HAPTICS AND ITS IMPLICATIONS FOR TECHNOLOGY MANAGEMENT

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Abstract

Haptics refers to the combination of the sense of touch with the sense of body position and motion. Research and experimentation in this field produced startling results with broad implications for technology fields such as medicine, the military, museum displays, scientific visualization, digital prototyping, interaction techniques, and assistance for the blind and visually impaired. While significant haptics work has been done, a literature search using conventional search engines does not reveal much research about what the technology manager should consider and do about haptics. This paper surmises and extrapolates, from the research, implications for the technology manager.

I. HAPTICS AND ITS IMPLICATIONS FOR TECHNOLOGY MANAGEMENT

Haptics refers to the modality of touch and the sensation of shape and texture an observer feels when exploring a virtual object (McLaughlin, Hespanha, Sukhatme, 2002). Touch is fundamental to the way we perceive objects (Thurfjell, McLaughlin, Mattsson, and Lammertse, 2002). Haptics dates to the time of Aristotle (Cook, 1999). Aristotle related features closely to function by identifying the sense of touch as the distinguishing feature of animals and associating it with the then accepted functional definition of animals as objects that move of their own volition (Cook, 1999, p. 231). There are two major questions for haptics research. First, is skin the organ of touch or is the organ situated somewhere else, probably deeper? Second, is touch a single sense or a group of senses? Aristotle surmised correctly that skin is not the organ of touch but simply the medium. We now know that there are several specialized tactile sense organs embedded in the dermis and epidermis (Cook, 1999, p.232).

Since Aristotle, there have been others who have hypothesized and thought about haptics. Diderot in 1794 discussed the tactile perception of the blind and in so doing laid the foundation for our understanding of sensory substitution. Ernst Weber in 1834, considered the founder of the field of psychophysics, formulated *Weber's Law*. The law states that one's ability to discriminate differences between a standard and a comparison is a function of the magnitude of the standard (Cook, 1999, p.233). As an example, a larger difference is needed to discriminate between two weights when the standard weighs 100 grams than when the standard weighs 20 grams. In 1925 David Katz published *The World of Touch* and was interested in the correspondence of an internal response with an external stimulus. One interest was movement's role in haptic perception. Generally, one can feel that a surface is flat with one's hand resting on the surface, but cannot tell the texture until there is movement of the hand on the surface. Thus, once there is movement, touch becomes more effective than vision in determining certain kinds of texture (Cook, 1999, p.233). Katz's research determined that there is a difference between active and passive touch. When someone is allowed to move his hand independently, he will be able to assess in greater detail the surface texture than when the object is moved under his passive fingertips. From this, Katz proposed that the true organ of touch was the hand because it combined movement with touch (Cook, 1999, p.234). Revesz focused on haptic perception in the blind. He theorized that haptic recognition of objects was not immediate and required constructive processing of sequential information. James Gibson proposed that perception is not simply a process of information gathering by the senses and successive processing by perceptual centers. Rather, he saw it as the result of a hierarchical perceptual system whose function depends on active participation by the perceiver (Cook, 1999, p.235). In this way, he saw the matter similar to Katz, especially the importance of intentional movement. Gibson went further by noting another reason for exploratory movement by the hand: to isolate things that don't change in the flow of incoming information. Extrapolating this, Gibson also noted that active exploration causes one to externalize the object (Cook, 1999, p. 236).

Today haptics as a field has many proponents in academia and industry (Cook, 1999, p.237). The field has many open questions but much research is being done, as evidenced by this writer's finding numerous articles documenting various types of research. The resurgence in interest has resulted from, among other things, the availability of an experimental apparatus called the haptic interface (Cook, 1999, p.237). The haptic interface is a special device that imparts reaction forces in response to movements by the user. The interface is similar to a mouse and computer screen with the key difference being that the interface face is used for input and output at the same time. Klatzky and Lederman conducted experiments that form is apprehended better in three dimensions than in two. Their work backs up the ideas of Katz, Revesz, and Gibson in terms of active touch.

Haptics research grew rapidly in the 1990s as researchers and corporations discovered more uses for this force-feedback technology. The technology has its origin in mechanical devices that were developed for the handling of hazardous materials (Thurfjell et al., 2002). This type of device allowed people to grasp a bottle containing dangerous liquid and pour it into another container. This type of device transmitted the sense of touch to the user. Later on, master slave remote manipulators were developed where sense of touch was created by the use of electric motors. These devices were the predecessors of modern haptic devices (Thurfjell et al., 2002). The PHANToM group of haptic displays, discussed in more detail below, was an important spur to the rapid growth of research (McLaughlin, Hespanha, Sukhatme, 2002, p. 48). The PHANToM works on the principle that we perform quite well manipulating and sensing our surroundings using a pen or a thimble (Thurfjell et al., 2002). We perform well at this task because we have only one point of contact. A similar type of haptic interaction is if one uses the tip of a pen to explore an object. In 1996, the first consumer level-haptic display, the Force FX joystick, was released. Microsoft followed in 1997 with the Sidewinder Force Feedback Pro joystick. Logitech added the Wingman Force joystick in 1998.

The purpose and rationale for this paper is to explain and describe haptics for the reader and provide a construct for the implications of this relatively new technology for the technology manager. In other words, how does haptics affect the technology manager in terms of what he should do?

II. TECHNICAL DISCUSSION

Haptics Devices

Haptics devices come in two distinct classes: impedance controlled and admittance controlled devices. Impedance control was first introduced in 1985. For impedance control, the user moves the haptics device, and the device will react with a force if a virtual object is contacted. The idea is displacement in and force out. The user may feel the mass and friction of the actual device but these can be made very small by good mechanical design. Admittance control is the inverse of impedance control. The device measures the force exerted by the human user. The paradigm is force in and displacement out. A model calculates the acceleration, velocity, and displacement which the *object* touched in virtual space would experience as a result of this force. This position is then commanded to the robot which makes the appropriate movement. There is considerable freedom in the mechanical design of impedance devices. Admittance control has been used for control sticks in the flight simulator industry for many years (Thurfjell et al., 2002). The impedance control device is typically lightweight and often small. Admittance control devices give a free feel to the motion. They are well suited to larger work spaces, to master-slave applications, and to carrying complex end effectors with many degrees of freedom (Thurfjell et al., 2002).

For haptics to work, a device must emulate the sense of touch. One device that does this is the impedance type PHANToM from SensAble Technologies. The PHANToM can be described as a desk grounded robot. The PHANToM is a small robot arm with three joints that can revolve. Each joint is connected to a computer-controlled electric DC motor (McLaughlin, Hespanha, Sukhatme, 2002, p. 1). The tip of the device is attached to a stylus held by the user. Voltages are sent to the motors and thus force is exerted at the tip of the stylus. About once a millisecond, the computer that controls the PHANToM reads information from the joints and determines the position of the stylus. This position is compared to the position of the virtual objects the user is trying to touch. For example, if the user is away from all of the virtual objects, then a zero voltage is sent to the motors and the user can move the stylus as if she were exploring empty space. If instead, the system senses a collision between the stylus and one of the virtual objects, it exerts a force on the user's hand. In effect, a user is prevented from penetrating the virtual object just as if the stylus had collided with a real object (McLaughlin, Hespanha, Sukhatme, 2002, p. 2).

A second device is the CyberGrasp. The Cybergrasp is an exoskeletal device that fits over a glove and thus provides force feedback. It is used with a position tracker to measure position and orientation of the forearm (McLaughlin, Hespanha, Sukhatme, 2002, p. 2).

Other devices include the Rutgers Master II and the Polhmeus Fastrak. Along with these other devices are systems that use photographs and a contact pin array, actuator arrays, magnetic levitation, and tactile strips with an array of sensors. There are other glove-like devices as well as some 2D haptic devices. These devices have been developed in a wide array of places from Pennsylvania to Iowa to California to Japan to Italy (McLaughlin, Hespanha, Sukhatme, 2002, p. 49).

Haptics devices also include the software needed to make them work. These software devices are part of the field of computer haptics. Computer haptics defines methods for providing the sense of touch. The software uses a set of algorithms to render the scene's geometrical, material, and dynamic properties. These haptically rendered scenes must be updated at 1kHz or about 30 times faster than visually rendered scenes. This is because our touch sense is much more sensitive (Thurfjell et al., 2002). This means that the algorithms must be implemented efficiently. Additional tools are used for this implementation. These tools are known as applications programming interfaces (APIs). Since most applications provide the user with visual feedback, there is also a need for software for graphics rendering of the scene. This can be done with two APIs or one multi-sensory API (Thurfjell, et al., 2002). Some of the APIs used include GHOST (General Haptic Open Software Toolkit), a C++ software toolkit. GHOST is solely used for haptics rendering. It is a haptics engine and takes care of the haptic rendering and allows developers to deal with simple, high-level objects and physical properties such as location, mass, friction, and stiffness (Thurfjell et al., 2002). The Reachin API is also used (Thurfjell et al., 2002). It was developed as a way to overcome the difficulties involved when having separate rendering engines for graphics and haptics as required for GHOST.

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