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A Proposed Framework of an Interactive Semi-Virtual Environment for Enhanced Education of Children with Autism Spectrum Disorders

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Abstract

Education of people with special needs has recently been considered as a key element in the field of medical education. Recent development in the area of information and communication technologies may enable development of collaborative interactive environments which facilitate early stage education and provide specialists with robust tools indicating the person's autism spectrum disorder level. Towards the goal of establishing an enhanced learning environment for children with autism this paper attempts to provide a framework of a semi-controlled real-world environment used for the daily education of an autistic person according to the scenarios selected by the specialists. The proposed framework employs both real-world objects and virtual environments equipped with humanoids able to provide emotional feedback and to demonstrate empathy. Potential examples and usage scenarios for such environments are also described.

1. Introduction

Recent advances in computer based educative methods for people with special needs led to significant changes in the way specialists and educators face the daily impairments posed by abnormal behaviors [1]. A common type of such deficit is autism disorder, which is known to be characterized by a 'triad of impairments'[2]:

I. The primary one is the social impairment: an autistic person has difficulties in relating to other people.

II. A second one is the communication impairment: both verbal and non-verbal communication channels are hard to be understood and used by people with autism.

III. Finally, autism can produce rigidness in thinking, language and behavior.

According to [3] the common traits of autism are abnormal reaction to input stimuli, lack of human engagement and inability to generalize between environments. It is widely accepted that people with autism understand the world and human behavior in a unique manner.

Education is considered as the most proper solution for the problem of autism [4]. Early stage education might help autistic persons in coping with the "theory of mind deficit – difficulty in understanding mental states of others and ascribing them to themselves or others" [2]. Computers have been considered as a promising educational aiding tool for autistic persons. Nevertheless, the significance of computers in the educational process for people with autism was realised only recently and there has not been much progress until nowadays. Nowadays, with the advancement of Information and Communication Technologies (ICT), computer-aided learning (CAL) is considered as a key method for handling autism interventions, particularly for young children [13]. Moreover, collaborative interactive controlled environments, being virtual environment (VE) or not, have recently attracted much attention in educating persons with autistic spectrum disorders [4][5]. In such environments input stimuli can be controlled and the behaviour of the child can be monitored.

3D humanoid characters (avatars) inhabit virtual space, with varying degrees of animation and behavioral abilities. The ability to be envisaged with emotional and facial expressions is considered as a valuable avatar characteristic [6]. Recent literature reveals the importance of using emotionally expressive avatars in the educational process of autistic persons. It has been argued that the ability to show emotions and empathy through using this technology is central to ensuring the quality of tutor-learner and learner-learner interaction [7].

Acting not only as machines (objects) but also as if they were people (subjects), computers represent a considerable and valuable part of the educational techniques [3]. According to the literature, autistic persons, children in particular, enjoy interacting with computers since they are experienced as "safe" [8]. This stems from the theory that computers are not having the expectations and judgments that make social interaction problematic for autistic persons. Recent literature reveals that computer systems represent a controlled environment

with minimum or no distractions that is crucial in the education process for autistic children [9]. It has been reported that in interactions with computers, children with autism can feel certain level of control over the environment, which cannot happen when interacting with human beings [10]. Moreover, this feeling of control is independent of the type of software interface and is said to be generic to all interactions with computers.

Autistic persons demonstrate frequent behavioural alterations during educational procedure [11]. Specialists could infer a person's state by means of the educational parameters, such as the time and the way needed to complete a goal and the percentage of success. Moreover, by monitoring the behavior during a period of time may reveal important factors for the children's progress.

A main problem in the vast majority of the proposed educational processes is that in contrast to virtual environments, real world is more difficult to be understood from people with autistic spectrum disorders [12]. Real world seems to be rapid in relation to the way of their thinking. Real world's expectations and judgments seem to appear as an "unsafe" environment that makes social interaction problematic for autistic persons.

A real world environment cannot be fully controlled because of the lack to provide the same set of conditions more than one times. Besides that, by using the appropriate means (i.e. sensing elements), such an environment could provide information about actions taking place in it. So, a semi-controlled real world environment would be beneficial for the education of autistic children if it would resign some prerequisites. Moreover, it would be beneficial for the specialists helping them to understand better the persons' with autistic spectrum disorder reactions in contrast to the virtual environment.

We propose an educative architecture that it could be used not only as a tool to help autistic persons understand their surrounding environment better but also as an indicator for their level in autism spectrum disorder. Moreover, the hypothesis motivated this piece of work is that specialists and educators may extract significant conclusions about how autistic persons behave in a virtual environment in contrast to the real world. The same scenario is possible to take place both in virtual world and in real world (not simultaneously). The child's reaction in the two familiar situations will reveal conclusions on how an autistic person reacts in a scenario on virtual environment and how on a "safe" semi controlled environment. Specialists are given the opportunity to decide which environment is better for education for every single scenario for each child.

So, in the remaining of this paper, related environments and proposed tools in the field of education of children with special needs are described in section 2. The framework architecture is explained in section 3 and discussed in the last section.

2. Related Work

Several interactive environments as learning and teaching tools for the rehabilitation of children with autism have been developed. Most of them are based on computers by means of software educating platforms [13,14]. Software platforms use entertaining content in educational settings in order to present knowledge in an attractive way. By providing photos of real objects (used in daily life) or sketches of them, software platforms encourage people with autism to distinguish objects based on their size, color, type, etc. Moreover, this kind of interactive learning platform motivates the children to correlate the objects with sounds and words. For adding to the attractiveness, platforms make use of animated pictures.

Furthermore, robotic systems are included in the interactive environments [15]. Humanoid robots are 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.

Other systems use virtual environment for educating autistic children. Virtual environments have proven to be another active area of research for social interventions. Various successful software platforms with virtual environment for autistic people have been developed since the beginning of the last decade [16,17]. The most important advantage of VEs is that users can role-play in an environment designed to mimic specific social situations. Moreover, one of the most interesting options of such an educating system is the usage of emotionally expressive avatars. Current literature reveals that the avatar advances the educational process [18](Fig. 1). Educators suggest that most of the times persons with autism are able to recognize the avatar's mental and emotional state provided by facial expressions [18]. Findings in psychology and neurology suggest that emotions are important factor in decision-making, problem solving, cognition and intelligence in general. The results of a survey among educators of autistic children illustrate that not only most of the children recognize the avatars emotion but also the avatar's emotional state advances the educational process [18]. Moreover, the findings are better in case of the avatar using native voice [18]. In a controlled environment with virtual and real world objects, an avatar plays essential role in giving the instructions. Furthermore, the responses to the child's action can be provided in the form of an avatar with the appropriate emotion (happy for success and sad for failure).

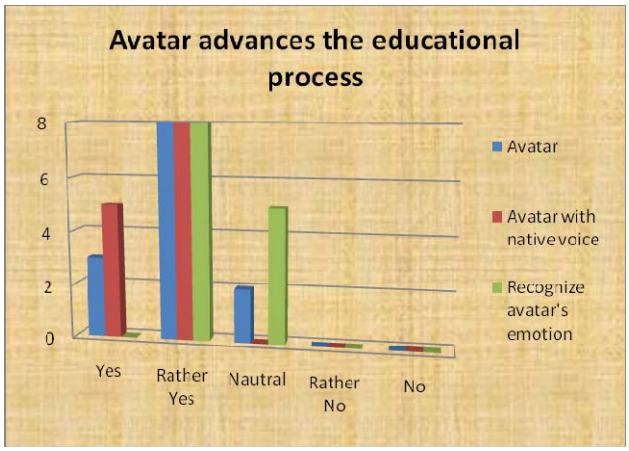

Fig. 1 Avatar advances the educational process. Persons with autism recognize avatar's emotional state.

In [19], training studies have suggested that children with autism show greater improvements in emotion recognition when programs include cartoons rather than photographs of real faces. Clinical and parental reports also state that autistic children spend long periods of time looking at cartoons [19]. Furthermore, parents and professionals often report that "autistic children know more about cartoons than about people" [19]. More experiments can take place, based on virtual environment benefits, in order for the specialists to understand this statement. By contrasting real life objects and humans with virtual ones, specialists will be advanced in a better way to compare the recorder (by a system) results. Moreover, as it is mentioned in the introduction of this paper, an autistic person has difficulties in relating to other people. This "impairment" can be meliorated by virtual human "friends" who could be more engaging in autistic people's socially desirable consequences [20].

Educators and specialists try to provide a controlled environment to the children during their normal educational process in order not to confuse the autistic children. For example, the TEACCH intervention program (Treatment and Education of Autistic and related Communication handicapped CHildren) involves a structured teaching approach and the use of visual materials [21]. TEACCH principles involve changing the behaviour and skill level of the person as well as developing an environment that matches the person's needs. TEACCH is a structured technique especially targeting to the person's visual processing strengths by organizing the environment and providing a visual conduct to supply information about activities. Visual structure is provided at a variety of levels such as organizing areas of the environment, providing a daily schedule using pictures or written words, as well as visual instructions and visual organization signalling the beginning and end of tasks. This technique is based upon the observation that children with autism learn and connect information differently than other children.

3. Framework architecture

Virtual environments represent the real life based on real-world or abstract objects and data. In most cases, these are depicted on the user's screen (being a PC or a projector – wall). The child interacts with the environment through a joystick or mouse, through a touch screen or through his/her movements. In case of virtual objects the environment is fully controlled and safe. The software platform can produce the same set of conditions more than once. Consequently, all the means of interaction are based on virtual, not real situations and responses. Besides that, as it is mention in the introduction, computers are not having the expectations and judgments that make social interaction problematic for autistic persons. As a result, the children behave in a different manner in the real life than in the "safe" controlled virtual environment.

Furthermore, most of the times, sounds of real life are included in a VE. They are in correlation with the object or the environment that is appearing to the "screen". Sounds help people with autistic spectrum disorder understand their surrounding better. Besides that, a virtual environment can include unrealistic objects, like cartoon heroes.

Adding the affective dimension in avatar expression provides more natural computer appearance and can improve the comfortness and pleasantness of autistics persons with the education system. Affect expression by avatars have been proven to have enormous significance in human-computer interaction [22]. Emotionally expressive avatars have been developed as part of the most recent applications of collaborative virtual environments for autistic persons [23].

Apart from the virtual environment sub-component, a controlled environment with objects and data of the real life would make more impact to the specialist in monitoring autistic persons' progress during education. The main elements of the proposed framework are real objects (tracked by means of wireless sensors), sounds, avatar, interactive screens, etc as depicted in Fig. 2

The major difference between the two environments is that in the semi controlled one the system cannot initialize the environment with the initial set of conditions although it can monitor all the performed activities. For instance, if a child kicks a ball, the system cannot initialize the environment with the ball to its initial position. In contrary, it could recognize if the ball kicked by the child or not. By combining virtual environment elements with real world objects by a controlled way the educational and expertises' monitoring process would be more beneficial, as shown in Table 1 Moreover, specialists would have the

option to compare the child's reaction between the two familiar but also different worlds.

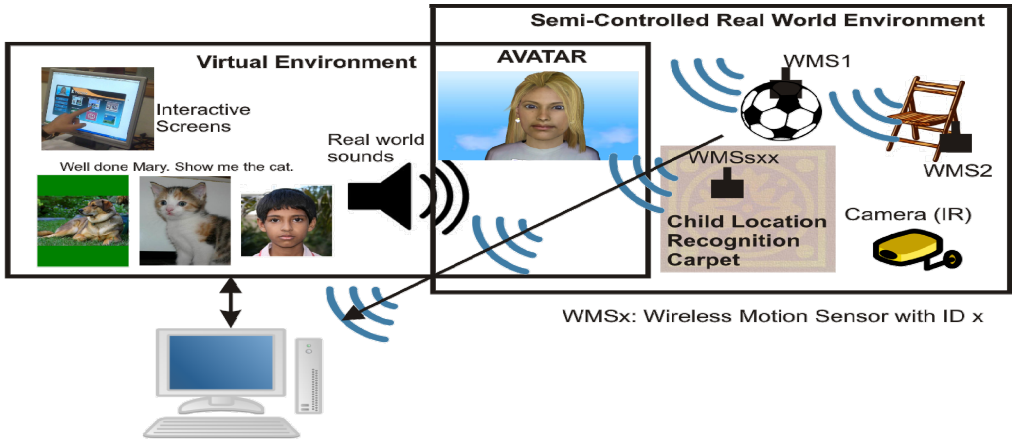

Fig. 2 A diagram of the proposed framework architecture

In such a semi controlled real-world environment an avatar would play the role of not only the instructor but also the means of awarding or encouraging the children to try again in order to achieve the target. In order for the avatar to be capable of understanding the children behaviour, the system has to be enhanced with sensors that will provide indicators of the children behaviour. Recent technological achievements led to a variety of small wireless sensors. Accelerometers, widely used sensors in human body networks, are meaningful in the discussed field [24]. This type of sensors, wearable or not, can provide lots of information about:

1. Body movement and position
2. Object movement and position
3. Stillness or not natural behaviour

It is obvious that objects' position can be monitored and tracked by means of this technology. These sensors give the ability to the system to recognise each object to the semi-controlled real-world environment. Besides that, results about the child's comprehension can be produced depicting if a child followed the avatars instructions or not. For example, a semi-controlled environment could be a special room in which wireless motion sensors have been attached to some real objects (ball, bag, chair, etc). The avatar motivates the child to play with the ball. In case of bag's sensor triggering the systems realizes that the child had a failure. The avatar tries to encourage the child to try more by correcting his/her first action. The avatar, with a sad emotion on its face, could say: "This is the bag. I would like you to play with the ball. Leave the bag and play with the ball". If the child starts playing with the ball then the avatar's response is a: "Well done. This is the ball. Play with it". In case of using such sensors attached in real objects the system can estimate (in our example) the time period that the child played with the ball.

Although a wearable sensor can be used in order to track a child's movement, it will call of children of their target. Educators suggest that if the autistic's environment has changed then he/she has problems to react in his/her proper manner. As a conclusion, it is advisable for wearable sensors to be avoided. A solution to this problem in order to monitor the child's position (and also stillness or movement) is to use a carpet with motion sensors attached. Using a satisfying number of sensors and making use of the triangular method, the system would know the child's position and his/her state (stillness or movement).

Additionally, technological achievements led to several ways for interactive surfaces [25]. Infrared cameras for a wall interactive surface and touch screens for PCs are used nowadays for this purpose [26]. Interactive surfaces (a wall in case of projector usage) will collaborate with the real world. Real objects of daily life that are included in the semi-controlled real environment will be depicted on these surfaces. Teachers and facilitators will have the opportunity to understand the child's reaction in real and virtual world.

Another point of the discussed topic is the opportunity to build stories in which the child plays essential role. A story with real humans and cartoons can take place by depicting animated images to a wall (or two walls of a room). The person with autistic spectrum disorders) will play the role of the main actor. Real monitored (as described above) objects will be included in the concept of the story. The rest virtual actors of the story will try to interact with the child in the proper manner. For example, an actor of the story will say: "John brought the ball to his friend, Alice". John is the autistic person and Alice is a virtual actor. The system can recognize if John caught the ball (monitored objects of real world) and if he carried the ball near to Alice (carpet monitoring position and movement). If John fetches the ball near to Alice the story is keep on. If the autistic person finds difficulties to react

or response, the story will change by the customized needs and the virtual actors ask for something else. In such a scenario the autistic person participates to the story by his/her body. The case study of the stories should be prepared by specialists in order for the results to provide significant factors about the child's progress. Educators and facilitators will benefit of the result if they prepare stories based on the special needs of each autistic person.

Educators, suggest that one of the most important part of the autistic's education is the self-service everyday activities. Apart from the stories, the proposed system is able to host scenarios based on this type of activities; namely take a bath, prepare a sandwich, go to supermarket etc. Educators and specialist are provided with extra information about the difficulties a child meets in order to complete a scenario. Furthermore, the "safe" semi-controlled real environment in combination with the virtual environment elements can act as a catalyst for the specialists in understanding the way to educate autistics in order to overcome daily difficulties.

Equally important to the mentioned facilities could be considered the situation in which an environment motivates more than one child to interact together and with the system. Estimating the relative distance between two children (by using data of the carpet), the system could act in the proper manner so as the two children to cooperate. Thus, the avatar plays essential role in such a situation by providing the suitable instructions to facilitate this kind of cooperation. Specialists would have the opportunity to examine which approach followed by the system and especially by means of the avatar is more beneficial in order to motivate autistic persons to interact with each other.

Table 1 Benefits of the various components used in the proposed architecture.

Method	Benefits
Avatar	Emotional expression, Real face or cartoon character, patient, without expectations and judgments, avatar's emotional state advances the educational process.
Controlled Virtual Environment	Provide same set of conditions more than once, "safe", abstract objects and data, sounds of real life.
Semi Controlled Real World Environment	Objects and data of the real life, monitoring of all objects and performed activities by means of sensing elements, comparing scenarios in VE and real world.

4. Conclusions

As a result, the system will provide information about the autistic's person behaviour depending on the various stimuli stemming from the avatar's instructions. Besides that, a specialist trainer will benefit from the results on the child's nature and mobility. Based on the time needed for reaction and success of the aim, a specialist would be able to extract useful information about autistic person's comprehension of the real world. Moreover, findings in relations between child's movement or not, avatar's instructions and real world's objects will conclude on the child's special needs and likings. For instance, if a child prefer to plays with a ball rather than a bag then both teacher/facilitator and trainer will customize the personal program of the child to the special likings. Future steps include testing of learning effectiveness of the suggested model in various autistic profiles of children, as well as in different learning contents. Moreover, the integration of the various independent components will take place in the next months in order to provide us with experimental data which will be evaluated towards the proposed hypothesis verification.

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