

## PROGRAMMABLE TACTILE STIMULATOR ARRAY SYSTEM AND METHOD OF OPERATION

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### BACKGROUND OF THE INVENTION

This invention relates to computer-controlled time-varying stimulation of sense organs such as the skin on a person's finger, hand, or other organ in order to convey information. In particular, the invention relates to a device for presenting patterns of tactile stimulation which can represent symbols, warnings, a sense of "feel", or data on which the user is able to act. The invention can be used in conjunction with other sensory input such as simulated vision, sound, and force feedback.

Virtual reality studies as reported in the October, 1987 edition of *Scientific American* employ stereo visual and auditory feedback along with force and tactile stimulation to create, by computer simulation, an artificial environment for the purpose of teaching or entertaining a human subject. In one practical application, these stimuli represent the real environment of a remotely-located tele-robot equipped with cameras, microphones, force transducers and tactile sensors. Alternatively, the environment can be a completely artificial one created by computer software. A particular practical use is for interfacing with computer-aided design systems.

Visual feedback is accomplished by means of stereo television goggles. Sound stimulation is provided aurally by a conventional headset. Force feedback is provided by electric motors which resist motion of the hand or arm. A sense of touch is similarly provided by tactual stimulators which press against the skin in time-varying patterns.

Tactile stimulation feedback is desirable in virtual reality scenarios, but conventional means for providing tactile stimulation are very limited. The conventionally available methods include electrocutaneous stimulation, single point stimulators driven by electromagnet, and vibrotactile pattern generators driven by piezoelectric actuators. Single point stimulation conveys no information about shapes. Electrical stimulation may be painful. Piezoelectric actuators are bulky and noisy.

The need has been recognized for a stimulation device providing an array of actuators on each tactile surface, such as the finger tip, so that patterns may be distinguished. The device should be small and light enough to fit inside a glove to be worn by the user, and thus to move with motion of the hand.

Teleoperator systems may also be used in situations where conditions in the environment are too dangerous for a human operator. Similar technology may be used in simulation of operation in a size domain in which actual human operation is awkward or impossible. Exoskeletons may increase strength of the bare human arm in handling massive objects. On the very small scale, manipulation of individual cells or cell components, such as DNA, have been contemplated using microactuators. In either case, the computer provides the operator with information which simulates the "sensing" of textures, edges, shapes and the like which the robot encounters in accomplishing its task. This information is presented in a manner such that it aids the operator in

accomplishing the required task. This simulation may emulate natural events such as when the remote robot finger makes contact with a nut which is to be tightened onto a bolt. Alternatively, information may be conveyed in ways which do not emulate nature but must be learned. An example is a vibration to warn a pilot of an impending stall.

In a variety of diseases such as diabetes and AIDS, peripheral sense is diminished early in the progress of the disease. This is due to degeneration of the nervous system which results in peripheral neuropathy. Methods of diagnosis and evaluation are needed for these and other diseases. A versatile, portable, programmable tactile stimulation device may prove to be an inexpensive method of quantifying the extent and quality of neuropathy.

Heretofore, little has been known about the limitations and appropriate methods for tactile stimulation for the purposes of tactile feedback and clinical evaluation. For example, it is uncertain exactly how many elements should be used.

The prior art includes the vibratactile stimulator OPTACON, which is a brand name for a device produced by James Bliss and sold by Telesensory Systems of Sunnyvale, Calif. This device uses vibrating pins, driven by piezo-electric bimorphs, to provide vibratory stimulation to the finger tip. Among the disadvantages of the Optacon are the large size of the actuators, the undesirable noise generated during use, and the very small forces that are generated.

### OBJECTS AND SUMMARY OF THE INVENTION

It is a general objection of the present invention to provide new and improved apparatus and method for tactile stimulation.

Another object is to provide method and apparatus of the type described which provides individual control of a plurality of tactile elements.

Another object is to provide method and apparatus of the type described in which movement of the tactile elements is by means of a shape-memory alloy material.

Another object is to provide a fast, durable, compact, silent, forceful tactile stimulation device.

Another object is to provide a tactile stimulation system which provides adequate stimulation under varying conditions of finger pressure.

Another object is to provide a tactile stimulation device of the type described in which the tactile elements can be mounted together with a high density, such as with micron or sub-millimeter spacing, for compactness.

Another object is to provide a tactile stimulation device which moves a fixed distance above a plane, such as on the order of one millimeter.

Another object is to provide a versatile method of stimulation with multiple elements spaced appropriately for optimum transfer of information.

Another object is to provide an actuator capable of either rapidly-varying or steady-state signals.

Another object is to provide a method of actuation of the type described in which rapid onset is accomplished by resistance heating of the actuator element, followed by controlled current which maintains the up position without overheating the actuator element.

Another object is to provide a device of the type described which is readily interfaced to a digital computer.