Force and touch make video games ‘serious’ for dexterity rehabilitation

Michele CONFALONIERI a, Giovanni GUANDALINI b, Mauro DA LIO a and Mariolino DE CECCO a

a University of Trento, DIMS, via Mesiano 77, 38100 Trento, Italy
b Abilita - Ospedale Villa Rosa, Loc. Vigalzano, 38057 Pergine Valsugana, Italy

Abstract. Computerized interfaces are able to represent 3D immersive simulations. Most of them make use of joystick, mouse, gloves or grasp pressure transducers. Those have the drawback of ‘filtering’ the user interaction and/or de-locate the touch with respect to the visual stimulus. To overcome this we developed dexterity rehabilitation games on a novel touch interface that measures also force. The system allows dexterity training through ‘direct’ manipulation of virtual objects in 3D. Two dimensions via the touch screen, the third by the force channel. Tactile feedback is provided with a vibration device mounted on the screen back.

Keywords. Serious games, touch systems, neuromotor performance assessment.

Introduction

Serious games for health include psychological therapy, cognitive training, physical rehabilitation, as well as exergaming - games used as a form of exercise. Serious games can be embedded into custom VR environment or use off the shelf computerized systems. The benefits of using VR technology for rehabilitation have been the subject of many studies [1]. Several outcomes demonstrate that people with disabilities are capable of motor learning within virtual environments and movements learned in VR transfer to real world equivalent motor tasks, and can even generalize to other untrained tasks [2]. There is evidence that proprioceptive and exteroceptive feedback, associated with the execution of skilled tasks, induces brain changes at cellular and synaptic level. In a virtual environment feedback about performance can be augmented with respect to the real world case [2].

Several games for health are available on the market. Nintendo Wii Fit invites gamers to try aerobic activities and balance while interacting with a movement-sensitive board, assisted by an on-screen trainer. Dexterity is not taken into consideration due to the limitation of the sensory system. RANJ Serious Games developed Juf-in-a-Box, a game for children with fine motor deficits. The child writes with a stylus on a tablet while receives feedback on a monitor. In this case force is not considered. GestureTeck developed IREX, an Interactive Rehabilitation System. Patients interact with on-screen objects in sporting and adventure simulations. The system is a custom apparatus based upon vision technology. Tactile interaction is
lacking while it is more focused on balance, hand-eye coordination, flexion, rotation and other whole body movements. An exercise based on Microsoft Xbox was developed at the Rutgers University. The system help patients recover hand dexterity by using special gloves. Finger dexterity is trained without considering the force channel. Furthermore touch is de-located with respect to the visual stimulus.

Touch sensing interfaces have rapidly increased their technological level. 3M MicroTouch™ provides tactile feedback effects for on-screen video buttons to make users actually "feel" like they are depressing mechanical buttons. Apple Multi-Touch™ technology enables to detect click, scroll, swipe and rotate independently. The Korean Institute of Science and Technology developed a touch that measure normal and tangential forces [3]. This, overtaking the actual limitations of touch screens that currently fail to properly distinguish force intensity, will certainly open new possibilities for serious games in the field of dexterity rehabilitation. We believe touch technology has not yet been completely exploited and, following the path of its huge improvements, clinical applications will certainly benefit.

On this track we developed a custom instrument, the Force Panel, in the framework of the VERITAS FP7 project with the aim to quantify the dexterity of different categories of impaired peoples. VERITAS employes those data to simulate the use of different products in the design phase in order to assess its accessibility even before prototyping. The same instrument we realized could also be used for serious games for health. It is also important to note that the system makes use of technologies partly already available, although actually measuring pressure instead of force and with screen sizes generally limited due to the main focus on phone applications, but that will be certainly widespread in the near future both on computers and mobile phones.

1. Materials and Methods

The proposed apparatus is made of a 15” LCD plus a touch panel and force sensors to acquire the user actions [4]. The LCD is mounted onto the base by means of three load cells that measure the exerted force in the direction vertical to the screen.

The instrument can be decomposed into three main parts:

- a suspended mass made up of an LCD and a touch screen mounted on an aluminum support;
- a lower base composed of an aluminum base, two limit switches and the electronics of the system (electronics of the display, conditioning modules, an embedded system);
- restraint composed of three load cells and a system of harmonic wires.

Touch position and force exerted are acquired by the embedded system while the PC controls the LCD to generate images for user interaction. To optimize the user posture the instrument is mounted on a reclining table.
2. Serious games for dexterity diagnosis and rehabilitation

Two main concurrent goals can be identified: diagnosis and rehabilitation. Touch technology, force augmented, allowed the development of three diagnosis tests: point-to-point, continuous tracking, force control. For rehabilitation, in order to create an entertaining context, several video games were implemented to target reaction time, limbs coordination, finger control and position versus force control skills.

2.1. Tests for dexterity diagnosis - Continuous Tracking test

The procedure requires that the user moves its finger following a box that travel along a circumference at a constant speed trying to follow as much as possible the circular path.
(see Figure 1a). It is possible to adjust the angular velocity of the cursor and the direction of rotation.

![Diagram of Continuous Tracking Test](image)

**Figure 3.** A scheme of the ‘Continuous Tracking test’ and conventions that define the acquired parameters.

Measured parameters are:

- **PTT** = Percentage of time in target. Percentage of the time the touch is inside the circular target traveling along the circular path [%]. Referring to figure 3 it is the percentage of time $|P_T - P_F| < R_T$.

- **MD2T** = Mean Deviation to Trajectory (deviation between the cursor point and the point touched by the subject) [mm]. It is defined as $mean(|P_T - P_F|)$.

- **MD2P** = Mean Deviation to Path (minimum deviation between the circular path and the point touched by the subject) [mm]. It is defined as $mean(|P_T - P_C - R_C|)$.

### 2.2. Video games for dexterity rehabilitation

The game requires that the user drag a life belt from the bottom left corner to the upper right corner of the screen avoiding the circular vortices and passing under the wooden board applying a force on the touch-screen. See Figure 2b for the game layout. The third dimension impression, controlled by the exerted force is fed back to the user by objects transparency properties.

The software embodies tools to provide users with feedback about performance. This, together with repetitive practice and motivation to endure practice are key functionalities in rehabilitation. The performance feedback is provided through: total time, number of obstacles hit, time within obstacles, length of trajectory, deviation to optimal target force.
3. Discussion and Preliminary Results

In the study held at the rehabilitation center of the Hong Kong polytechnical University resulted that more than 80% of the therapists were in favor to the introduction of virtual reality games as an assistive tool to help them to manage the rehabilitation of patients recovering from stroke [1]. In our study we didn’t get a significant statistics about the therapist’s acceptance, nevertheless all the three therapists involved in the test setup declared a good approval. More significant is the users feedback. About twenty subjects with stroke, mild Parkinson and quadriplegia used the system about five times during rehabilitation, 85% of which were over seventy. About 90% expressed a good impression about the "fun" and "motivation" induced by the exergames, among them 60% expressed a very good opinion. This is particularly significant if it is considered that the over seventy are generally not used to VR and/or computer technology.

The first table shows the results obtained by two users in performing the Continuous tracking test. The first is suffering from hemiparesis due to ischemic stroke, the second is an healthy person. The healthy person shows good and stable performances. On the other side it is evident an improvement of the disable subject skills. Deviation from trajectory and path deviation are progressively reduced during test sessions.

In the second table the parameters obtained during ‘life-belt3D’execution are shown. Subject 1 is elder, while the second is a young and healthy person. The younger parameters show an optimal execution: the length of the trajectory (TT) is close to the minimum and the average force (MF) is maintained within an optimal threshold. Elder user gets a low performance although improves in the second session.

Table 1. Continuous Tracking test results.

| Day | Subject 1 | | Subject 2 |
| --- | --- | --- | --- | --- | --- |
| | PTT (%) | MD2T (mm) | MD2P (mm) | PTT (%) | MD2T (mm) | MD2P (mm) |
| 1 | 75.88 | 13.41 | -4.07 | 99.38 | 5.03 | -2.54 |
| 2 | 69 | 18.13 | -4.95 | 98.85 | 5.83 | -3.44 |
| 3 | 99.84 | 7.03 | -5.10 | 100 | 5.22 | -2.43 |
| 4 | 98.11 | 7.47 | -4.98 | 100 | 4.64 | -2.48 |
| 5 | 100 | 6.97 | -5.22 | 100 | 5.15 | -1.69 |

Table 2. Video games results.

| Subject 1 | | Subject 2 |
| --- | --- | --- | --- | --- | --- |
| T (s) | TT (mm) | MF (N) | STD_F (N) | F_MAX (N) | HIT (n°) |
| 18.47 | 1320.49 | 9.1 | 2.88 | 15.40 | 6 |
| 10.64 | 422.35 | 4.9 | 1.66 | 15.06 | 4 |

| Subject 2 | | 
| --- | --- | --- | --- | --- | --- |
| T (s) | TT (mm) | MF (N) | STD_F (N) | F_MAX (N) | HIT (n°) |
| 3.3 | 224.87 | 3 | 0.56 | 19.45 | 0 |
| 4.88 | 257.9 | 3.6 | 0.66 | 23.75 | 0 |
Although preliminary results have been reported, the potential application of creating simple 3D interfaces using touch and force sensing to exercise position and force control of upper limbs has been highlighted.

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References


