The Use of Haptic and Pseudo-Haptic Feedback for the Technical Training of Milling

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Abstract. This paper describes the use of haptic and pseudo-haptic feedback in a virtual reality system called the Virtual Technical Trainer (VTT). This system is dedicated to the technical training of milling. VTT proposes an interactive manipulation of a virtual milling cutter with haptic feedback. When the cutting tool mills the virtual workpiece, the trainees can feel its resistance according to different simulation parameters. The system proposes two types of haptic interaction using a generic haptic device or a simple input device combined with pseudo-haptic feedback.

1 Introduction and Related Work

Hundreds of people are trained to the use of milling machines in AFPA[1] centers each year. Learning with a milling machine is a long and complex process. It is expensive since it requires a large amount of material and it implies maintenance costs. Therefore, we propose a new system called the Virtual Technical Trainer (VTT). This system is dedicated to the technical training of milling in Virtual Reality. This paper describes the haptic interaction which was implemented in VTT.

Training is a major application for VR technology [1] [2] [4]. In many VR training applications, the pedagogical approaches are focused on the notion of "realism" of the situation. For this aim, most systems use and combine several sensory stimulations – i.e. visual, auditory [2] or haptic feedback [4]. Burkhardt et al. [1] have recently proposed an alternative to the realism-oriented approach. It is based on the use of multi-sensory structures to afford the cognitive and learning activity of the trainees. This approach is grounded on studies of perception which demonstrated new possibilities such as "pseudo-

[11] AFPA : French National Association for Vocational Training of Adults.

haptic feedback”. Pseudo-haptic feedback was initially proposed by combining the use of a passive input device with visual feedback [3]. For example, to simulate friction when inserting an object, researchers propose to simply reduce its speed visually. Assuming that the object is manipulated with an *isometric* input device, the user has to increase his/her pressure on the device to make the object advance. Therefore, “*the coupling between the slowing down of the object on the screen and the increasing reaction force coming from the device gives the user the illusion of a force feedback as if a friction force was applied”* [3].

2 Global Presentation

VTT is a virtual reality system dedicated to the technical training of milling. The visual feedback of VTT displays the complete milling environment with realistic details (see Figure 1). It displays the workbench, the entire milling machine, the rotating tool and the material workpiece.

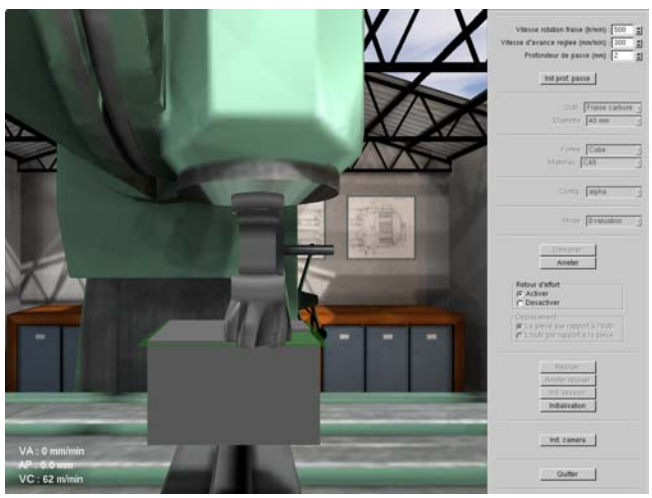

Fig. 1. Visual Feedback of the Milling Process.

The design of VTT is based on interactive manipulation with haptic (force) feedback. In the simulation, the trainees manipulate a virtual cutting tool on the horizontal plane. Force feedback is activated when the tool carves the virtual workpiece. Force feedback varies as a function of the different parameters of the milling simulation: the rotation speed of the tool, the advance speed, the type of tool used (number of teeth, material, diameter). The trainees can feel differences of resistance when the parameters are changed. We assume that the direct perception of the variations of resistance could improve the understanding of the milling process and of the relations between the mechanical parameters.

3 Haptic Feedback

The haptic rendering implemented in VTT is inspired by previous techniques of plastic deformation using voxels, such as the carving algorithm proposed by Yamamoto et al. [5]. Each voxel of the virtual scene resists the motion of the user by a small force which depends on the object's stiffness. The total interaction force depends on the number of voxels inside the tool at the time t and on other simulation parameters: rotation speed, type of tool, etc. At the next time step, the voxels are carved and a new force is computed.

VTT uses a generic haptic device: the PHANToM premium of SensAble Technologies (see Figure 2a). The user manipulates the extremity of the haptic device (a stylus) in 6 degrees of freedom. The manipulation is made in isotonic conditions: the motions of the stylus are directly transposed to the ones of the tool. However, only translations are actually used and applied to the motion of the tool in the simulation.

4 Pseudo-Haptic Feedback

VTT proposes a second solution using a passive input device combined with pseudo-haptic feedback [3]. The input device is used to control the motion of the tool in the simulation. The several levels of resistance of the milling process are simulated by simply modifying the tool's speed and changing the Control/Display[2] ratio. When the tool is not carving the workpiece, the C/D ratio is kept constant. When the tool is carving, the C/D ratio is modified and the speed of the tool is decreased on the computer screen. A strong resistance of the material is associated with a strong deceleration of the tool on screen.

This command is implemented with two possible devices: the Logitech Spaceball, and the LogiCad SpaceMouse (See Figure 2b). Both devices are passive and elastic, but they use different technologies. The Spaceball resists strongly and uses force sensors. The SpaceMouse uses position sensors and its workspace is slightly larger. The modification of the tool's speed is controlled differently according to the device used. In the Spaceball case, the user's input (i.e. Control) is the Force directly measured by the device. In the SpaceMouse case, it is the position measured by the device.

5 Preliminary Evaluation

A preliminary and informal evaluation of VTT was made with a group of 28 AFPA trainees at the beginning of their training period. It was made with the PHANToM device since it was the only solution technically available at this time. Trainers were present and

[2] Control/Display ratio : the speed of hand movement (Control) to speed of cursor (or any other virtual object manipulated in the simulation) movement (Display) gives a ratio called the Control-to-Display (or C/D) ratio.

lead the session. Trainees were asked to mill a virtual workpiece and to make oral comments about the prototype.

Fig. 2. (a) PHANToM-Based Solution (b) Pseudo-Haptic Solution with a SpaceMouse.

The results are globally positive. Trainees were enthusiastic about the technology. The force feedback was well appreciated. Trainers were particularly interested in using VTT at the beginning of the training period, to teach the basic principles of milling faster and in safer conditions. However, this informal evaluation also showed the current drawbacks of the PHANToM solution. The grasping of the device was not satisfactory. The stylus was perceived as a too fine element. The rotations of the stylus disturbed the manipulation. These drawbacks should be avoided by using the pseudo-haptic solution. Future work is now necessary to further evaluate the pedagogical use and the interest of each device.

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