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GestureCollection for Motor and Cognitive Stimuli: Virtual Reality and e-Health prospects

GestureCollection para estímulos motores e cognitivos: Realidade Virtual e perspectivas para e-Saúde

GestureCollection para estímulos motores y cognitivos: Realidad Virtual y perspectivas para la salud electrónica

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Keywords: User-Computer Interface; Motor Activity; Health Promotion

ABSTRACT

Objective: To present GestureCollection, a set of applications designed to offer cognitive stimuli and motor coordination, through an unconventional way of human-computer interaction. **Methods:** The applications were based on Natural User Interface, Open Natural Interaction and gesture recognition from depth images provided by the Kinect sensor. **Results:** GestureCollection contains three applications (GesturePuzzle, GestureChess and GestureMaps) that allow gestural interaction with virtual reality environments through movements of upper and lower limbs. **Conclusions:** This set of applications allows muscle recruitment in different ranges of movement and speed of execution, besides showing potential to reduce the monotony of motor therapy.

Descritores: Interface Humano-Computador; Atividade Motora; Promoção da Saúde

RESUMO

Objetivo: Apresentar o conjunto de aplicativos GestureCollection, desenvolvido para oferecer estímulos cognitivos e motores, por meio de uma forma não convencional de interação homem-computador. **Métodos:** Os aplicativos foram baseados na Interface Natural de Usuário, Interação Natural Aberta e reconhecimento de gestos a partir de imagens de infravermelho fornecidas pelo sensor Kinect. **Resultados:** GestureCollection contém três aplicativos (GesturePuzzle, GestureChess e GestureMaps) que permitem a interação gestual com ambientes de realidade virtual através de movimentos de membros superiores e inferiores. **Conclusão:** Este conjunto de aplicativos permite o recrutamento muscular em diferentes amplitudes de movimento e velocidade de execução, além de mostrar potencial para reduzir a monotonia da terapia motora.

Descriptores: Interfaz Usuario-Computador; Actividad Motora; Promoción de la Salud

RESUMEN

Objetivos: Presentar el conjunto de aplicaciones GestureCollection, diseñado para ofrecer estímulos cognitivos y motores, a través de una forma no convencional de interacción hombre-computadora. **Métodos:** Las aplicaciones se basaron en Interfaz de Usuario Natural, Interacción de Interfaz Abierta y reconocimiento de gestos a partir de imágenes de profundidad proporcionadas por el sensor Kinect. **Resultados:** GestureCollection contiene tres aplicaciones (GesturePuzzle, GestureChess y GestureMaps) que permiten la interacción gestual con entornos de realidad virtual a través de movimientos de miembros superiores e inferiores. **Conclusiones:** Este conjunto de aplicaciones permiten el reclutamiento muscular en diferentes amplitudes de movimiento y velocidad de ejecución, además de mostrar potencial para reducir la monotonía de la terapia motora.

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INTRODUCTION

Currently, there are technologies using virtual environments that stimulate some of the sensory systems and contribute to the maintenance of physical conditioning of the individual. These digital systems, presented as e-Heath solutions, can provide users with a non-conventional way (without using keyboard and mouse) to interact with virtual environments, by using gestural interfaces. Using gestures to command a computer is intuitive, physically active and essentially playful. Thus, the use of this technology can help fight the sedentary lifestyle, providing a paradigm shift in the interaction of young people with virtual environments and incorporating specific techniques to be used for cognitive and functional rehabilitation.

With the passing of age, the contemporary man develops diseases (such as osteoporosis, obesity and heart disease) that can be prevented by regular physical activity. The current scenario of physical inactivity is associated with public health problems and increase of noncommunicable diseases, such as atherosclerosis and type 2 diabetes. Considering culture and lifestyle as strategies for the prevention and promotion of health, this work aims to present a way to control virtual environments with physical activities that recruit muscle groups of upper and lower limbs, so that an increase in blood circulation and consequently in energy expenditure is promoted. The set of applications here introduced, called GestureCollection, has the general objective of providing a form of interaction with the machine through gesture movements, in order to increase daily physical activity with higher energy expenditure when compared to conventional interaction (mouse and keyboard), enabling a paradigm shift in the form of Human-Computer Interaction in the medium and long term.

This paper is organized as follows: first, the computational tools used for the development of the virtual applications are presented; then the applications that compose the collection: GesturePuzzle, GestureChess and GestureMaps, are discussed; and finally, a discussion is offered and a conclusion is drawn.

MATERIALS AND METHODS

The set of GestureCollection applications was developed in a multidisciplinary study in the Laboratory of Immersive, Interactive and Collaborative Visualization (LaVIIC) of the Computer Science Department of Federal University of Sao Carlos (UFSCar), which is linked to the Graduate Program in Biotechnology and Computer Science. The study was approved by the Ethics Committee on Human Research of the institution, under the Process number – CAAE 11319712.4.0000.5504, supported by the Center for Science and Technology / UFSCar.

In the development of the GestureCollection toolbox, the recognition sensor Kinect(1) was used, as well as the concepts of Natural User Interface (NUI) and Open Natural Interaction (OpenNI and NiTE), which are described below. The applications were written in the computer language Java and they run on Linux OS.

Body tracking device

The Kinect device consists of several electronic components that make it a gesture recognition sensor in real-time. This device has been explored and applied in other areas outside of entertainment, and has been highly diffused among applications that require body tracking, including the areas of health and education. Shotton and colleagues(2) highlighted the importance of fragmenting the skeleton parts for greater accuracy in tests with image recognition in humans. In this work, the tracked points that were used to animate avatars or control the interface were: hands, torso, hips and knees.

Natural User Interface – NUI

NUI is the name used by computer designers and developers to refer to the interaction with the computer in an effectively invisible mode. Most computer interfaces use artificial control devices such as an alphanumeric keyboard. A NUI only requires the user to be able to interact with the environment through interactions previously known to him, for example, gestures and voice(3). This type of interface also requires learning, but this is easier, given that the communication through gestures is something inherent to human beings.

Open Natural Interaction – OpenNI

The OpenNI is a framework that provides an Application Programming Interface (API) for development of applications that use natural interaction(4). This API covers the communication with low-level devices (vision sensors and audio) and high-level solutions (visual tracking using computer vision). The framework is written and distributed under the GNU Lesser General Public License (LGPL), with source code freely distributed and available to the public.

Natural Interaction Middleware – NiTE

NiTE middleware is used by the OpenNI framework, and was developed by Prime Sense[1]. It is distributed as closed source, but free to use in the development of commercial applications. NiTE is responsible for treating user input obtained by the framework OpenNI, converting it to gestures(5). The middleware provides two types of tracking: one for hands, capable of detecting gestures like a push, wave and circle; and one for the human body, which allows tracking of the entire body, providing information on the main body joints. The precision of gestures is limited to the sensor device and the tracking by cameras is not as accurate as that done by mechanical devices, such as mouse and keyboard.

The GestureCollection applications were developed in the C/C ++ programming language (GestureChess) and Java programming language (GesturePuzzle and GestureMaps). Figure 1 shows the standard development model used for the design of the applications. The model consists of three main modules: OpenNI, UIINPUT and proposed applications.

The OpenNI framework is used as a communication

[1] Prime Sense company was acquired by Apple in 2013.

interface between the application and the Kinect device. However, the use of a specific driver (Sensor Driver Avin 2) was necessary to enable communication between the device and the applications. The UIINPUT is used to convert the signals provided by Kinect to input commands compatible with the operating system.

GestureCollection

GestureCollection is a set of tools consisting of three applications that allow human- computer interaction through motor gestures (1. GesturePuzzle; 2. GestureChess and 3. GestureMaps). GestureCollection provides motor and cognitive stimuli in teaching- learning situations, neuromuscular rehabilitation and physically active entertainment. The logo of the toolbox is shown in Figure 2, where the pinwheel represents the idea of movement (trademark registration with Instituto Nacional da Propriedade Industrial (INPI) / Brazil, under Process Number 909054703/2015).

It is important to mention that all the applications that are part of GestureCollection have been registered in INPI, both software and trademark. The INPI software and trademark registration protocols are:

1. GesturePuzzle: BR 51 2014 001378 2 and 909054703/ 2015;
2. GestureChess: BR 51 2014 001377 4 and 909054460/ 2015;
3. GestureMaps: BR 51 2014 001376 6 and 909054410/2015.

GesturePuzzle

The development of the GesturePuzzle application focused on the implementation of a control interface of a puzzle game by means of hand movement. The objective is to order the pieces with the movement of the upper limbs. The natural movement to hold and drop the pieces is reproduced for achieving a reality feeling, allowing the user to freely explore the shoulder joint in all planes (coronal, sagittal and transversal) and ranges of motion. The shoulder joint complex is classified as a diartrodial joint (freely movable), which has three degrees of freedom and a large amplitude of motion with rotation in three orthogonal axes: X, Y and Z. Although skeletally weak due to looseness of the fibrous capsule surrounding the joint, the three glenohumeral ligaments (upper, middle and lower) strengthen their structure in conjunction with the extension from the muscle tendons: teres major and pectoralis major. The application startup follows the activities shown in Figure 3.

Figure 4 shows a subject using this application. The logo for GesturePuzzle is shown in the lower right corner of this figure, where the figurative image represents geometric elements, as in a game to fit pieces.

GestureChess

Created for the control of a chess game, as well as for control of the computer itself with hand movements, the GestureChess application aims to explore the concept of Dual Task, with simultaneous cognitive and motor

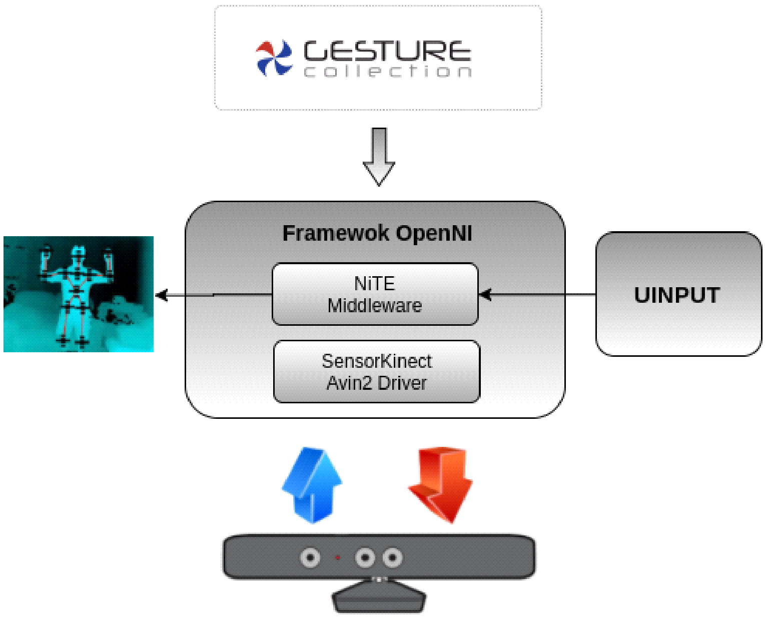

Figure 1 - Natural Interface modules input for GestureCollection applications

Figure 2 - High contrast logo (red/white) and logo (lower right corner) proposed for GestureCollection

stimulation. With GestureChess running, the first push of movement creates virtual spatial coordinates (0, 0), and from this point the software associates the hand movements traced to the mouse coordinates. To set the mouse pointer motionless, the user needs to return the hand to the initial position (where the values for X, Y are 0).

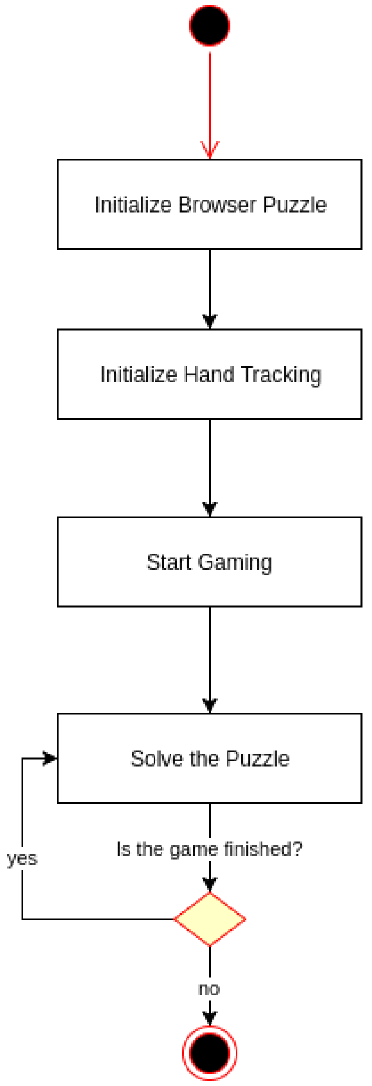

Figure 3 - UML activity diagram of GesturePuzzle

To ensure accessibility for people with different motor skills, a method for increasing the cursor position was implemented. A small hand movement away from the spatial coordinate (0, 0) allows the mouse pointer to also move, but from its present position, incrementally. To stop the pointer motion, the user must reposition the hand again at the (0, 0) point. This allows moves to be performed all across the board, even if the user has limitations in the range of motion. The application startup follows the activities shown in Figure 5.

An example of the GestureChess application is shown in Figure 6, with the respective logo shown in the upper left corner of this figure. The figurative image in this logo represents a stylized chess game.

GestureMaps

The GestureMaps application aims to provide virtual, spatial and geographical exploration through the Google Street View tool. The control is performed by movements related to stationary gait, with flexion of the hip and knee corresponding to a minimum displacement of 15 centimeters between the initial position and end of the patella, allowing the user to move the virtual map. The change of direction is allowed by trunk rotation to the desired side. Figure 7 shows a subject using this application, with the respective logo shown in the bottom center. The figurative image in the logo represents a map marker, characteristic of Google Street View.

The application startup follows the activities shown in Figure 08, where the user must indicate the address to be explored on Google Street View (it must be connected to the internet). From this moment, the body tracking of the user in the standing position begins; an avatar is created and the user must perform a movement of 90° of shoulder abduction and 90° of elbow flexion (in the coronal plane), without "walking", to start the gestural control of the application. After this step, the user can navigate through the virtual map of Google Street View using the motions of stationary gait and trunk rotation, described above.

Table 1 presents the forms of interaction (considering

Figure 4 - Example of subject playing GesturePuzzle, an application that can control a virtual puzzle using body gestures (upper limbs)

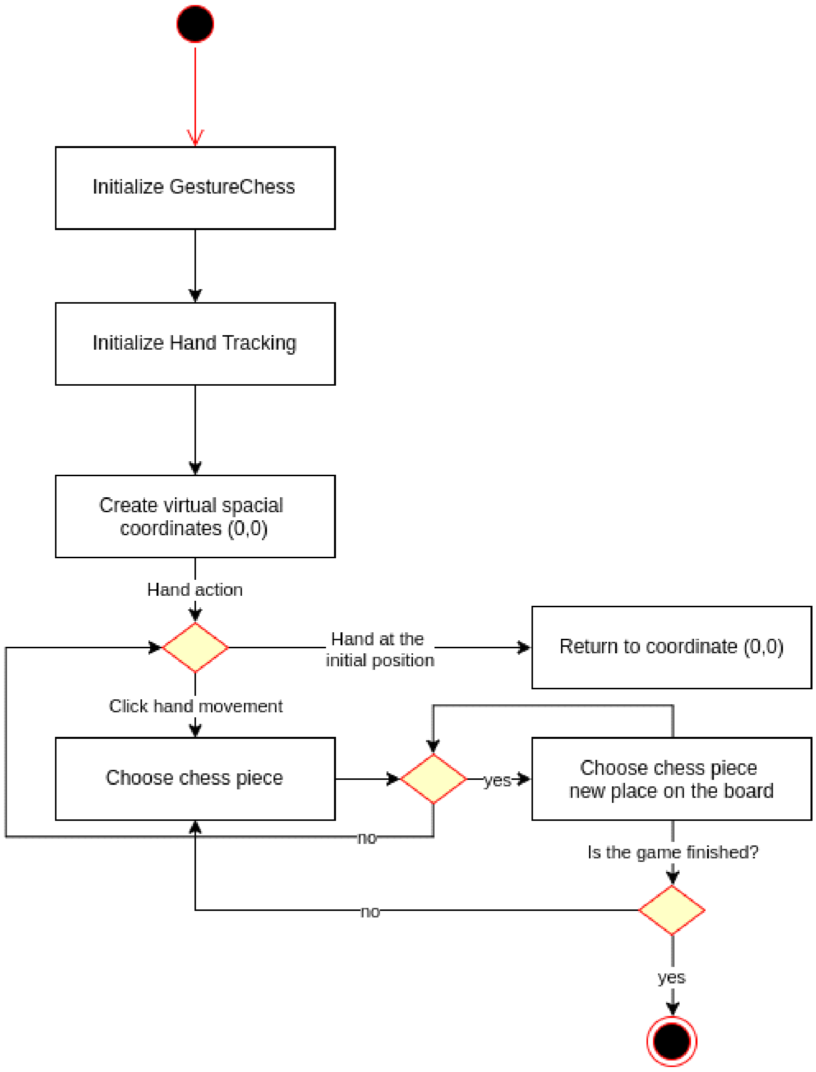

Figure 5 - UML activity diagram of GestureChess

Figure 6 - Subject playing GestureChess, using arm/hand movements (upper limbs) to control the application

the position and the body region that controls particular application) allowed by the different GestureCollection tools, with the corresponding motion intensity required and the type of associated stimulus.

DISCUSSION AND CONCLUSION

Execution of GestureCollection occurs with the user in the standing position, allowing higher energy

Figure 7 - Subject using the GestureMaps application that can control Google Street View using legs' (lower limbs) movements

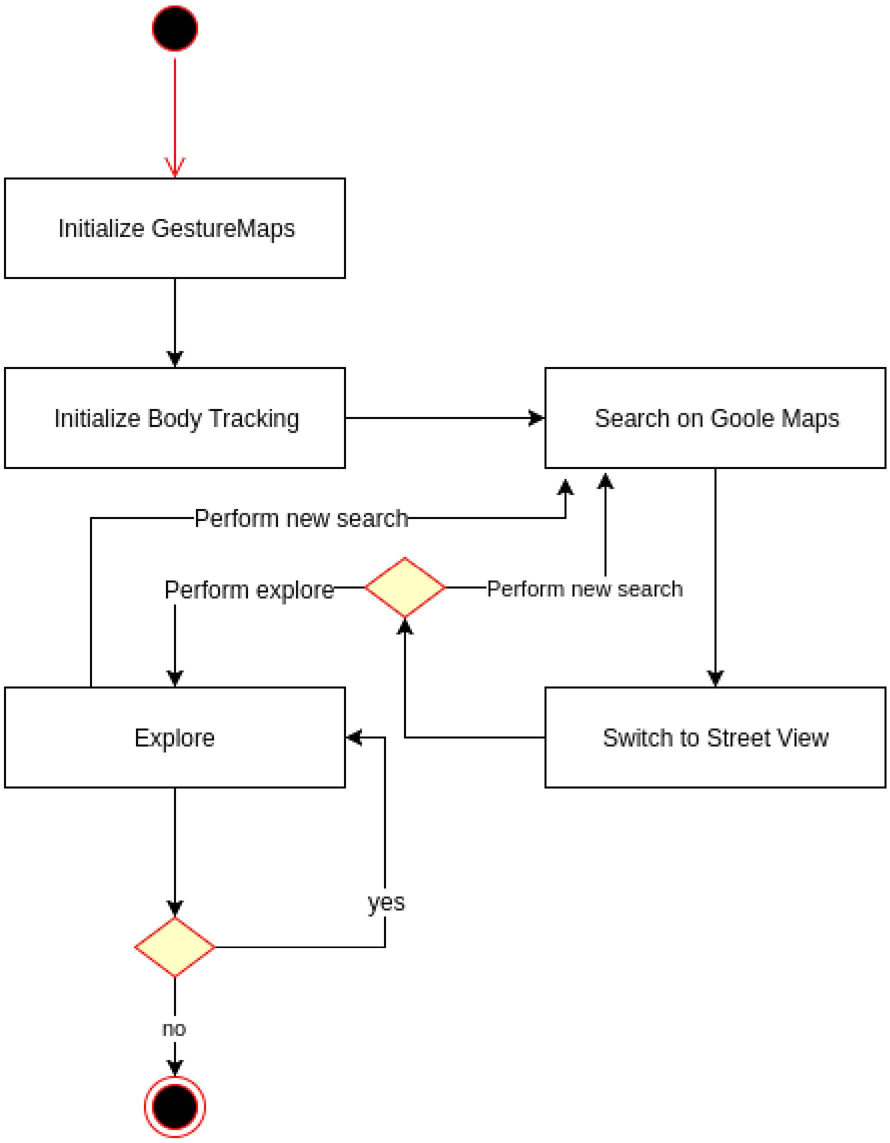

Figure 8 - UML activity diagram of GestureMaps

Table 1 - GestureCollection capabilities.

Capability	Gesture Puzzle	Gesture Chess	Gesture Maps
Upper Limbs	Yes	Yes	No
Lower Limbs	No	No	Yes
Trunk Rotation	No	No	Yes
Standing Position	Yes	Yes	Required
Sitting Position	Yes	Yes	No
Range of Motion	High	Low	Medium
Motor Coordination	Low	High	Low
Cognitive Stimulus	Low	High	Medium

expenditure due to the recruitment of some muscle groups, especially the erector muscles of the spine responsible for keeping the spine erect and the large leg muscles (quadriceps, biceps femoris, soleus and gastrocnemius). These muscular groups keep the user's position using static contractions (isometric), where the applied muscular strength is equal to the imposed resistance. In contrast to this, the muscle group responsible for coordinating the movements of the upper limbs acts through dynamic contraction (isotonic), where the force applied by the muscle is higher or lower than the resistance; this allows motion control both against gravity (concentric contraction) and in favor of gravity (eccentric muscle action).

The search for new entertainment modalities that contribute to a significant increase in physical activity are of great social interest and better accepted by the population when inserted through games and presented in interactive and immersive environments of Virtual Reality (VR). Maloney and colleagues(6) indicated that interactive video games are potentially beneficial for increasing physical activities in children.

VR has been used as a means of rehabilitation and physical assessment in general(7-9), more intensely so over the last few years. In relation to the upper limbs, Laver and colleagues(10) have indicated better results in the rehabilitation of motor function when conventional therapy is associated with VR applications in stroke patients ; they considered the recovery of cognitive function, gait, balance and daily life activities. Ustinova and colleagues(11) demonstrated that the use of gesture recognition increased the postural coordination of upper limbs in patients with traumatic brain injury. Other studies have pointed out the benefits of using the Kinect device in rehabilitation of children with cerebral palsy and muscular atrophy(12) and the effectiveness of VR associated with conventional therapy in the treatment of upper limb in patients whosuffered a stroke with different levels of severity(13). VR is capable of stimulating several sensory systems of the human body, including forms of visual and auditory perception, which facilitate the entry of information to the brain; it can be used together with other therapeutic interventions to increase the complexity of the task requested during the rehabilitation process(14).

The GestureCollection toolkit is presented here as a set of e-Health solutions for sedentary lifestyle prevention and health promotion; it can complement the rehabilitation process and promote user interaction with the virtual environment in a playful and physically active way. The underlying proposal includes an increase of physical activity during the interaction with computer systems, opposing the sedentary lifestyle. Research works that combine physical activity and VR point to promising results in different situations relating to the health areas. Nevertheless, GestureCollection has yet to be tested in a randomized and controlled way, over a representative sample of the population, in order to demonstrate the effects of this specific technology, to influence the creation of new therapies based on VR that can complement the rehabilitation process, and to consolidate the effectiveness of VR treatment in the medium and long term.

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DISCLOSURE STATEMENT

No competing financial interests exist.

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