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COMPUTER ASSISTED MEDIATION FOR BLIND CHILDREN*

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Abstract—A model for computer assisted mediation and its application to the field of special education for blind children is presented. The model consists of five elements: the domain model, the student model, the pedagogical model, and the dynamic and static projection of learning. The system, based on stored expert knowledge, guides the child in what he or she is able to do and able to learn. Success is dynamically evaluated in order to constantly adjust the teaching methodology. The system contrasts with previous work by giving the teacher a major role, so that the expert system, the child and the educator form a conceptual triangle. © 1997 Elsevier Science Ltd

1. INTRODUCTION

The evaluation and analysis of students is a main activity in the educational planning process, with the goal of developing and updating the instructional activities [1]. This involves discovering and identifying *what* to teach, *how* to do it, and the *level of expected learning*, in accordance with the pupil's characteristics.

The belief that pedagogic objectives are more efficiently achieved when adapting the instruction process to each student's requirements is not new. Vygotsky [2] proposed that effective teaching occurs within the *Zone of Proximal Development* (ZPD), which measures the learning potential by assessing the capacity of solving a problem both independently and with the support of a guide. An individualized educational program should be able to dynamically determine the students ZPD and continuously adjust the mediation mechanism (materials, methodologies and teaching heuristics), thereby avoiding to teach what is already known and what is beyond the child's capacity.

There is no agreement, however, on how this can be achieved. Regian and Shute [3] mention three alternative views from traditional teaching. Mastery Learning is based on the assumption that the key aspect differentiating students is their learning ability. It is therefore expected that eventually all students reach the same level of performance, even if their abilities are not the same. A second view of personalized teaching is the interaction between aptitude and treatment, which relates the effectiveness of different approaches to measurable attributes of the child. Attempts are made to decrease individual differences in knowledge, abilities, personality, etc. by compensatory activities. A third proposition is the incorporation of Artificial Intelligence into instruction. ITS (*Intelligent Tutoring System*, Wenger, 1987; *Exceptional Children*, 1994) is an educational software based on an expert system that stores expert educational knowledge. Such a system dynamically evaluates a child and takes instructional actions depending to his or her requirements. The main use of ITS has been to develop instructional programs which dynamically adjust to the child's requirements, and to create expert consulting systems that evaluate the child, provide a diagnosis, and suggest a strategy to the teacher.

A main advantage of this last approach is that it is free of the problems that other proposals use to have [4]. A first difficulty frequently encountered is the time programs consume for preparing material and evaluations. Another problem is the inadequate use teachers make of the data obtained from assessment to modify and adapt the instructional program of each child. Both difficulties can be avoided with the help of ITS.

Section 2 describes a model for an extended ITS. The first extension is the integration of the most common uses of ITS, i.e. the dynamical adjustment of activities and the support given to the teacher via on-line suggestions. The system not only adapts to the child's ZPD, selecting tasks and instructions according to his or her current learning potential, but also to the teacher's ZPD by providing expert

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educational knowledge according to the child's state, thereby enhancing the teacher's teaching potential. Marston *et al.* [5] mention the cost in time and resources required to adequately prepare teachers to master a new technology. These simultaneous activities are therefore strongly desired. The teacher is relieved from mastering completely the tool, thereby reducing demands on his instructional activity. At the same time, her or his abilities are enhanced by showing new teaching strategies and heuristics not necessarily restricted to the ITS domain.

A second advantage over standard ITS is the possibility of storing exhaustive statistical information regarding the child's activities. This is used as basic element for exploring how children learn in a given domain and how they react to different activities. An implementation of a prototype of a multimedia ITS system that incorporates our conceptualization is shown in Section 3. The prototype supports the teaching of reading/writing of blind children. In the final section, some conclusions concerning further developments of ITS are drawn.

2. A MODEL FOR COMPUTER ASSISTED MEDIATION

Traditional ITS are based on three models that interact dynamically: the domain model, the student model, and the pedagogic model [6], [7].

(a) Domain Model. The knowledge base stores objects and rules that represent the learning domain. For instance, when teaching problem solving, the expert knowledge consists of a set of problems and strategies for solving them.
(b) Student Model. The relevant characteristics of the student, e.g. level of understanding, frequent errors, speed of learning, etc. are represented. This dynamic model changes with the student's interventions.
(c) Pedagogical Model. This model is the conceptualization of the expert teacher in the domain. The stored pedagogical knowledge covers contents of the problems, methodology, dynamic usage of information, strategies to motivate students, sequencing of instructions, error recovery and understanding, etc. This model is obtained through a knowledge acquisition process where teachers with a large amount of experience in the field retrieve their experience through interviews, questionnaires and other data collection methods.

The present model introduces two new complementary elements: the dynamic and the static projection of learning.

(d) Dynamic Projection of Learning. Mediation can be either automatic, i.e. decisions are taken by the pedagogic model, or manual, i.e. the expert system inferences are used as a guide by the human instructor. In the first approach the human mediator is relieved completely from the teaching process, in the second he/she manages the process, being the expert system just a consultant. We prefer the second approach, because it furnishes knowledge transfer from the software to the instructor.

    For an effective knowledge transfer to the teacher according to his or her ZPD, the instructional advice has to be clear, communicated in an effective way, and connected explicitly with the corresponding educational foundation. The display of the decisions taken by the expert system is a dynamic projection of learning since it is an image of the child's state and learning history, with an instructional suggestion based on this picture. From a cognitive approach, the objective of the Dynamic Projection of Learning is to inform the teacher about the reasons underlying the child's mistakes. The educator has to conceive the error as an open door full of information on how to teach, understanding its origin [8]. It is this interpretation, plus the expert pedagogic knowledge base, which we intend to mediate to the teacher.
(e) Static Projection of Learning. Computerized mediation allows data from the teaching process to be obtained and we can then analyze student behavior over time to choose individualized teaching activities. It allows us to validate, modify, and enhance the expert pedagogic knowledge stored in the system. For this purpose, the system provides the expert user with detailed data concerning the interactions, e.g. strategies used and their effectiveness, results obtained, etc. This output should be designed especially for educational psychologists and expert teachers, so that they can use the information to assess the expert knowledge contained in the program. Though expert teachers are most important during the program development, it is convenient that they are present during its

assessment, so they can suggest modifications according to the information provided by the Static Projection of Learning.

The requirements for a Computer Assisted Mediation System, as the one described, are:

(a) To offer activities and games adequate for the instructional purpose. They have to be designed considering the state of the art in instructional science to select those activities that encourage the learning process in the child. In addition, they have to be game-like and motivating, especially when young children are taught.
(b) Being able to evaluate the child in the domain-relevant dimensions with adequate statistical parameters. Monitoring has to occur throughout the child's interaction with the system to dynamically update the instructional process and to obtain a complete record of it for later analysis.
(c) To have expert knowledge on how to use the data obtained from assessment in order to adapt to the child's current capacities and learning potential.
(d) The system has to be auto regulated, i.e. the system has to dynamically change its state adapting itself to the child's learning requirements. This may occur automatically, i.e. the system takes a teaching decision and implements it, or via mediator, i.e. the systems suggests to the teacher an instruction. The last option allows to supplement the instructor's knowledge with new one, giving him or her the possibility to learn different strategies while teaching in an appropriate way. Furthermore, an experienced teacher can validate the system's behavior.
(e) The system has to register and store the relevant data from the interaction to analyze individual and group behavior. This allows to validate the knowledge and infer new rules from the previous experiences.

Three kinds of users can be distinguished in the previously defined interaction model:

1. The child, to whom the activities are directed. The aim is to give rise to effective learning in the child and to evaluate him/her by dynamic assessment in order to make use of the child's learning potential.
2. The instructor to whom the guiding advice of the teaching process is directed. The teacher's activities are supported by data obtained in the learning process. Additionally, he or she can acquire additional knowledge from the suggestions given by the system.
3. The psychologist or expert teacher, who analyzes the processed data to validate and enhance the stored knowledge.

3. IMPLEMENTATION OF A PROTOTYPE

A prototype of a mediation system was implemented in the domain of recognition and reproduction of Braille signs for blind children. This topic was selected since the software "Canta Letras" [9] for teaching reading and writing to blind children was already available. In the original system auto regulation was not implemented, so its application relied on the teacher's ability of mastering the system. Experience in using "Canta Letras" showed that teachers made no use of the interaction records, i.e. feedback from the system was not used to modify teaching methods [10]. Due to these problems, it was decided to add a mediation module to the system.

The implementation of mediation in "Canta Letras" has the following architecture:

(a) Domain Model. The learning goal supported by "Canta Letras" is to recognize and reproduce the 28 letters of the alphabet plus the 10 Braille digits. The child has to learn the correspondence between auditory sign and letter. Games for children aged between 4 to 6 years were used.

Example 1. The game Show You Letters: When the child selects a letter from the keyboard the phoneme corresponding to the letter (e.g. "i"), a word that begins with the letter (e.g. "Indian"), and a sound related to the word (e.g. an Indian song) are presented via audio. The teacher can activate the letters he wants to work with; when a letter not belonging to the set is chosen, the system says it is "sleeping". When the child selects a key not representing letter, a different characteristic sound is given.

Example 2. The game Hidden Letters: The machine asks the child to find a letter on the keyboard. When the child finds it, he/she is congratulated; otherwise, a spatial clue is given via audio ("to the right", "to the left", "upwards", "downwards").

Both games speak to the student with a digitized child's voice, since there is no other means of communicating with a (blind) child that can not read. The child responds through the keyboard, where the Braille signs have been attached to the corresponding keys.

(b) Students Model. The system suggestions are triggered by the child's behavior, measured by statistical parameters that are updated throughout the interaction. For instance, to know whether the child discriminates keys with and without Braille signs attached, the ratio of the number of Braille keys and the total number of keys pressed is calculated. Three types of statistical parameters are defined: Scalars (direct measures from the process), Lists (sets of elements relevant to identify), and Vectors (results from direct measurements for each of the activities and sub-activities).

(c) Pedagogic Model. Once several expert teachers in the field of blind children education were interviewed, and after reviewing the literature concerning reading instruction in sighted and blind children, a pedagogic model was constructed. First, a set of rules was inferred from what teachers said about their daily practice. Then, these rules were implemented to interpret the statistical parameters of the student model, to infer the adequate intervention in each case. Two sets of rules are distinguished. One of them responds to the child activities. For example, a high key hit rate can be interpreted as impulsive behavior, in which case the mediator is advised a strategy to encourage self control in the child. A second set of rules guides the instruction process. For instance, to determine the adequate sequence of teaching individual signs to the children, the systems computes the number of new signs that are necessary to succeed within a particular session.

Forward Chaining [11], where rules are triggered by the observable changes, was used as the inference process. Figure 1 shows graphically a knowledge base where rhomboids represent the conditions that trigger the rules, which are represented as squares. Since there are many independent statistical parameters defined, it is possible to trigger more than one rule simultaneously. Since only one rule can be followed at a given time, it is necessary to solve this

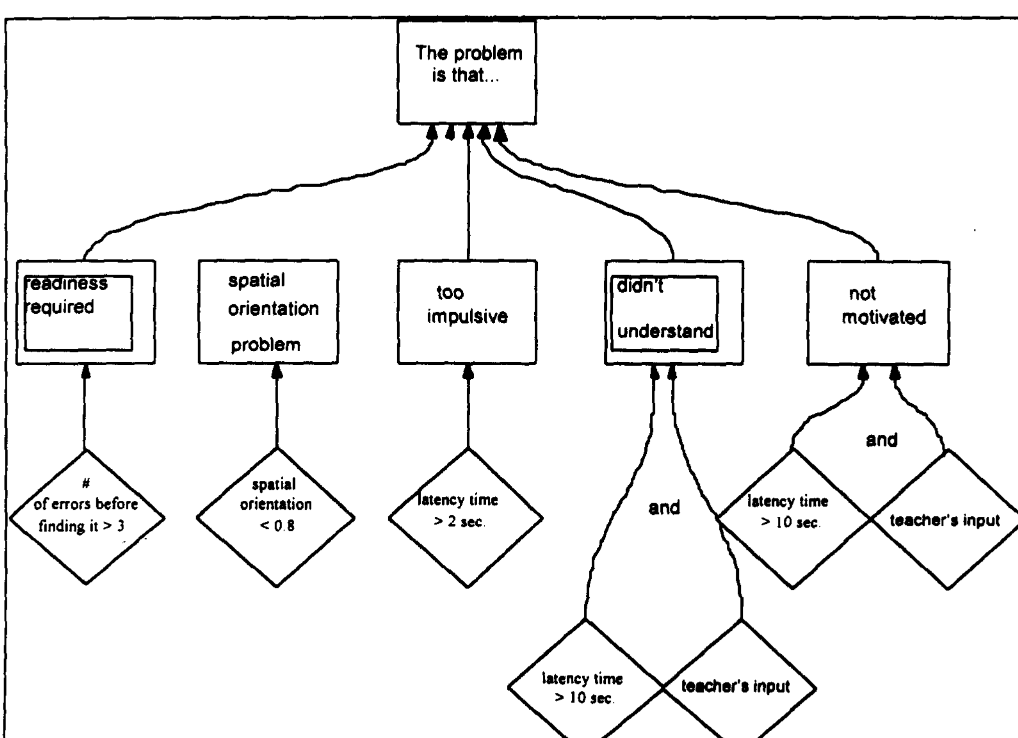

Fig. 1. Pedagogic knowledge representation model.

indeterminacy through the teachers intervention, realized as an input to the system. For instance, when the child is not pressing a key, or at a very slow rate, the teacher is asked if the child is motivated, i.e. if he or she shows any interest in the activity. When the teacher's answer is yes, the systems concludes that the child's behavior is due to a lack of understanding of the game and suggests repeating the instructions. When, on the other hand, the teacher answers that the child looks not interested, the systems suggests moving to another game.

(d) Dynamic Projection of Learning. The instructional suggestions made to the teacher have two parts: the relevant data for the decision, e.g. *the child still does not know this letter*, and suggestions for the activity, e.g. *choose three known letters plus three more*. This allows not only to guide the educator in the adaptation of the educational process to the student, but also enables the teacher to internalize the rules stored in the system for future application.

Child and teacher interaction occur in independent media (Fig. 2). The screen is divided in one half with brilliant colors and big pictures (for visually handicapped children having yet some visual capacity), while the teachers half shows small letters and dark colors. The child communicates via keyboard, while the teacher does it via mouse, selecting the corresponding keys on his/her side of the screen. Interference between both users is minimized in this way even though both are using the same machine.

(e) Static Projection of Learning. A huge amount of statistical data can be recorded, aggregated in three levels. A first level covers a generalized view of all children's behavior, or a subgroup of them (Fig. 3). In the game "Hidden Letters", the variables shown for each of the sessions (*N*) are: the number of known signs, the response latency, spatial orientation, key discrimination, and the number of trials needed for one letter.

A second level provides detailed information on each variable of Level 1. For example, in "Hidden Letters", for the recognition of signs it is possible to know which are the signs the child discerns, how much it took him or her to learn, and which was the order in learning them. Figure 4 shows the proportions of correct answers for each measured letter (N/M = not measured).

The third and last level stores all system variables for all the sessions in a data base. This allows "data mining", i.e. to do a visual or computerized analysis to infer new rules, or simply validate

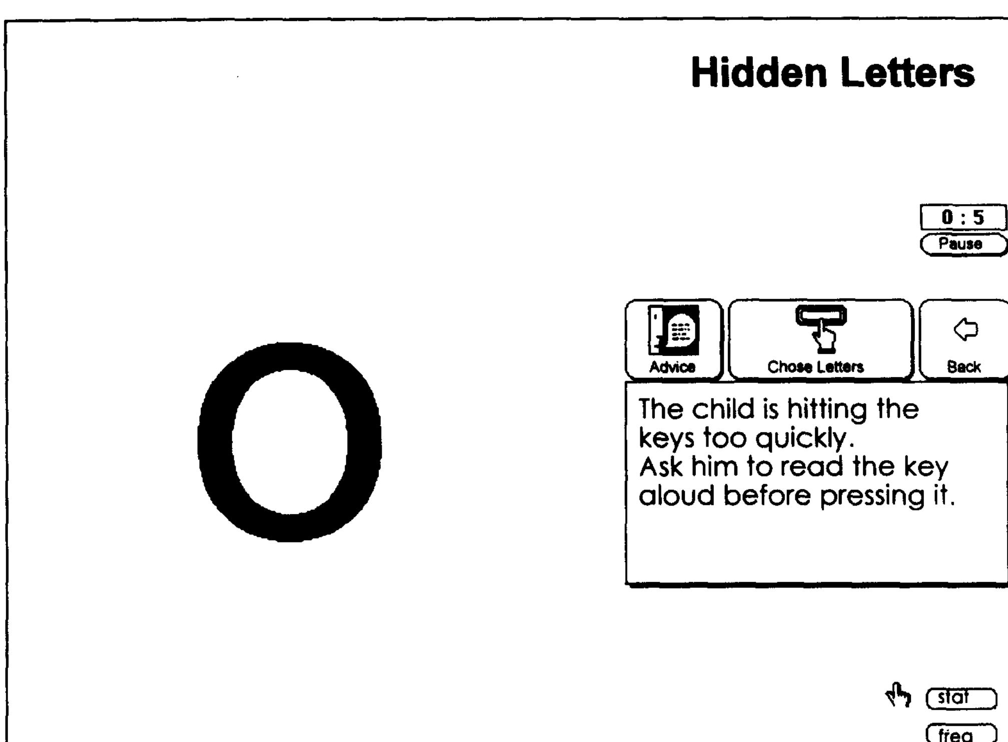

Fig. 2. Screen of "Hidden Letters".

Variable / Session	1	2	3	4	...	...	...	N	
									not motivated
			x						
				x	x				
response latency time	x	x							impulsive
									fulfilled
				x	x				
spatial orientation	x	x	x						failed
									28
				x	x				
			x						
keys discrimination	x	x							0

Fig. 3. Static Projection of Learning. Level 1.

the old ones. Additionally, it is possible to register all teacher's activities to study which behaviors are more effective in order to acquire new knowledge by using the tool.

4. CONCLUSIONS

The proposed system, classified as an ITS presents two advances in the area of expert systems applied to education. These can be synthesized as follows:

1. Simultaneous intervention to teacher and student. The system not only works within the ZPD of the student, i.e. the capacity of the child to solve some problems with the software which could not be solved otherwise, but also within the instructor's ZPD, i.e. the difference of his or her educational skills with or without the system. While the child is supplied with activities, the teacher receives information on the child's performance as well as instructional suggestions. The benefits over traditional ITS are the reduction in teacher training costs and the fact that in each session both the child and the teacher are trained by the system, adapted to their respective requirements.
2. Automatic generation of a report of the instructional interaction. Most reports of experiences with educational software evaluate the contents or the technical properties, but do not analyze the obtained instructional results [12]. In the proposed model, the static projection of learning allows to evaluate the whole educational process. It can therefore be also used as a tool to validate the implemented heuristics.

To successfully make use of our conceptual model, a system must be able to:

(a) Model the student's and instructor's ZPD. The child's ZPD is modeled as the set of activities the child can solve, regulating the level of intervention of the guide and/or the system. Regarding the conceptualization of the teacher's ZPD and his capacity as a mediator, a record of his or her interventions with and without the system's advice has to be taken, in order to measure the distance of the teacher's knowledge from the expert knowledge. The instructor's behavior throughout the process can be evaluated in order to measure the system's impact in the teacher's tutoring.

(b) Consider not only the data of one activity, but the whole child's history in the corresponding domain, when giving an instructional intervention or advice. In Dynamic Assessment [13, 14] the

Session	1	2	N
[illegible]	0,2	0,8	1
[illegible]	0,1	N/M	1
[illegible]			
[illegible]	N/M	N/M	0,3

Fig. 4. Static Projection of Learning. Level 2: recognition of signs.

test instruments are almost the same as those used in the child's instruction. During the examination process the instructor helps the child to acquire, at least temporarily, some cognitive tools to solve new problems. This allows to evaluate which tasks can be learned by the child with an effective mediation, i.e. to measure the child's learning potential. Teaching can therefore be seen as assessment and vice versa. When this fact is considered, it is possible to simultaneously teach and evaluate obtaining a complete diagnostic process.

Concerning the implementation of this model in the field of reading instruction for blind children, progress is made in two respects:

(a) The system encourages the use of a standard computer by visually handicapped children, who will in future be able to use these technologies as an important means of communication. The learning of basic skills of using a keyboard gives the child access to this technology during the first school years.
(b) Teaching blind and visually handicapped students usually requires the presence of highly trained teachers, which are not always available in those centers which happen to have a visually handicapped student. In these cases, the program allows the center to provide the student with adequate specialized instruction, even when lacking qualified special education staff.

The software has, nevertheless, the weakness that it cannot be used independently by blind teachers, because of its graphic interface and the use of the mouse. This issue will have to be addressed in future versions of the software, since frequently the education of visually handicapped children is performed by visually handicapped teachers. Access through the keyboard is a feasible alternative, which is now being widely used in the development of computer applications for visually handicapped people.

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