Depth Images Processing Algorithm to Analyze and Correct in Real Time the Verticality of Multiple Sclerosis Patients during Exercise

Gonzalo Eguiluz-Perez
DeustoTech-Life Unit, DeustoTech Institute of Technology
University of Deusto
Bilbao 48007,
Spain
+34-94-413-90-03
geguiluz@deusto.es

Begonya Garcia-Zapirain
DeustoTech-Life Unit, DeustoTech Institute of Technology
University of Deusto
Bilbao 48007,
Spain
+34-94-413-90-03
mbgarciazapi@deusto.es

ABSTRACT

Any person with Multiple Sclerosis (MS), regardless of the severity of their disability, needs regular physical activity. Poorly performed exercises could aggravate muscle imbalances and worsen the patient's health. In this paper, we propose a human body verticality detection system using a time-of-flight camera as a tool to detect incorrect postures and improve them in real time. The prototype uses a depth images processing algorithm to analyze and evaluate the position of patients during exercise. Preliminary results, based on a test with people without musculoskeletal problems and/or neurodegenerative diseases are promising and suggest that the system may be useful both for patients and medical professionals.

Keywords

Image processing, Time-of-flight, Verticality Improvement

1. INTRODUCTION

Multiple sclerosis (MS) is a chronic inflammatory demyelinating disease (CIDD) of the central nervous system leading to progressive impairment of various Central Nervous System (CNS) [1] that poses many complications for the affected person; both physical and psychosocial. Patients with chronic disorders need to exercise and keep exercising continuously to improve their condition and motor skills. Rehabilitation is a comprehensive and continuous time-limited process with defined goals to promote and achieve optimal levels of physical independence and functional abilities of people with disabilities. It also envisages achieving the necessary psychological, social, vocational and economic levels so that they can lead an independent life. Rehabilitation based on video and multimedia applications, either web-based or stand-alone applications, tries to make the therapeutic process more attractive to the patient, increasing motivation and improving treatment efficacy [2–6]. These approaches incorporate an environment where the patient is able to work with an interactive application to perform the rehabilitation in an innovative way. Poorly performed exercises could aggravate muscle imbalances and worsen health. The way we sit, stand and walk has a long-term effect on the musculoskeletal system [7-9]. Poor posture can simply be a result of the adoption of bad movement habits over many years. When a joint works in an abnormal pattern, the ligaments can be stretched and the efficiency of the joint will be reduced. As the surfaces of the joint are not aligned correctly, this produces abnormal load-bearing on both joint and ligaments. The rehabilitation-associated improvements may also be capable of detecting incorrect movements/postures and provide sensorial and/or visual feedback to the patient and/or physiotherapist.

In this project, we intend to address the following points:

- To maintain the whole amplitude of the movement of joints and soft tissues, and to teach the patient and/or the relatives adequate tightening procedures to prevent contractures.
- To make treatment techniques a part of everyday life, relating them with appropriate daily activities, ensuring maintenance of all the improvement obtained in this manner.
- To analyze and evaluate in real-time the position of patients during the workout session to avoid unsatisfactory practices that may result in more severe muscle imbalances and worsen their health.

The paper is organized as follows: first of all, the materials and methods section gives details of the experiment. System Design section describes the technological solution and the findings of the study are then presented in experiment results section, followed by a conclusion explanation.

2. MATERIALS AND METHODS

2.1 Materials

EM (Multiple Sclerosis Basque Foundation Eugenia Epalza) created a set of exercises to perform the pilot test. These materials include pictures, both static and animated (n=70, approx. 63 MB) and videos (n=110, approx. 850 MB) focused on two main areas: Physiotherapy and Rehabilitation. Videos and images are used to teach the patients in how to perform their rehabilitation through exercises (n=166) developed by EM. Along with this, we developed a system (alpha version) which tracked the movement of patients and detected their position, in particular, the verticality of the patients' trunk with a time-of-flight (ToF) camera. This system uses image processing algorithms, taking advantage of the depths images provided by the camera sensors. In order to achieve

REHAB 2014, May 20-23, Oldenburg, Germany

DOI 10.4108/icst.pervasivehealth.2014.255322

this, we used a ToF camera, specifically the Depthsense® 311 (DS311) camera developed by SoftKinetic, Inc. DS311 internals consist of an OPT8130 ToF sensor with one pair of single-ended outputs, a VSP5324 which acts as an Analog Front End (AFE) and an OPT9110, which acts as a Time of Flight Controller (TFC) [10].

2.2 Participants
Because the system is in rather preliminary stage (alpha), it has been tested with persons without musculoskeletal problems or diseases like multiple sclerosis (n = 6, three men and three women). Nevertheless, no distinctions were made in recruitment on grounds of origin, ethnicity, religious belief or social status; and no inclusion and exclusion criteria were defined.

2.3 Methods
To perform the tests, during the development phase of the prototype, each elected person was convened at a meeting of about 30 minutes in length to explain the test and briefly the system, emphasizing the most important parts for testing. Then, their profiles were created in the system. During the next seven days, each person performed the test under the supervision of a technician in our laboratory facilities. These tests consisted of calculating the time that users were in poor posture, reaction time after reporting poor posture and the maximum angle in poor posture.

3. SYSTEM DESIGN
The correction system analyzes and corrects in real time the verticality of the patient's trunk (positions leaning forward or leaning backwards not included). It is a desktop application and it needs to be executed by the user before the exercise starts. The system consists of three main blocks (see Figure 1): Acquire data, Image Processing Algorithm and Correction system.

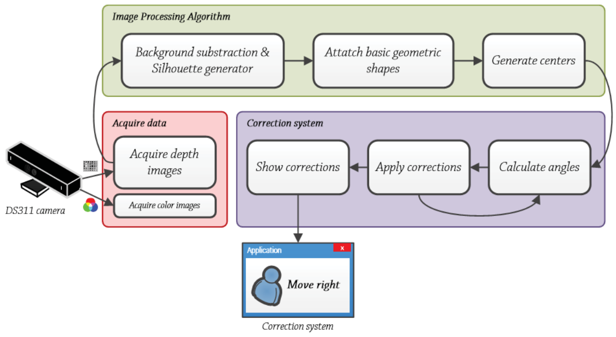

Figure 1. System's block diagram

3.1 Acquire data
This block is performed automatically by the camera, the DS311 model by Softkinetic. Acquiring color images and depth images is done simultaneously by the camera through two lenses, one for acquiring color images and one for acquiring depth images. To obtain color images, DS311 camera uses an Active Pixel Sensor (APS) based on CMOS technology. To obtain depth images, the unit of active illumination emits modulated intensity light near infrared range. The light strikes the object or surface and it is reflected back to the camera. The reflected light is projected onto the image sensor used in the lens, CMOS in this case. The ToF camera sensor captures the reflected light and evaluates the distance information of every pixel

3.2 Image processing algorithm
The image processing algorithm is based on several steps executed consecutively, so the output of one is the input of the next one. These steps are described below:

- **Background subtraction and silhouette generator**. To delete the background information of depth images, we established a threshold to discard pixels with a depth value below the threshold, constructing a new matrix with depth values over the threshold and with a 0 value in discarded pixels. To achieve this, we used a Joint Bilateral Filter, which allows to preserve human body edges, replacing the intensity value at each pixel by a weighted average of intensity values from nearby pixels, combining RGB and depth images.

- **Attach basic geometric shapes.** Once the silhouette is calculated, we approximate the silhouette to regular shapes like circles, oval, square, rectangle, trapezoid, etc. To improve the recognition, we used fuzzy logic to associate degrees of certainty to recognized shapes. The fuzzy logic system consists of a fuzzification, fuzzy inference system, and defuzzification.

- **Calculate centroids.** With the basic shapes calculated, we obtained the centroid of each shape assigning an internal label to interact. Those points are the ones that are used as input to the correction system.

3.3 Correction system
The correct alignment of the spinal column is the key to the proper posture. The developed system evaluates trunk's position in the frontal plane, the upper part specifically, and vertical axis, so movements like leaning forward or leaning backwards are not taken into account. To calculate the trunk's angle, we apply the following steps:

- Obtain 2D coordinates, in pixels, of central point of the calculated torso and some pixels of the upper of this point. Using these two points, construct a vector V that passes through them. This is calculated at the very beginning, and then used as a reference value.

- Get 2D coordinates, in pixels, of the head bottom point and torso point. Using these two points, construct a vector U that passes through them.

- Calculate the angle between these two vectors U and V

Due to the resolution of the camera, depth resolution is 160 x 120 pixels, we established a threshold. A threshold value helps prevent false positives, so the system does not continuously notify for poor positions. If the angle is greater than the threshold, the system will warn the user, indicating where to move, left or right and how much he/she should move, a little or a lot.

4. RESULTS

4.1 Experiment example
The picture below, Figure 2, shows the tracking system in action (poor position on the left, and good position on the right) and Figure 3 shows two physiotherapeutic exercises (neck flexion on the left and neck relaxation on the right).

Figure 2. Correction system in action

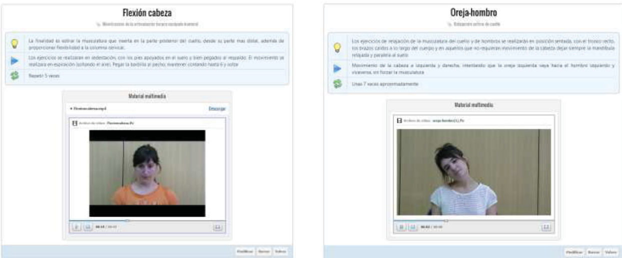

Figure 3. Physiotherapeutic exercises

4.2 Assessment analysis

The data collected during the test were angles (maximum value) related to the verticality, reaction time (seconds), and time in poor posture (seconds). These values represent the average values obtained for each user during exercises (n=10). Table 1 shows these values:

Table 1. Values obtained in the test (avg)

User	Max angle	Reaction time	Poor posture
#1	15º	1.7”	2.6”
#2	20º	1.5”	2”
#3	18º	1.9”	3.2”
#4	16º	1.3”	2”
#5	20º	1.5”	2.2”
#6	16º	2.1”	3”

These data do not represent a real scenario, since the sample consisted of people without musculoskeletal injuries or degenerative lesions such as multiple sclerosis, but validate the system as a control group. In real scenario (multiple sclerosis), the data will show the real evolution of patients, improving their posture and consequently, their quality of life [11].

5. CONCLUSIONS

The tracking system we developed offers a new information channel for professionals and patients to improve the monitoring of the physical aspect of the pathology. Through the tracking system, patients see their position during the exercise in real time, helping them to perform the exercise correctly, because poorly performed exercises could aggravate their muscle imbalances and worsen their health. The technology used, time-of-flight, is new in this kind of systems, and until now has only been used in assembly lines, bioengineering, medicine and videogames. Preliminary results, based on a limit number of users (n = 6) are promising despite the sample was a group of people without physical disabilities. Also, this system can be used with other interest groups and even with people without physical disabilities, just to control the posture while sitting.

The next steps are to test the system in a real scenario, improve the algorithm, and create a data model to analyze the information generated through the exercises to provide information to support traditional evaluation.

6. ACKNOWLEDGMENTS

The authors wish to acknowledge the University of Deusto, which kindly lent infrastructures and material for this project. We would also like to express our gratitude to EM for their work and finally, we want to express our gratitude to BIZKAILAB initiative of the Biscay Council and the Basque Country Department of Education, Universities and Research for their support.

7. REFERENCES

[1] Hu, W.; Lucchinetti, C.F. 2009. The pathological spectrum of CNS inflammatory demyelinating diseases. *Semin. Immunopathol*, 31, 439–453.

[2] Azpiroz, J.; Barrios, F.A.; Carrillo, M.A.; Carrillo, R.; Cerrato, A.; Hernandez, J.; Leder, R.S.; Rodriguez, A.O.; Salgado, P. 2005. Game Motivated and Constraint Induced Therapy in Late Stroke with fMRI Studies Pre and Post Therapy. *In Proceedings of the IEEE-EMBS. 27th Annual International Conference of the Engineering in Medicine and Biology Society* , Shanghai, China.

[3] Camurri, A.; Mazzarino, B.; Volpe, G.; Morasso, P.; Priano, F.; Re, C. 2003. Application of multimedia techniques in the physical rehabilitation of Parkinson's patients. *J. Vis. Comput. Animat.*, *14*, 269–278.

[4] Weiss, S.M.; Indurkhya, N.; Zhang, T; Damerau, F.J. 2005. *Text Mining: Predictive Methods for Analyzing Unstructured Information*.

[5] Yellowlees, P.M.; Holloway, K.M.; Parish, M.B. 2012. Therapy in virtual environments—clinical and ethical issues. *Telemed. e-Health*, *18*, 558–564.

[6] Bart, O.; Agam, T.; Weiss, P.L.; Kizony, R. 2011. Using video-capture virtual reality for children with acquired brain injury. *Disabil. Rehabil.*, *33*, 1579–1586.

[7] Fowler, K., & Kravitz, L. 2011. The perils of poor posture. *Idea Fitness Journal*, 8(4).

[8] Nilsson, B.-M.; Söderlund, 2005. A. Head posture in patients with whiplash-associated disorders and the measurement method's reliability-A comparison to healthy subjects. *Adv. Physiother.*, *7*, 13–19.

[9] de Haart, M.; Geurts, A.C.; Huidekoper, S.C.; Fasotti, L.; van Limbeek, J. 2004. Recovery of standing balance in postacute stroke patients: a rehabilitation cohort study. *Arch. Phys. Med. Rehabil.*, *85*, 886–895.

[10] 3D Time of Flight Analog Output DepthSense® Image Sensors (OPT8130 and OPT8140). Available online: http://www.planar.ru/project//documents/44001_45000/44005/slab063.pdf (accessed on 29 October 2013).

[11] Imagama, S., Matsuyama, Y., Hasegawa, Y., Sakai, Y., Ito, Z., Ishiguro, N., & Hamajima, N. 2011. Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males. *European Spine Journal*, 20(6), 954-961.