A passive stringed haptic system for immersive environments

Alexis Paljic and Sabine Coquillart

i3D-INRIA
655, avenue de l'Europe
38330 Montbonnot Saint-Martin, France
alexis.paljic@inria.fr, sabine.coquillart@inria.fr

Abstract. We propose a passive haptic feedback system that can provide the user with grounded forces in a 3D manipulation space. A visual/haptic interaction is used to control forces returned by the system, which is composed of cables and a braking system. An experiment, consisting of two sessions of stickiness comparison tasks, is conducted to evaluate the device. The first session is done with the proposed haptic feedback, the second is purely visual, without haptic cues. We propose indicators for task performance and we measure the forces fed back by the device during the experiment. Results show that the device provides the users with actual forces that are consistent with simulated physical properties, and that it enhances user performance compared to the purely visual situation. Finally, the system is installed on a Responsive Workbench on which informal tests show that it provides the users with haptic sensations.

1 Introduction

A definition of passive haptic systems is systems that are not computer controlled. "Props" [1] are an example of passive haptic systems; they are rigid or deformable objects which provide feedback simply by their shape or texture, unlike active haptic devices that use computer controlled actuators.
Another possible definition was proposed by Swanson [2]: "*passive haptic displays are systems that are energetically passive, in the sense that they don't add kinetic energy to the system*" -unlike active systems- "*but are only capable of removing, storing, or redirecting kinetic energy*". It is this definition that we will use in this work.
Props seem well suited to simulate reaction forces from solid objects such as a virtual cockpit, command buttons or walls, and might also be suitable for compliant objects (sponge, spring). However, it is difficult to change the simulated resistance or compliance of virtual objects since their haptic representation -the physical object- would have to be changed.

Some passive devices can adapt to changes in the virtual environment. The PTER (Passive Trajectory Enhancing Robot) was developed by Book et al. [3]

and makes use of electromagnetic brakes to constrain user movements. Such systems, that feed back forces to the user by constraining his movements (dissipating his kinetic energy), with computer controlled brakes or clutches are called *dissipative passive devices* by Swanson [2]. Cobots [4] are steerable systems that can constrain a user's movements by reducing his degrees of freedom. These systems use computer driven actuators, and can be costly and complex to maintain.

Pseudo-haptic feedback was proposed by Lecuyer et al. [5], who defined pseudo-haptic systems as "systems providing haptic information generated, augmented or modified, by the influence of another sensory modality". The experiment conducted by the authors showed the possibility of providing the user with haptic information by means of a passive input device combined with visual feedback. This passive technique makes no use of computer driven actuators and can be used to simulate different values of mechanical properties such as stiffness.
Haptic systems can provide grounded or non-grounded forces. Grounded systems can constrain user movements relative to the ground, such as the Cyber-Force [6], or the Phantom^{TM}[7] and return grounded forces. They are opposed to non-grounded forces that are provided by portable systems, and can constrain the user's movements relative to his own body.
The objective of this work is to propose a passive feedback technique that cumulates the advantages of totally passive devices (low cost, no computer driven actuators) and the advantage of computer driven passive devices (adaptation to changes in the virtual environment), that can simulate grounded forces in a 3D workspace.
The main question is how to constrain user movements in 3D space, depending on variable forces in the virtual environment, without an active, computer controlled device? The proposal of this work is to use a visual/haptic interaction, inspired by pseudo-haptic feedback. The visual/haptic interaction is meant to induce actions from the user to trigger reaction forces from a passive haptic device based on grounded cables and a braking system.
In Section 2, we describe the proposed passive haptic system and evaluate it in Section 3 in a virtual stickiness discrimination task. In Section 4 we discuss the results of the experiment on the basis of user performance and force measurements on the device.

2 Proposed passive haptic device

Pseudo-haptic feedback, proposed by Lecuyer et al. [5] makes use of an interaction between two sensory modalities, visual and haptic, without using a computer controlled actuator. The authors conducted an experiment using an isometric device (a Spaceball) allowing the user to move a virtual cube on a plane where a "sticky" zone is represented. When the cube is in the sticky zone, the displacement gain (object movement/user movement ratio) of the object is lowered. The reaction of the users was to press the device harder, causing higher reaction force from the device. The authors also conducted an experiment showing that pseudo-