The PANTOGRAPH: a Large Workspace Haptic Device for a Multi-Modal Human-Computer Interaction

Christophe Ramstein
Centre for Information Technologies Innovation
1575, Chomedey Boulevard
Laval, Quebec, Canada, H7V 2X2
E-mail: cramstein@citi.doc.ca

Vincent Hayward
McGill University
Research Centre for Intelligent Machines
3480 University street
Montreal, Quebec, Canada H3A 2A7
E-mail: hayward@larry.mcrcim.mcgill.ca

ABSTRACT
A multi-modal user interface taking advantage of kinesthesia, force display, sound, and graphics, to improve human-computer interaction is described. This design primarily addresses the needs of visually impaired persons working in an office situation, but is presently applied to numerous other instances of human-machine interaction; such as operator workstations in control rooms or cockpits. The main technological item introduced here is the haptic interface itself (nicknamed the "Pantograph") which measures position and velocity of a manipulated knob and displays forces in two dimensions over a wide frequency range. Programmed mechanical models are used to kinesthetically describe the features of the interface. These models are analogous to iconic representations in conventional graphic interfaces. Users, acting and perceiving through the haptic channel, simultaneously perceive simulated objects through the visual and auditory channels. Further developments are briefly reported.

KEYWORDS
Multimodal human-computer interaction, haptic device, physical model

INTRODUCTION
Graphic user interfaces (GUI's) have significantly enhanced human-computer interaction, but communication typically remains limited to only one efferent motor channel (via a mouse or a keyboard) and one visual feedback channel (via a screen). An individual, capable of using complementary and supplemental information from multiple senses, is restricted to basic somatic capabilities. Moreover, such a situation provides a visually impaired person with no access to graphical applications.

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According to Foulke [2] and Sperandio [5], an interface design will benefit from multi-modal feedback, as it allows for the requirements of a disabled person, and also provides non-disabled persons with better communication possibilities, as in the case of real-life experience.

THE PANTOGRAPH: A LARGE WORKSPACE HAPTIC DEVICE
The "Pantograph" (see figure 1) has a large workspace and uniform response: 10 Newton peak force, and ± 3db open loop, within a 10 cm X 16 cm (4" X 6") rectangular area. It is a two degrees of freedom haptic device that was initially designed to address the needs of visually impaired persons. This work has been carried out in the framework of a project called Audicon [4] aimed at giving visually impaired persons access to graphic user interfaces.

The design is based on a linkage which, in order to provide high bandwidth response, has been optimized from the viewpoints of its (a) workspace, (b) kinematics, (c) dynamics, (d) and structural properties (see [3] for further details), while fulfilling the ergonomic requirements demanded by the application.

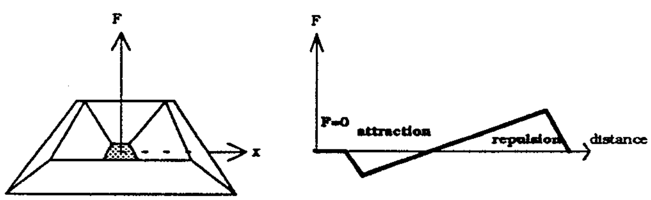
PHYSICAL MODEL AND MULTIMODAL HUMAN-COMPUTER INTERACTION
Under proper digital control, the Pantograph can reconstruct in real-time interactions with mechanical objects having stiffness, damping, or any other constitutive properties. The response is of sufficient quality to give the users the tactile and kinesthetic sensations of rigid, continuous outlines, sharp edges, etc... As it turns out, the device is also useful as a general purpose computer interface.

The complete experimental system as it is configured at the time of this writing, includes a low cost personal computer, a conventional 12 bit analog to digital, digital to analog conversion board, and a pair of linear power amplifiers. It provides for communication via three combined channels: visual, auditory and haptic. The auditory signals occur naturally and are generated by the transient components of the actuator signals applied to the motors which in turn excite the high frequency natural resonances of the structure.

Physical models [1], were used to program the constitutive properties of each interface feature, such as buttons, window outlines and menu bars. A force field is calculated as a function of the value of the state variables: position and velocity, over which the user has control. The users can explore this field moving the Pantograph, much like it would be done using a traditional mouse. The forces transduced by the device are capable of replicating with fidelity mechanical interactions occurring between a pointer and a surface having features. With proper programming, users are in a position to perceive physical objects through touch and kinesthesia. Moreover, in a physical model, visual, auditory and haptic channels are intrinsic to the representation and are displayed synchronously and coherently.

EXAMPLE OF A PHYSICAL BUTTON

The figure below shows an example of the force profile for a button. The force is calculated to be a function of the distance between the pointer and the center of a rectangle. This profile is split into three parts: a featureless flat region, an attraction, and a repulsion. This is entirely specified by modifying the value of a stiffness coefficient as a function of position. Analogously, viscous damping can be thus specified as a function of position. If these quantities are made to depend on velocity too, certain non-linear effects can be programmed, chiefly among them solid friction which depends on the sign of velocity. More generally speaking, arbitrary constitutive properties can be programmed within the limits of the device capabilities.



There are two advantages of this particular force profile: it allows users to sense the outline of a rectangle with their eyes closed, and when the pointer has crossed the repulsing force area, it is attracted toward the center, thus causing effortlessly an accurate positioning.

CONCLUSION

The fully operational Pantograph system, connected to a low cost personal computer (IBM 486 DX2/66MHz) has been demonstrated. Several examples of mechanical interface features, such as a pointer, rectangular enclosure and buttons which have been successfully programmed, indicate the urgent need for further research toward the improvement of multi-modal person-machine communication.

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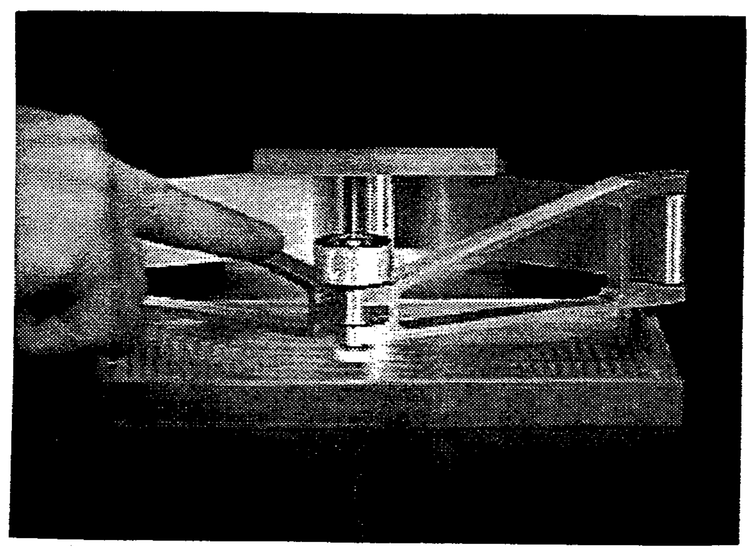

Figure 1: A view of the Pantograph with a 10x16cm workspace.