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Multi-modal virtual reality system for accessible in-home post-stroke arm rehabilitation

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Abstract— **This paper presents a health economic system for motor recovery in patients with the commonest cause of death in some countries, stroke. The system is based on immersive, real-time motion capture (MOCA) available for private use and at the bedside. An interactive virtual reality (VR) interface designed with auditory and visual feedback. It consists on two scenarios and a 3D character that follows the user's arm movements by using the first and third person view metaphors of interaction. Two easy and enjoyable games are proposed for each scenario. The system is designed to be adapted to several tasks with different index of difficulty (ID) for gradual motor recovery in patients with stroke. The experiments carried out on eight healthy neurologically interact volunteers have shown that our system is suitable to be used at home on training programs, giving good references for future applications on stroke arm recovery.**

I. INTRODUCTION

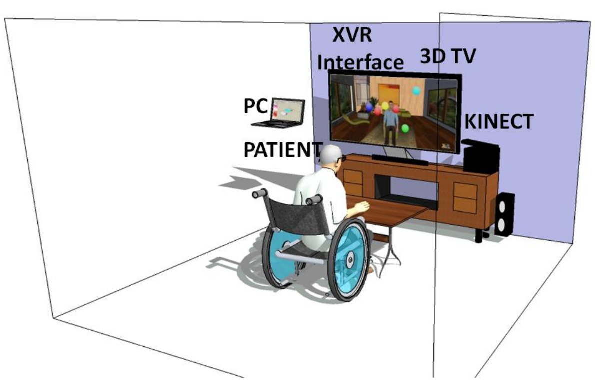

Fig. 1. *The experimental Virtual Reality Environment.*

A stroke, or cerebrovascular accident (CVA), results in a rapid loss of brain function(s) due to disturbance in the blood supply to the brain. It can be due to ischemia (lack of blood flow) caused by blockage (thrombosis, arterial embolism), or a hemorrhage[4]. When it happens an exercise re-conditioning program may help the patient to gradually speed-up his motor recovery and retake some of his pre-stroke activities. These general conditioning programs provide a wide range of exercises. These must ensure a safe and effective programs for patients. In practice, the exercises should be performed under a therapist's supervision. However, sometimes it may not be possible for patients to keep a therapist nearby to control and correct the way they perform their exercises. Even if there were a therapist nearby to control the patient motions, sometimes the therapist can't properly ensure the correct performing of the exercises with a simple gaze. Recently, researches has strongly demonstrated the effectiveness of use videoconferencing for in-home rehabilitation in patient with stoke[14]. Others studies on rehabilitation at home after stroke has demonstrated that early supported discharge following acute stroke, with community of rehabilitation at home by a team associated with the Department of Neurology, implied a considerable reduction in bed-days [21]. Moreover, VR and video game applications are novel and potentially useful technologies that can be combined with conventional rehabilitation for upper arm improvement after stroke[23], [22]. These must be designed for specific tasks and biofeedback methods such auditory and visual feedback which may help to improve gait and balance in patient with stroke[2], [7], [9], [6]. MOCA is the first step of any motion recognition system. We distinguish between marker and markerless based approaches. The former rely generally on tracking optical markers attached to a person [16], [17], while the latter analyzes human motion through more complex mathematical algorithms and by using different methods and devices for MOCA [19], [20] included different cameras that track the person by recognition of certain features in images [11], [12], [13]. The optical marker system has exact evaluation of positions and trajectories, multi point tracking, real time acquisition, etc. However, these are expensive and sometimes encumbering. Furthermore, they need calibration. According with [10] the cost-effectiveness data for stroke treatment are limited, but they support the use of dedicated stroke units and early supported discharge services. They agree that a priority areas for further research should be "health economic data for all stroke interventions". In order to achieve that, we consider an accessible marker-less new system device (camera Kinect) that cost only € 200.00. This camera enables MOCA by joint motion measurements. And it is suitable to implement in a rehabilitation multi-modal platform with a high grade of transparency and perception. Our goal was to develop an accessible in-home multi-modal VR system with an enjoyable interface for stroke rehabilitation programs. It should be easy to use at the bedside and at home under therapist or family supervision. Being the main goal to help patients gradually improve its gait post stroke. By allowing them to interact and perform specific tasks, using for that a 3D character, sitting down in front of a table, who gives

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visual feedback of the user's movements. A virtual character produces good stimulation for patients during training programs. The objective of this study was to provide some references of the system functionality that may help for future applications on arm recovery for patient with stroke.

II. Methodology

A. The device platform.

Nowadays the use of MOCA devices is very common by researchers to capture real motion executed by one or several users. For this research we use the Microsoft's Kinect camera, which is a cost-effective device for human-computer interface, composed by a RGB camera and a depth sensor based on an infrared camera, which is able to detect the human skeleton. Thomas Kühn[1] already explained the internal design and properties of the Kinect device. An interesting characteristic of this device is the combined projector and camera instance of the usual two cameras for stereo vision. The IR projector and camera are used for depth calculation, this data is then mapped to the color pixels taken from the color camera, so that each single frame has the 3D coordinates of each pixel. Sending these static frames in a sequence is called RGB-D stream. The device can be switched between default and near mode as appropriate for the scenario. It tracks up to two skeletons, and detect up to 6 people within view. The devices tracks skeletons on: a) default standing mode and b) seated mode skeletons. The latter track 20 joints from all the skeleton while the former only the top 10 joints.

B. HW specifications.

Kinect for windows sdk, PC Dell, model Studio 1557, Processor: Intel(R) Core(TM)i7 CPU Q720 @ 1.60GHz , 4,00GB memory (RAM), Operative System to 64 bit, 3D television.

C. Data acquisition

One of our main goals on this research is to develop an algorithm capable to analyze the dimension and position of each segment of the user arms and adjust the coordinates and trajectories by matching the ideal trajectories of a 3D virtual character. To do that, we propose the use of the RGB-D camera for skeleton MOCA that gives some references to develop the proposed system. For our application we decided it will be used only with one user, for that we choose the seated mode function of the camera. The reason is that by activate this mode the device tracks only the top 10 joints of the skeleton. The joint's positions obtained from the RGB-D camera are used to estimate the absolute arms joints orientations. In order to estimate the joint rotations, two vectors are uses to represent the 3D joint positions obtained by the camera: $\boldsymbol{AB} = B - A$, $\boldsymbol{BC} = C - B$. (See fig. 2). Therefore, the unit vectors $\widehat{x}$, $\widehat{y}$ and $\widehat{z}$ are estimating as shown in Eq. 1, 2 and 3 while the Eq. 4, $\boldsymbol{R}$ represents the joint's rotations estimation.

$$\widehat{x} = \frac{\boldsymbol{AB}}{\|\boldsymbol{AB}\|} \tag{1}$$

$$\widehat{y} = \| \boldsymbol{BC} \wedge \hat{x} \| \tag{2}$$

$$\widehat{z} = \widehat{x} \wedge \widehat{y} \tag{3}$$

$$R = (\widehat{x},\ \widehat{y},\ \widehat{z}) \tag{4}$$

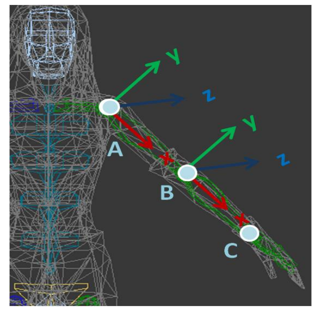


Fig. 2. *Two vectors are uses (AB = B - A, BC = C - B) to estimate the joint rotations, the blue dots illustrated the 3D joint positions obtained with the sensor.*

The joint rotations are used to animate the virtual 3D character into the XVR. The Microsoft Kinect library contains filters for skeleton positions, such as the Kinect filter based on the Holt Double Exponential Smoothing method used for statistical analysis of economic data, which provides smoothing with less latency than other smoothing filter algorithms. A single call of this filter function updates all currently-tracked skeletons [8]. This filter helps to reduce jitter between frames and obtain enough accurate data to estimate joint positions and rotations, without the implementation of an extra filter that could be counterproductive. The character bones were re-targeting with the skeleton obtained with the RGB-D camera to get more realistic character animation.

D. Specifications of the prototype

To ensure the correct functionality of the RGB-D camera capable to detect IR lights (some capabilities of this device are explained on previous paragraph II.A), the users of this system should follow some specific protocols:

- The user must be positioned in front of the RGB-D camera.
- The distance between the camera and the user should be between 1.2 to 3.5m.
- The user must be within the angles of the camera vision (depth and RGB): horizontal: 57.5° and vertical: 43.5° with ±27° tilt range up and down.
- The equipment should not be placed in front of windows, strong direct lights must be avoided.
- The user can choose between two interfaces: seated down or stand up during interaction. However, the seated mode and the use of a table during interaction are strongly suggested for this system, in order to avoid some fatigue to the patient.

E. Motion sensing and stroke rehabilitation task.

Different rehabilitation tasks require the use of arms; this is the reason of our special interest on the upper limb MOCA. Behavioral evidence from studies of individual with stroke demonstrates that, regardless of the locus of damages, speed is sacrificed during goal-directed movements (Winstein and Pohl 1995). In order to design the right scenario, we took into account the index of difficulty of the implementation associated with the Fitts's law. This law, applied to aimed movements, predicts that the time required to move a target is in function of the distance and the size of the target [18]. According to Liu the Fitts's law is formulated as:

$$T = a + b \ \log_2\left(\frac{D}{W} + 1\right) \tag{5}$$

Where a and b are constants that can be determined experimentally by fitting a straight line to the measured data; D and W are the distance to the target and size of the target, respectively; T is the movement time. Therefore, according to the Fitts's law who said that the execution of the gesture to reach a small size target that is far away requires a greater concentration than a large target that is near. For such reason, the present application proposes different levels of IDs, allowing some open variables for the target's size, color, position and time of exposition, easy to be set by users. It was done in order to wide the interaction options with several variations of exercises and IDs. Two scenarios with different tasks are presented, they are described on paragraphs III.A and III.B, where the main goal is to improve the gradual motion of the patient's arms and stabilize his gait. For that reason the user is asked to touch or catch the different targets (spheres). The way the user must touch the target will be indicated by the therapist.

F. System Setup

The framework used to develop the system was the XVR (eXtreme Virtual Reality), used for virtual reality applications. [15]. This framework manages the infrastructure dealing with libraries communication, networking, hardware support, etc. making all these integration aspects completely transparent for the final user. A dynamic link library (DLL) was programmed in C++ language on the Visual Studio 2010 environment. The DLL serves as a linker between the RGB-D camera and the XVR framework. This DLL is a module that contains the RGB-D camera functions and it exports data into the XVR module application. This module helps the system to reduce memory overhead, to save some computational power and make a more efficient real-time interaction. This is because the applications may share the DLL code. The interface is composed of a 3D virtual character that has a biped skeleton (see fig. 2), and allows MOCA technology for its animation. The library used to control the character is HALCA (Hardware Accelerated Library for Character Animation) [3].

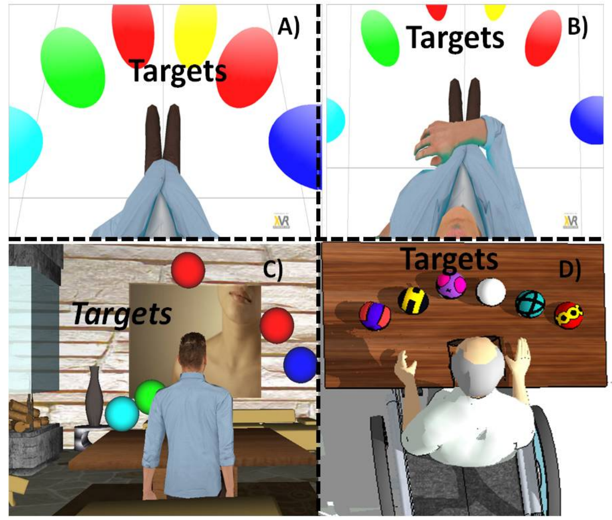


Fig. 3. *The north and east west of the fig. shows the first person view metaphor of interaction, designed with the 3D character and A) 10cm and B) 6cm targets. While the south west of the fig. shows the third person view metaphor of interaction with the cascade game. The south east of the fig. shows the top-view of the patient and how he should perceives the virtual targets in real world.*

G. The VR system design

The multi-modal system consists on two scenarios that uses direct manipulation metaphor composed with a sit down 3D character. According to the interface paradigm, the use of a 3D Character increase the complexity of the VR scenario management, but it also increases the realism and immersion in the VE. The full interface was designed to be interactive by letting the patient modify, touch, hear sound's effects and perceive the created virtual world, while improving his/her gait post stroke, using for that auditory and visual feedback. The models used in the VR environment were designed in 3D Studio Max. This model consists on a comfortable room with two windows which let the user see a green garden and a mountain. It seems a living room with furniture such a sofa, a table, a carpet, etc. which has the finality to create a sensation of comfortableness to the patient. (Fig. 1). For the first scenario the user's gaze on the VE is controlled with the user's arms movement. If the user moves his arms the character's gaze changes immediately on such way that it may perceive the VE with his virtual arms relaxing on a table in front of him. The character was a courtesy of the Consortium of the Beaming project, realized by the experimental virtual environments (EVENT) lab for Neuroscience and Technology, Barcelona. The interface has a help menu with some relevant instructions of system uses, which will appear if the user press the "H" keyboard. In both scenarios the user interacts with a virtual environment displayed on a screen of a 3D TV in front of them. From each scenarios was designed a game with six colored targets with sound's effects when targets appear, disappear or are touched. The task consists in touch them with the hands. A target is touched or caught when the hand is near enough

TABLE I

SUMMARY OF IDS BY TARGET'S DIAMETERS AND DISTANCE

Target Diameter(*cm*)	10.0	6.0	2.0
Target Distance (*cm*)	80	80	80
ID	4.08746	4.75489	6.33985

and when it happens it disappears. Such references also may help to stimulate the interest and immersion of the patient with the crated VE. More specific details of the games are described in the following two paragraphs.

III. EXPERIMENTS AND RESULTS

The ideal experiments should be done with real stroke patients, unfortunately this time we could not do them in this way. As an alternative, we asked eight healthy neurologically interact volunteers to participate in this study, aging between 14 and 42 years. All of them have normal or corrected to normal vision. The goal of the present experiments is to test the system functionality and give some references for future applications on stroke rehabilitation programs.

A. Initial rehabilitation task

For an initial rehabilitation a simple application is proposed, it is designed with the first person view metaphor which is self perception metaphor. By using it, the patient may perceive the character arms as if they were his own arms in front of him. (See the north and east west of the fig. 3). In order to increase the ID of the target three sizes of spheres were tested (10.0*cm*, 6.0*cm*, 2.0*cm*), the real world equivalent size. A set is composed of six targets of the same size. (See table I). At the beginning of the game, a set of targets appear in front of the user. The distance between the target and the user is the arm's length and it is constant. Each set of targets is exposed (4*s*, 3*s*, 2*s* and 1*s*) and the user must repeat the same task 10 times for each set of targets. The user gets a score when he is able to touch all the targets of the set. When the time of exposition of the set is over, the game automatically stop 1*s* in order to let the user relax his arms. If the targets are not touched in the specific time these automatically disappear and new set of targets appears.

B. Higher level rehabilitation task

This application is designed with the third person view metaphor of interaction and it consists on a cascade game, where six spheres fall down in front of the user. (See the south west of the fig. 3). The virtual spheres falling at constant speed, but appear at different times from the top of the screen. A new sphere is created each half sec., with random horizontal position: if it is not touched or caught, it falls until the table. Even this game uses the same targets that the first game (see table I), we consider the ID of this game higher than the fist one. The target in this game are generated randomly and are in motion during interaction. The fountain game is exposed (6*s*, 5*s*, 4*s* and 3*s*) for each target size and the user must repeat the same task 10 times. The score is increasing when the user touch a sphere suring each period of time. When this period finished, the spheres automatically disappear for 2*s* then new cascade game began. The break of 2*s* is done to let the user relax his arms. The characteristics of this game makes this application to be a high ID and it is proposed for advance stroke rehabilitation program.

C. Test Setup

For this system, we suggest the use of a 3D TV during rehabilitation training to experience more immersion [24], [25], [26]. However for the present experiments a normal TV was used. The user interact with the VE displayed on the screen of a 2D TV in front of him giving him the feedback of his motion. The TV is connected with the CPU and the RGB-D camera device used for MOCA. (See fig. 1). The screen was projected with a 60*Hz* refresh rate, enough to handing the motion recognition in real-time. The user sit down in front of the TV keeping a distance of 3*m* more or less. This time we did not use the table for the users as they are healthy users.

IV. RESULTS

Learn is to acquire knowledge or skills. When a new task is learned the first time, the time to perform such task may be longer than when it is skilled. The figures (4, 5) shows, the arm motion of a user (position and angles). The first time that the person play the game with 10*cm* spheres, the arm motion was longer (red dots) than when he skilled the task after 10 repetitions (see the violet dots of fig.). The result of our experiment shows clearly that learning also may involve a change in attitude or behavior. The blue dots of the figures (4, 5) show the first performed task (position and angles) of the user with spheres of 2*cm* while the green dots represent the last performed task after 10 repetitions with the same sphere. The graphic 6 shows that when the targets are static the ID between two different targets (10*cm* and 6cm) is relative. But, considerable differences are visible between big targets (10 and 6cm) and small targets (2*cm*) (last four bars of the graphic). While the graphic 7 shows that, IDs are clearly visible between different motion targets, the user obtained higher score when they touch the bigger targets (Fit'low is proven). The results on the graphics (6, 7), clearly show that the cascade game have the higher IDs. The IDs of the cascade game must be adjusted to lower IDs if it will be used with stroke patients. The proposed IDs for the cascade game were difficult even for healthy users. The figures (8, 9) show the users score results for each level task. In the cascade game, the target's time of exposition and the break time used to relax the user's arms is longer than in the first game. This could be a chance to have better score in the cascade game however, the score average was higher in the first game. These results let us understand that the first game could be relatively easy for normal people. But not for a stroke patients, where the speed sometimes is sacrificed at the beginning of the training.

A. Users natural comments to the system

They liked the games; the games was fun; the small balls looked like fly. They suggested put more attractive colors to the targets if it is a game to stroke patients; they suggested put the score in the screen to see how much target they touch. Some of them said that the character was so serious it does not smile. They thought that by using the 3D TV the game could be more interesting and realistic, it may help them to better understand the target position on the space. At the end of the experiments, we could notice some little fatigue on participants, even there was a stop between each task performance. We believe it was because the cascade game requested more effort and concentration from users. It was the opposite with the first level game, once they understood the task, they seem to be relaxing. On the first game, they found out more difficultly to perform the task with the smaller targets. During experiments we noticed that it was little bit more difficult to understand the task and to be adapted to the interface the older participant.

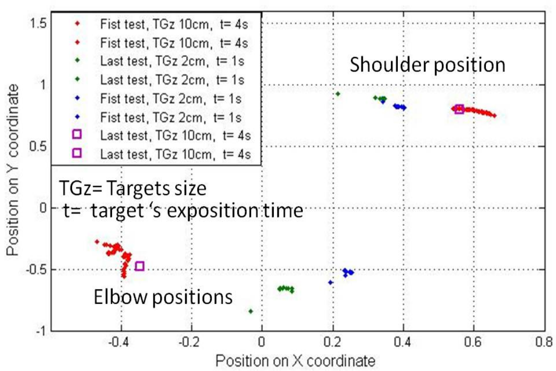


Fig. 4. *Initial rehabilitation task: the shoulder (up dots) and elbow (down dots) 2D positions of an user during task with targets of 10cm (red dots) and 2cm (green and blue dots). The shoulder positions does not change much during performance as it is normal. Opposite to the elbow position, the motion pattern is not stable at the begging of the tasks (red and blue dots) but, it is at the last performed task (violet and green dots).*

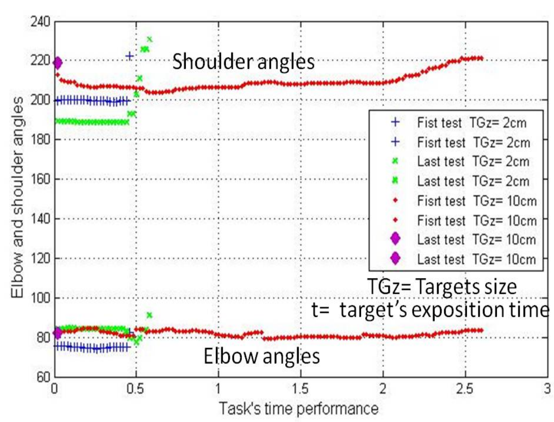
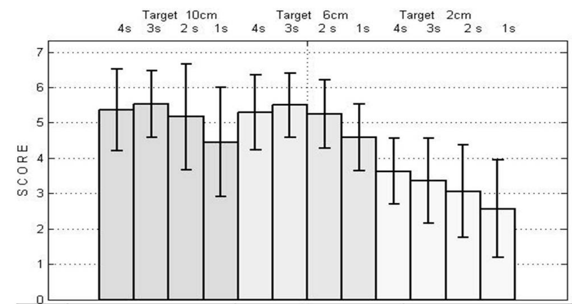
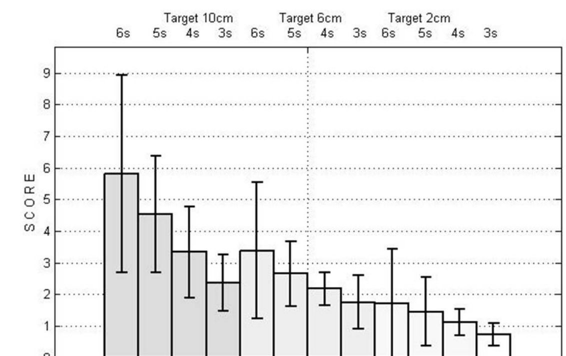


Fig. 5. *Initial rehabilitation task: the shoulder (up dots) and elbow (down dots) angles of a user during task performance with targets of 10cm (red dots) and 2cm (green and blue dots). The angles looks unstable at the begging of the task (red dots) even if targets are bigger (10cm). The angles looks stables during the last perform tasks using small targets (2cm) with some variation at the end of the task (blue dots).*



	Target size 10cm				Target size 6cm				Target size 2cm			
Time	4s	3s	2s	1s	4s	3s	2s	1s	4s	3s	2s	1s
Mean	5,363	5,525	5,163	4,450	5,300	5,500	5,250	4,588	3,625	3,363	3,056	2,563
STD	1,155	0,936	1,501	1,540	1,064	0,904	0,961	0,946	0,932	1,203	1,307	1,380

Fig. 6. *Initial rehabilitation task: the bars, stand users score average, the lines represent the standard deviation. The last four bars shows that smaller targets (2cm) has the higher ID (Fitts's low).*



	Target size 10cm				Target size 6cm				Target size 2cm			
Time	6s	5s	4s	3s	6s	5s	4s	3s	6s	5s	4s	3s
Mean	5,821	4,538	3,338	2,363	3,388	2,650	2,175	1,753	1,713	1,450	1,113	0,716
STD	3,126	1,849	1,440	0,886	2,152	1,018	0,512	0,846	1,733	1,078	0,416	0,358

Fig. 7. *Higher level rehabilitation task (cascade): the bars, stand users score average, the lines represent the standard deviation. The last four bars shows that smaller targets (2cm) has the higher ID. The present results shows clearly that this game has higher ID than the first one. (See fig. 6).*

TIME (s)		4sec		3 sec		2 sec		1 sec	
USER	TARGET SIZE	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
1	10 cm	5,9000	0,3162	6,0000	0,0000	6,0000	0,0000	5,9000	0,3162
	6 cm	6,0000	0,0000	6,0000	0,0000	5,6000	0,5164	4,6000	1,5000
	2 cm	3,1000	0,8756	3,6000	0,8433	2,4444	1,4240	1,6000	0,8433
2	10 cm	5,7000	0,9487	6,0000	0,0000	5,9000	0,3162	6,0000	0,0000
	6 cm	5,3000	0,8233	6,0000	0,0000	6,0000	0,0000	5,5000	0,8498
	2 cm	4,3000	0,6749	4,4000	0,8433	4,7000	0,6749	4,4000	1,0750
3	10 cm	4,5000	0,8498	4,7000	0,9487	3,9000	1,1005	3,2000	0,9189
	6 cm	5,1000	1,1005	4,8000	1,8738	5,1000	1,3703	5,5000	0,7071
	2 cm	2,2000	1,8738	1,7000	1,4181	2,0000	1,5635	3,7000	1,4181
4	10 cm	6,0000	0,0000	6,0000	0,0000	6,0000	0,0000	5,2000	1,8738
	6 cm	5,8000	0,4216	5,9000	0,3162	5,5000	0,8498	4,2000	1,4757
	2 cm	3,7000	1,1595	3,6000	1,2649	3,7000	1,2517	3,4000	1,8974
5	10 cm	6,0000	0,0000	6,0000	0,0000	6,0000	0,0000	5,8000	0,6325
	6 cm	5,9000	0,3162	5,9000	0,3162	5,5000	0,7071	5,1000	1,2867
	2 cm	3,8000	1,5492	4,4000	0,6992	4,2000	0,7888	2,8000	1,2293
6	10 cm	6,0000	0,0000	6,0000	0,0000	5,6000	0,6992	3,4000	1,4298
	6 cm	5,5000	0,7071	5,9000	0,3162	5,3000	0,6749	5,2000	0,9189
	2 cm	4,4000	0,8433	2,9000	1,1005	2,1000	1,5239	1,0000	0,6667
7	10 cm	2,8000	1,0328	3,5000	1,7159	1,9000	0,7379	1,8000	0,4216
	6 cm	2,8000	1,9322	3,5000	1,1785	3,0000	1,0541	2,8000	1,2293
	2 cm	2,6000	0,8433	1,6000	0,9661	1,1000	0,9944	0,5000	0,7071
8	10 cm	6,0000	0,0000	6,0000	0,0000	6,0000	0,0000	4,3000	1,2517
	6 cm	6,0000	0,0000	6,0000	0,0000	6,0000	0,0000	3,8000	1,4757
	2 cm	4,9000	0,3162	4,7000	0,4830	4,2000	0,9189	3,1000	0,7379

Fig. 8. *Initial rehabilitation task: the second column represent the targets size (10, 6 and 2cm). The upper columns shows the target time exposition 4s, 3s, 2s and 1s. The two sub-columns of the time shows the average and standard deviation score of 10 repetition task for each person.*

TIME (s)		6 sec		5 sec		4 sec		3 sec	
USER	TARGET SIZE	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
1	10 cm	9,3000	2,8694	4,2000	1,0328	2,6000	1,0750	2,2000	1,2293
	6 cm	7,6000	1,1738	4,1000	0,8756	2,1000	1,3703	1,4000	0,9661
	2 cm	5,8000	1,7512	3,6000	1,5776	1,6000	1,6465	0,8889	0,6009
2	10 cm	10,4000	3,2728	5,3000	1,8886	2,3000	2,3000	2,2000	1,0328
	6 cm	3,3000	1,7029	1,9000	1,5239	2,3000	1,4181	1,9000	0,9944
	2 cm	1,7000	1,3375	1,7000	0,9487	1,0000	0,8165	0,6000	0,6992
3	10 cm	4,6000	3,0623	4,2000	2,1499	3,0000	1,4142	2,5000	1,3540
	6 cm	3,9000	1,7288	2,9000	1,1005	2,1000	0,9944	1,6000	1,0750
	2 cm	1,5000	1,5811	1,2000	0,7888	1,3000	1,0593	1,0000	0,8165
4	10 cm	5,6667	2,6926	6,1000	2,0248	4,6000	1,0750	2,2000	1,7512
	6 cm	3,0000	1,0541	2,2000	1,5492	2,5000	1,6499	0,4200	0,4216
	2 cm	1,4000	1,1738	0,9000	0,7379	0,5000	0,7071	0,6364	0,8090
5	10 cm	2,7000	1,7029	4,2000	1,9889	3,2000	2,0440	3,8000	1,3984
	6 cm	2,2000	1,3984	2,1000	1,5951	1,9000	1,5239	2,1000	1,1972
	2 cm	1,1000	0,7379	0,6000	0,6992	0,6000	0,5164	0,5000	0,5270
6	10 cm	7,8000	2,9740	7,1000	1,8529	5,3000	1,9465	3,3000	1,5670
	6 cm	2,5000	1,0801	2,4000	1,2649	1,3000	0,8233	1,0000	0,8165
	2 cm	0,5000	0,7071	0,5000	0,7071	1,3000	0,9487	0,1000	0,3162
7	10 cm	1,5000	0,9718	0,8000	0,9189	1,0000	1,2472	0,9000	0,9944
	6 cm	0,1000	0,3162	1,4000	1,4298	2,1000	1,2867	3,1000	1,4181
	2 cm	0,2000	0,4216	0,7000	1,0593	1,0000	0,9428	0,7000	0,6749
8	10 cm	4,6000	1,7127	4,4000	1,0750	4,7000	1,4181	1,8000	1,1353
	6 cm	4,5000	1,7795	4,2000	2,2010	3,1000	1,8529	2,5000	0,9718
	2 cm	1,5000	1,1785	2,4000	1,7764	1,6000	0,8433	1,3000	0,4830

Fig. 9. *Higher level rehabilitation task (cascade): the second column shows the three tested target sizes (10, 6 and 2cm). The upper columns shows the target time exposition 6s, 5s, 4s and 3s. The two sub-columns of the times represent the average and standard deviation score for each person. The users repeated 10 times the same task with each set of target.*

V. CONCLUSIONS

This paper presented a solution for health care economical program, a real-time sensor system for human arm motion recognition usable for private use and at the bedside to stroke treatment for rehabilitation. In order to test the system and functionality, eight healthy neurologically interact volunteers were asked to touch or catch targets (spheres) that appeared around the 3D character in the designed VR interface. The goal of this exercises was to make the participants exercise the arms. Although the ID of the targets were analyzed carefully using the Fitts's low, the user motion and the speed needed to perform the tasks are unpredictable.

The experiments have shown that when the IDs of the targets are change suddenly, the user motion is unbalanced at the beginning of the task. Usually users do not perceive small gradual changes on the ID during playing games, opposite the motion behavior change when the ID of the targets increase considerable. For such reason we realized that the present system is suitable for future applications on post-stroke gait recovery. The two games may help patients to improve his gate by changing some attitude on movements and acquiring new skills and knowledge. With cooperation of a therapist the ID of the presented games may be adapted to be used for rehabilitation programs on patients with stroke.

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