A REVIEW OF HAPTIC FEEDBACK IN VIRTUAL REALITY FOR MANUFACTURING INDUSTRY

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Abstract: This paper discusses the application of haptic feedback in Virtual Reality to enhance user performance in manufacturing industry. Haptic interfaces have the potential to enhance communication and interaction via the computer enabling affective expressive interpersonal communication and enriching interaction by haptic feedback. The aim of this study was to investigate and develop a better understanding of using haptic feedback in manufacturing.

Keywords: Virtual Reality, haptic, manufacturing

INTRODUCTION

Virtual reality (VR) is a human-computer interface in which a computer system generates a three dimensional, sensory, immersing environment that responds in an interactive way to the behaviour of the user. VR technology can be very helpful in visualizing complicated 3-D models of parts and assemblies. VR is useful to visualize how parts fit together and to understand their spatial inter-relationships. VR technology can also be applied to simulate situations where companies need to test health and safety measures, or where there is a hazardous environment and they need to avoid exposing employees to unnecessary risk.

The VR technology has become more real and achievable for industrial applications. A VR system should consider at least three elements: response to user action, three-dimensional graphics in real time and a sense of immersion. Interactivity considers two unique aspects in a virtual environment: navigation within the environment and the dynamics of the environment. The navigation is the ability of the user to move around independently inside the environment. The dynamic of a virtual environment defines the rules about how the contents of an environment interact in order to exchange information.

VIRTUAL MANUFACTURING (VM)

Virtual manufacturing concepts originate from machining operations and evolve in this manufacturing area. However one can now find a lot of applications in different fields such as casting, forging, sheet metalworking and robotics (mechanisms). The general idea one can find behind most definitions is that "Virtual Manufacturing is manufacturing in the computer". This short definition comprises two important notions: the process (manufacturing) and the environment (computer). Areas that are concerned in VM are (i) product and process design, (ii) process and production planning, (iii) machine tools, robots and manufacturing system and virtual reality applications in manufacturing. Chablet et al.[1] define Virtual Manufacturing as "an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control".

The VR model redefined and clarified the original design concepts from architect's drawing. It is a working model of the new facility and it is also used to handle the logistics for the new assembly line. After the modelling the assembly line, the racking to held different components is visualized. In the virtual model, it's easy to visualize re-stocking, access for workers to the components and to the assembly line and stuff position for communication. Figure 1 shows an example of virtual environment.

The use of VR technology in manufacturing application such as layout planning, allows avoiding costly mistakes in the planning and building processes. Siddique and Rosen[3] described the application of Virtual Prototype (VP) in product disassembly. VPs that can be used for designing a product and also disassembling it, as in cases of large machines, which have to be manufactured and then disassembled, transported and assembled again. The disassembly process can be performed by automated techniques or through interaction with the user. Virtual prototyping is a complex process, which enables engineers to communicate collaboratively during the product development process, ranging from design, planning, and manufacturing to assembly.

Assembly processing is a part of the manufacturing line that needs to be taken under special consideration, due to the large involvement of human workers. Haptic sensing in human provides non-visual information about 3-D shape of objects. Based on a qualitative study done by Kim et al. [4] it is shown that the haptic feedback obtained during remote assemblies with dependent collisions can continue to improve the sense of co-presence between users with regard to only visual feedback.

HAPTIC FEEDBACK IN VIRTUAL MANUFACTURING

There are various kind of feedback in VR like visual, auditory and haptic that provides feedback in virtual environments. Visual and auditory feedbacks are relatively well developed and attract a great deal of research. In contrast, the feedback associated with touch (or haptic) remains a challenging research problem. Several researchers agree that the principle reasons why no device has been fully capable of supporting the haptic system are the complicated structure of the underlying physiology of these processes, expense, their complexity and limited workspace[5, 6].

Haptic interaction consists of providing the user of a Virtual Reality system with the sensations involved in touch, i.e., tactile, proprioceptive and force feedback[7]. The word 'haptic' is derived from the Greek "haptesthai" meaning "to touch" [8]. Ellis et al.[9] describe the human haptic system as ''the sensory system which includes proprioceptive sensing of muscle/tendon states as well as tactile sensing of skin deformation''. Burdea [10] explained that force feedback integrated in a VR simulation provides data on a virtual object such as hardness, weight and inertia. Tactile feedback is used to give the user a feel of the virtual object surface contact geometry, smoothness, slippage, and temperature. Finally, proprioceptive feedback is the sensing of the user's body position or

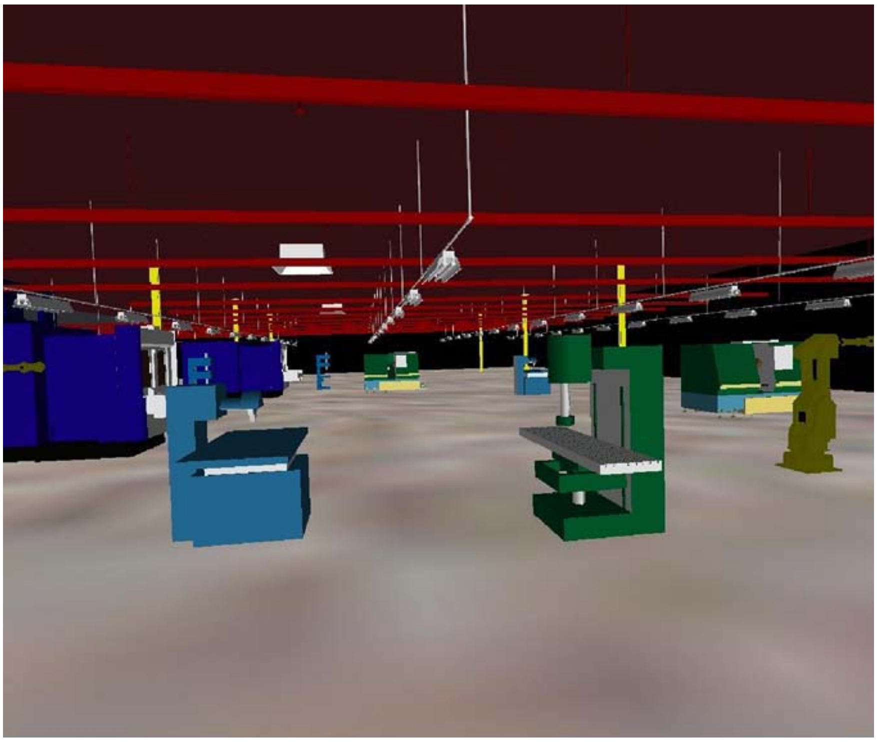

Figure 1. A view of the VRFact virtual environment[2]

posture. Details of the definition of each term related to haptic sensation is tabulated in Table 1.

Table 1: Definitions of Terminology[11]

Term	Definition
Haptic	Relating to the sense of touch.
Proprioceptive	Relating to sensory information about the state of the body (including cutaneous, kinesthetic, and vestibular sensations).
Vestibular	Pertaining to the perception of head position, acceleration, and deceleration.
Kinesthetic	Meaning the feeling of motion. Relating to sensations originating in muscles, tendons and joints.
Cutaneous	Pertaining to the skin itself or the skin as a sense organ. Includes sensation of pressure, temperature and pain.
Tactile	Pertaining to the cutaneous sense but more specifically the sensation of pressure rather than temperature or pain.
Force Feedback	Relating to the mechanical production of information sensed by the human kinaesthetic system.

Providing haptic feedback to the user requires the use of special purpose I/O devices and demands fast calculations and updating of the forces. At this moment, only a few haptic devices are commercially available. Figure 2 shows the most useful device in research and industry called PHANTOM haptic master[12]. It tracks the x, y, and z cartesian coordinates and pitch, roll, and yaw of the virtual point-probe as it moves about a 3D workspace, and its actuators communicate forces back to the user's fingertips as it detects collisions with virtual objects, simulating the sense of touch. This stand-alone virtual environments (VEs) using haptic devices have proved useful for assembly/disassembly simulation of mechanical components. Nowadays, collaborative haptic virtual environments are also emerging. A new peer-to-peer collaborative haptic assembly simulator has also been developed whereby two users can simultaneously carry out assembly tasks using haptic devices.

Two major challenges have been addressed: virtual scene synchronization (consistency) and the provision of a reliable and effective haptic feedback. A consistency-maintenance scheme has been designed to solve the challenge of achieving consistency. Based on a qualitative study, it is shown that the haptic feedback obtained during remote assemblies with dependent collisions can continue to improve the sense of co-presence between users with regard to only visual feedback.

Lecuyer et. al[6] have suggested other replacement solutions such as pseudo-haptic feedback, which combined visual feedback with the use of a passive input device. This kind of haptic has interested many researchers, which studies the use of passive haptic devices together with visual feedback. These can produce a sense of touch with minimal cost and without complex mechanical devices. Static haptics, tactile augmentation, and instrumented objects are among the alternative terms used to refer to approaches using rigid objects in the real world to provide a sense of touch to users interacting with virtual environments[5,13,14]. Hoffman[13] explored the impact of physically touching a virtual object on how realistic the VE seems to the user. His research was the first to empirically demonstrate the effectiveness of mixed reality as a simple,

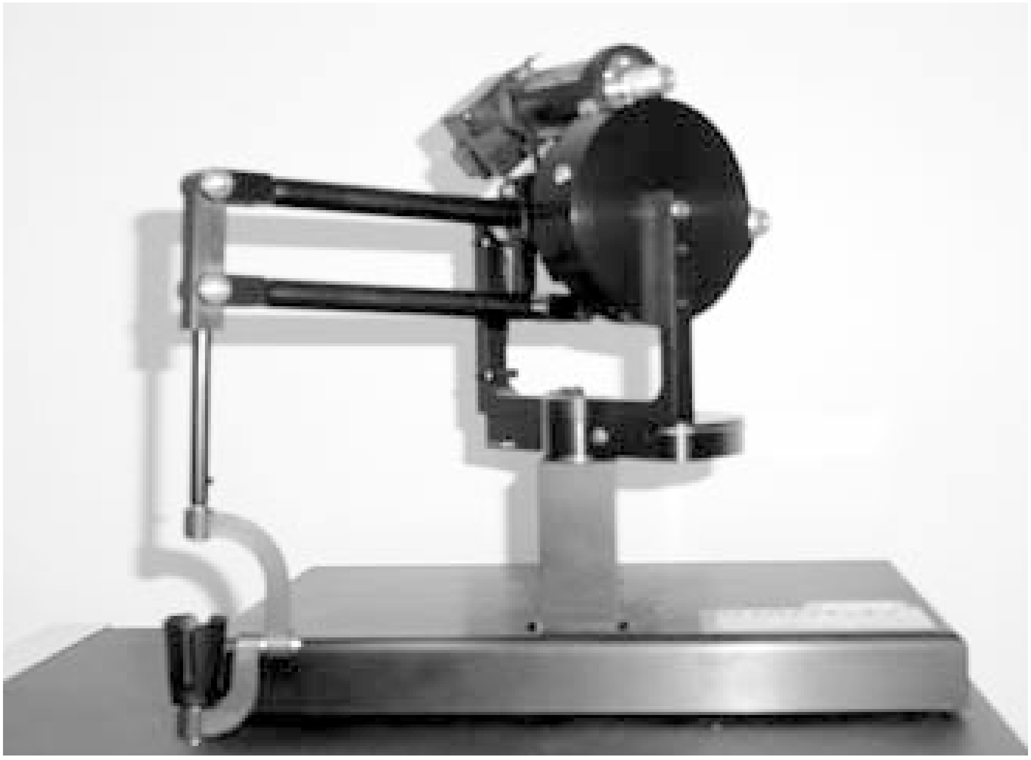

Figure 2. The PHANToM haptic interface[12]

safe, inexpensive technique for adding physical texture and force feedback cues to virtual objects with large freedom of haptic feedback using real instrumented objects, where the user can grasp, pick and manipulate objects, thus providing the user with tactile, force and kinaesthetic feedback. Another study done by Faieza et. al.[15] showed that the introduction of a real weight provides the user with real haptic feedback. Their findings suggest that after a human was exposed to a self-training lifting technique in a virtual environment with the feedback provided, they would be able to conduct the manual lifting task in the real world without affecting their performance and quality of work carried out[16].

CONCLUSIONS

With a recent tendency on working closer to user's domain when performing 3D tasks, it has been suggested that instrumenting the real device/props would allow the user to work as in a real environment. Researchers claimed that providing feedback by manipulating physical input devices which closely correspond to virtual objects is an important step towards bridging the gap between knowing what we want to do and knowing how to do it.

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