Dynamic Manipulation Tools for the Responsive Workbench

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Abstract

In this paper we introduce springs, spring-forks and spring-probes as new tools for assisting direct manipulation of objects on the Responsive Workbench. The springs simulate the application of forces on virtual objects, which introduces a realistic dynamical behaviour of manipulated objects.

1 Introduction

In user interaction with virtual worlds, consistent and realistic behavior of objects is very important. We want objects to respond in a natural and predictable way to our actions. But usually VE objects are massless and unsubstantial, and they move without friction of inertia; this leads to altogether 'unphysical' behavior and unpredictable responses, especially in semi-immersive environments such as the Responsive Workbench (RWB), where real and virtual worlds co-exist, and should follow the same natural laws.

We present a graphical force-feedback method and we provide a visual interface to substitute direct force input. We do this by the use of spring-based tools attached to objects assisting the manipulation, based on the following assumptions:

- a linear relation of force with spring compression / extension is intuitively understood and shown by the spiraling shape of a spring. Thus, even without exerting real force, a user has an intuitive notion of transforming a change of spring length to a force.
- bending and torsion of a shaft is used to show forces and torques exerted on virtual objects
- stability is introduced by friction and damping
- physical contact of objects is intuitively equivalent with geometric intersection

We introduce a set of spring-based tools for providing the basic manipulation tasks (see Figure 1).

- **spring:** attached to the center of an object. It supports linear motions. The tool has 1 DOF (degree of freedom), the length of the spring, and controls 3 DOF (xyz) of an object.

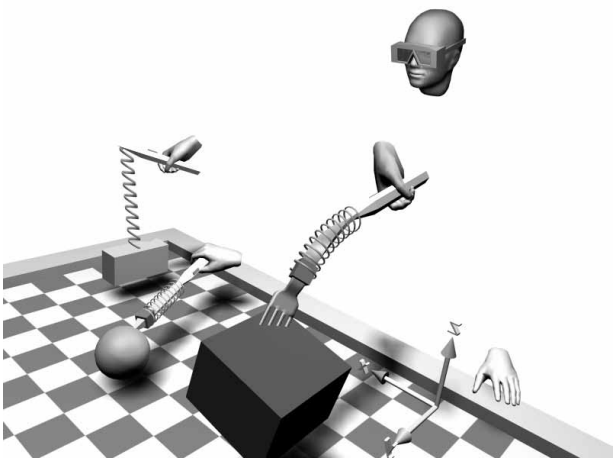

Figure 1 Spring-based tools

- **spring-fork:** attached to an object and defines a contact point for transfer of forces and moments to the object. It assists translations and rotations. The tool has 3 DOF (extension, bend & torsion) and controls 6 DOF (xyz+hpr) of an object.

- **spring-probe:** to be used for probing the material stiffness of an object or pushing an object. The tool has 1 DOF (length) and can control 3 DOF (xyz) or 1 DOF (pressure) of an object.

We propose the use of spring-tools as a link between user's hand and a manipulated object. When the user lifts a heavy object, the spring will extend proportionally to the object's weight and its motion.

The fork metaphor seems to be very intuitive. For object selection the fork has to be inserted into an object. The user can fix the position and the orientation of the fork inside the object. Then the spring part of the fork gives a visual dynamic feedback during the manipulation of the object. The user controls one end of the fork and the other end is influenced by the object. The fork can bend, extend (compress), or twist according to the mechanics.

If virtual forces and moments are applied to virtual objects using the tools, they will show appropriate inertial effects according to the object's mass and moments of inertia.

In this paper, we present an approach of a set of very simple manipulation tools which reflect dynamic object behavior during manipulation.

We extend the spring metaphor [1] to improve the user's feeling of mechanics and dynamics in virtual environments, and we will concentrate on controlling the rotation and the translation with the spring-fork tool.

2 Spring-fork Manipulation

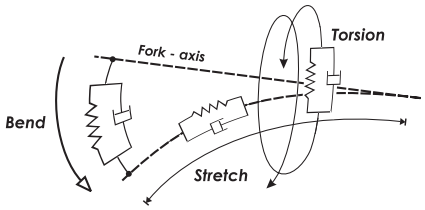

Figure 2 Spring-damper systems for each deformation parameter of the spring-fork

We introduce here a 3 DOF spring-tool, the spring-fork. Each spring-damper in each DOF is calibrated to hold the attached object with a certain extension. In case of the spring-fork (see Figure 2) there are three spring-dampers, one for each DOF: bend, stretch and torsion.

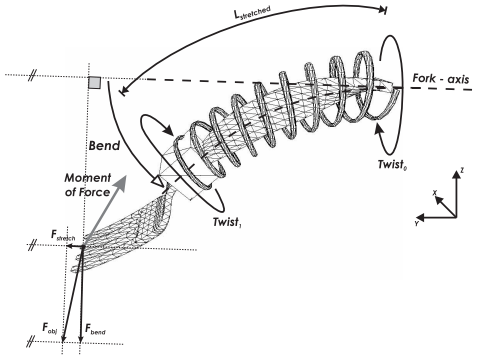

Figure 3 Deformation of the spring-fork

Using the tracked stylus, the user controls the initial position of the tool: the fork axis and the twist angle. The attached object applies a force and a moment to the fork-end and causes a deformation of the spring part of the tool (see Figure 3).

3 The Results and Conclusions

To test the concepts of this paper, we have implemented an experimental application where the user can perform dynamic spring manipulation with virtual objects in a mini-world.

We did informal object manipulation tests with a group of VR experienced and un-experienced people. As expected, the spring tools were easy and intuitive to use and also the subjects performed better with the assembly task.

The results show that object behaviour appears more natural and predictable than the 'unphysical' objects in most virtual environments.

However synthetic the models of the spring-tools are, they look and feel surprisingly real. The approximation of the mechanics seems to be good enough to create the illusion of mass and substance. Also the performance of the dynamic simulation keeps up with the tracker speed (50Hz). Of course, the actual performance and frame rate varies with the amount of collisions and collision behavior which seems to be the bottleneck.

Figure 4 RWB-overview: the spring-fork manipulation with objects in the mini-world

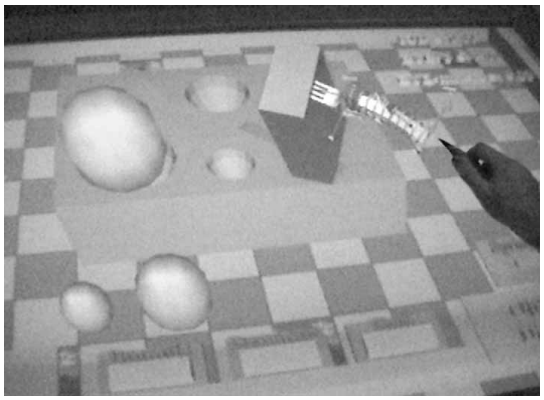

Figure 5 RWB-detail: the spring-fork

References

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