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Mobility and Memory Training through Movement Interaction

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***Abstract*—Movement interaction devices offer important capabilities to create learning systems where students are able to interact with them through natural movements and gestures. In this paper, we present a system based on Kinect, whose main objective is to improve and train two important students' faculties: memory and motor abilities. The system is inspired on the Simon Says game where students have to repeat postures that the system shows previously. By means of this educational technique, young students and students with low disabilities may find the system an adequate environment to improve their memory and motor disabilities in addition to rehabilitation centers, such us hospitals and clinics. They can perform rehabilitation exercises in the same place and in the same way where their classmates train similar faculties.**

I. Introduction

THE traditional context of learning has evolved to a wider context due to the current technology. Teaching and learning are no longer restricted to traditional classrooms [1]. Electronic learning[1], referring to the use of electronic devices for learning, includes delivery of content and learning assessments via electronic media such as Internet or interactive TV.

The development of natural user interaction is expected to make learning systems more intuitive and showier. Current technology allows to create educational systems including multiple interaction modes in order to satisfy needs for every kind of user. Those needs are not the same for a teacher than students with problems such as memory or motor disabilities, who represent an important number of affected people [2]. Currently, movement interaction devices are one of the most useful technological advances, which help in the development of virtual environments where educational techniques may be carried out. Students are part of the virtual environment as the protagonist of the activities, but at the same time, they can see all their own actions as if they were a third person. In this type of environments it is necessary to distinguish two student groups: students who may train their abilities and capabilities, and students with disabilities who may also improve abilities and capabilities in coordination with specialists. Both groups represent and offer different objectives that may be considered when using the system. The most delicate cases are therapy activities or games to improve disabilities. It may be adequated to each student in order to maintain his motivation. Chales et al. [3] suggest that those systems should find a balance between the level of an activity or exercise perceived as easy or trivial and the frustration of one perceived as impossible. In this way, the ability to dynamically adapt the activities to be performed will create tailored solutions to improve disabilities and of course, to train abilities.

Movement interaction devices help when creating learning systems with capacity to interact with users in a continuous and active way. Those devices are able to analyze user postures, gestures, locations, etc. However, one of the most important benefits of those devices is the opened opportunities to people with disabilities [4]. Concretely, people with low motor disabilities can participate in movement interactions through the adaptation of the own interaction to their needs. Actually, there are a wide range of movement interaction devices, among which we mention Kinect[2], Asus Xtion Pro/Pro Live[3,4] and SoftKinect DepthSense[5].

In this paper, we present a system based on Kinect which trains student memory and movements through movement interaction. The system is oriented to two differentiated groups. Students without disabilities compose the first one, so they use the system to train their memory in coordination with rehabilitation processes. And students with memory and movement disabilities compose the second group. The system offers an important feature in order to be useful to any of those users; it adapts its behavior in order to train each user, based on his needs.

Authors have selected Kinect as the most adequate movement interaction device following two reasons. The first reason is its quality-cost rate in relation to the rest.

[1]e-Learning glossary, Kaplan-Leiserson, E: http://www.learningcircuits.org/glossary.html

[2]Kinect, Microsoft, 2012: http://www.xbox.com/es-es/kinect

[3]ASUS Xtion Pro, ASUS, 2012: http://www.asus.com/Multimedia/Motion_Sensor/Xtion_PRO/

[4]ASUS Xtion Pro Live, ASUS, 2012: http://www.asus.com/Multimedia/Motion_Sensor/Xtion_PRO_LIVE/

[5]SoftKinetic DepthSense, SoftKinectic, 2012: http://www.softkinetic.com/Solutions/iisuSDK.aspx

Kinect has a lower cost but its features and capabilities are enough. The second reason is the main purpose of Kinect, to be used as a peripheral of the Xbox 360[6] console. This domain, the videogame world, is very important commercially, which is a compelling reason due to present important and well-defined developments that imply complex interactions. The direct consequence is the possibility to extend the use of virtual solutions to real environments because of how videogames are usually near to the real world; or at least, it can be used as the basis for more specific deployments that solve problems of the everyday life.

Teachers have to organize students' tasks so they need that the system offers them an easy way to adapt the game to each user. In this way, the system has two important features to be adaptable [5][6][7]: ubiquity [8][9][10][11][12] and context-awareness [13][5][14][6]. Teachers can manage their classes and activities communicating their plan to the system at anyplace and anytime. Then, the system adapts their functionality and information based on the management made by the teacher previously. In this way, the teacher adapts the system to the needs of the students that will use it, at any time.

The rest of the paper is organized as follows: a description of Kinect's fundamentals with related works and developments tools are presented in Section 2. Then, Section 3 presents the learning system we have developed based on movement interaction to train abilities and improve disabilities of students. Also, this section describes the basis of memory and motor disorders, which are the abilities in which the system is focused. Additionally, we exposed a discussion of how the system is able to improve and train those aspects in students. Finally, Section 5 presents some conclusions and future works.

II. KINECT AS A SYSTEM INTERACTION DEVICE

Kinect is device created by Microsoft whose main objective is to give users the capacity to interact through movements with the console Xbox 360. In this way, Kinect can be considered as a device that allows natural interactions.

The device implies important challenges due to the fact that users have the capacity to interact with systems through natural and common gestures. Research world has found Kinect as an adequate element to experiment in order to reach solutions and improvements in fields such as medicine in which a wide range of aspects have been threaten (medical images [15], haptic problems [16] and the rehabilitation of chronic diseases [17]), augmented reality [18], and fall detection [19] [20]. Even though, learning environments continuous are being an approach to exploit, some movement interaction systems have appeared. A good example is Kinerehab [21] whose objective is to rehab motor disabilities in a public school setting. The main differences

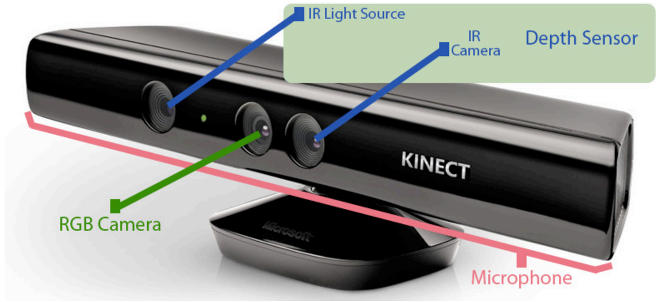

Fig. 1 Hardware components of Kinect

with our proposal are focused on three essential aspects. First, the proposed system incorporates the capacity to rehab and improve memory diseases or problems, apart from motor ones. Additionally, the system is centered not only in people with those disabilities, but also it allows students without disabilities to train their memory and mobility. And finally, the system is ubiquitous and context-aware to be able to precisely adapt its behavior to the needs of each user.

A. *Kinect's Fundamentals*

From the point of view of the hardware (see Fig. 1), three main elements compose Kinect: *RGB camera*, *depth sensor* and *a set of four microphones* The first element detect the color components, red, green and blue, as well as the different user bodies and facial gestures. These capabilities allow the RGB camera to help in the facial and corporal recognition process. The depth sensor generates 3D images about anything into its vision making measurements of the distance from the device to different user body points Finally, the microphones set allows to obtain voices without noise.

Together with hardware elements, Kinect has specific software that uses to detect a set of points of each user skeleton with which represents users' joint. Systems based on Kinect work with those points in order to work with the users' interactions. The process followed to obtain the points

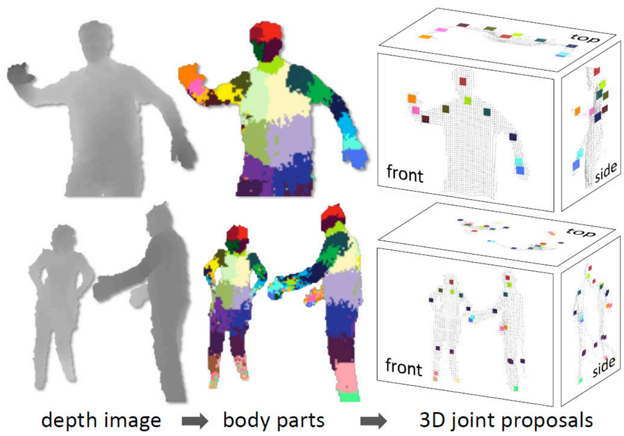

Fig. 2 Recognition process of users' skeleton parts carried out by Kinect ([22])

[6] Xbox, Microsoft, 2012. http://www.xbox.com/es-ES/

is the result of a study performed by Microsoft researches in Cambridge [22]. Basically, the process (see Fig. 2) consists of obtaining an image where each user appears segmented, so each user is separated from the background. The identification of body parts is the next step; it is made through a machine-learning which trains using millons of images ensuring that Kinect is able to work with any type of bodies, sizes and postures of people. Following, the system obtains a points set of the body of each user, which represents joints. Kinect performs the whole process two hundred times per second, so it ensures that the tracking of the users is reliable. Additionally, the algorithm works separately fo each frame, then the system does not lose the tracking of the users.

Kinect toolkits (SDKs) and libraries are an essential point to exploit the device adequately. Their appearance has allowed to create the application which make use of the interaction capabilities of the Microsoft device. Those SDKs can be classified depending on if they are for general purpose or they are focused on natural interactions. The first group has one of the oldest libraries, *libfreenect*[7], as well as *OpenCV*[8] *and PCL*[9] *(Point Cloud* Library). Regarding the SDKs or libraries whose objective is the natural interactions, *OpenNI*[10] and the SDK elaborated by Microsoft[11] are the most remarkable. This last set is particularly interesting because of the topic to be solved in the next section which need to work with corporal movements and then, with natural interactions.

III. Improving Memory and Mobility in Educational Environments through Movement Interaction

Memory and mobility may be trained from childhood. In case of disability, those faculties may be improve through proper rehabilitation exercises. In this way, we have developed a system based on Kinect whose main objective is to reach the training and improvement of memory and motor abilities in students. The system centers its efforts in students with and without motor and memory disabilities. Students without cognitive and motor disabilities improve their memory and psychomotricity through the game while students with those disabilities can also improve their memory and mobility in coordination with specialists varying the difficult degree and movements in the game. Students are able to use the system with natural interactions offering an attractive environment where people with disabilities can coordinate their rehabilitation with specific centers such as hospitals or clinics.

A. Memory and Motor Faculties

Memory is the mental faculty through which people are able to hold and remember the past, allowing to codify, store and recover information. People who suffer from memory disabilities present important disadvantages. They need help in a greater or lesser extent due to the variability of the level of forgetting processes, mechanisms or in general, information.

This faculty can be classified into three types: *sensorial memory*, *short-term memory* and *long-term memory*. The first one represents the capacity to register sensations perceived through the senses, and it composes the initial stage of the attention process. The sensorial memory is characterized by its large capacity to process a big amount of data at the same time during a short period of time. However, the elements that will be transfer to the short-term memory are those to which the user pays attention. This type of memory can be divided into *iconic*, *echoic, olfactory*, *haptic* and *taste*, where the first two are the most studied ([23]).

The short-term memory is the system where the user handles information with which s/he is interacting through the environment. Even though it is a memory with a longer duration than the sensorial one, it is limited to 7±2 elements for 20 seconds. Two effects show the limitation, the primacy and recency. When a user has a list of elements to be memorized, s/he remembers the first and last elements easier than the intermediate ones. The short-term memory is composed by three systems: *supervisor system*, *a verbal information store* and *a visual or spatial store.* The supervisor is responsible for coordinating and controlling the stores, which contains spoken information and the visual and spatial data.

The long-term memory can be defined as the knowledge repository of each person, which is name the real memory. It contains information about experiences, the knowledge of the world, images, concepts, etc. The main features are its large capacity, a slow access speed and its information is forgotten slowly. This memory is classified into two types: *procedural* and *declarative.* The procedural is used to stored information about processes (executed automatically and unconsciously) and strategies that allow to interact with the environment. The declarative memory stores knowledge about the world and experiences (*episodic memory*), concepts and its relations (*semantic memory*).

The described memory types are closely related, as shown in Fig. 3. Firstly, the sensorial memory obtained information from the environment through the senses. The user pays attention to a specific amount of sensorial data which is the information that will be part of the short-term memory. Finally, only the information, which is treated in a repeated way, will be inserted in the long-term memory.

Regarding the motor control of the people, it is another faculty of the people which is the ability to control the movements of their body parts in a coordinate way. Deficits on motor control can limit the ability to perform daily tasks,

[7] Libfreenect, 2012: https://github.com/OpenKinect/libfreenect/
[8] OpenCV, 2012: http://opencv.willowgarage.com/wiki/
[9] PCL, 2012: http://pointclouds.org
[10] OpenNI, 2012: http://openni.org
[11] Kinect for Windows SDK, 2012: http://www.microsoft.com/en-us/kinectforwindows/

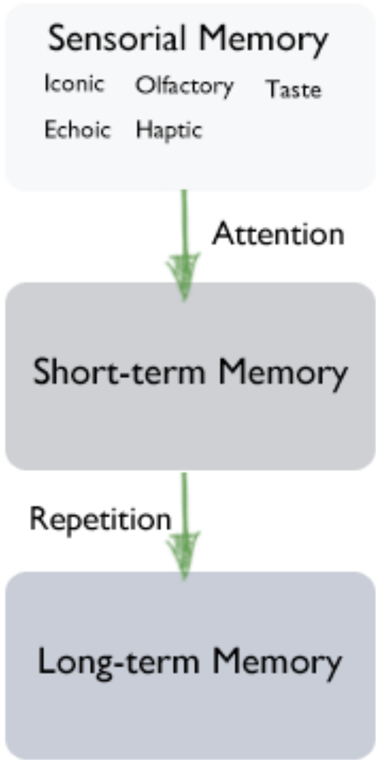

Fig. 3 Relationships between memory types

such us bathing, working, eating, etc., independently. In addition, these disabilities can dramatically reduce participation in community of the people, an important lack in the society [24] [25] [26].

Participating in repetitive exercises is a recommend need to train and a key need to improve motor disabilities. However, a related study shows that only 31% of the people with motor disabilities realized rehabilitation exercises [27]. In this way, it is a necessity to encourage people with new rehabilitation mechanism and techniques in order to increase the commented percentage. The main reason for lack of people to not complete rehabilitation processes is the motivation [28]. Finally, it is necessary to consider two factors which make difficult the rehabilitation process, the number of exercises (typically insufficient [29]) to be done and the need of staff intervention. Therefore, the new techniques may have these facts as main objectives to create adequate rehabilitation processes.

B. Application

The developed application can be defined as a game inspired in the game called *Simon Says*. Concretely, the application consists of offering students postures to be repeated through a screen. In that screen, students can see his own body inside the game, so they can see all his movements and postures. The postures have to be repeated in the same order than they are shown. In this way, once the users have finished the repetition exercise, the application gives them their punctuation, based on the level, and the correct and incorrect postures in their own sequence. However, if the user if a student with memory or motor disabilities the system works with a specific punctuation way. They system shows the punctuation as the progress level to ensure that the student is aware about how s/he evolves. If the evolution is correct the system shows to the student congratulatory messages and the list of their achievements; in other case, the system encourages them with new challenges. In this way, the system not only adapts their messages with the students, but also it is able to adapt their exercises. The system changes automatically the postures to be repeated by the students based on their progress. It is an important feature because allows their evolution and it eliminate bad sensations if the student does not progress adequately. In this case, the system reduces the level of the exercises trying to adapt to the student state.

The application offers users the possibility to play with stored postures in the system, but they can create their own postures. Therefore, they can increase the number of possibilities and also, adapt the postures to their needs. For example teachers can create specific postures set based on children with special needs.

The workflow of the application is described in order to know how it works for each user step (see Fig. 5). The main thread of the workflow starts with the option to be logged in the system or not; in the first case the system stores the user progress and the accomplished levels. Then the system shows three options: (1) play the game, (2) create postures, and (3) exit. The option to play contains the main functionality of the application, that is, the process of repeating postures in order to complete the most amounts of points in the game or perform a concrete evolution. Therefore, the system shows the posture to repeat. The system adds point or increase the evolution of the user if it detects the correct posture; in other case, the system reduces the number of points or decreases the evolution and the number of possible repetitions (see Fig. 4). In this case, if the user has no more opportunities, the game finishes and the system shows the final mark (points or evolution with encourages messages). However, if the user has more opportunities or s/he has made a correct posture, the system generates another posture and then the user has to repeat it again. At this point, the application for students with disabilities analyzes the current evolution and adapts the next postures according to it.

Regarding the creation of postures, the system follows the workflow shown in Fig. 6. The application indicates the user to be in front of the Kinect device. If the user is detected past ten seconds, the application invites user to take the new posture to be stored. Then, a countdown is initialized for five seconds. When this time has passed, the application stores the new posture in the database of the system with a level of difficult. The posture level is an important aspect for the system in order to be able to be adaptable for students with memory and motor disabilities.

Fig. 4 Example of correct and incorrect postures in the game

Two problems arise during the deployment of the system: the camera location and the data storage. The camera location is an important aspect to have into account because it is no trivial. The main reason is the high degree of influence of the location when searching and calculating skeleton points. Initially, the camera was located on a common height, which is at the top of a personal computer screen. However, this situation did not allow a correct identification of every movement; for example the system did not detect always a standing student. The problem appeared when the student was totally in front of the camera and he turned ninety degrees. Then, the system could not detect the user and his movement.

These circumstances created the necessity to perform some tests in order to find the most adequate location of the camera. The result, after testing different perspectives, was that the height of the camera is very influential because it allows Kinect to detect skeletons in a better way. This improvement comes from the need to detect a set of skeleton points of each user in order to identify movements and postures. Kinect in a correct height are able to visualize more parts of students' body with more quality. More height does not imply more quality because Kinect can lose so much detection area; therefore the detection of the correct and maximum height is essential. In this way, the studies allow us to know that the location for Kinect is two meters from the floor.

Regarding the storage of the data, it is a problem which comes from the necessity to compare postures, (the expected by the system and which is made by the user). The system needs to be able to work quickly with easy format data, and then we adopted the XML format to store it. The stored data in a XML file is the coordinates of each skeleton point. Once a student makes a posture, it is stores and the system compares it with the expected one which is stored too.

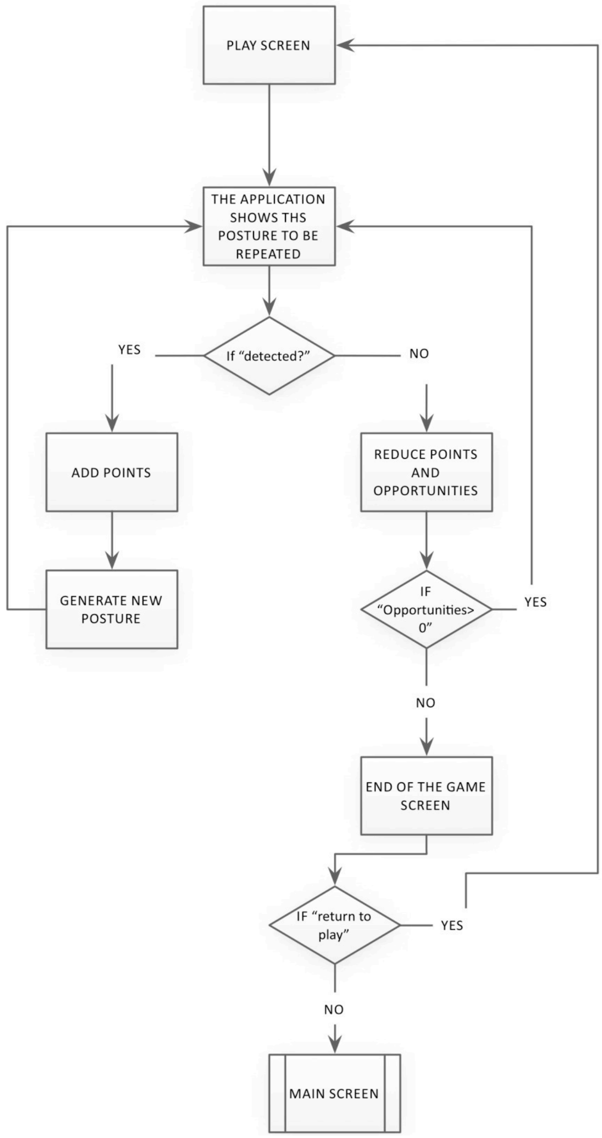

Fig. 5 Game Workflow

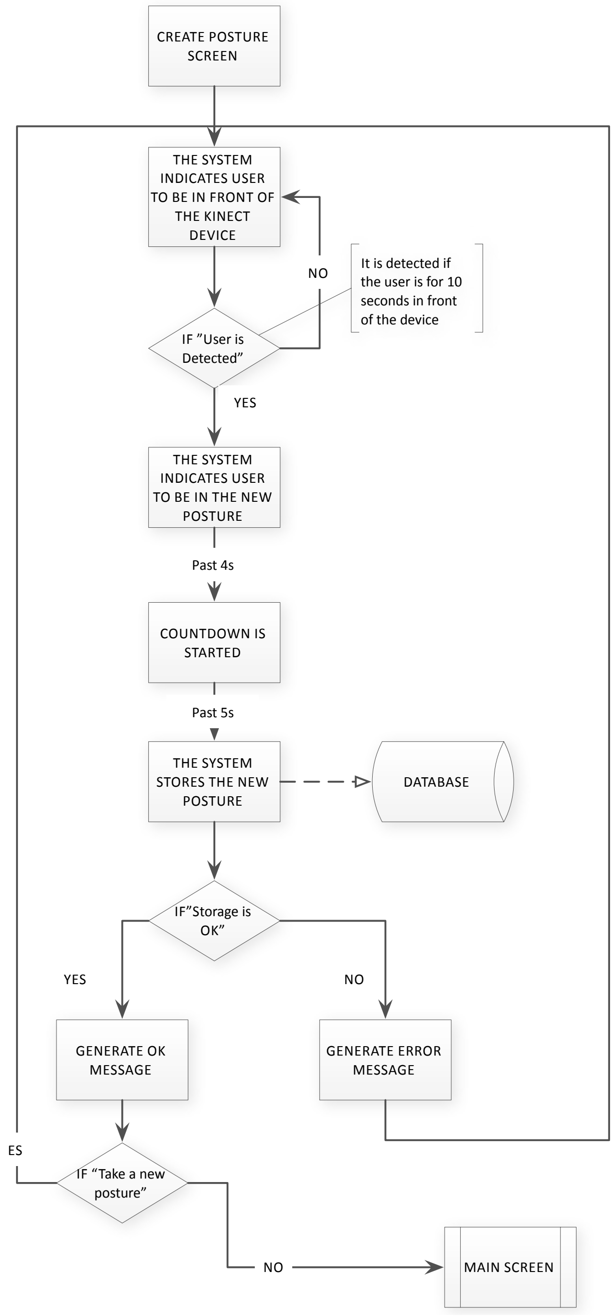

Fig. 6 Creation of new posture workflow

C. Discussion

The proposed system is focused on two students groups for which are an adequate learning tool to improve two basic faculties: the memory and the mobility. Students without disabilities compose the first group and they will be able to train those faculties. This training is an important fact in order to allow students to evolve in their capabilities. In addition, the system allows students with memory problems or motor diseases to improve their conditions. The system is able to adapt their exercises based on the needs of each user creating specific improvement processes. These students with disabilities find the environment a place where improve their problems, which has very different conditions than in normal rehabilitation places. A typical rehabilitation place is a hospital or a clinic where people have to go, quitting from their routine or what is worst, converting it in their routine. For that reason, the proposed system helps children with memory and mobility disabilities who are able to find the way to improve their problems in a less cold than a hospital, their educational center. The system offers the possibility to obtain help students in their rehabilitation through similar activities than their classmates realize.

Regarding memory, the deployed application improves sensorial and short-term memory through forcing to remember postures to be repeated. Therefore, the sensorial memory is trained when users see each posture the first times; the short-term memory is trained once users show a posture that they remember because it has been repeated some times previously.

The motor capabilities are improved because users may repeat postures through the movement of some parts of their body at the same time. When the users are children with cognitive and mobility problems, the application adapts its behavior and exercises according their conditions.

The fact of the students use natural movements to interact with the system is an important feature. Kinect offers students an attractive way of training their capabilities by a game and a game console device, something that most of the children knows. This interaction and gaming mode solve the problem with children which is the way to attract students' attention during a minimum and enough period of time.

IV. Conclusions and Future Work

Current technology has helped in the evolution of learning environments offering a wide range of new elements, techniques and devices. Actually, movement interaction devices imply new possibilities in order to offer new learning systems controlled by natural interactions. Students can find systems more intuitive and showier, something that can help to attract their attention and interest.

Kinect is one of the best-known movement interaction devices. Research world has found on it a perfect tool to be used in a great number of fields, such us medicine and augmented reality. In comparison with other similar devices, Kinect offers an adequate quality-cost rate.

In this paper, we have presented a learning system based on Kinect. The system is inspired on the game Simon Says which consists of showing a set of postures to be repeated by students following different levels. The main objective is to help students to work two basic and essential faculties: the memory and mobility. Concretely, the system helps students to improve sensorial memory and short-term memory because they have to remember postures they have seen for the first time and others that they know by repetition. Additionally, students improve their mobility because they have to change rapidly their postures moving various body parts continuously while they are playing.

The system works in order to help two student groups. On one hand, the system is a tool for students without disabilities, which trains their memory and mobility. On the other hand, the system helps students with motor and cognitive disabilities. Those students find the system an adequate tool which adapts their activities (level and type) based on their needs. In addition, the system controls their evolution allowing students to be aware about it. The system creates for people with disabilities an environment with which improve their problems in coordination with rehabilitation processes carried out in hospitals or clinics. Therefore, the system offer to these children help in their rehabilitation process through similar activities than their classmates and friends perform.

The described system presents an interesting future work based on Kinect's sound capabilities in order to improve and complete their functionality. We are analyzing the Kinect's microphone system to be able to solve or improve voice problems in young children which can reduce errors for example in their pronunciation.

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