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# Computer graphics applications in the education process of people with learning difficulties

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**Abstract**

This paper describes the use of Real Time graphic applications as educational tools, specifically oriented to working with people who have certain learning difficulties. We first focus on identifying the most relevant traits (from a psychological point of view) of those disorders, then we continue by analysing the advantages of graphics in Real Time in this context, and how they can be used to complement the conventional teaching methods. Finally, we review the main characteristics of two applications belonging to this category, which serve as a practical example of this encounter between education and technology.


*PACS:* 01.50.−i; 01.50.H; 01.50.ht

*Keywords:* Learning difficulties; Virtual reality; Special education; Computer graphics

## 1. Introduction

Nowadays, the area of computer graphics is widely used in a variety of applications for specific purposes. We can find information about virtual simulators for training in driving vehicles, like cars, buses or trains; 3D representations of future buildings or houses most of the times only with the objective of visualization; computer and console games with high-quality graphics, where the player can live a different experience inside the virtual world; or film scenes and characters that are generated using computer graphics. Simulation, training, visualization and entertainment are environments where the use of computer graphics is very popular.

In this context, the possibilities of using computer graphics applications for education are opening an important research area. The technology is every day nearer to children, not only at home but also at school. There are scholarly subjects only related to technology and there is a common interest in all schools to introduce new computer-based programs and applications, for teaching specific concepts included in the school curriculum.

In the area of people with special needs, the application of new technologies is starting to produce good results in the education and intervention process. The idea of creating useful applications for teaching and training specific concepts (such as academic, social or communicative skills) seems to be of interest to all associations and special schools. There are efforts to describe the characteristics and possibilities of the use of new technologies (TIC) in the education of students with especial needs [1]. The idea of TIC is defined as "technological instruments for the compensation and help in the intervention of students with special needs" [2].

This paper is based on the idea of using new technologies, in our case, computer graphics applications, for people with special needs. The projects described in this paper try to promote the use of computer graphics to create helping tools for teachers and professionals in special education, in their intervention and educational process for people with special needs. In our context,

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"intervention process" can be understand as the daily work with people with learning difficulties developed by professionals in psychology and special education, to work on the specific skills in which these people have difficulties.

In the following sections we describe the group of people to whom the graphic applications developed are addressed, the state of the art in computer graphics for education, advantages of the use of computer graphics applications as educational tools and the description of the two projects developed in this area. Finally, we present a conclusion and the possible future work.

## 2. Learning difficulties

Concepts like special education and people with special needs are very general and in most of the cases it is difficult to structure a tool that is useful for every kind of disability. It is important to specify the public to whom each of the applications to be created is oriented.

First of all, we want to introduce the concept of "learning difficulties", that in our case, describes the group of potential final users of our applications. We speak about "learning difficulties" to make reference to those whose origin stems from a biological impairment rather than socio-environmental factors.

Learning difficulties are impairments that limit development and put into practise communicative and/or academic and/or social abilities. The degree of development in this set of abilities is intimately related to the degree of autonomy and community integration (social, educational, labour) that the individual reaches, and it is also related to their quality of life.

The kind of condition referred to here fits well with what is named "mental retardation" (MR), formally defined in the Diagnostic and Statistical Manual of Mental Disorders of the American Psychiatric Association [3] as a developmental disability that first appears in children under the age of 18. In this manual, it is defined as an intellectual functioning level (as measured by standard tests for intellectual quotient) that is well below average and significant limitations in daily living skills (adaptive functioning) are present.

A closer definition and concept for the subject of this paper is one of "learning disability", defined in the "Individuals with Disabilities Education Act (IDEA)" of the United States as a "disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written language, which may manifest itself in an imperfect ability to listen, think, speak, read, write, spell or to do mathematical calculations." (Public Law 101-476, IDEA, USA).

Among all the "labels" mentioned above for this condition, we prefer that of "learning difficulties", as it is not pejorative and it is the most positive one in the sense that it transmits the idea that "very much can be done to overcome these difficulties", from an educational point of view.

Down syndrome is an example of this condition. These people present deficits in attention, perception (with better visual perception than auditory), language and in different cognitive aspects.

Another condition often associated with learning difficulties are autism spectrum disorders (hereafter referenced as "autism"), as three out of every four individuals with autism show mild–severe learning difficulties (MR). The American Psychiatric Association defines this disorder as the presence of a triad of impairments in social interaction, communication and restrictive, repetitive and stereotypic patterns of behaviour, interests, and activities (see DSM-IV, 1994 for more details and [4]).

The enormous attraction that people with learning difficulties (down syndrome and autism) feel towards computers has been one of the sources of many developments in this field.

## 3. State of the art in computer graphics for people with special needs

The most popular software and tools available for special and mainstream education are based on 2D graphics and web pages, with interactive content organized depending on the specific area of knowledge to work with. Most of these applications have interactive games to work in most of the areas included in the school curriculum. In most of them you can find contents in these four topics:

- *Tools to work on social skills*: In this area it is possible to find games or interactive lessons to learn about personal cleanliness, products for personal cleanliness, external appearance, clothes, kitchen utensils and the rules and usage of kitchen utensils.
- *Tools to work on cognitive skills*: In this area there are applications to learn about colours, shapes, basic concepts, objects classification, order, likenesses and differences.
- *Tools to work on written language*.
- *Tools to work on numeric skills*: Where you can find concepts like decimal numeration, addition and subtraction.

Some examples of these kinds of applications are SEDEA Program, a computer application for the intervention process in the development of the hearing and language of children [5] (see Fig. 1); PEAPO, a web site with an easy to use resource that tries to promote the communication and autonomy capabilities in people with Austism Spectrum Disorders (ASD) [6]; EDU356, a web site with multimedia activities oriented to promoting and reinforcing the educative contents for children of different ages [7]; Hola Amigo, an educational graphic interface for learning non-verbal communication using the language of SPC (or Pictographic Symbols System for non-verbal communication) [8].


Fig. 1. Snapshot of the interface used in the SEDEA program.

But if we pay attention to the state of the art of computer graphics applications and specifically 3D graphics, there are not many research projects developed in the area of education for people with learning difficulties. We can highlight the developments done by two main groups, the VIRART Group at Nottingham University and the Artec and Autism and Learning Difficulties Groups of the Robotics Institute at the University of Valencia, whose members are authors of this paper.

The VIRART Group, using the author tool named Superscape (from Dimension International) has developed some software aimed both at people with learning difficulties and autism [9]. Their software includes a set of virtual environments (VEs) (see Fig. 2) with the graphics quality and degree of adaptability to specific needs that this author tool allows (which are much lower than low-level Real Time Graphics Libraries, such as those that we mention further on). This software can be downloaded for free from the project web site and is only available in English. Within those environments, it is possible to work on a wide variety of abilities [10]. Whether or not individuals with autism adhere to particular social conventions in VEs was assessed. Different degrees of success were found [11], with results suggesting that some individuals with an ASD, low verbal IQ and weak executive ability require the most support to complete tasks successfully in the VE.

At the University of Valencia we have developed a Virtual Supermarket for teaching environmental understanding and for training in imagination (see Fig. 3). This tool is freely distributed in Spanish, with a demonstration version in English, with the complete version being under development [12]. We are also developing another application, a Virtual School oriented to working on the social, cognitive and imagination skills for children with autism and down syndrome [13]. We will explain the main ideas of both applications in Section 5.

Fig. 2. Virtual environment used in the software developed by the VIRART Group.


Fig. 3. General view of the Virtual Supermarket application.

Even though these groups have done the largest amount of research into those aspects of learning difficulties related to this paper, other groups and studies also exist whose focus is slightly different from this subject. This is the case of the Virtual Environment Laboratory at the University of Southern California (USC), with an immersive virtual reality environment (a classroom) for the assessment (non-educational) of attention deficits [14] or the University of Texas Medical branch, which developed a virtual reality meal preparation for the treatment of mental deficits due to traumatic brain injury [15].

## 4. Computer graphics applications as educational tools

Computer graphics is a very wide discipline, so we want to focus our attention on one type of these kinds of applications, the Real Time ones. Their main characteristics are, the use of 3D graphics, a very important degree of interaction, a realistic answer to the user actions and immersive possibilities, depending on the equipment used.

Due to the kind of people who are going to use our tools, all of them are non-immersive Real Time applications,

which only need a computer (with screen, keyboard, mouse and joystick) to use and interact with the tool easily. This option was selected in front of other more immersive versions (like using head mounted displays, cyber globes or caves installations) because it is cheaper and accessible for all the schools, associations and special centres, it is less invasive than other elements, the user can interact with the application easily almost without previous training and it allows for collaborative work between the teacher and the child. Some tests were done with the same version of the tool but one using immersive equipment (head mounted display and cyber globes) and another using tactile screen and joystick. The answer of the participants (all of them with learning difficulties) suggested higher levels of acceptance and interaction in the non-immersive version, easier adaptability to the interfaces used with less previous training and better interaction between the child and the teacher.

When the type of application to be used is clear, it is necessary, during the design process of any tool, to specify the characteristics of the final group of people who are going to use it. In our case, it is important to know the specific profile of individuals with learning difficulties and to determine the content that the application may have to satisfy in the areas of knowledge that are necessary for their intervention and educational process.

For that reason, before defining the possibilities of using this kind of software to help people with learning difficulties, we want to define in more detail the group of people to whom these tools are addressed.

### 4.1. Learning difficulties characteristics

People suffering from learning difficulties not only show a delay in their mental development, but also have a specific learning profile that includes both strong and weak points.

Professionals who are experienced in giving attention to these people indicate the attraction that these individuals show towards visual contents, such as those of videos and computers, and highlight this attraction as a way of improving attention patterns, which is more difficult when other conventional resources are used, as they tend to be more diffuse and less intensive.

People with learning difficulties show deficits in attention, perception, memory and a lack of interest in educational contents. They find it difficult to cope with abstract concepts and to generalize and apply acquired knowledge to other environments, and also have a different cognitive style, with differences in their cognitive processes and strategies (such as poor private language and difficulties when thinking for and about themselves).

Those people with down syndrome show, in addition to their learning difficulties, a weakness in their auditory channel. They also find it easier to manage with written language than with spoken language. These facts increase the importance of the visual channel in their educational intervention.

Among the preferences or strong points of people with learning difficulties, together with their preference for the visual channel, they also show great curiosity for the objects of their environment. We can also find a preference for simultaneous processing rather than sequential and good imitation abilities, with these two points being different in autism. The interaction of both conditions in those who suffer from autism as well as learning difficulties limits both their development and the effectiveness of intervention, with additional adaptations required in those cases [16].

Therefore, the use of computers and the development of graphic tools that strengthen these strong points to work on the specific skills in which this group of people have deficits, could be of great interest in helping with their education.

### 4.2. Use of Virtual Reality for people with learning difficulties

After the specification of the final users, it is important to define the contents of the Virtual Reality applications. For that, it is necessary to describe the concepts that may be potentially treated thanks to the use of computer graphics.

Virtual Reality, as occurs with other computer-based programs, has been claimed to provide a particularly facilitatory environment for people with learning difficulties in that it also offers structure, opportunities for repetition, affective (emotional) engagement and, additionally, control of the learning environment. Virtual Reality shares the advantages of computer-based learning, and has the additional advantage of making it more likely that the results can be generalized to real-world settings in that it is a simulation of them [17].

From a more accurate pedagogical point of view, VR offers advantages for the following areas:

#### 4.2.1. Environment understanding

*Spatial concepts understanding*: As it is possible to manipulate the height and the width of virtual objects at will, it is also possible to do it in order to illustrate the concept of size, including distinction between narrow and wide. The same advantage can be found when talking about concepts of relative position: in front/at the back, on top/below, first one/last one, put together/move apart, inside/out.

*Quantity concepts understanding*: It is possible to change in real time the number of objects that can be seen in a VE, as well as being possible to change other variables for illustrating a lot/a few, everything/nothing, more/less, full/empty.

*Visual concepts and adaptation to visual profiles*: The sensory profile of people with learning difficulties may be very different to the typical one [16]. As it is possible to change the colours, shapes, texture and luminance of any

component at will, it is possible to adapt any VE for the convenience of the sensory profile of a given individual with learning difficulties and/or autism. This possibility also allows teaching on recognizing colours, lights and differences among a variety of things.

VEs are also an ideal setting for working on those abilities that would be potentially hazardous when trained in reality, such as crossing the road, fire practice or how to face personal injuries.

Another abstract concept is time, and it is also another thing that can be manipulated through programming. For example, it is possible to play with time in order to show the changes that occur between two different seasons, or to show the growing of a plant, or to teach concepts such as before/after or quick/slow.

#### 4.2.2. *From literality to symbolism*

Children's play evolves from simple manipulation of immediate reality to include more and more issues of a symbolic nature. As an example, at the beginning, the child starts playing functionally with realistic toys and later starts to make imaginary substitutions of some objects for others. Pretence itself offers a framework for the child to become familiarized with non-literal language.

Within a VE, it is possible to teach the preferred cultural use of each object (by showing virtual actors doing this use) and then teaching how an object can become or act as if it were a different thing (as in [18]). The possibility of participating in first person in such processes is something that, a priori, would lead to a better learning (at least in those who have difficulties with imitation, as occurs with people with autism).

#### 4.2.3. *Social abilities*

People with learning difficulties often have problems in understanding people and themselves, what people think or feel and their expression of emotions.

It is hard to isolate and teach all these cognitive ideas in real-life situations due to competing and confusing stimulation from the social and environmental context. In reality, everything occurs very fast, with it being difficult to highlight subtle but relevant details that lead individuals to behave in a given way.

As another way of manipulating time, in virtual reality it is possible to "freeze" people's interaction's and then carefully explain all the variables involved to those who find it difficult to understand or manage it socially.

Taking all these aspects into account, it is possible to create a complete tool which can help professionals in special education, to teach basic concepts and a variety of skills, most of them difficult to explain and show in the real world. Moreover, most of the concepts that can be integrated in the application are part of the school curriculum, thus being of special interest in the educational process of children, who can learn while they are playing (very important in making the system more appealing).

## 5. Case study: two different Virtual Reality applications

With all the previously described concepts in mind, we can review in more detail two of our computer graphics applications developed for people with learning difficulties.

As we mentioned before, the first case is a Virtual Supermarket and the second one is a Virtual School, this one still under development. Both environments were selected because of their familiarity to almost everybody. For that reason, entering in these places can be easier and more relaxed than in others, and the knowledge acquired in them can be generalized to the real world.

### 5.1. *Virtual Supermarket*

This application consists of a 3D supermarket with a variety of products, virtual actors representing different employees and different functionalities available. The basic task in this tool is to do the shopping. The user has to move inside the supermarket searching for the products specified in a shopping list (see Fig. 4). This shopping list is selected at the beginning and contains the objects to work with in each session. The teacher needs to organize each session to determine which lists they are going to use depending on the objects selected to work with.

Navigation inside the environment is done by using a joystick or the keyboard arrows. The use of a joystick facilitates the interaction for all users because it is more intuitive and easy to use than the keyboard. Location inside the supermarket is subjectively represented by a virtual trolley that moves with the user. This trolley also has the functionality of a real trolley in a supermarket, that is, it works as a container for the products that are necessary to buy to complete the list.

For selecting objects or interactive elements in the virtual setting, is possible to use the mouse or a tactile screen. Both

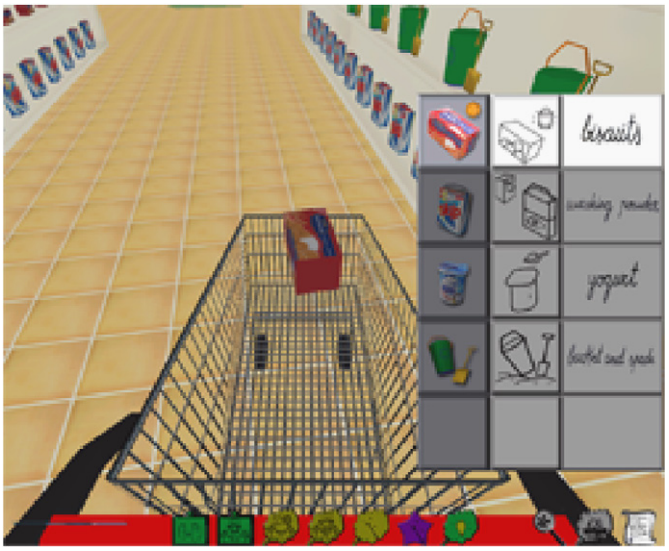


Fig. 4. Picking a product into the virtual trolley with the shopping list spread out, in the Virtual Supermarket.

Fig. 5. Button board with all the functionalities.

interfaces are possible, depending on their availability in the school or centre where the software is used, but the tactile screen is easier to use for making selections inside the virtual world, because the individual only has to use his/her finger to touch the element to be selected.

Besides the traditional tasks inside a supermarket, we offer different functionalities to work in specific skills in people with learning difficulties, using the capabilities of the Virtual Reality applications to introduce educational contents [19].

These functionalities are represented by pictograms in a toolbar, and it is possible to change between them only by selecting the adequate button representing the mode to activate (see Fig. 5). These modes are:

- *Functional use and play*: In this case it is possible to teach about the traditionally accepted usage of each object and how it is possible to play with miniatures of the object selected. In both cases the information is shown using pre-recorded videos integrated in the virtual world. These modes can be used to teach important concepts for daily life, associated with the work on cognitive skills and environment understanding. All the videos finish with a little social interaction to make it possible to also work on social skills.
- *Imaginary play*: With this functionality it is possible to teach about imaginary play with miniatures of the objects. Again, the content is shown by videos integrated in the supermarket and can be associated with the work on cognitive skills. Although the imaginary play shown is individual, it is possible to arouse certain social skills with them, if the teacher tries to promote the same imaginary play but outside the computer and between him/her and the child.
- *Imaginary transformations and magic*: This is a more abstract concept and tries to take advantages of using Virtual Reality to show information difficult to explain and see in the real world. In this case, the user is shown an imaginary transformation of the object selected in the supermarket into another completely different one and with another functionality. This transformation consist of a 3D graphic animation integrated into the virtual scene (see Fig. 6).
  This attempts to promote the development of certain imagination abilities, considering them as a part of the cognitive skills. As was explained before, the task of the teacher is very important in all the functionalities, since it is possible to promote social skills from the information contained in these transformations.
- *Imaginary use*: In this case it is possible to learn about the imaginary usage of each object in a different context.

Fig. 6. Imaginary sequence in the Virtual Supermarket.

Each product in the supermarket has a video associated with this information, trying to provide another tool to work on cognitive skills.

Another way used in the application to promote social skills in the user was by integrating some virtual characters representing different employees inside the supermarket. The user can listen to how the avatar says hello or other expressions and offers some products.

The individual has to interact with it and wait for the object that he wants to buy, making it possible to train in another important social skill which is the waiting ability (see Fig. 7).

Finally, the session finished when the user buys all the products indicated on the list. With all these objects in the trolley, it is necessary to go to the cash desk to pay for them. The user has to interact again with the virtual actor representing the cashier and give her the credit card to pay. After that, the user can exit and the session finishes.

The ideas behind this development are of double value as it is not only an educational game but also a tool for teaching symbolic play. The attraction that people with learning difficulties show towards computers increases the possibilities that this tool have in their educational process. They find it easy to use the hardware devices (tactile screen or mouse and joystick) and the graphical interface (with the help of the teacher in the first sessions), achieving high levels of interaction with the tool and, what it is more important, increasing their interest in educational contents.

Relevant results have been published in [18], where some case studies are described and analysed. The results obtained with some children, after near three months of

Fig. 7. Butcher's employee greeting the user, in the Virtual Supermarket.

Fig. 8. General view of the classroom in the Virtual School application.

intervention, with sessions of about 20–30 min each, suggested very high impact on play scores after using the tools, measured with the Symbolic Play Test [20], and a very good level of generalization of acquired knowledge to real settings in those who spontaneously initiate communication with others. The information provided by the tool to work on cognitive skills and environment understanding (such as the functional and imaginary use and play) helped them to better understand the usage and how to play with most of the objects included in the supermarket. Additionally, some of them improved their imagination skills and generalization to the real world.

In the near future we would like to add more social components to the application, integrating more complicated interactions between the user and the virtual characters. For that, we would simulate different social situations in which the user may try to respond in a specific way to the avatars. Additionally, we would like to make the characters more empathic, making them able to recognize and predict (from video or voice information when possible [21,22]) the mood of the user in each moment and adapt their behaviour and emotion to it.

### 5.2. *Virtual School*

By its own nature, the school shapes in a bigger and more complex environment than the supermarket does—and also offers a wider range of pedagogical possibilities. It includes a whole set of sub-environments typically found in the most of real schools, with hall, classroom, dining room, playground and locker room, each of them including a variety of objects and virtual actors to work with (see Fig. 8).

At the top level, the user is introduced with the role of a pupil in a school day. Activities taking part in the different sub-environments are arranged in a daily timetable, which serves as a task index and guides the user's evolution along the session. This timetable can be previously configured by the teacher, together with other session parameters, and selected at the beginning.

Navigation, object selection, and user-application interaction model in general, are all similar to those used in the supermarket. Subjective point-of-view is kept, too, but in this case the user has no visual representation inside the environment. Inside each one of the sub-environments shaping the virtual school, the user can learn a big variety of concepts and train specific skills. Available working modes can be grouped in the following four categories (see Fig. 9):

- *Exploration*: A certain set of objects is highlighted while becoming selectable to the user. Selection of an object causes the object's name to be shown to the user through both visual and auditive channels. Explorable objects in a certain sub-environment are arranged in groups, in order to emphasize the closer relations between them, and in order to make easier the interaction by limiting the amount of information—explored objects—presented simultaneously to the user.
- *Learning*: This group is intended to teach the user the typical usage of objects, introduce him/her to ways of playing with them, and showing existing symbolic relations between objects. Between those inter-object relations taught here, there can be found generalization (different instances of a same object), alternative usage (different, non-trivial ways of using the same object) or substitution (other objects adopting the role and being used like the object selected).
  Typical usage and playing modes are presented through a pair of virtual hands, shown from a subjective perspective as if they were the user's own hands, which directly manipulate the object inside the VE. On the


Fig. 9. Detail of the user interface corresponding to the four main groups of operation modes in the Virtual School.

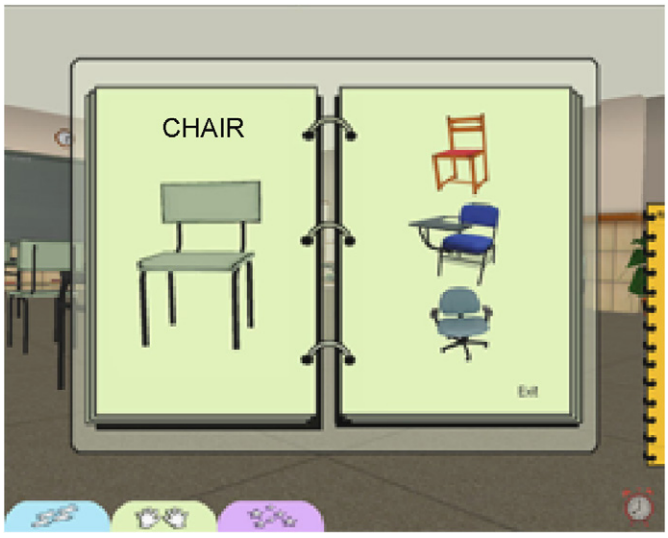


Fig. 10. Example of the generalization information provided by the program.

other hand, inter-object relationships are better explained with real examples, and so are shown to the user using sets of photographs (see Fig. 10).

- *Fantasy*: Here the imagination and fantasy features are emphasized. Virtual 3D objects are presented to the user and then transformed into other non-related, different ones. Morphing technology becomes the most suitable option here, because this allows the integration of imagination sequences in the VE itself.
  The first stage begins by working with imagination/fantasy on single objects, showing individual transformations of the object selected (see Fig. 11).
  The second, more advanced stage introduces more complex collective fantasy sequences, by transforming a whole group of school objects into a set of interrelated imaginary alter egos, all going around the same theme, to finally perform an imaginary animation including all of them.
- *Activities*: The last group presents different activities intended to work around spatial, timing or social relationships. A first group of generic activities lets the user learn basic spatial relationships and concepts described before, such as the size, quantity or relative position, as well as time-related concepts (such as slow/fast or before/after).
  A second group of activities is intended to work with social relationships, by putting the user in the middle of specific situations where interaction with virtual actors is required in order to solve them.

Fig. 11. Four steps of imaginary transformation of scissors into a train sign, in the Virtual School.

Adaptability is a very important feature of this application, referring to the range of disorders it can be used to work with. From the very essentials of design, a requirement has been the ability to adapt sessions to the concrete user features, including in those features the kind of disorder involved. In this way, the application is being developed to be used with individuals with down syndrome, as well as with people with autism spectrum disorders, by simply changing the set of activities programmed for each specific session.

At the moment, the application is under development, with the collaboration of different professionals in the area. Most of the functions described above are completely developed, the 3D objects integrated in the environment have been tested with children to know the level of understanding of these virtual representations of real objects and we are finishing the first prototype, for testing the interaction and environment understanding with people with learning difficulties. Additionally, we would like to integrate virtual characters inside this environment, as school friends and teachers. We are interested in making them able to have an empathic interaction with the user, in order to improve or arouse social skills in them.

### 5.3. Development

The characteristics of the applications presented before made it necessary to make a decision on the software to use for their development. We decided to use a Real Time Graphic Library (OpenGL Performer) integrated in an Object Oriented Language (C++), because of the potential of this kind of libraries for the creation of customized tools and the possibilties of achieving better quality and results than any other methodology. This library provides us with the basic scene graph and graphical control needed to structure and interact with the application in real time. The modularity of all the elements involved in the system allows the reusability for other new environments and the flexibility to integrate all

the desired functions. The design and models creation as well as the animations integrated in the environments were developed using well-known graphic tools such as 3D Studio Max and Photoshop. All these components, integrated in a well defined and structured system, results in computer graphics applications used for a special group of people, trying to help them in their knowledge development and quality of life.

## 6. Conclusions

The development of graphic applications in Real Time, specifically addressed to people with special needs, constitutes an emerging field of work inside the area of computer graphics applied to educational processes, being of special interest due to the learning difficulties inherent in these individuals.

This kind of applications offers a wide set of advantages over conventional pedagogical methods. On the user's side, people with learning difficulties show a special affinity towards computers; regarding the technology, Real Time graphics offer a complete control over the environment presented, and facilitate abstract concepts, very difficult to represent in real world, to be explained to the user in a visual and intuitive way.

The tools presented in this paper are good examples of this kind of applications, where technology meets education to improve the learning experience and, at the end, the quality of life of final users.

## 7. Future work

Currently, we are immersed in the development of the Virtual School, in which the previously acquired experience obtained from the Virtual Supermarket—together with the experimental results derived from its use in educational centres—and the availability of new technologies are allowing us to improve educational contents, introduce new learning methods and expand the range of potential users.

In the near future the authors will end this software development and will face its testing using children with different learning difficulties, by assessing specific variables in order to validate the benefits of the Virtual Reality as an educational tool. We hope the referred to tests and subsequent extended use of this tool will show us new directions to aim towards graphic educational work. As we mentioned before, one of this possible directions will lie in adding more social situations and empathic interactions between virtual characters and children with learning difficulties in order to work in improving their social skills.

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## References

[1] Watkins A. Aplicaciones de las Nuevas Tecnologias (NNTT) a las Necesidades Educativas Especiales (NEE). Middelfart: European Agency for Development in Special Needs Education; 2001 ⟨http://www.tecnoneet.org/index.php?f=agencia⟩.

[2] Tortosa F, de Jorge E. Uso de las tecnologias informaticas en un centro especifico de niños autistas. Nuevas Tecnologias, Viejas Esperanzas: las nuevas tecnologias en el ambito de la discapacidad y las necesidades educativas especiales. Murcia, Spain: Consejería de Educación y Universidades; 2000.

[3] American Psychiatric Association. diagnostic and statistical manual of mental disorders. 4th ed. Washington, DC: American Psychiatric Press, Inc.; 1994.

[4] Wing L, Gould J. Severe impairments of social interaction and associated abnormalities in children: epidemiology and classification. Journal of Autism and Developmental Disorders 1979;9:11–30.

[5] Onda Educa and the Rehabilitation Group of the School La Pursima of Zaragoza. Sedea Application, 2003 ⟨http://www.ondaeduca.com/index.php⟩.

[6] Perez de la Maza L, et al. Peapo, Centro Pauta de Madrid, 2000 ⟨http://peapo.iespana.es⟩.

[7] Education Department of the Cataluny Government. Edu356, Catalunya, Spain 2002 ⟨http://www.edu365.com/index.htm⟩.

[8] Centro Obregon, Asprona, Valladolid. User Manual of the Application Hola Amigo, 1999.

[9] Brown DJ, Shopland N, Lewis J. Flexible and virtual travel training environments. In: Sharkey PM, Sik Lányi C, Standen PJ, editors. Proceedings of the 4th international conference on disability, virtual reality and association technologies. Veszprem, Hungary, 18–20 September 2002, p. 181–8.

[10] Brown DJ, Standen PJ, Proctor T, Sterland D. Advanced design methodologies for the production of virtual learning environments for use by people with learning disabilities. Presence: Teleoperators and Virtual Environments 2001;10(4):401–15.

[11] Parsons S, Mitchell P, Leonard A. Do adolescents with autistic spectrum disorders adhere to social conventions in virtual environments? Autism: an International Journal of Research and Practise 2005;9:95–117.

[12] Herrera G, Labajo G, Fernandez M, Lozano M, Vera L, Carrasco J. INMER-II. Una Nueva Herramienta Educativa en Autismo basada en Técnicas de Realidad Virtual. Congreso Nacional de Informatica de la Salud, Inforsalud, March 2001.

[13] Vera L, Herrera G, Vived E. Virtual reality school for children with learning difficulties. ACM SIGCHI ACE05, June 2005.

[14] Rizzo AA, et al. The virtual classroom: a virtual reality environment for the assessment and rehabilitation of attention deficits. CyberPsychology & Behavior 2000;3:483–99.

[15] Christiansen C, Abreu B, Ottenbacher K, Huffman K, Masel B, Culpepper R. Task performance in virtual environments used for

cognitive rehabilitation after traumatic brain injuries. Archives of Physical Medicine and Rehabilitation 1998;79:888–92.

[16] Bogdashina O. Sensory perceptual issues in autism and asperger syndrome. London: Jessica Kingsley Publishers Ltd; 2003. ISBN 1 84310 166 1.

[17] Rose D, Brooks B, Attree E. Virtual reality in vocational training of people with learning disabilities. In: 3rd International conference on disability, virtual reality and associated technologies, Sardinia, 23rd–25th September 2000.

[18] Herrera G, Alcantud F, Jordan R, Blanquer A, Labajo G, de Pablo C. Development of symbolic play through the use of VR tools in children with autism. In: Garcia Sanchez JN, editor. Aplicaciones para la intervención en los trastornos del desarrollo. Spain: Editorial Pirámide; 2005. And in: Autism: the International Journal of Research and Practice 2005.

[19] Herrera G, Vera L. Abstract concept and imagination teaching through virtual reality in people with autism spectrum disorders. In: AAATE2005, Assistive technology from virtuality to reality. 8th European conference for the advancement of assistive technology in Europe. Lille, France, September 6–9, 2005. And in: Technology and Disability 2006; 18(4): 173–80.

[20] Lewis V, Boucher J. Manual for the test of pretend play. London: Psychological Corporation; 1997.

[21] Litman D, Forbes K. Recognizing emotions from student speech in tutoring dialogues. Automatic Speech Recognition and Understanding, 2003: 25–30. ASRU '03, 30 November–3 December.

[22] Cowie R, Douglas-Cowie E, Tsapatsoulis N, Votsis G, Kollias S, Fellenz W, Taylor JG. Emotion recognition in human–computer interaction. Signal Processing Magazine 2001;18(1): 32–80.