# HAPTIC DEVICES USING ELECTROACTIVE POLYMERS

## CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation application which claims the benefit of U.S. patent application Ser. No. 09/866,385, filed May 24, 2001 by Bruce M. Schena, entitled, "Haptic Devices Using Electroactive Polymers", which claims the benefit of U.S. Provisional Patent Application No. 60/206,929, filed May 24, 2000 also by Bruce M. Schena, entitled, "Haptic Feedback Devices Using Electroactive Polymers".

## BACKGROUND

[0002] The present invention relates generally to interface devices for allowing humans to interface with computer systems, and more particularly to low-cost computer interface devices that allow the user to provide input to computer systems and allow computer systems to provide haptic feedback to the user.

[0003] A user can interact with an environment displayed by a computer to perform functions and tasks on the computer, such as playing a game, experiencing a simulation or virtual reality environment, using a computer aided design system, operating a graphical user interface (GUI), navigate web pages, etc. Common human-computer interface devices used for such interaction include a mouse, joystick, trackball, gamepad, steering wheel, stylus, tablet, pressure-sensitive sphere, or the like, that is connected to the computer system controlling the displayed environment. Typically, the computer updates the environment in response to the user's manipulation of a physical manipulandum such as a joystick handle or mouse. The computer senses the user's manipulation of the user object through sensors on the interface device that send locative signals to the computer. In other applications, interface devices such as remote controls allow a user to interface with the functions of an electronic device or appliance.

[0004] In some interface devices, force (kinesthetic) feedback and/or tactile feedback is also provided to the user, more generally known collectively herein as "haptic feedback." These types of interface devices can provide physical sensations which are felt by the user manipulating a user manipulandum of the interface device, such as a joystick handle, mouse, wheel, etc. One or more motors or other actuators are coupled to the manipulandum and are connected to the controlling computer system. The computer controls forces on the manipulandum and/or device housing in conjunction and coordinated with displayed events and interactions by sending control signals or commands to the actuators. The computer system can thus convey physical force sensations to the user in conjunction with other supplied feedback as the user is grasping or contacting the interface device or manipulatable object of the interface device.

[0005] One problem with current haptic feedback controllers in the home consumer market is the high manufacturing cost of such devices, which makes the devices expensive for the consumer. A large part of this manufacturing expense is due to the inclusion of complex and multiple actuators and corresponding control electronics in the haptic feedback device. In addition, high quality mechanical and force transmission components such as linkages and bearings further add to the cost of the device. Some low cost haptic devices exist, but are highly limited in their ability to output haptic sensations.

[0006] A need therefore exists for a haptic feedback device that is lower in cost to manufacture yet offers the user compelling haptic feedback to enhance the interaction with computer applications.

## SUMMARY

[0007] The present invention is directed toward providing haptic feedback in an interface device using electroactive polymer (EAP) actuators, which can provide haptic sensations more efficiently and at lower cost than many existing technologies for haptic devices.

[0008] More particularly, a haptic feedback interface device of the present invention is in communication with a host computer implementing a host application program and is manipulated by a user. The interface device includes a sensor device that detects the manipulation of the interface device by the user and outputs sensor signals representative of the manipulation, and an electroactive polymer actuator responsive to input signals and operative to output a force to the user caused by motion of the actuator. The output force provides a haptic sensation to the user. The interface device may also include a device housing that is physically contacted by the user. In some embodiments, the force and haptic sensation can be correlated with an event or interaction implemented by the host computer.

[0009] Various embodiments of interface devices employing EAP actuators are described. The force output by the electroactive polymer actuator can be an inertial force that is caused by moving an inertial mass. The force output by the electroactive polymer actuator can be a rotary force, a linear force, or a force caused by bending of the EAP element or area expansion of the EAP element. The electroactive polymer actuator can move a button on the interface device to output the force to the user, or the actuator can move one or more portions of the device housing. The EAP actuator can also move an element acting as a brake shoe against a moving part of the interface device to cause a resistance to the moving part, such as an axle for a wheel, a medical tool, a disc, or other part. The EAP actuator can provide haptic sensations for a rotating wheel on said interface device, a trackpoint controller, a rotating knob, a rotating sphere, a stylus, or other manipulandums. One or more (e.g. an array) electroactive polymer actuators can also be used to move members directly into contact or in shear with skin of the user to provide tactile sensations. A method similarly provides EAP actuators in haptic sensation output.

[0010] In other aspects of the present invention, a haptic feedback interface device in communication with a host computer includes a device housing that is physically contacted by said user and an electroactive polymer (EAP) element that is able to detect a manipulation of a manipulandum of the interface device by the user and output sensor signals representative of the manipulation, as well as output a force to the user in response to an input signal, the force caused on motion of the EAP element and providing a haptic sensation to the user. The EAP element can detect contact of the user with the manipulandum, or detect an amount of pressure on the EAP element caused by the user.