Force feedback slider (FFS): Interactive device for learning system dynamics

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Abstract

Physics education often relies on visualization of theoretical laws. While Java animations are widespread, they mostly lack user interaction. We propose a haptic device inviting users to interact with the law of physics. Based on an in-house design – a generic force feedback slider (FFS) – we have realized a software application simulating a catapult. As users interact, they receive both tactile and visual feedback. By calling upon two perceptual channels at a time, here tactile and visual, we assume users may construct their mental model more easily. This paper presents our application, the underlying FFS technology, a user study, future uses, and a discussion.

1. Introduction

It is known that touch-sensing is a fast human capability [1]. To capitalize on this capability, already researched in a few projects [2] [3], we have developed a generic prototype force feedback slider (FFS) in hardware and software. The FFS is connected to the computer via a USB interface and the software is written in Java. This maximizes compatibility with different operating systems and Java applets. Using this device as a proof of concept, we have realized a specific application to interact with a projectile motion model: catapult and target[1] (Fig. 1). From a user's point of view, this is a simple task although the underlying physical theory is not. We chose this application to enable users to think at a higher abstraction level than just a pure physical model. The image of the catapult should help users in creating a mental model to understand the laws of physics.

[1] A video demo is available: http://people.ee.ethz.ch/~kretza/ShootingDemo.avi

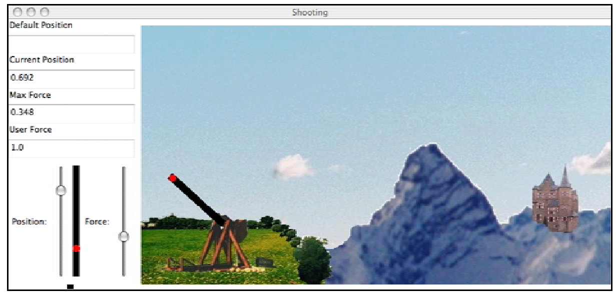

Figure 1: Java catapult application; target right.

2. Technical realization of the FFS

The FFS is a re-used motorized potentiometer, previously part of a sound mixer. It is limited to one-dimensional linear movements; users can push and pull its handle along a line. The slider's motor can be used to position the handle, thereby providing force feedback (FF). When the slider force depends on the actual position of the handle, an interactive dimension can be gained. Multiple sliders set in parallel can split complex systems into orthogonal vectors where each slider represents an orthogonal dimension. When a dependency between sliders is programmed in a meaningful way – reflecting the underlying system model – it is possible to achieve haptic representation of the multi-dimensional vector space. This should hold for underlying multi-dimensional systems, such as economic ones, where 3D graphics would be too simplistic.

Since portability and flexibility are major concerns, the FFS communicates with the PC via a standard USB connection, much as in [3]. Intra–FFS communication is in Java, relying on a virtual machine implemented for most operating systems [4]. Hence, FFS can connect to various systems supporting audio class USB and Java.

FFS features five predefined modes. In *position*, the slider is used only as input device, the motor is switched off, and the user can move the slider without FF. In *elasticity*, default position and maximal force are set and the user's fingers have to overcome this force. When the handle is released, it returns to the default position. *Gradual* offers a number of discrete steps into which the handle can snap. In *texture*, high-frequency low-intensity vibrations are applied to the handle, thus giving users an impression of a rough surface. In *oscillation*, the handle comes to rest after a damped sine movement. These five haptic profiles are abstract descriptions of FF capacities; other applications can be composed from these modes. Our prototype provides an easy to use application program interface (API) to create new haptic profiles. Any finite function that can be written as a mathematical expression is allowed.

3. User study

We tested the application with a small number of students as users, instructed as follows: "This is a catapult and your task is to hit the castle." All users grabbed the slider and tried to move the handle. They first applied a low force, which later increased. After a few trials, the users tried to figure out the purpose of the message boxes and widgets (Figs. 1 and 2). We assume that users' inhibition with FFS was lower than with a conventional graphical user interface (GUI).

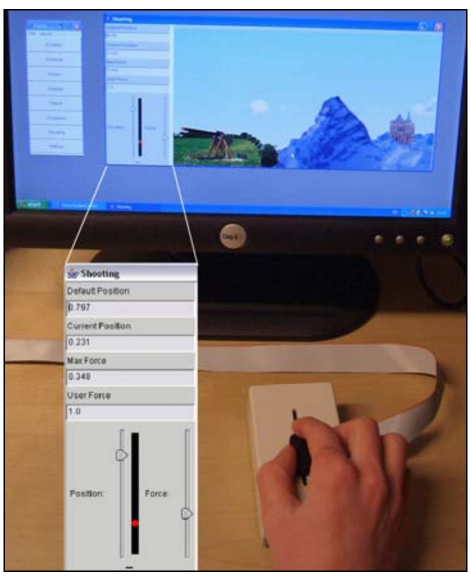

Figure 2: The FFS in operation with catapult.

4. Discussion and future aspects

The catapult application allowed us to study some user behavior with the FFS. We observed that users explored the system without inhibition. This may seem trivial, but is important when evaluating alternative user interfaces. In this sense, a comparative evaluation of learning effectiveness in FFS vs. GUI is planned.

Extensions of the system can be used to develop interesting applications. With multiple sliders set in parallel, powerful visualization systems can be created; we next present two potential applications. Firstly, *economic systems* are highly complex and difficult to understand despite elaborate models. We may learn economic system dynamics from a book, but have difficulty in creating a mental model. Understanding may come more easily if we could use our fingers to sense and manipulate factors such as inflation and growth rate. One slider may control years, emulating discrete *gradual* steps. Secondly, *relieving user visual overload* is another use [5]. While seeing is important for learning, most everyday actions trigger a feedback: visual, auditory, or haptic. If we touch a door knob, we know what to do without seeing. That is an advantage that we seldomly use when interacting with computers. FF could enable us to work more safely and efficiently.

To realize potential applications, we foresee arrangements of multiple sliders with a µcontroller for inter–FFS communication. This should give effective, low-latency user interaction. Further uses for FFSs are collaborative editing, interpersonal communication, and haptic alphabets [5] [6] [7].

5. References

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