directions, and verbal content at levels and formats that make them accessible even to poor readers.
- Ensure that response requirements do not allow students to complete programs without engaging with target concepts.
- Design feedback sequences that explain the reasons for student's errors and lead students though the processes necessary for responding correctly.
- Incorporate reinforcement techniques.

Shneiderman's studies reinforce the need for direct-manipulation of visible objects of interest [9]. Following these studies, we have selected an interaction style based on direct manipulation of the visual representation of the objects and actions. This has been described previously as the interface object-action model and it is specially recommended for pupils that require a simpler and more immediate interface [10].

An important aspect in designing an interface is building an information tree. The educational contents are transmitted through an environment and a context. The environment has a graphic and conceptual representation, i.e. the metaphor. The events and their related contents are organised following a tree structure. The information tree is a way to represent the guidelines of a program both in its structural and dynamic aspects. The metaphor, the structure, and the functioning dynamic make a coherent universe both from the graphical and conceptual points of view.

Our universe is composed of objects that are representations of concepts. The implementation of the relations among objects and concepts has been carried out through object indexing. Each index represents the belonging of each object to a particular subsets of the universe.

One of the requirements is to represent the object in its more common framework. It is important to choose for each object the more adequate set of media. In addition, we present each object together with a set of words that define the concept (spoken and written).

An important source of stimuli, comes from the inclusion of animated agents. The role of these elements in the presentation is to interact and co-operate with the pupil in order to make more natural the way in that this interaction is performed. The animated agents present the problem, they drive the execution of the presentation and they answer in a positive or negative manner according to the obtained results(Fig. 1). A very important benefit of using this kind of animated agents is that the motivation of the pupil is enhanced.

Other important requirement is to keep the attention of the student (Fig. 2). In order to get this, we have to provide the system with a rich variety of alternatives (different stimuli) for describing each concept. This allows the system to present the same concept in many ways. In other words, it is important to avoid the tedious repetition of presentation patterns because this goes against the attention and motivation of the student.

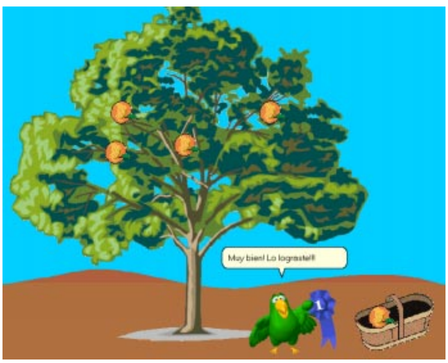

Fig. 1. Positive stimulus	**Fig. 2.** To keep the attention of the child

3.2.2. Dynamics

The dynamic of the presentation is specified in a stage called construction of the presentation. This stage takes into consideration the characteristics and preferences of the user. Therefore, given a concept to teach, the information about the student and the learning goals, the presentation is composed identifying which media and styles are the most adequate to communicate the concept.

We have systematised the construction of the presentation using a methodology based in the formation of a sentence composed by a subject and a set of complements. The subject is the object under study, and the complements are the external elements related with the object such as the scenario where the object has been embedded or other objects in the proximity. The complexity of the task for the pupil can be controlled by changing these complements. This sentence is built dynamically according to the known specific features of the child and the learning goals. The particular object determines the media (static image, sound, video or animation).

In the dynamic construction of our presentation is necessary to define our primitives (concepts=objects=stimuli) and the relations among them. We have defined different categories in the universe of object that are going to be used to represent the concepts. A category of objects is used to represent a thematic area and all the objects belonging to this category are related with this area. It is necessary to determine which objects are going to be used to teach a concept. It is also necessary to identify the category where these objects are included and the relations with other categories. As a final stage, the system determines the relations between the different elements of the category, the scenario where the object under study is going to be embedded (this selection is carried out taking into account the desired complexity for the task) and the complements that are going to be presented in the proximity of our object under study. Therefore, an object in a presentation belongs to one of the following classes: study object, scenario and object's complements.

Other important feature of this interface is the application of a random mechanism. This mechanism is used to present random positive and negative reinforcement, and combination of different media to represent concepts.

3.3 Reaching the Proposed Pedagogical Objectives.

Designing an instructional system consists of sorting sequences of instructions in such a way that they lead to reach a specific learning goal.

The learning goals are defined for a particular student and a sequence of actions to reach these goals is considered. This is a search in a space of states, where only the sequences that leads to reach the proposed goal can be considered.

One of the subsystems drives the sequence of instructions and operates with the interface to guide the student through the set of tasks that are necessary to reach the learning goal.

Following the Gagné's theory [11] we have used in the teaching process the following sequence of events:

Event 1: Calling the attention of the pupil.
Event 2: Giving some information to the student about the learning goals.
Event 3: Giving some information to the student about previously learned concepts.
Event 4: Presenting different stimuli. (images, animations, sounds, video).
Event 5: Guided learning.
Event 6: Reporting the result of the activity.
Event 7: Evaluation of the performance.

These events will be carried out according to the state of the pupil determined by his profile and by his record. Both the sequence of activities and the presentation of contents will vary depending on this state. For example, with a pupil who has as a characteristic of his personality the fear to fail, we intensify the self-confidence using tasks that he has previously made successfully, we lower the difficulty level and we teach him again the concept in which he failed. We increase the maximum interaction waiting time and we present fast tasks. If he is hyperactive, we use short steps, and fast and effective tasks. We will also use this strategy to present a new concept, as a motivating introductory task and every time we want to motivate. If he fails, we stop teaching this concept, we give examples and we explain step by step how to solve it. Then we teach him again but changing the way to do it: we use other activities, or the same activity but changing the organisation and the stimulus. If he fails again, it can be due to problems of previous learning, concepts that he has not acquired properly, and therefore, the application present activities which allow the system to consolidate those concepts.

If he fails another time, the process is stopped because it can cause frustration in the child. It may happen that the difficulty and the handicap are the barriers that make impossible to learn the concept.

Adapting the curriculum to make it suitable for this kind of children means sequencing: divide the objectives in smaller sub-objectives. The learning objective can be still reached, but in smaller steps, although many times this means eliminating contents.

4- Conclusions

In this paper we have described a methodology to construct an adaptable presentation that changes its contents according to the particular needs of each handicapped student (pupils with learning difficulties). The KADS methodology has been chosen for designing the KBS part of the ITS. This had given us a structured way to represent the acquired knowledge.

The structure of the Universe of objects that are going to take part in the presentation has been defined in a compatible way with the guidelines given by the knowledge and functioning patterns included in the KBS. This process has been included in a general methodology, allowing us to work from simpler to more complex ITSs. We have followed the recommendations of previous works in the area for deciding about specific components of the interface, for instance the interaction style. Additional elements as using agents to keep the attention of the children on the proposed task have been included.

With this methodology, we have implemented several prototypes that have been used in a preliminary experimental stage. Specific modules have been tested in the *Acaman Special School* and in the *Asociación de Trisómicos 21* both of them in Tenerife. The presented multimedia interface has had a good acceptation both by children and teachers. Children see the activities presented by the system as a game, and the commentaries of the teachers were positive especially in relation with the possibility of designing their own multimedia materials.

This first stage of the research has provided us with new results and observations that are being used to refine our conceptual models. Especially we hope to improve two models: the student model and the didactic model.

One of the most important problems that has arose is the extraction of the pedagogic knowledge. This type of knowledge takes a fundamental role in deciding the strategies that this interface is going to follow: the pedagogic, didactic and student models can only be extracted using this knowledge. A promising way to refine these important models is through experimentation with the basic prototypes. From this experimentation, we have found that there are other important characteristics that should be included in the student model. For this reason, we are researching the importance of additional features in the basic sets "profile" and "record" that represent the student model.

Nowadays, we are designing software applications that help in the acquisition of the expert knowledge. We have considered two simultaneous goals. a) To make easier for teachers, the construction of their own learning activities. b) To register what activities the teacher carries out in order to explain a particular concept to a specific student, what goals he considers, what kind of media he utilises, and finally, what positive and negative reinforcements he applies after the result of the activity has been obtained. We have found a bigger difficulty in representing the didactic model, but once the mentioned tools work properly the task to find an adjusted didactic model will be facilitated.

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