

# 3D Virtual System Using a Haptic Device for Fine Motor Rehabilitation

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**Abstract.** It is presented a 3D Virtual system with a haptic device that allows the interaction between a user and a virtual environment developed in Unity3D. This System was designed for rehabilitation of paretic hands in adult people with Stroke; the virtual environment was developed considering a daily life's activity (watering plants in pots). The system was used by five people with mild and moderate Stroke according to ASWRTH 1+ scale, which completed the exercise showed in the virtual application. Patients performed a usability test SUS with outcomes (79,  $5 \pm 3$ , 67) this allows to define that the system has a good acceptance for rehabilitation.

**Keywords:** Haptic device · Software Unity3D · Stroke · Virtual environment

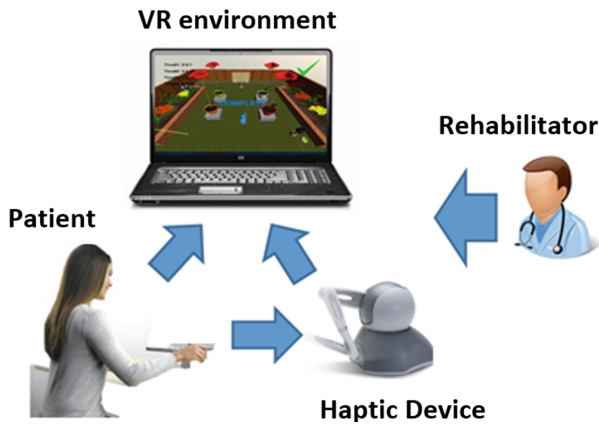
## 1 Introduction

Stroke is considered as the main cause of death in the world [1] one in four people who suffers Stroke dies for this cause [2]; survivors show a neurological deficit that affects one or more cerebral function according to the region of the brain where the accident occurred; main consequences after a Stroke are speech and language alterations, impaired vision, instability, and the most common are motor disorders [3]; A recent study shows that 80% of all patients with Stroke present impaired motor function in upper limbs and 30% to 40% achieve to recover motor function after six months of therapy [4]. Rehabilitation after Stroke is important because it can get the brain to learn new ways for working [6]; factors such as repetition, motor learning, feedback [5–9] and tasks focused on activities of daily life have been shown to be fundamental in recovery after Stroke [10]. Recent technological advances have allowed that the treatments are adapted to virtual applications that help patients to have a better recovery.

Virtual reality (VR) has been gaining a wide field in the motor rehabilitation process by offering personalized experiences that involve different sensory channels, such as

sight, hearing and sometimes touching [11]. The VR with external devices such as Wii (Nintendo) [12], Kinect sensor (Microsoft) [13], haptic devices [14], and others allow the patient to work with a targeting system thus has an extra motivation to accomplish all the objectives. Nowadays, the number of studies based on virtual reality has been increased having good results in motor rehabilitation in upper limbs [15–18]. The interaction of haptic devices with virtual environments with tactile feedback allows more patient immersion in the performed task [19–21].

The purpose of the application is to implement a 3D virtual system that will be used in rehabilitation of paretic hands in people with Stroke; the creation of the virtual game is focused in fine motor exercises for rehabilitation mainly in “scissors” exercises. The application integrates the Geomagic Touch (haptic device), the software Unity3D and a laptop which includes a video card. In the design of the 3D virtual environment is considered an activity of daily life like watering the plants in a garden. In Fig. 1 a diagram of the system is presented.



**Fig. 1.** Virtual 3D system using haptic device.

## 2 Technologies Used

### 2.1 Geomagic Touch Haptic Device

The device provides an authentic three-dimensional navigation and force feedback and integrates the sense of touch into commercial and research applications [22]. The device can accurately measure the 3D spatial position (along the X, Y and Z axes) and the orientation (rotation and direction) of the hand pen. Geomagic Touch is a motorized device that applies force feedback on the user’s hand, allowing them to feel virtual objects and producing true-to-life touch sensations as user manipulates on-screen 3D objects. Leading companies integrate the Geomagic Touch and haptics into their work to achieve compelling solutions using the realistic sense of touch.

## 2.2 Software Unity3D

Unity3D is a complete platform to develop videogames in existence, it allows the creation of games for multiple platforms from a single development, including the development of games for console (PlayStation, Xbox and Wii), desktop (Linux, PC and Mac), browser, mobile and tablets (iOS, Android, Windows Phone and BlackBerry). The Unity 3D editor is one of the simplest and most powerful in the market, divided into 5 main views: explorer, inspector, hierarchy, scene and game.

## 2.3 Portable Computer

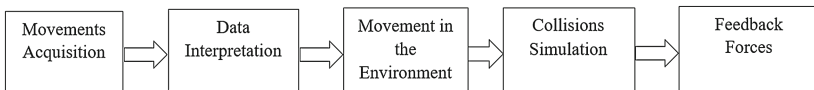
The computer used for the creation and generation of Virtual Reality environments has the features presented in Table 1.

**Table 1.** Characteristics of the computer.

Features	
Processor	Intel® Core™ i7-3610QM CPU @ 2,30 GHz
Cache L2	32 KB
Memory	8,092 MB
Integrated Graphics Card	Intel® HD Graphics 4000
Dedicated Graphic Card	NVIDIA GeForce GT 630M 1 GB
OS	Windows 8.1 o Windows 10

## 3 Methodology

Development of the 3D virtual system was considered stages in Fig. 2.



**Fig. 2.** Block diagram of the stages in virtual 3D system.

### 3.1 Description of the Stages in the 3D Virtual System

#### 3.1.1 Movements Acquisition

The Geomagic Touch Haptic device picks up the movements in the real space on the X, Y and Z axes; this is done through digital encoders inside the device. The kinematics model of the device position is given by equation [23]:

$$x = f(q) \tag{1}$$

Where  $x \in \mathbb{R}^{3 \times 1}$  denote the operational coordinates vector and  $q \in \mathbb{R}^{3 \times 1}$  is the vector of joint coordinates.

### 3.1.2 Data Interpretation

The computer receives position information with Ethernet communication; this data will be interpreted later through the special Unity 3D libraries programmed in C# designed for the communication between the virtual environment and the Geomagic Touch.

### 3.1.3 Movement in the Environment

We implemented a virtual garden developed in Unity 3D, where a virtual sprinkler acquires the movements in the virtual axes X, Y and Z, that are performed in the real axes X, Y and Z by the haptic device.

### 3.1.4 Collisions Simulation

When a collision occurs between the mobile virtual object (sprinkler) and a static virtual object (flower pot) Geomagic Touch will give a force feedback, this class of events occurs through special libraries programmed in C# for communication between Unity3D and the Geomagic Touch device.

### 3.1.5 Feedback Forces

When a collision occurs between objects in the virtual environment, an output data packet is generated towards the haptic device, which through the motors inside will give a feedback force to the user. The torque generated by the haptic device is defined by the following equation:

$$\tau = J^T F \quad (2)$$

Where  $\tau \in \mathbb{R}^{3 \times 1}$  defines the torques vector,  $J^T$  is the transpose of the Jacobian matrix and  $F \in \mathbb{R}^{3 \times 1}$  is the forces vector defined by the interaction in the virtual environment.

## 4 Description of Operation to Use the 3D System

Using this 3D virtual system in fine motor virtual rehabilitation the following procedure is performed:

1. Patient should be placed in a seated position so the exercises to be performed are not tiring, then the patient must take the manipulator of the Geomagic Touch as a clamp (like if the patient takes a pen).
2. When the patient is positioned in the virtual environment, a sprinkler appears in the screen which carries water to grow garden's plants as shown in Fig. 3. This virtual sprinkler takes the movements that the patient performs with the pen in real space.
3. Sprinkler should be placed on top of each pot and the water should be dropped on them for a period determined by the user to grow the plant. In case the sprinkler is in wrong position or if it collides with the pot, a force feedback occurs, giving the patient the sensation of presence of the virtual object (Fig. 4).



Fig. 3. First position in the virtual environment



First target completed



Collision between virtual objects

Fig. 4. Virtual environment in operation.



Fig. 5. Virtual environment in operation and presentation of the new target to be completed

4. When the first target is completed appears in the top right of screen the color of the next target to be watered as illustrated in Fig. 5, the movement between targets is determined by a targeting system that indicates the next movement of the patient. In total, the virtual environment has four targets that must be completed.

## 5 Tests and Results

In order to determine usability of the implemented system, the system was tested by five people aged 50–85 years (4 men and 1 woman), who had suffered Stroke for one year or more, the patients had mild or moderate spasticity according to the ASWRTH 1+ scale [24]. Patients receive the information about the functionality of the system through a rehabilitator, then they use the 3D system according to the procedure described previously, complete the developed stage in the virtual environment and then fill the SUS questionnaire. In Fig. 6 the users of the Virtual 3D system are presented.

The questions asked to users about 3D virtual system and the results of the usability test are presented in Table 2.

The result of SUS questionnaire made by five patients after complete the 3D virtual system is:  $(79.5 \pm 3.67)$ .

**Table 2.** SUS results

Question	Result (N = 5)	
	Mean	SD
1. I think I would like to use this Virtual Reality system frequently	4.6	0.49
2. I found the Virtual Reality system to be unnecessarily complex	2.4	1.02
3. I thought that the Virtual Reality system was easy to use	4.2	0.75
4. I think I would need the support of a technical person to be able to use this Virtual Reality system	2.6	0.49
5. I found that the various functions in this Virtual Reality System were well integrated	4.2	0.75
6. I thought there was too much inconsistency in this Virtual Reality system	1.8	0.75
7. I would imagine that most people would learn to use this Virtual Reality system very quickly	4	0.63
8. I found the Virtual Reality system to be very cumbersome to use	1.8	0.75
9. I felt very confident using the Virtual Reality system	5	0
10. I needed to learn a lot of things before I could get going with this Virtual Reality system	1.6	0.8
GLOBAL SCORE (total)	79.5	3.67



**Fig. 6.** 3D virtual system used by patients with Stroke

## 6 Conclusions and Future Work

The 3D virtual system was used by 5 patients with Stroke who have mild or moderate spasticity according to the ASWRTH 1+ scale, the results of SUS are  $(79.5 \pm 3.67)$ , in [25], Bangor et al. determined that a result in an interval ranging from 70 to 85 in the SUS questionnaire is a good result, so this 3D virtual system has acceptance to be used in rehabilitation.

The 3D virtual system was developed based on one of the activities of daily life (watering plants in a garden), considering that it will be used by adults who have a great affinity with daily tasks they have performed. As well as the system provides feedback by detection of obstacles, this feedback provides an immersion when developing rehabilitation.

As future work the implemented system will be used in rehabilitation therapies of patients with Stroke; the patients who interacted the system are very interested in using it as an alternative to fine motor rehabilitation.

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