GESTURE-GROSS RECOGNITION OF UPPER LIMBS TO PHYSICAL REHABILITATION

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Abstract. *Nowadays, modern computational technologies used in rehabilitation processes have grown considerably in health care centers. These open a broad of new paradigms which improve the rehabilitation process, robotic hardware, virtual reality system and others. Particularly, Virtual Reality systems are notable for having a high interaction with the user based on real-time responsive actions. In rehabilitation, these systems are offered as modern strategies where a patient performs a set of therapy activities recognized as integration tasks through games or simulations. Several health care centers are using these strategies as part of the regular therapy due to the treatment time is less than using the standard ones. If a therapy is focused on upper limbs, a set of specialized gestures are necessary for the total recovery of patients. In this paper we present an effective solution dedicated to capture and recognition of movement of the upper limbs based on gross motor skills. Our proposal integrates corporal gross gestures used as the main user interface in an entire platform for physical rehabilitation of children with motor disabilities in upper limbs. It is designed based on a Microsoft Kinect as a low-cost hardware to capture the motion. Several gestures are achieved to test our proposal given excellent results.*

Key words: physical rehabilitation, gesture recognition, virtual reality, motion capture

1 INTRODUCTION

The body language can be defined as a nonverbal form of communication through any body movement. In Computer Science, gesture recognition is a topic that studies the reading of these movements using algorithms. These gestures recognition algorithms are mainly focus on the movement of arm, hands, eyes, legs, and others. The main idea is to capture body movements using capture devices and send the acquired data to a computer. Several approaches employed in gesture recognition are used in the Computer Vision research field.

The interpretation of human gestures is a well-known computational problem in Computer Vision field. The GUI (Graphics User Interface) used must be friendly and simple to perform particular movements required by a software application. Based on that, the hardware to capture the gestures has a relation with the GUI as well as the established set of body movement which represent a gesture. For example, a camera can capture the hand movement over a flat surface considering only when fingers draw something over the surface and these movements generate an image in the application.

Nowadays, there are studies dedicated to achieve gesture recognition algorithms for health purpose to improve the quality of certain tasks. A remarkable example is shown in the Physical Rehabilitation field where the low-cost hardware and algorithms accomplish outstanding results in therapy over patients with mobility issues [7]. However, the gesture recognition and the effective calibration between the hardware and the software application is still a challenge to be solved. In this paper, we describe a solution to capture and recognize the movement of upper limbs based on gross motor skills using low-cost hardware with application in the physical rehabilitation therapy. Thus, we define a automaton for gesture recognition of upper limbs based on 3D points captured from the game console hardware Microsoft Kinect®.

This paper is organized as follows: Section 2 presents a briefly overview in gesture recognition on rehabilitation systems. Next, Section 3 describes our approach proposed in recognition using low-cost hardware, specifically the Microsoft Kinect. In Section 4, we show the obtained experimental results. Finally, Section 5 presents conclusions and future work.

2 GESTURE RECOGNITION ON REHABILITATION SYSTEMS

At the present, many modern health care centers have computational systems based on virtual reality games oriented to the motor training and motor learning through both, fine and gross movement exercises [3]. These centers are focused on accessibility and low-cost hardware in order to reduce costs and spread out the virtual rehabilitation process.

The rehabilitation activities based on gross movements are growing very fast. The gross movement responds the body movements that requires a drastic change of position. Thus, a gross gesture is defined as a movement that demands big amplitude in its execution. Besides, fine gestures are movements with a high precision requirement and a high coordination level.

The gross motor gesture recognition has been employed for many systems as strategy to supply motor exercises. A remarkable example is the system BioTrak [1] which is a platform for training and rehabilitation of many diseases as result of some pathology. This system includes a magnetic tracker which can detect gross gestures from the upper limbs. Another example is shown by the system IREX (Interactive Rehabilitation and Exercise System) [2] which includes a wide range of interactive games focused in gross motor movement for the arms. All these systems are efficient showing good results. Nevertheless, their acquisitions are expensive due to the employed hardware. Therefore, the requirement of low-cost options is necessary. Thus, the hardware provided by the video game consoles emerged as an excellent option because they are designed to obtain the 3D position of game players in real time. Thereby, researches focused on the Microsoft Kinect®, Nintendo Wii®, PlayStation Move®, and others are outstanding examples.

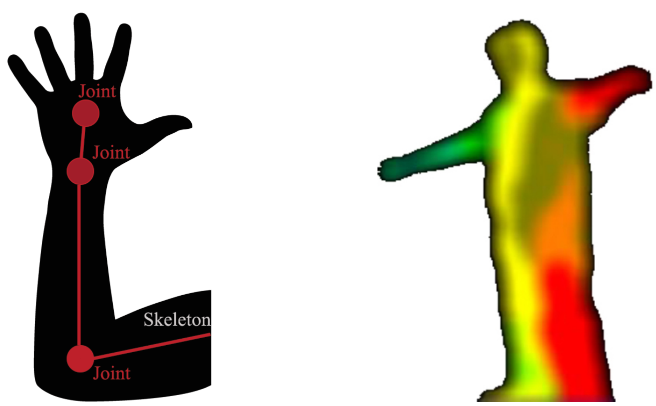
Particularly, the Microsoft Kinect is a low-cost hardware which captures the gross-movement of a patient as a system player. This tool has been used in various systems for physical rehabilitation under Virtual Reality (VR). In 2004, Sveistrup [3] presents a complete review of several systems based on VR to motor rehabilitation. Recently, Cameirão et al. [4] developed a Kinect-based tool for the rehabilitation of motor deficits of upper extremities (Rehabilitation Gaming System - RGS) after a brain lesion due to stroke. In addition, researches like those made by Hayes et al. [5] and Lange et al. [6], show platforms of video games for rehabilitation using the Kinect as a rehabilitation tool.

In this paper we present effective machinery for gross gestures recognition in upper limbs, oriented to physical rehabilitation, using a Microsoft Kinect. Our development is part of a solution based on virtual rehabilitation designed and developed by our research group [7].

3 KINECT-BASED GESTURE RECOGNITION APPROACH

Our approach is based on a platform which allows managing the connection between the Microsoft Kinect and the software application, even monitoring the hardware activity and its associated errors. With this architecture, it is possible maintains a configuration for a stable gesture recognition given the error originated by the device.

To the input data detection, a class named Skeleton is created to allow the easy access from the application. This class manages a set of joints or connection between bones as shown in Fig. 1a. Then, the verification of a body positions as 3D points in a time k is always possible due to it has a unique identification tracking for a patient. Note that, the application could have several patients detected but only one is consider as the main patient. Accordingly, this main patient can be isolated from the environment captured, allowing a more dependable gesture detection.



(a) (b)

Figure 1: Representation of the Skeleton with (a) his joints and (b) the complete silhouette.

The Kinect captures two different data images on each frame: a color RGB image and a depth image, representing the distance device-patient. These image are pre-processed to make a silhouette or contour of the patient, and to draw the 3D spacial position of a patient.

In order to raise the feedback and giving to the patient a best correspondence between the virtual space and real world as a connection, a silhouette is drawn. Using the depth image, an algorithm iterates over all pixels uncompressing their values and normalized to range [0, 1]. The silhouette represents the body of the patient including a chromatic behavior that depends of the distance between the user and the Kinect. Figure 1b shows an example of such a silhouette.

The gesture-gross recognition machinery of upper limbs is divided in three stages called as Controller, Gesture and Deployment.

3.1 Controller

The Controller stage handles the event generation given by the state changes and manages the data capture from hardware. This stage verified the connectivity of the Kinect with the system and its operational status. Also, it contains all essential procedures for the correct working of Kinect including the images stream detection, error management and Skeleton building.

3.2 Gesture

This stage control the user behavior, detecting all matches over predefined gestures in the system. At this point, the platform handles 2 structures: pose and gestures. A pose can be defined as a set of condition referred to the position of skeleton joints that can be verified in a time k. On the other side, gesture is a set of poses performed with compliance in a specific order. The Fig. 2 shows an example of the gesture "good bye" using the right arm formed by 4 postures.

Figure 2: An example of the "good bye" gesture composed by 4 poses (from left to right).

Generally, the definition of a pose requires some global conditions; these should be common at least for consecutive poses that form a gesture. This guarantees that exist a completed checking in the verification process between a pose and the next of them. A gesture can be in one of three possible states: pause, failure or success. If a pose had being performed, its state changes to success and the platform proceeds to evaluate the next pose according to the definition order. Similarly, if just a first condition (i.e. a base condition) had being achieved, the state changes to pause, allowing the platform verify this condition again.

Figure 3 shows an example using 3 poses to define a gesture. The first pose was achieved successfully. If the second pose is success the gesture machinery will verify the third one, otherwise the gesture changes its status to pause. While the gesture is in pause state, the process will continue checking the current pose for a number of iterations i. If the $i > MAX\_ITER$, where MAX_ITER represents a maximum number of iterations, then the gesture changes to failure.

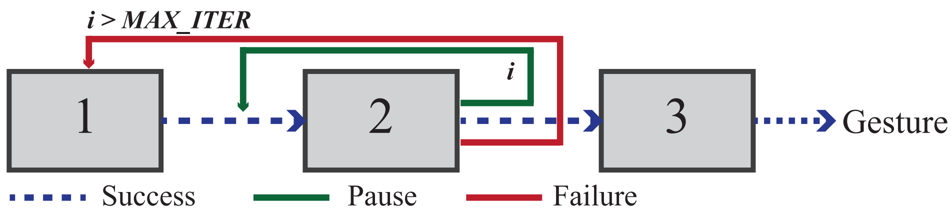


Figure 3: Execution process of three poses of a gesture and their states.

3.3 Deployment

In our approach, the application extracts color image stream (for each frame) and a depth image stream from the hardware. Both are processed to obtain images that can be entries for other algorithms or simply deployed.

To increase the feedback, the silhouette of the patient drawn is based on a depth color scale. The depth image is mapped to a color palette where colors are assigned according the depth value of each pixel. An example of the colored body silhouette can be seen in Fig. 1b. Also, a Gaussian smoothing algorithm is applied to improve the quality of the silhouette.

Despite of that our system is capable to process all body captured by the Kinect, we only focus on the upper limbs where the gestures and poses are defined.

4 EXPERIMENTS AND RESULTS

The system developed is based on C# programming language, using the framework XNA provided by Microsoft to implement the interaction with the Kinect under Windows operating system. To perform our tests, the data is obtained through the evaluation of several position captures of a right hand around one minute by test. The fundamental goal is to verify the error grade between the position of the skeleton joint and the patient real position. This error corresponds to the error detection and interpretation of a gesture owing to their deterministic characteristic definition and verification of it.

The analysis of 4 postures were considered for verification of our approach as a rehabilitation activity. Each of them was accomplished by a patient who holds a specified position for 1 min holding as best as possible the same position since starting. It is important considers the inherent error itself provided by the Kinect in detection and mobility problems of patient on remaining an static position.

It was possible to determine a measure called *precision error* which represents the difference between an static position and the average of several captures made by the Kinect for a patient. For tests, this precision error was performed to the first posture. The evaluated gesture consists in holding the right arm extended in lateral form with a mean height. Considering 30 fps as frame rate of the Kinect, a total of 1.800 points were captured (30 frames $\times$ 60s) with a standard deviation $\sigma_x = 0.1185$ and $\sigma_y = 0.2490$ which are acceptable considering the ends points and the number of these.

Based on the gesture definition, the data detection could have huge influence for their occurrence because errors with major deviations could generate state changing, and as a consequence the restarting of the verification process.

We test the limits of the skeleton defined in section 3.2, storing the minimum and maximum reached possible position for a patient. This limits making a boundary of action which is adjusted for each patient with different mobility issues (limitations). This characteristic adds dynamism to the approach proposed.

5 CONCLUSIONS AND FUTURE WORK

In this paper, we present a simple and effective machinery for the gesture-gross recognition of upper limbs for physical rehabilitation using the Microsoft Kinect as an acquisition device. An automaton state to control and manage a posture based on different poses was developed. Also, the data interpretation acquired from the device was performed. In order to study our solution precision, a quantitative evaluation over the gestures is performed showing a high precision in the data captured and interpreted. Thus, it is possible to verify the functionality during the corporal movement of a patient placed in front of the Kinect.

Our tests are achieved over different gestures with a high degree of assertion. However, in some gestures where data detection is imprecise, due to very fast movements or obstructions during capture, they are considered as limitations of our approach but are isolated cases. For future work, adding new parameters will offer greater adaptability and flexibility in the platform to embrace a wider range of motion detection applications. Other applications can be benefited with our gesture recognition system due to the extensibility and dynamism. Also, it would be possible to add more precision and versatility with technologies as XB1 or Leap Motion device.

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