Haptic Displays - Information Displays for the Sense of Touch

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Haptic display

What does the word "display" make you think of? We must look at a "visual display," such as a "liquid crystal display" to "see" or understand information processed by a computer. In other words, a visual display is a device that presents information to our vision.

A "haptic display" is a device that enables us to "touch and feel" information in a computer. The word "haptic" means "relating to or based on the sense of touch." A haptic display allows us feel such information as an object's hardness, viscosity, and warmth that would be difficult to see on a visual display.

Haptic ≃ Cutaneous + Kinesthetic ?

The eye is the only organ of vision that accepts light signals. In contrast, the sense of touch is a very complex and unified sensation felt by many kinds of receptors in the body. In this article, let us divide "haptic" into two categories, "cutaneous" and "kinesthetic."

The cutaneous sense is mainly felt by the skin, which is the largest haptic organ and contains several different kinds of receptors responding to pressure, temperature, skew, and tension. With this sense, we recognize the roughness of a surface, or surface texture, vibration, and temperature of an object.

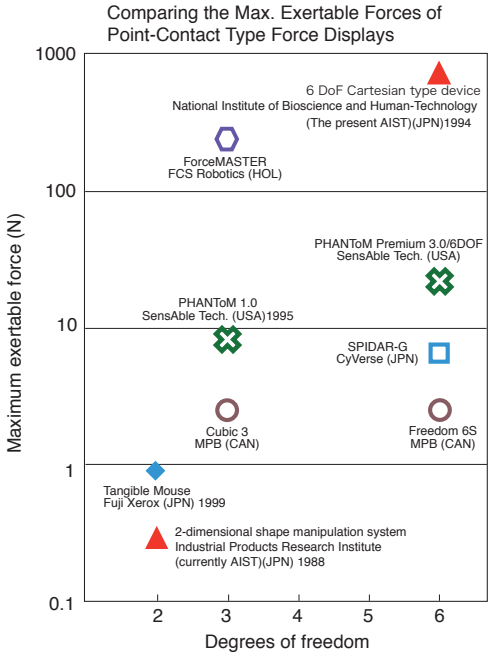


Figure: Comparing the Max. Exertable Forces of Point-Contact-Type Force Displays
The point-contact type is the most widely used force display (commercial products are shown as outlined symbols).

The kinesthetic sense, or kinesthesia, is a sense mediated by receptors located deep inside the body, such as muscles, tendons, and joints, and stimulated by bodily movement and tension. We use this sense to recognize the physical shape and softness of an object in the hand; we capture its shape through joint angles and feel its softness by the tension of associated muscles or the force we apply.

These two categories actually are not so clearly separated, however; for example, it is reported that skin stretching or shrinking (i.e. cutaneous sense) around a joint affects the sense of its angle (kinesthesia).

Various haptic displays

In the last two decades, many kinds of haptic displays have been researched and developed. The variety of devices is a consequence of the complex nature of this sense and the mechanisms to artificially stimulate it. Cutaneous displays showing surface texture by stimulating the skin can be implemented using an array of thin rods that vibrate or poke out (Photo 1), a thin film with well-controlled vibrations, and even an electromagnetic stimulator of skin receptors.

The basic idea of a kinesthetic display, or a force display, is to immediately evoke the "right" reaction force when the user touches a virtual object. Displays in this category can also vary widely, including an "exoskeleton" type (the user wears an "armor suit" device controlled by motors and computers to

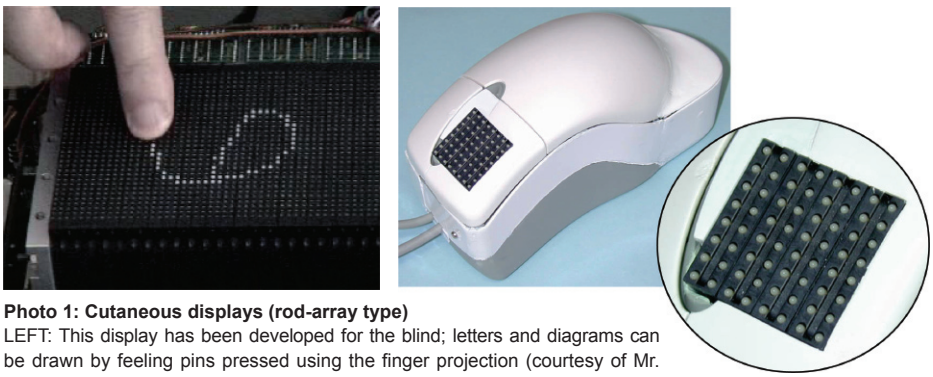
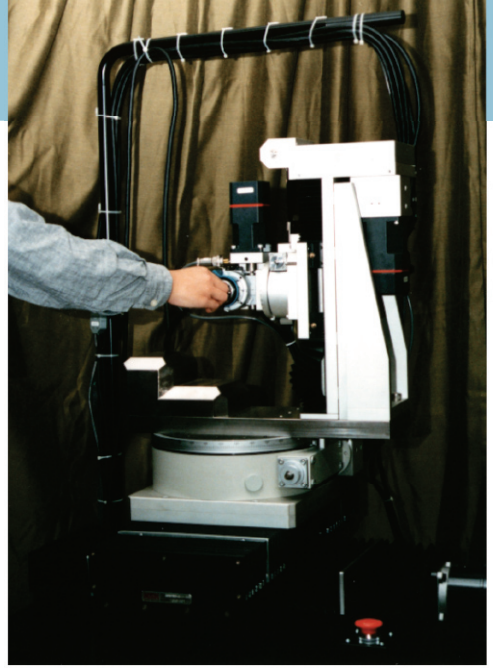


Photo 1: Cutaneous displays (rod-array type)
LEFT: This display has been developed for the blind; letters and diagrams can be drawn by feeling pins pressed using the finger projection (courtesy of Mr. Shinohara, Human Science and Biomedical Engineering, AIST, Japan).
RIGHT: A computer mouse equipped with a small pin-array display (see enlarged image in the circle). A user can feel information around the mouse cursor through level-controlled pins (courtesy of Prof. Shimojo, The University of Electro-Communications).



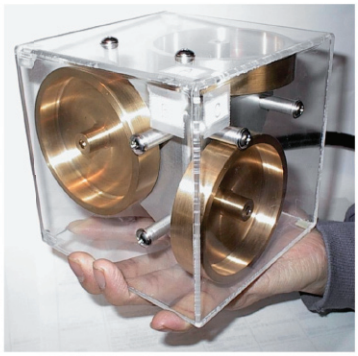


Photo 2: Examples of "Force Display"
LEFT: Six degrees-of-freedom (DoF) Cartesian-type force feedback device (National Institute of Bioscience and Human-technology (currently AIST), 1994.) "DoF" indicates the number of directions in which force can be rendered by the device. In the three-dimensional world in where we live, six is the maximum DoF (three each for parallel and rotation). The device is a point-contact type force feedback device with six DoF with the largest exertable force (see Figure).
Right Top: PHANToM Haptic Interface (SensAble Technologies, Inc., U.S.A.) This is the most commercially successful device in the world (point-contact type, 3 DoF), developed in the MIT AI Laboratory in the early 1990's. With this device, you can touch a virtual object with the tip of a stylus in your hand.
Right Bottom: GyroCube (AIST, Japan, 2001.) This is a torque display of three DoF, developed as a portable direction pointer (courtesy of Dr. Nakamura, Human Science and Biomedical Engineering, and Prof. Fukui, University of Tsukuba).

create reaction forces through the armor), a "point-contact" type (making the user touch a virtual object using the tip of a "tool" in his hand; the "tool" is controlled to show a reaction force to the user so that he can feel the tip touching the object; Photo 2), and a "torque" (a force that produces rotation or torsion) display (Photo 2). Among these, the point-contact type has already been commercialized (see Figure). Since the late 1990's, point-contact-type force displays have been used as three-dimensional input/output devices in computer-aided design systems, virtual surgical simulators, and rehabilitation systems.

At AIST, we conduct research into the display of haptic information by measuring and clarifying the haptic characteristics of humans and the development of haptic devices.

Research and development of olfactory displays

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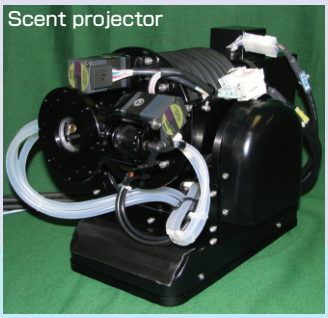
Recently, researchers of the information-related technology have come to join research and development work on olfactory displays; new approaches are now being pursued in this field. These researchers aim at using smells as computer-controlled media, as well as using olfactory displays as tools for aromatherapy or for research on the sense of smell. Various trials are now underway, for example, to use smells as an implicit information output from computers, or to add an odor to the world of multi-media applications and virtual reality (VR).

Among others, VR-oriented olfactory displays are actively pursued in Japan. For example, a wearable olfactory display has been developed at the University of Tokyo that can supply odors to a person who walks around in a VR space. An arm-mounted interactive olfactory display has been developed at Nara Institute of Advanced Science and Technology, focusing on the behavior when a person tries to pick up something to smell. In ATR, a scent projector, which delivers the odor locally to the nose without requiring a user to wear anything on the face, has been developed.

These types of olfactory displays are capable of providing smells synchronously with other interactive contents, so that they are expected to stimulate people to find a new way of using odors.



System concept