Interactive Educational Games for Autistic Children with Agent-Based System

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Abstract. This article addresses design issues that are relevant in the Autism project which aims at developing a computer games, for diagnosis and training of the children with autism and accompanying mental disorders. This approach is put in the broader context of interactive environments, which computer games are a special case. The characteristic of our approach is that it has the capability of user adaptation. The user adaptation is based on the model they maintain the observation of user interactions, the knowledge of therapists and the case-based reasoning paradigm.

1 Introduction

The characteristics of infantile autism are the severe disorder of the communication functions, the cohabitation of cognitive deficiencies and performances focalized on specific domains, and the avoidance of change, all of which often block educational attempts in a repetitive behavioural sameness.

The computer tool enables to focus the child's attention on a specific task, which also allows parameters and possible to reproduce to infinity, but which may also evolve following a model adjusted to the age, competencies and type of pathology of each child.

Computer games applied to autistic children must be sufficiently flexible to adapt to the specifices of each child and integrate the personal data of his/her own world and the beliefs attached. On the screen we therefore privilege the stimulus, which represents an object that has previously drawn the attention of the child and which carries a satisfying emotional significance. This object will then undergo physical transformations (for example in the speed of movement) which will allow the setting-up of basic categories (rough-weak, fast-slow, big-small) which the child may even mime or reproduce as weIl within other educational or re-educational situations.

Our research is to promote the set-up of computer games in order to :

- Complete the more traditional psychological and educational assessment procedures by offering software capable of appreciating attention spans and of

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understanding the adaptive strategies of the child to the stimuli presented.(to observe whether the action produced is linked to an understanding between cause and effect).
- Allow to modify the child's beliefs by offering virtual images which interreact with the child, but at the same time taking into account his autistic specificities, such as by slowing down their movement, so that the child can extract a general pattern, usable in the re-education of emotional, language, perceptual and cognitive problems.
- Favor the need for reassuring sameness of autistic children, while setting-up procedures for introducing the "un-sameness", so avoiding the isolation of perpetual repetition.
- Develop the encoding of time through the subordination of the software to a narrative role which specifically identifies the child within a chronology interacting with his/her environment.

We present the implementation of a prototype architecture we used in a recent field trial. The architecture draws on the educational games dedicated to children with autism. This paper is organized as follows. The next section presents and discusses a variety of systems dedicated to autistic persons. Section 3 gives a brief *Autism Project* description. Section 4 describes the principle of our architecture. The decision process is detailed in section 5. Section 6 presents the implementation. Finally, section 7 presents the conclusion and perspectives.

2 Related Works

Several interactive environments as learning and teaching tools for the rehabilitation of children with autism have been developed (see for example [7] [8] [16] [18]). In this context a variety of different robotic and software systems can successfully interact with humans.

Among interesting interactive robotic systems are the KISMET platform [4] and the ROBOTA dolls [2] [3]. KISMET is a humanoid face that can generate expressive social interactions with human 'caretakers'. Such 'meaningful' interactions can be regarded as a tool for development of social relationships between a robot and a human. The ROBOTA dolls are humanoid robots developed as interactive toys for children and are used as research platforms in order to study how a human can teach a robot, using imitation, speech and gestures. Increasingly, robotic platforms are developed as interactive playmates for children [5] [16]. Besides commercial purposes (see Sony's Aibo robot), such interactive robotic systems can potentially be utilised as learning environments and in rehabilitation applications, as studied in the AURORA project [1].

Other systems [8] [17] use virtual environment for understanding the emotional expressions of children with autism. The emotional expressions are used in order to allow systems to enhance or subdue signals, and indeed introduce new signals to support interaction with the children. [11] is interested in the design of human-computer interfaces for children with autism.

However, to our knowledge, there is no model that proposes an adaptive approach that takes into account the experts directives in an educational context. The modeling of this approach requires modeling of the knowledge of experts, the users profile and the dynamics of their interactions.

This paper proposes an intercative model between users (children with autism) and system taking account into the expert's directives. It offers a model that analyzes children behavior from their actions. The model is based on multi-agent systems which, as will be shown in this paper, allows the simultaneous study of:

- Selection and adaptation a individualized activities plan defined by the expert. The activities plan is a sequence of educational games (called *Protocol*) dedicated to children with autism.
- Observation of the user's actions in order to ensure a real-time interactivity between user and activities of protocol.

3 Brief Project Description

Given the centrality of the interaction in a multi-agent systems, our investigations thus far have concentrated on the ability of agents to interact with children with autism in order to rehabilitate them. This is important since interaction is central on multi-agent technology, and since the understanding of their emotional expressions is important to assure a concordance of presented games and child's behavior. To facilitate such an investigation, we have defined:

- **Game** is characterized by: *statical decor*, *objets* (pictogram, music, picture...) and *functioning rules*. It has configuration parameters and the objectives to be reached.
- **Activity** is an instance of a game (with a particular configuration and, qualified and quantified objectives).
- **Protocol** is an activities sequence, given in order to make it possible to the user to reach complex objectives.
- **Directive** characterizes a system state (in particular its evolution related to the user behavior) and associates treatments which adapt during the activity execution.

The project that we carry out, called ***Autism Project***, is in partnership with the psychiatric service for children with autism of *Department of Child Psychiatry of La Rochelle hospital*. Our objective is to implement a software and hardware system that could help the children with autism during the rehabilitation process. It consists in establishing a multimode and multimedia dialogue between the assisted child and the system. The role of such a system is to provide to the children the personalized activities in the form of educational games. During a session, the system collects by various devices (camera, touch screen, mouse, keyboard) the child reactions, in order to understand her/his behavior and response to it, in real time, by adequate actions considering *the expert's directives*.

The directives concern rupture, avoidance, stereotyped patterns of behavior... for instance, the system may attract child's attention by posting of a familiar image, or by launching a characteristic jingle.

4 The Multi-agent Architecture

Each child is characterized by particular competences and preferences, so he requires an adapted treatment. It is impossible to generalize activities without precaution, but we have to favour adaptability of system to take into account specific deficits observed for each child. It is important to locate and interpret carefully these intrinsic behaviors, in order to help him/her to rehabilitate.

Our approach aims to bring flexibility and modularity in the individualized rehabilitation of children with autism. Accordingly, we propose a multi-agent system architecture which allows children and experts to interact with different agents, according to the activities they will carry on and the educational approach.

In order to be able to design needs, the expert makes the following actions :

- characterizes the activities i.e defines instances of games with particular configurations.
- defines some educational objectives and associates them with appropriate protocols.
- specifies the directives.
- characterizes the children's profiles.

During the session, each child is supported by three artificial agents:

User Observation Agent (UOA): It is an agent associated with the child's interface with a wide range of goals. Mainly it observes the child's actions, notifying other agents when needed and giving access to system resources. Figure 1 gives the principle of UOA mainly inspired on *the theory of affordances* [9] [10] and *the theory of Procedural Semantics* [14] [22] [23]. From its observation, UOA associates to child's actions some states words that characterize behaviors. The

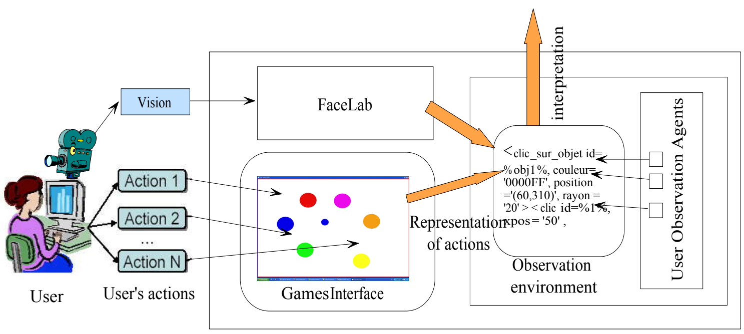

Fig. 1. User's observation mechanism

observation is based on two approaches, *Software action* and *Vision*. The first one, recovering the child's actions carried out on: mouse, touch screen, keyboard. The second one, ensured by the software/hardware system **FaceLab**, it consists in measuring the characteristics concerning the 3D representation of the face and the orientation of the gaze.

Tutor Agent (TA): A tutor agent tries to choose its strategy according to the needs and the child's profile. It can interact with UOAs and other tutor agents, access the child's profile to retrieve and adapt the protocol activities to child, retain the new experiences, and update the child's history. Tutor agents are didactic agents whose decision process is described in more detail in the next section.

Exceptions Management Agent (EMA): In order to assure an interactivity between protocols generated by TA and the child, the protocols can be modified during the training session if they are incoherent with the child's behavior. This is ensured by the Exceptions Management Agent inspired by [20]. Its role consists in identifying, indicating and treating a special cases like rupture or avoidance detected by UOA.

5 Decision Process

The selection of the most suited strategy is the result of the decision process. Several mechanisms can be used to represent this decision making process. Among these mechanisms are: Rule-Based Systems, Case-Based Reasoning Systems and Learning Classifier Systems. These mechanisms are either reactive or adaptive (see [13]).

Reactive mechanisms are based on a fixed set of rules provided by the expert before run time. The rule-based paradigm shows some drawbacks [21]: the development and maintenance of rule-based system is costly, moreover it is hard to adapt rule-based instructional planners to new domains and also to situations not foreseen in advance, e.g. children with special behaviors.

Adaptive mechanisms deal with the dynamic variations of the child behavior. Each agent builds a symbolic internal representation of child. It then uses this representation and the internal state to determine the most suited strategy.

To explore adaptive mechanisms, we propose to use a Case-Based Reasoning [15]. It is a paradigm for problem solving that has an inherent learning capability. The basic underlying principle of Case-Based Reasoning (CBR) is to solve new problems (called *Target Case*) by adapting solutions that were used to solve problems in the past. A case-based reasoner uses a *Case Memory* that stores descriptions of previously solved problems (called *Source Cases*) and their applied solutions.

The CBR process consists of seeking source cases that are similar to the target case and adapting the found solutions to fit the current situation. A case-based system learns from its experiences by storing these in new cases. In our application, a **case** is defined as follows:

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Application Context
  [descriptors sequence]
Protocol
  [activities sequence]
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The Application Context describes the situation in which the Protocol was applied and is implemented as a list of pairs [attribute, value]. In general, it contains information related to the children profile and the goals of case. The descriptors related to child profile define its preferences and knowledge e.g. [level-of-acquisition, high], [color, green]. Various goals can be expressed as Perception, Attention, Gaze... The descriptors of Application Context are used to calculate the similarity between cases and also to structure the case memory.

Once the basic structure has been presented, in this section we will show a deeper view of the Case memory organization, the Child's profile and the Reasoning process of Decision Agent.

5.1 Case Memory Organization

The organisation of the case memory has been based on the more general Schank's Dynamic Memory Model [19]. The fundamental idea is to organize various cases having similarities in the form of a more general structure called *Generalised Episode* or GE.

GEs generalise the common features of a set of cases. Each GE is composed of:

– *A Norm* is attached to each GE and contains the descriptors of the application context shared by a group formed by cases and GEs; it is represented by means of a list of pairs [attribute, value].

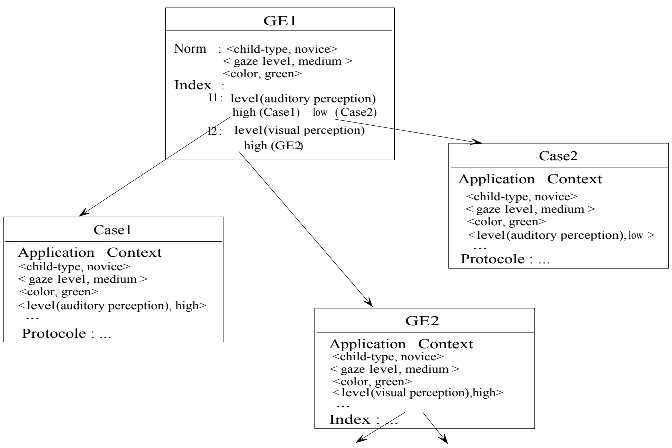

Fig. 2. Case memory organization

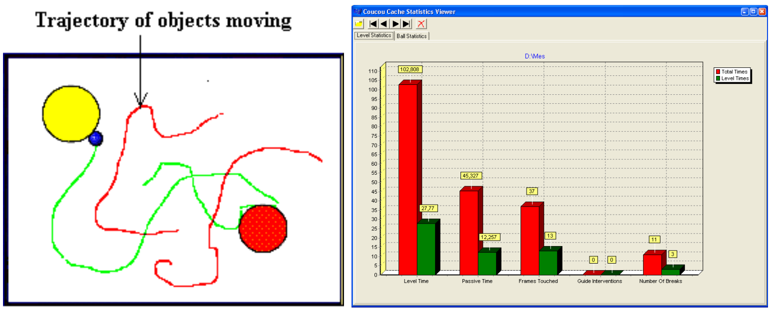

Fig. 3. Execution trace

- *The Indices* link the network elements of the memory in such a way that each GE contains a set of indices that link it with and discriminate among its descendants. Each index is related to one concrete attribute of the application context and contains a list of pairs [value, node[1]].
- *The Cases* represent a individual experiences

Thus is formed a hierarchical graph (see the example of figure 2) whose nodes are either EGs or cases. The arcs represent the links between the indices and the nodes.

5.2 Child's Profile

The child's profile has multiple functionality, used at various moments by the TA, particularly in the reasoning process (see section 5.3). It also involves in the interpretation of the child's actions by UOA. Several types of information concerning the child are present:

- General information
- Domain knowledge
- Preferences
- History

The general information concerns the child identity such as name, identifier of the child group; child's preferences and domain knowledge give a description of the child's profile similar to the case description. Thus, this information is represented by means of a list of pairs [attribute, value].

The history is a diary of activities suggested by system and the results carried out by child. The history allows tracking of the evolution of the child; it is also at the origin of many rules of TA. In order to give an interest of the history, the expert can visualize *the Execution Trace*. It concerns the child-activities interaction. Visualization can be in two forms: animation or statistics (see figure 3). The execution trace allows the expert to draw conclusions and adapt the defined protocols. He can also modify the directives, resources or functioning rules.

[1] Node of case or GE (see figure 2).

5.3 Reasoning Process

Tutor Agent uses the Case-Based Reasoning [15] to generate protocols by retrieving similar cases and adapting them to the current situation. We have listed three phases for reasoning process: Retrieving, Reuse and Learning.

During the *Retrieve* phase the agent obtains a set of protocols with a high level of similarity to the current situation of target case. The similarity is measured in terms of the relevant attributes that specify the application context. This task can be considered as the search of the most appropriate case through the case memory. We have used the matching method based on *the nearest neighbour matching* of REMIND [6] that calculates the similarity among cases by using a numeric function.

The similarity function ϕ is defined as the sum of the similarity measures values of each attribute in the application context of each case, multiplied by the importance of the attribute; this value is divided by the sum of the weights in order to normalise the value. The weights estimate the degree of importance of the attributes.

$$\phi(C_1, C_2) = \frac{\sum_{i=1}^{n} w_i * \varphi(v_i^1, v_i^2)}{\sum_{i=1}^{n} w_i} \quad (1)$$

Formula 1 shows the similarity function where:

- C_1, C_2 are cases defined by a set of descriptors d_i ($i \in [1..n]$) of Application Context.
- w_i is the importance of the attribute of the descriptor d_i.
- $\varphi(v_i^1, v_i^2)$ is similarity function for two primitive values v_i^1 and v_i^2 are the values for the attribute of d_i in the compared cases.

The similarity function is also defined between the application context and a GE in the Retrieve phase, in this situation the function is restricted to the attributes included in the GE norm. Therefore, the selection criterion is based on a comparison between the result of the similarity matching formula and a heuristically established threshold.

During the *Reuse* phase the decision agent combines and adapts the retrieved cases to form a protocol suitable for the current situation of target case. The adaptation of the retrieved cases to the description of target case is a knowledge-intensive task and therefore, needs a different treatment for each experience. In order to have a generic technique, two types of adaptation are identified:

- *The global adaptation* consists in replacing sub-protocols of candidates cases, selected in the Retrieve phase, by other protocols more adapted.
- *The local adaptation* consists in regulating of the activities configuration of protocol of candidat case to the target case description.

During the *Learning* phase the agent evaluates each protocol by observing the outcome of the session. The evaluation is carried out along two dimensions: *educational* and *computational*.

The relevant data of educational dimension concern just the Child Profile. Basically, the Agent revises the changes in the attributes that represent the preferences and knowledge of the child. In addition, we think that the agent's beliefs about the child should be supplemented with some feedback from the expert. Therefore, the agent interacts with the expert after each session to gather directly the beliefs of the expert about the whole session as well as her/his own knowledge of the different activities played during the session.

The objective of the evaluation along the computational dimension is to assess the goodness of each case as the basis to create the new source case.

6 Implementation

The proposed model was implemented with the platform DIMA [12]. DIMA provides a library of JAVA classes (Agent Classes and Agent Component classes) that have been used to build the various agents. In the first step, we have developed agents that ensure the user observation, reasoning process and exceptions treatment.

In the second step, we have developed an interface that allows the expert to define the activities, the cases, the directives and the distances between the various values of the attributes of each descriptor. This information as well as the child's profile are stored in a data server.

Figure 4 illustrates our example. Firstly, the user connects to the server, his profile will be loaded. The user is requested to specify the goals which wants to reach. Once this information has been entered, a target case is created. The target case is transmitted by a message to the server. The message is received by the decision agent. The role of this agent is to generate a adapted protocol to the current situation of the target case by using CBR.

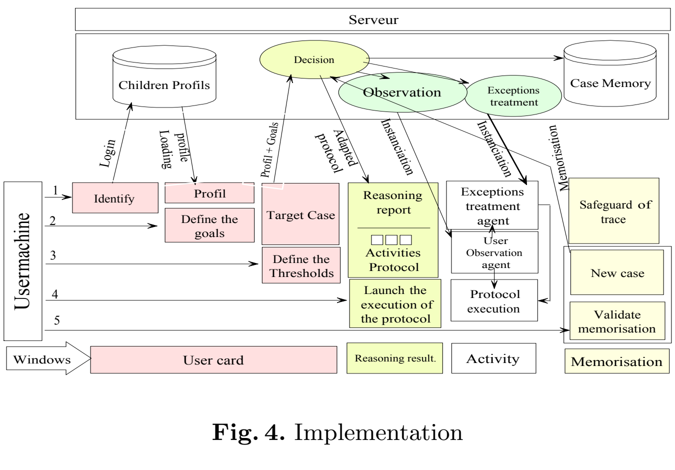

Fig. 4. Implementation

During the session the UOA and EMA assist the user. For each exception detected on the level of child's behavior by UOA, the EMA adapt the protocol by taking into account of the expert's directive.

7 Conclusion

This paper presents an architecture of interactive educational games. Our approach is applied to rehabilitation of children with autism. The application reflects significant characteristics of user-adapted interactions according to the perceived behavior. Moreover, an model was introduced. The model represents the child's profile, the expert's directives and the dynamics of their interactions.

The paper illustrated first the different robotic and software systems that exist for rehabilitation of children with autism. We propose to use agent-based systems in an educational way. The agents provide the capacity to interact with humans. It showed the observation and analyze of child's behavior in order to adapt the activities execution.

Experiments with our model have been presented. The obtained results by simulation are interesting and promising. However, more experiments are needed to validate the proposed models and architecture. Moreover, a validation of the system by experts are in current experimentation in the service of psychiatric of *La Rochelle* hospital. Future works include the dynamic generation of child's profile and the design of an agent that can request the proof verification in order to ensure the protocols coherence.

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