Virtual Application for Preventing Repetitive Strain Injuries on Hands: First Insights

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Abstract: This paper is focused on the problem of repetitive strain injuries in hands. These injuries are mostly related to professional activities, especially in people that work at high levels of industrialization, patchwork or in use of advanced technology in productive process, as they are subject to a high rate of work where the performed tasks often lead to repetitive actions. The objective of this paper is the development of an application for hands detection and their movements to develop a game for preventing strain injuries. The activity will be developed in the software Unity, where it will be associated a 3D sensor, Intel RealSense 3D Camera F200. During the activity, the user will execute several prevention/relaxation exercises. With the activity implementation in companies and establishments, the employees will be able to exercise their hands, thus reducing the risk of being affected by strain injuries, contributing to the decrease or even elimination of the subsequent related costs with these injuries.

1 INTRODUCTION

This paper presents the problem associated to repetitive strain injuries in hands. These injuries happen due to the repetition of a certain movement, which leads to the excessive use of certain joints and muscles of the body (Moreira, 2015).

The main injuries in hands due to repetitive efforts are carpal tunnel syndrome, tendonitis and Tenosynovitis (DeQuervain disease). These injuries are responsible for pain and functional incapacity on upper limbs, which involve tendons, muscles, joints, nerves and blood vessels (Aptel et al., 2002).

Nowadays, strain injuries affect more and more people and are mostly related to professional activities, especially in people that work at high levels of industrialization or in use of advanced technology in productive process (Oliveira and Barreto, 1997), as they are subjected to a high rate of work where the tasks they perform often lead to repetitive actions.

Strain injuries negatively influence the employee performance since it leads to a reduced productivity as they have to perform their tasks with pain and discomfort on extreme cases. Moreover, they can even lead to the interruption of the professional career (Moreira, 2015).

The lack of awareness for prevention often leads the employers to believe that costs associated to prevention are unnecessary expenditure. However, in long term and with onset of these injuries on their employees the associated expenses become higher than expenses in prevention. Sometimes the treatment implies leads to periods of temporary incapacity for work and, occasionally, to early retirement. This situation is difficult to manage for businesses, because prolonged absence of an employee requires a distribution of his/her duties by other employee or the temporary hiring of a new employee, being necessary to invest in his/her instruction (Serranheira et al., 2003). This leads to production breaks and brings some setbacks that may condition the company goals.

The objective of this paper is the development of a game application for hands detection and their movements for preventing strain injuries in hands. This is a current and pertinent case that addresses the needs of prevention to people who are typically subject to strain injuries. After literature reviewing, it is verified that several authors argue that performing

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a set of muscle stretching and warming exercises daily prevents hand injuries. Thus, a future developed game will provide several mandatory prevention/relaxation exercises to make possible to progress in the game.

The users will perform the exercises at least twice a day, this is, at the beginning and at the end of their daily work (Moreira, 2015).

The activity will be developed in the software Unity, the software recognized as the engine for developing cross-platform games (Unity n.d.). It will be employed a 3D sensor, Intel RealSense 3D Camera F200, which is responsible for the image capture, allowing hands recognition and movements caption.

Implementing this game in companies and establishments, the employees will be able to exercise their hands and preventing future strain injuries on hands. It is the authors´ believe that, with the goal of improving their scores in the game, the employees will voluntarily perform the exercises that will be beneficial to their well-being.

Following this trend, this paper is divided into seven sections. In the second section, Hand Injuries from Repetitive Strain, there are mentioned the repetitive strain injuries in the hands due repetitive efforts. The third section, Related Work, presents the work referred in the literature in this topic. The fourth section, Movements Description, details the stretching and warm-up exercises to prevent repetitive strain injuries on hands. Then, the fifth section, Implementation, presents the development of the application. The sixth section, Results, presents the obtained results. And finally, in section seven, Final Comments, some conclusions and future perspectives of work are described.

2 HAND INJURIES FROM REPETITIVE STRAIN

The occurrence of hand injuries due to repetitive strain has proved to be a problem in industrialized countries, because many work activities are characterized by repetitive movements and required great effort to perform them (Silva, 2015).

There are several musculoskeletal injuries that affect hands due repetitive strain, where the most common are the Carpal Tunnel Syndrome, Tendinitis and Tenosynovitis.

2.1 Carpal Tunnel Syndrome

Carpal tunnel syndrome is a peripheral neuropathy caused by incarceration in medial nerve by compression, stretching, friction or angulation in a confined space (carpal tunnel) (Serranheira et al., 2003).

Figure 1 shows a hand with the median nerve, indicating the fingers this nerve affects. Also, it shows a cross section to differentiate a healthy wrist from a wrist with carpal tunnel syndrome.

The carpal tunnel syndrome injury mainly occurs due repetitive wrist movements and his major symptoms are pain, numbness, tingling, burning sensation and muscle weakness in the lower part of the thumb (Nunes & Bush, 2011).

The carpal tunnel syndrome affects about 0.6 to 2% of working age population (Palmer, 2011).

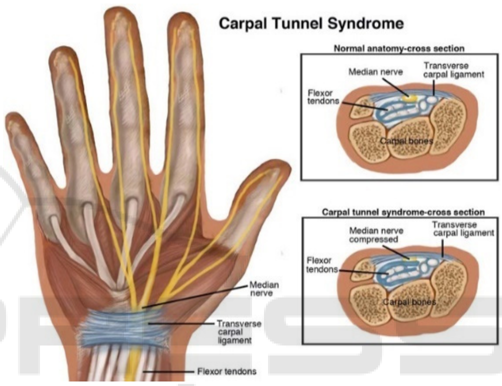

Figure 1: Carpal Tunnel Syndrome, adapted from (Move Forward n.d.).

2.2 Tendinitis

Tendonitis is an inflammation of the tendon sheaths around a joint (Nunes and Bush, 2011). Tendons are structures that attach muscles to the skeleton.

The excessive use of the wrist allows an underload in tendons, which generates microscopic lesions. Thus, the body will try to recover from these micro lesions. However, if overuse persists, it can occur inflammation through swelling, making the injured tendon more vulnerable to overload, causing tendinitis (Simoneau et al. n.d.). The major symptoms of tendonitis are pain, weakness, swelling, burning sensation in the affected areas (Nunes and Bush, 2011).

2.3 Tenosynovitis

Tenosynovitis is the simultaneous inflammation of a tendon and surrounding synovial sheath, that is, when a tendonitis occurs the tendon swells and compresses the sheath, causing the inflammation (Simoneau et al., n.d.).

Figure 2 shows a hand affected by DeQuervain's disease, which is one of the most known tenosynovitis (Nunes and Bush, 2011).

The tenosynovitis injury affects the tendons and sheaths of the wrist at the base of the thumb and has symptoms like tingling, numbness, swelling and pain in the lower part of the thumb (Nunes & Bush 2011). The occurrence of this injury can lead to the development of carpal tunnel syndrome.

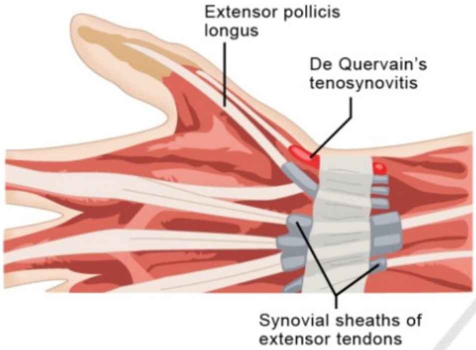

Figure 2: DeQuervain Tenosynovitis, adapted from (Chiropractic, 2015).

3 RELATED WORK

There is research on repetitive strain injuries in several fields. However, in addition to the recommendation of physical exercise there is no method for the prevention of these injuries (Serranheira et al., 2003; Silva, 2015; Aptel et al., 2002; Nunes and Bush, 2011; Simoneau et al., n.d.).

In order to develop an application to the prevention of these injuries, it is necessary a sensor capable of detecting hands in 3D. The literature refers to sensors as Kinect, Leap Motion and Intel RealSense 3D Camera F200.

The Leap Motion is a new gesture and position tracking system with the accuracy level of sub-millimeter (Weichert et al., 2013).

There are already some applications developed with Leap Motion: the activity developed for enhancing motor skills of children with autism (Zhu et al., 2015), the development of an interactive application for learning Portuguese Sign Language (Torres et.al, 2016), and also the activity developed to physiotherapy for people suffering Parkinson's disease (Colgan, 2015), among others.

Intel has already hand recognition modules, and also developed recognition algorithms for some gestures (IntelRealSense 2014). There are also other applications developed using Intel cameras, for example, applications for emotion recognition (Silva et. al., 2016), medicine rehabilitation, defending penalty games or play drums games (Han et al., 2015).

Moreover, there are also several applications developed with Kinect, among them the recognition of sign language (Miguel and Sotelo, 2014) or applications for rehabilitation of upper limbs (Calin et al., 2011) and both limbs (Martins et. al., 2016).

Although, from the literature review undertaken, no solution was identified for the problem proposed in this paper.

4 MOVEMENTS DESCRIPTION

In this section, it will be discussed the various warm-up and stretching exercises for the hand. The execution of these exercises are important, since the main reason for the existence of repetitive strain injuries results from that the part of the body has not been sufficiently exercised to perform a task (Aparício and Silva, 2014).

To prevent the injuries indicated in the previous section there are two sets of exercises that can be implemented: warming up and stretching off exercises, to the wrists and fingers for each hand.

4.1 Stretching Exercises

Stretching exercises should be performed at least twice a day, at the beginning and end of daily functions (Moreira, 2015).

4.1.1 Wrist

Being the wrist where all the nerves, tendons and blood vessels pass to the hand it is very important to perform an appropriate stretching.

Figure 3: Stretch exercise, wrist bend upward.

Figures 3 and 4 demonstrate the execution of the stretching exercises for the wrist. To stretch the wrist, it is necessary to keep the arm extended and bend the wrist upward, figure 3, with the help of the other hand. Then, it is required to perform the same exercise, but this time it is necessary to bend the wrist down, figure 4.

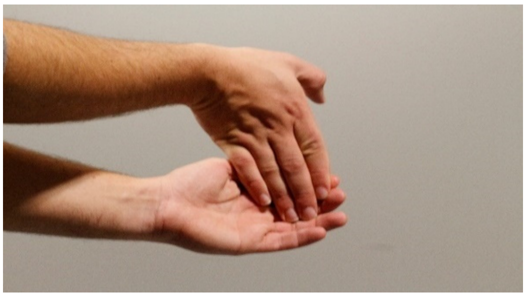

Figure 4: Stretch exercise, wrist bend downward.

4.1.2 Fingers

The stretching of the thumb, figure 5, the index and middle fingers, figure 6, are very important, since they are the most used fingers on day to day work. Also, these fingers are affected by the median nerve, which passes through the carpal tunnel.

Figure 5: Thumb stretch exercise.

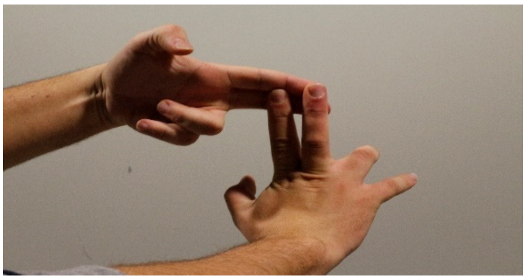

Figure 6: Index and middle finger stretch exercise.

Figure 5 shows the execution of the stretching exercise of the thumb.

Performing regular stretching exercises increases flexibility, and it can promote injury prevention improving the recovery ability, in case the worker eventually suffers from any injury (Branquinho & Fragelli, 2012).

4.2 Warm-up Exercises

The heating of muscles and joints will prepare the user for intense muscular activities (Moreira, 2015).

4.2.1 Wrist

There are several exercises to warm-up all the muscles and joints of the hand.

Figure 7 represents a warm-up exercise. To perform this exercise. It is necessary to keep the arm extended and slowly rotate the hand in a circle. Starting in figure 7a and rotating passing through figure 7b, 7c and 7d, ending in position 7a, then repeat the same exercising process a couple times.

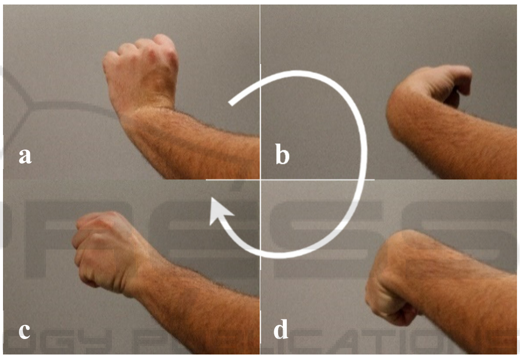

Figure 7: Warm-up exercise, wrist rotation.

Figure 8 shows a pulse heating exercise. To perform this exercise, the arm should be extended and still, where only the hand should perform horizontal movements, moving the hand from position in figure 8a to position in figure 8.b then go back to the position in figure 8.a and repeat the same movement few times.

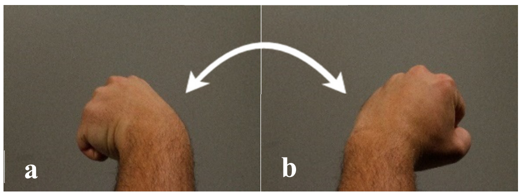

Figure 8: Wrist warm-up exercise, horizontal movements.

Figure 9 shows another warming-up exercise for the wrist. This exercise is similar to the previous one, but this time the hand should perform vertical movements, going from position 9a to 9b and coming back to position 9a, and repeat.

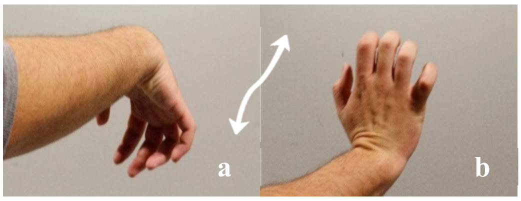

Figure 9: Wrist warm-up exercise, vertical movement.

4.2.2 Fingers

The following exercises are performed to warm up fingers.

The exercise in figure 10 consists on gather to the thumb each of the remaining fingers, one at a time. In figure 10a the thumb is gathered to the index finger, in 10b it is gathered to the middle finger, in 10c it is gathered to the ring finger and in figure 10d it is gathered to the pinkie finger.

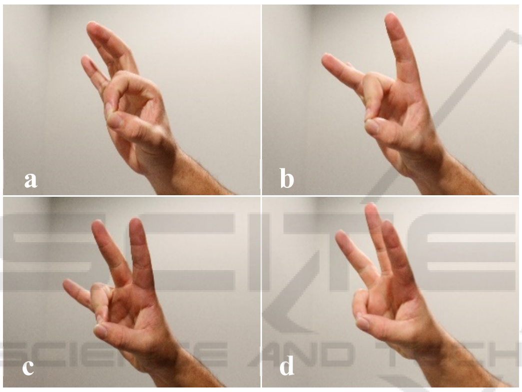

Figure 10: Warm-up exercise, gather to the thumb each of the remaining finger.

The represented exercise in figure 11 consists in a random movement of the fingers. Figure 11a, 11b, 11c and 11d represent the different random positions of the fingers.

Figure 11: Warm-up exercise, random movement of the fingers.

Finally, in figure 12, there is another heating exercise consisting of stretching, figure 12a, and flexing off, figure 12b, all the fingers at the same time then repeat the process a couple of times.

Summarizing, the warm-up exercises activate blood circulation and warm up muscles and joints (Marques, 2011).

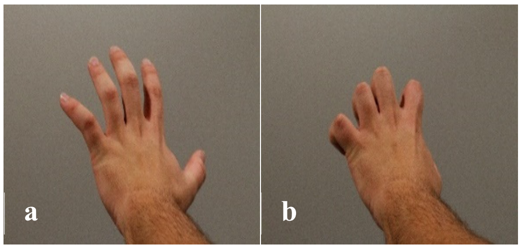

Figure 12: Warm-up exercise, Stretching and flexion exercises.

5 IMPLEMENTATION

In this chapter, it will be discussed the system developed for the activity, the Unity programming and the main features of the Intel RealSense 3D Camera F200.

The use of the Intel RealSense 3D Camera F200 is essential for the activity, once it is responsible for the 3D detection of hands. The Intel RealSense 3D Camera F200 has a colour camera, infrared laser projector and a depth camera. The effective range for gesture capture is between 20 and 60 centimetres (IntelRealSense 2014). Table 1 presents the main camera specs.

Figure 13 show all tracking points tracked from the hand by camera. However, on the application only the red tracking points are tracked.

Table 1: Camera Specs, adapted from (IntelRealSense 2014).

Color Camera	Depth (IR) Camera
Resolution	
Up to 1080p@30FPS	Up to 640x480@ 60FPS (VGA) or 120FPS (IR). HVGA@120FPS.
Active Pixels	
1920x1080 (2M)	640 x 480 (VGA)
Frame Rate	
30/60/120 FPS*	30/60/120 FPS (Depth), 120FPS (IR)
Field of View (DxVxH)	
77° x 43° x 70° (Cone)	90° x 59° x 73° (Cone) IR Projector FOV- N/A x 56° x 72° (Pyramid)

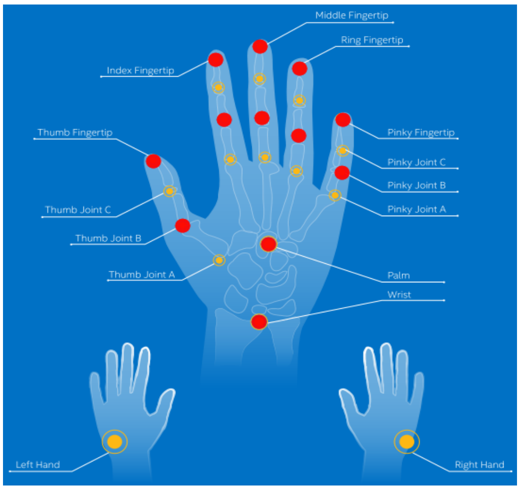

Figure 13: Hand Tracking Points, adapted from (IntelRealSense 2014).

The implemented system contains the Intel RealSense 3D Camera F200 and a computer. The user is placed in front of the camera to perform the movements to be tracked. The application is developed in Unity software, an editor which allows game development. It is also compatible with various image, audio, video and text formats. In addition, it allows to target many devices more easily (Unity Editor n.d.; Unity n.d.).

Figure 14 represents the general flowchart of the application.

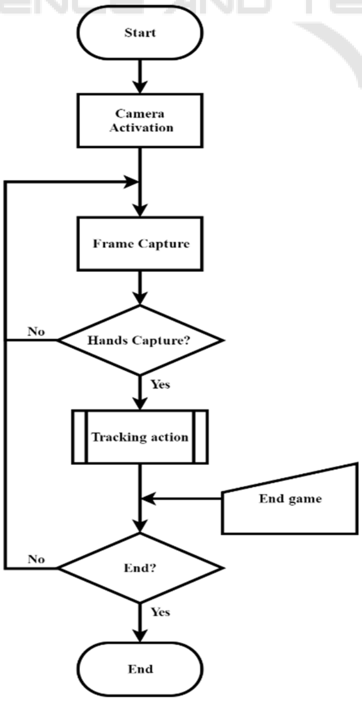

Figure 14: Implementation flowchart.

Starting the activity, the camera will be activated and a frame will be captured. From this frame, it will be verified the hands presence. If they are not detected, the system captures a new frame, otherwise the subroutine Tracking action will be performed. Then, until the End game command is given the application will continue to run.

The sub-routine Tracking action, figure 15, is responsible to move the game objects to the position where hands and fingers are placed on a 3D space.

Figure 15: Tracking action flowchart.

6 RESULTS

In this section, there are shown how hands are detected, for several stretch and warm-up exercises referred in the third section.

Figure 16 shows the warm-up exercise tracking. This exercise consists in gathering to the thumb each of the remaining fingers, as previously referred.

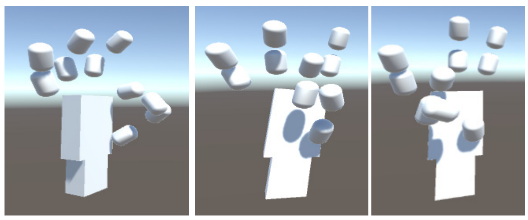

Figure 16: Tracking result, worm-up exercise gather to the thumb each of the remaining finger.

Figure 17 shows the tracking result of some wrist warm-up exercises, in figure 17a and 17c are presented the wrist warm-up exercise, horizontal movements, and in figure 17b and 17d are presented the wrist warm-up exercise, vertical movements.

Figures 18 and 19 show the tracking result when stretching exercises are performed. Figure 18 presents the tracking result for wrist stretch exercises. In figure 18a the wrist is bend downward and in figure 18b the wrist is bend upward. Figure 19 presents the tracking result for thumb, figure 19a, and index and middle finger, figure 19b, stretch exercise.

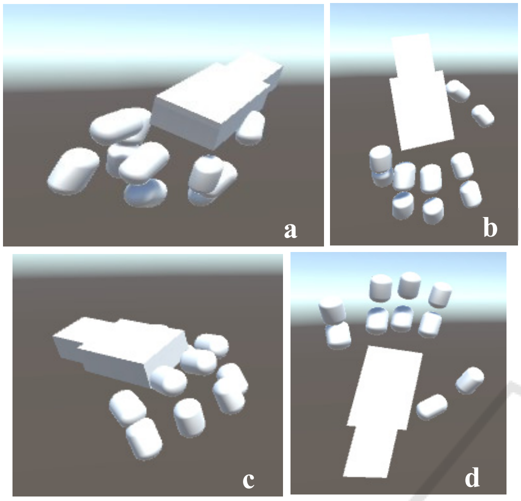

Figure 17: Tracking result for wrist warm-up exercises with horizontal and vertical movements.

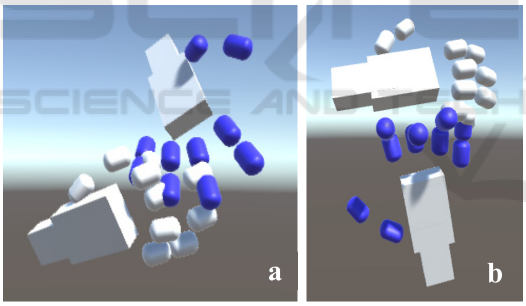

Figure 18: Tracking result from wrist stretching.

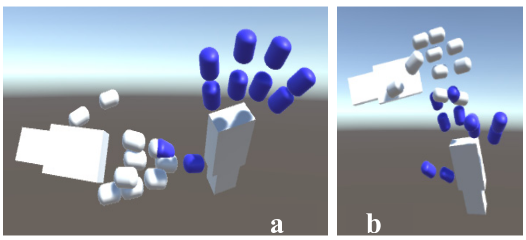

Figure 19: Tracking result from stretching thumb, index and middle finger.

7 FINAL COMMENTS

The goal of this paper is the development of an application for the detection of hands and their movements, in order to develop a game application for preventing strain injuries in hands. The present activity was developed in Unity software using the RealSense F200 camera from Intel. Considering the results obtained, it is observed that it is possible to detect hands and their movements.

As future work, it is necessary to improve the efficiency in the detection of the exercises, namely the recognition of the stretching exercises.

The strain injuries are mainly related to professional activities, so the implementation of this game in companies would be an added value, since this game could decrease or even eliminate the arise of these injuries in employees, reducing the subsequent related costs.

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