Development of an Open Electronics User Inerface for Lower Member Occupational Health Care Exergaming

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Abstract. According to the World Health Organization 15 % of the global population suffers some form of musculoskeletal disorder. To prevent such affection, workers are encouraged to engage into active pauses during work hours to lower the risk of suffering any type of disorder. Although aware of the consequences, workers tend to avoid active pauses due to lack of time or motivation, unclear guides or ignorance regarding the effects of bad occupational health habits. An approach to overcome such challenges can be found in exergames, as they provide means to increase user motivation and clear instructions by taking advantage of motion tracking to better execute the active pauses. Wearable sensor are currently providing affordable solutions that track data more accurately in contrast to gaming devices, in this work, an open electronics interface is implemented within an exergame to motitave the execution of lower member active pauses within an office environment.

Keywords: Health · Sensor · Tracking

1 Introduction

Musculoskeletal disorders is a major concerned recognized by the World Health Organization that affects the quality of life, these can result from occupational health risks caused by excessive work, bad postures, sedentary and repetitive tasks, among many others [1, 2]. A strategy to minimize the risks and improve the worker's health is achieved through the practice of active pauses, however, it success is challenging because it depends on motivation and understanding on what needs to be correctly done. Current assessments in occupational health use visual observation and surveys, making it subjective and difficult to follow as the worker may not perform the pauses or report them when examined [3].

The engagement and assessment challenges can be approached with exergames, research in this area has resulted in the development of applications in fitness, rehabilitation and entertainment involving different scenarios and body parts [4]. These developments have been evolving along computer graphics and user interfaces (UIs), resulting in more realistic and natural interactions with motion controllers that can provide experiences which can be assessed by a health care specialist to improve the benefits and impact of the physical activity [5].

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Interactive motion capture developments have provided approaches using expensive equipment, such as high performance motion capture systems using suits and multiple infrared cameras [6], however these technologies face a major challenge due to costs and space requirements [7]. This problem has been recently tackled using affordable devices such as gaming controllers like the Kinect and the Wii remote control [8], and smartphones and custom devices [9]. The Kinect for example, requires adequate space to properly capture the player and depending on lighting conditions its accuracy may be affect, however it has been in used in full body and segmented body parts exergames with success [10]. The Wii remote control also poses challenges in terms of its attachment to body due to its size and weight (initially only had an accelerometer, but current version includes a gyroscope as well), it has also been used in several exercising scenarios, proving adequate for exergaming [11]. Smartphones have also been studied as tools for encouraging healthier activities because they are commonly used and most have several sensors that allow detecting user motion to use it as game mechanics [12, 13]. Finally, the use of wearable sensors is providing more accurate solutions to track motion capture; these can be tailored to specific needs and don't depend on a manufacturer's choice (common scenario in smartphones where every device has different types and quality of sensors), current developments are focusing on wireless and realistic motion tracking to provide sufficient data to better assess the exercising activities [14, 15].

In this paper the authors focused on a computer work scenario, in this case, the most common health risks are due to repetitive tasks, bad postures and sedentary caused by being seated most of the day. A lower member exergame was chosen as the leg is the most important body part used for locomotion, hence its care is of great importance to avoid circulatory and muscle disorders. The goal is to provide motivation and data with an affordable solution based on Arduino + Processing to accurate capture flexion and extension movements that can be perform within a computer working environment without requiring guides or attending to exercising sessions. The tracked information allows the worker and the health care specialist to learn about how well the exercises are being performed.

2 System Development

The system development is comprised of a lower member kinematics and active pause analysis to design the game and the system architecture, with this information the motion capture device is implemented using open electronics equipment and commercial inertial sensors with wireless communications to allow motion freedom to the player without constraining the exercise.

2.1 Lower Member Analysis and Exergame Design

The lower member is composed of a support (bones) and actuator (muscles) system with six degrees of freedom (DOF) from the hip (3) to the knee (1) and finally, to the ankle (2). An active pause requires the worker to take at least five minutes from

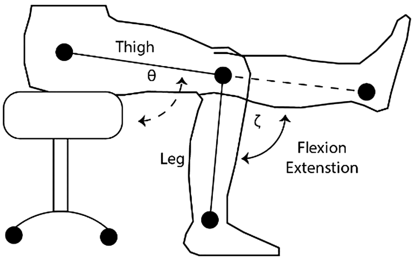

Fig. 1. Lower limb links, DOF and active pause movement

working activities to perform a series of exercises focused on different body parts. A common practiced exercise is the seated hamstring curl that requires repetitive leg rotations from 0º to 90º as presented in Fig. 1. This movement requires only one DOF, allowing to analyze the leg as a serial kinematic chain with three joints, the length of each link depends on the player's leg and thigh measures, and the flexion/extension rotations vary accordingly to the active pause exercise.

To represent the movement of the leg a forward kinematics analysis is performed as the angles are known from the exercises executed by the player; this model allows mapping the user's motion capture data with the virtual avatar in the exergame.

2.2 System Architecture

To develop the exergame the system architecture is defined as presented in Fig. 2, the main input is received from the player who can configure the thigh and leg lengths for the game to properly display the avatar and motion capture movements; another input is provided by the health care specialist, who indicates the amount of repetitions and acceptable ranges of motions, which may vary from player to player. The main mean of interactions is a the wearable sensor that the player places at the leg, the device is composed of an open electronics Arduino Uno board with a 9 DOF sensor that sends the information to the computer program through Bluetooth. When the game application receives the data, the virtual avatar's leg accordingly to what the player did, assigning scores and recording the movements for later assessment.

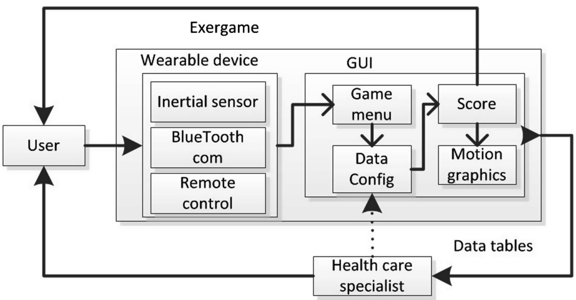

Fig. 2. System architecture

2.3 Game Design

The first elements to define for the exergame are the goal, the rules and the feedback. The system presented in this project has two main goals quantify the lower limb– leg active pause with motion captured data and encourage the workers into executing them within a more compelling setup. The rules of the exergame require the player to correctly execute the movements as these allow reaching the goal through flexion and extension rotations. The feedback is provided in several forms, one is the displayed score in the GUI, the avatar performing the movements, the motion graphics and the data tables, all of these allow improving the active pause execution by the player and the health care specialist.

With these elements in mind and considering the chosen the active pause exercise, the designed gaming scenario consisted in a ball kicking game where depending on the angle and angular velocity the player needs to reach certain objects at different distances.

2.4 Programming and Motion Capture

The exergame programming required reading the accelerometer and gyroscope data and write the values into the homogenous transformation matrix presented in (1). In this case as the model requires only one DOF the matrix is simplified with the following Denavit-Hartenberg values: $\boldsymbol{\theta_i}$ (Thigh: $\boldsymbol{\theta_1}$, Leg: $\boldsymbol{\theta_2}$), $\boldsymbol{d_i}$, $\boldsymbol{\alpha_i}$: 0 (no abduction or adduction considered), $\boldsymbol{a_i}$: (Thigh and leg lengths depending on each user) [16].

$$^{i-1}T_i = \begin{bmatrix} Cos\theta_i & 0_i & 0 & a_i Cos\theta_i \\ Sin\theta_i & Cos\theta_i & 0 & a_i Sin\theta_i \\ 0 & Cos\alpha_i & Cos\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

With the rotation information the kinematics model allows transforming the virtual avatar leg with the player's movement. The game was programmed using angular movement, collisions and parabolic motion to kick the ball and send it to the objectives.

3 Results

To use the exergame, the user attaches the wireless device to his leg as presented in Fig. 2. To start the game the user uses a wireless controller to access menu and settings where it configures the lengths of the avatar's leg and exercise duration and repetitions. The game provides information regarding how to perform the exercises, its benefits and how to use the wearable sensor, once the setup is finished the player can start the game and engage into the active pause, while standing or seating.

The exergame was tested with ten users (five practiced sports and the other five didn't) kicking the ball with occupational health care specialists also participating. Motion capture data was obtained from the thigh and leg by placing the sensor around

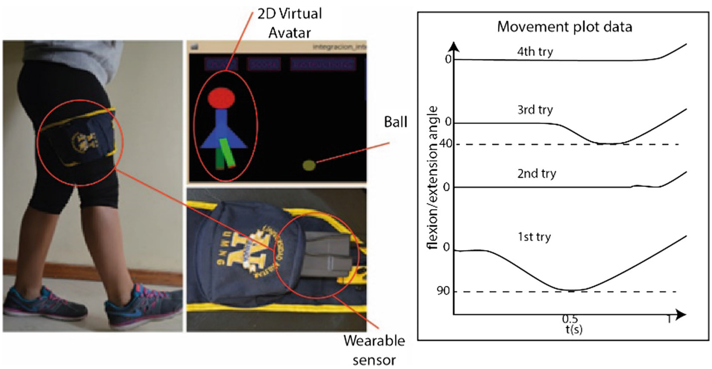

Fig. 3. Exergame components, test and motion graphics

them as presented in Fig. 3. A survey to acquire information about the experience and potential future works was applied to the participants.

From the survey it was possible to observe the users attention being caught, both groups found the development interesting, however, those who practice sports only manifested interest in the data as it could help them improve the performance while the other group concluded that gaming elements could motivate them into engaging and continuously practice the active pauses. Some challenges that arose from the test that affected the motion capture where the placement of the sensors and the comfort associated if it was tight or loose, where they asked if it was possible to have a smaller device, however, when placed correctly the users engaged into the game to get the score while perfecting the motion through the game's visuals and graphics. Regarding the graphics, players where focused on getting the game right that the geometry primitive avatar didn't caused any negative feedback, however, they manifested that a 3D scenario would also be interesting due to depth perception.

4 Conclusions

The developed exergame provided an entertaining scenario to practice leg hamstring curl active pauses; the game can be configured to work with gaming and monitoring elements modules to address the needs of occupational health care and fitness. A size restriction was met with the chosen materials as a consequence of using elements easily found in the market, however, the size can be reduced and this is part of future works, along with further developments in full body models and motion capture.

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