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Instrumentation of Activities in Clinical Routine of Functional Neurorehabilitation of Upper Extremity

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Abstract— This article describes in detail the process of capturing a neurorehabilitation activity in an upper limb for clinical routines, using devices that enable the extraction of variables of clinical interest within the patient's task of execution, within which there is a focus on time, mobility and angles. These variables will be stored quantitatively, so that it is possible to have continuous and exhaustive follow-ups of the rehabilitation of the patient, thus having compliance authenticity in these routines.

Keywords— Upper extremity, biomechanical modeling, clinical routines, Kinect, neurorehabilitation.

INSTRUMENTACIÓN DE ACTIVIDADES EN RUTINA CLÍNICA DE NEUROREHABILITACIÓN FUNCIONAL DE EXTREMIDAD SUPERIOR

Resumen— En este artículo se describe detalladamente el proceso de captura de una actividad de neurorehabilitación en miembros superiores dispuesta en rutina clínica, utilizando dispositivos que permiten extraer variables de interés clínico, dentro de las cuales se encuentra el tiempo, la movilidad y ángulos. Estas variables se almacenarán cuantitativamente, de manera que sea posible tener un seguimiento continuo y exhaustivo sobre la rehabilitación del paciente, y así tener verosimilitud de cumplimiento en estas rutinas.

Palabras clave—Extremidad superior, modelado biomecánico, rutinas clínicas, kinect, neurorehabilitación.

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INSTRUMENTAÇÃO DE ATIVIDADES EM ROTINA CLÍNICA DE NEUROREABILITAÇÃO FUNCIONAL DE EXTREMIDADE SUPERIOR

Resumo— Neste artigo descreve-se detalhadamente o processo de captura de uma atividade de neuroreabilitação em membros superiores disposta em rotina clínica, utilizando dispositivos que permitem extrair variáveis de interesse clínico, dentro das quais se encontra o tempo, a mobilidade e ângulos. Estas variáveis se armazenaram quantitativamente, de maneira que seja possível ter um rastreamento contínuo e exaustivo sobre a reabilitação do paciente, e assim ter verossimilitude de cumprimento nestas rotinas.

Palavras-chave— Extremidade superior, modelagem biomecânico, rotinas clínicas, kinect, neuroreabilitação.

I. INTRODUCTION

Neurological rehabilitation surges in the 1960s as a method for the treatment of after-effects in patients with vascular brain illness and brain and spinal cord trauma affecting motor and sensory capacity [1]. According to the World Health Organization (WHO), neurorehabilitation is a life quality improvement process for the person with an illness or lesion in the nervous system, achieving optimal recovery in his social, physical and mental fields [2]. Neurorehabilitation consists of fostering cellular plasticity processes from the retraining of repetitive activities for the purpose of maintenance, strength and reacquisition abilities.

Survivors of a cerebrovascular accident (CVA) or head trauma (CET) face multiple difficulties that must be intervened with efficient neurorehabilitation systems capable of tending to needs in each one of the settings required by the patient. The consequences of these accidents translate to repercussions on the level of motor and cognitive functions depending on the area of the affliction [3]. Based on the evidence, it can be affirmed that a wide range of technologies are applied to neurorehabilitation of extremities [4]. Traditionally, robotic devices of neurorehabilitation of extremities have focused on the lower body because they are less complex in the biomedical modeling of the footing [5].

This project initially aims for the instrumentation of a functional neurorehabilitation activity in the upper extremity displayed in a clinical routine, using a device sensitive to the movements to subsequently extract variables of clinical interest, such as, angle, displacement and execution time. These will be qualified and registered as evidence for future evaluations, which will enable the continuous and thorough follow-up of the rehabilitation sessions regarding the state of the patient and the specific form of execution of the exercises evaluated.

The aim of this project is immersed in a more ambitious framework where the availability to objective and quantitative data of the activity followed will enable carrying out clinical strides regarding the subject's rehabilitation. This will translate to an element of support for clinical decision making, in the same way tending toward a paradigm of personal rehabilitation and based on evidence.

II. MATERIALS AND METHODS

A. Subjects

Firstly, the axis activities are evaluated executed by a healthy female adult, aged 22. The subject was randomly selected for initial evaluation. This paper's scope is on an adult population suffering from cerebral paralysis and previously approved by a predetermined ethics committee.

B. Neurorehabilitation activities

Each one of the rehabilitation processes for upper extremities is supported by activities that offer and provide certain developmental advantages in the patient's recovery processes. In our case, and in accordance with the experience of occupational and physical therapy professionals, it is important to consider activities which "train" the person to develop everyday actions, such as, getting dressed, eating, hair brushing, among others. As such, said professionals have provided two activities in the clinical routine, named "every body in his house" and "step-by-step toward my daily activities." The first set of activities exercises and evaluates the patient's fine motor skills. The second exercises and evaluates the reaches and grasps with varying ranges and amplitudes [6].

Considering the aforementioned, the study focuses on the second set of activities for an essential reason: these activities promote ranges of movement and articulate the amplitude necessary for carrying out activities with a high degree of fine motor skills. Since they are instrumental, one can determine their efficacy and efficiency.

C. Experimental protocol

The person will be in a sitting position in front of a table on which she will place her upper limbs, forming a bending angle of her elbows of no more than 15°. Her back will be straight and her lower limbs will be at a 90° angle. Once having achieved this position, the subject will find a transparent, cylindrical flask and a board which has three circular spaces, each one with a 15 centimeter diameter. Each space will contain an image attached by Velcro.

Then, we will explain to the participant what the activity is, in short, simple and sequential instructions.

a) First, the subject must visually detect and grab the object in front of her, making wide extension and bending movements of the shoulder and elbow with each one of her arms. This will be called "warm-up."

b) After completing the warm-up, the subject will be asked to grab the cylinder found on her right or left, effectively grasping the cylinder.

c) Finally, the subject will be told she must move the cylinder to the selected image, placing it above said image [6].

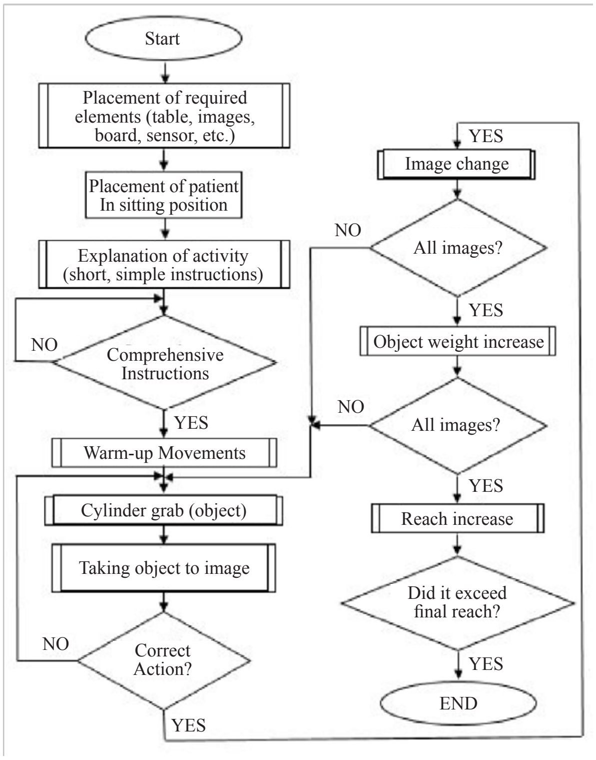

Fig. 1. Flow chart of rehabilitation protocol

The activity is presented with three levels of difficulty, taking into account levels of proximal, medium and distal ranges, with the starting level requiring proximal range and the last level requiring distal range.

The images will be related to topics having to do with basic routine activities of daily life, such as bathing, toothbrushing, hair brushing and learning of colors, numbers and shapes, among others.

During task performance, the professional will attempt to get the patient to carry out all three types of ranges, proximal with a 10 cm distance, medium with an 18 cm distance and distal with a 28-30 cm distance. The activity will be adjusted, increasing the weight of the cylindrical flask as necessary. The sensor begins its capture simultaneously at the time the professional indicates the start of the activity to the patient. All the aforementioned is summarized in the flowchart in Fig. 1.

D. Instrumented system

The instrumented system is basically made up of a Kinect Version 2 sensor, which has a servo drive, an RGB color camera, a 3D-camera, an infrared light projector and microphones [6]. The data processing and storage module, presentation of results and the interface are condensed in a computer that preferably meets the following characteristics: hard drive above 500GB, RAM above 6GB, Windows and Matlab software, a third to fifth generation processor and a high resolution monitor.

E. Data acquisition via Kinect sensor

The Kinect sensor is a device which enables the detection of joints, enabling skeletal tracking. This function is carried by means of infrared ray emissions and a VGA infrared receptor camera. The infrared emitter emits a ray of light to the space of incidence, which reflects to the VGA camera, with a delay proportional to the distance of the object intersected by the beam. Once the set of pixels are emitted, the sensor is in charge of calculating the difference to later reconstruct the image. The capture speed is 30 squares per second at a resolution of 16 bits of depth (640 x 480) [7] [8].

Once the sensor has completed the primary processing, the data is acquired in the computer by the Matlab software which has toolkits, SDK destined for the management and control of the Kinect sensor and image acquisition toolbox for the processing and acquisition of data. Based on this, final data and processing and storage takes place.

F. Nature of research

All the tools presented in this paper have a qualitative nature since it assumes a first approach to the sensor and its control. However, it suggests a subsequent implementation with a quantitative nature, aiming to aid in the strengthening of therapy applied to subjects.

III. Results

This experimental phase implies the development of activities linked to gross motor skills, such as the bending-extension movement of the shoulder. Results are obtained from the execution of movements, such as flexing, hyper-extension, abduction and adduction of the upper body extremities. The following figures acquired by means of the Kinect V.2 show each one of the movements.

When performing the first flexing movement of the shoulder, we can see that there are three marked joints in the upper limb. Also, they mark 6 in the vertical axis of the subject, as described in Fig. 2.

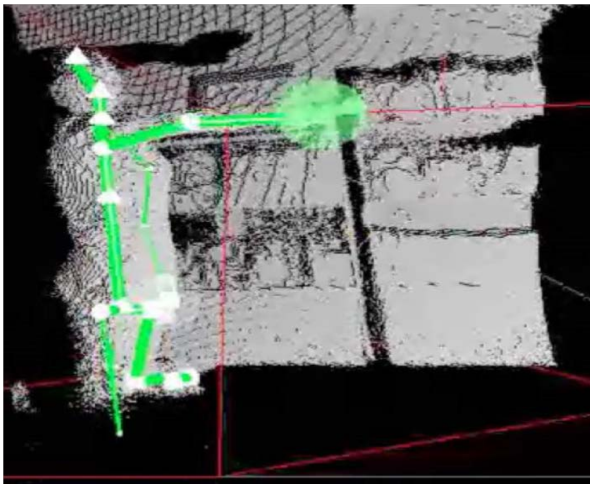

Fig. 2. Image capture of flexed shoulder joints (joints: white points inside circles or triangles)

For the movement of shoulder extension, we can see the identification of the joints of the two upper body limbs, in spite of the obstruction nature of the lateral captures, as is shown in Fig. 3.

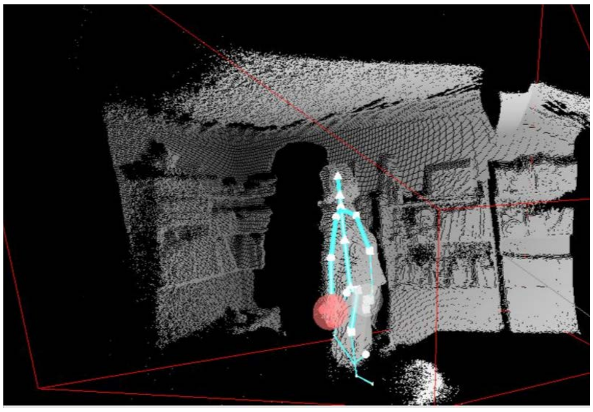

Fig. 3. Image capture of extended shoulder joints

In the hyperextension movement of the hand is significantly recognized since, as we can see in Fig. 4, the thumb and wrist are highlighted with the characteristic mark according to the sensor.

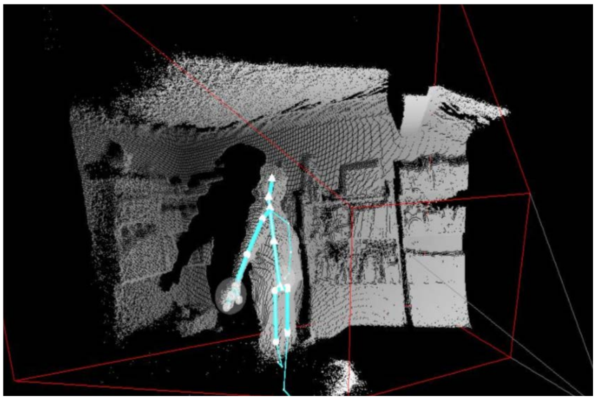

Fig. 4. Capture of hyperextended joints

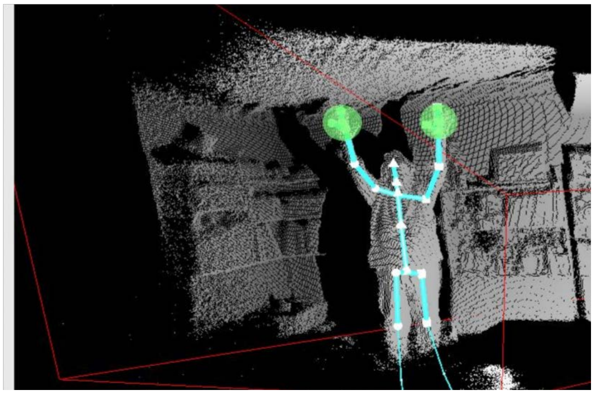

Fig. 5. Image capture of abducted joints of both arms

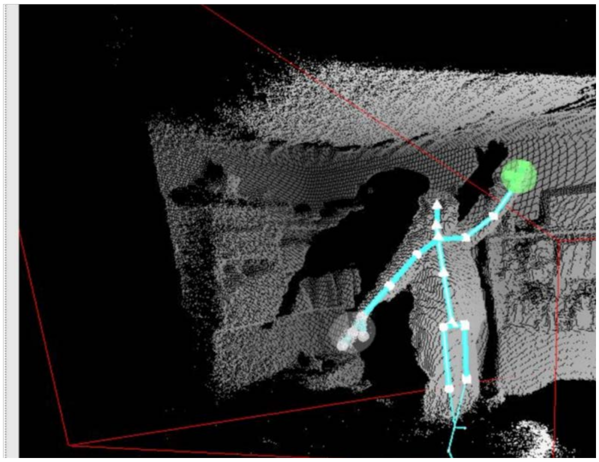

Fig. 6. Image capture of abducted joints of one arm

The capture of joints in the abduction of the upper limbs eighteen (18) joints are recognized in the entire body, of which 10 correspond to upper limbs. These points are clearly recognized and marked on the joints at their real position, as seen in Fig. 5. Likewise, upon making this movement with only one upper limb, we can see a notable difference between the two limbs and their positions, as shown in Fig. 6.

In the abduction movement of the upper limbs, we can see that the shoulder, elbow and wrist joints, output relevant information regarding movement and location of the joints of interest on each one of the upper limbs, as described in Fig. 7.

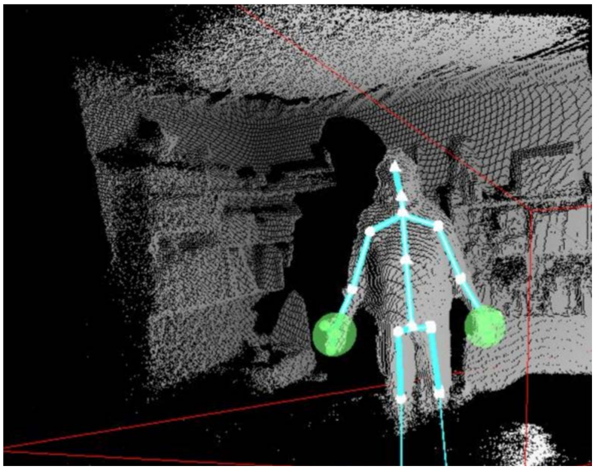

Fig. 7. Image capture of adducted joints of both arms

Lastly, in all captures, we were able to see that the acquisition of the Kinect V.2 provides the location of the joints in the shoulder, elbow and wrist, and two joints in the hand. In addition, in the vertical axis of the subject, 5 joints were acquired in the brain, cervical, thoracic and lumbar regions, with an additional 8 points of the lower extremities.

This way, 18 total points were acquired, 8 of them in lower limbs and 10 in the trunk and upper extremities. Likewise, we can state the the Kinect V.2 sensor becomes a tool for the acquisition, follow-up and quantification of the data related to the subject's body movement.

IV. DISCUSSIONS

It is estimated that 20 of 1,000 inhabitants in Colombia older than 50 years of age suffer from CVA, most prevalent in the female gender [9]. After cardiovascular illnesses and multiple traumas, CVA is the third leading cause of death, being one of the main causes of handicap and loss of health, including women between 15 and 44 years of age. There is now a CVA rate in the country of 300 for each 100,000 people [10]. Regarding CTE, a prevalence of after-effects of 6.9 for each 1,000 inhabitants, there being a noticeable difference with respect to the aforementioned that can be attributed to socio-cultural aspects of the country [9].

Currently, the activities carried out in functional neurorehabilitation of upper extremities in developing countries, such as ours, do not allow clinical therapists to have objective patient information regarding his execution and evolution in exercises performed. This impedes achieving patterns of normalcy in affected individuals, making it difficult to achieve a whole rehabilitation, focused on rational rehabilitation (social, family and individual) [2]. In current rehabilitation processes, the most significant changes considered are the implementation of equipment and measuring devices directly related to monitoring, assistance and feedback of the activity without ignoring activities associated to the process of automation [11].

Neurorehabilitation has constantly evolved, stemming from the traditional work carried out by the patient and guided by the therapist, until the implementation of multidisciplinary technologies to tend to the affliction. These latest technologies, such as the Isokinetic Ergometer [12] MITManus [13] Armin [14], Armeo Power [15], Armeo Spring [16], and including the same work presented by Muñoz et al. [17] in 2013 and Morales et al. [18] in 2013, don't take into account rehabilitation activities stipulated in the clinical routine and the information these provide. What they do is incorporate new models and ways of evaluating rehabilitation.

The objective information of traditional neurorehabilitation activities, such as the one carried out in this study, shows that the implemented system is useful for the capture of the joints in this first stage of our experimental phase, since we can evidence in all captures that the Kinect V.2 sensor provides the location of the joints of the shoulder, elbow, wrist and two points corresponding to the hand. Additionally, on the vertical axis of the subject, 5 joints in the cranial, cervical, thoracic and lumbar regions were acquired, with an added 8 points for lower body extremities. This was how a total of 18 acquired point were obtained, 8 in lower limbs and 10 in the trunk and upper extremities. Likewise, we can state that the V.2 sensor offers an optimal location regarding joints and satisfactorily responds to interferences from the body that result from the same movements.

V. CCONCLUSION

The instrumentation system proposed in the experimental phase can recognize movements of joints in space. The use of a Kinect sensor will enable the monitoring and follow-up of the joints' movements in a clinical routine in order to carry out quantification. The information gathered during each one of the sessions means having objective data with respect to movements the patient is executing. Likewise, indicators will be generated which will evaluate and measure the execution of routines. The quantified information and continuous follow-up could be very useful in order to achieve the characterization of better decisions in the patient's rehabilitation, through which we aim to offer support to the practice of professionals in charge, simply and making use of devices that a are easily obtained.

In foresight, we aim to implement a complete system that will be able to acquire, quantify and register variables associated to each one of the treated patients. This way, the clinical therapists related to the area will have objective information, quantitative and in retrospect in order to determine optimal treatment for their patients in accordance with the registered evidence.

Conflicts of Interest

The authors declare there are no conflicts of interest.

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