Scalable Interactive Surfaces via Charge Source Tomography

E. Rehmi Post, Ankur Agarwal, Udai Pawar, Neil Gershenfeld

MIT Media Laboratories
Center for Bits and Atoms
20 Ames Street, E15-411
Cambridge, MA 02139 USA

{rehmi,ankur,udai,neilg}@media.mit.edu

ABSTRACT

As computers move off the desktop and become part of the global environment, there is a growing need for *scalable interactive surfaces*. These surfaces should cost very little to build at scales ranging from centimeters to meters; be mechanically robust and simple to fabricate; allow use with nothing but the bare hands; and finally, be easy to embed into (or print onto) a wide variety of surface materials and shapes. To meet these requirements we are developing the technique of *charge source tomography* (CST).

KEYWORDS[1]

User interfaces, charge source tomography, electric field sensing, capacitive sensing, 2D input devices.

INTRODUCTION

One of the major challenges faced by today's computing technology is its limited acceptance in many segments of society. Particularly in developing nations, language barriers and social differences have restricted the social acceptance and relevance of computers in their present form. We would like to enable widespread use of information technology by providing an interface that can be largely independent of social or cultural background.

Perhaps the most familiar two-dimensional input devices are the computer mouse, the graphic input tablet, the computer touchpad, and the touchscreen. All of these enable a user to interact directly with a 2D input space, typically displayed on the computer's screen. These devices are typically fragile, expensive, cannot easily cover large areas, and are unsuitable for use outdoors or in uncontrolled environments.

As our goal is to develop a user interface device that is inherently customizable, embeddable, robust, and inexpensive, we are developing a novel 2D input device that can be made as small as a business card or as large as a blackboard for essentially the same cost. Furthermore, this device can be embedded within handheld objects, furniture, or walls. An input surface may also be used as a keyboard by printing letters and symbols on its surface, to permit both literate and non-literate interaction metaphors. Such an interface may be especially appropriate for use in "hole-in-the-wall" computing initiatives.

CHARGE SOURCE TOMOGRAPHY

CST is a method of sensing user interaction with flat or curved surfaces made sensitive by the addition of a conformal resistive sheet that guides electric fields in a preferred manner. This sheet may either be applied to the surface itself or embedded in a subsurface layer. We commonly refer to this family of sensing techniques [6] as the *resistive fish* or "resistofish", in reference to the many species of fish that have evolved similar techniques [5]. CST also bears certain similarities to *electrical impedance tomography* [2].

During operation, the resistofish controller applies voltage patterns to points on the perimeter of the sheet and measures the currents that arise as a consequence. The user appears in this system as a capacitive load localized to some region of the resistive sheet and is effectively connected to the perimeter by resistances R_i that vary as the distance between the load and the measurement points (as in Figure 1). The control electronics then reconstruct the charge distribution corresponding to the user and present this information to the computer as a two-dimensional position (x, y) and a height measurement (z). The height measurement is used to identify events such as contact, release, and tapping.

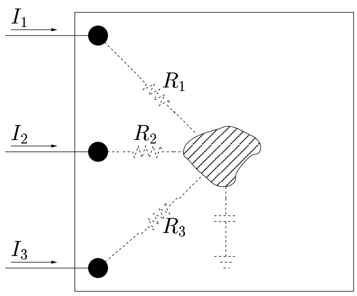

Figure 1. General case of 2D projective position measurement.

By projecting the 2D impedance distribution onto observable electrical quantities at the manifold's 1D boundary curve, the dimensionality of measurement

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(and its associated cost and complexity) is likewise reduced. The original 2D charge distribution may then be reconstructed to an arbitrary degree determined by the number of boundary measurements. The position measurement resolution is determined by the precision of current measurement, whereas the ability to distinguish separate charge sources is related to the number of independent current measurement axes.

Our technique is derived from common models of capacitive position measurement [4, 1] in which a linear resistive element acts as a voltage divider to encode contact position. Figure 2 illustrates this case with source voltage V_{src} at frequency ω and impedance R_{src} driving each side of a resistive divider $R_1 + R_2$ into a capacitive load C representing the user's hand. The currents I_1, I_2 depend on the implicit resistors R_1, R_2 and their difference (read out as V_{diff}) is a measurement of load position.

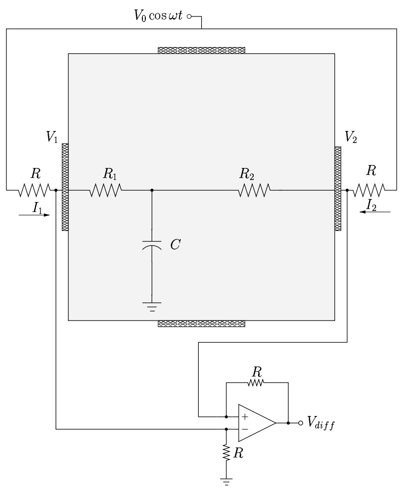

Figure 2. Schematic view of the analog measurement along one axis.

Crucially, this differential measurement is independent of the size of the surface, permitting the creation of arbitrarily large (or small) interfaces.

To apply potentials and measure currents at several points on the surface of an arbitrarily large resistive medium we have devised a simple circuit to control each electrode, comprising a register and buffer mechanism which may be enabled to charge or discharge the load capacitance in the sheet. This maps the current measurement into the time domain [3]. The time taken to charge electrode m is directly proportional to the distributed load capacitance C induced by the user and the resistance R_m from the electrode to the load.

Electrode controllers placed at several points on the perimeter of a resistive sheet may be daisy-chained and individually addressed through a serial bus. A microcontroller sequences measurements across pairs of electrodes in turn and passes those data to the host computer. The host then calculates hand position and generate corresponding keyboard/mouse events.

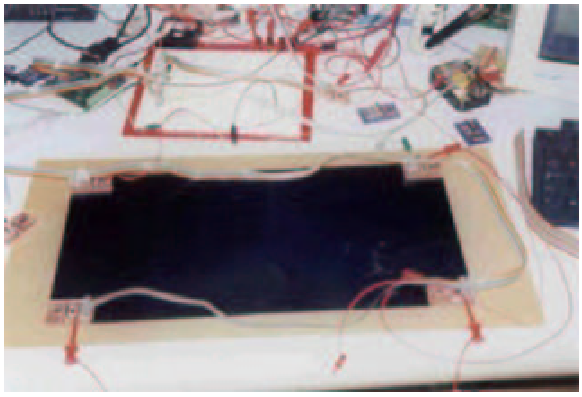

Figure 3. A prototype resistive-sheet-based interface.

The resistofish appears to the user interface designer as a surface that returns position and contact information, similar to the conventional touchpad described above. We have developed drivers for Linux and Microsoft Windows to allow users to "point and click" on existing user interfaces with no additional training and to allow the resistofish to be used as a "programmable" keyboard.

FUTURE WORK

Having proven the technical feasibility of the resistofish method described above, we now plan to conduct field tests in order to incorporate feedback from users of diverse socioeconomic backgrounds. A comprehensive interactive set of software tools will enable the end-user to define the layout and functionality of the interactive mechanism. At the same time, we are developing resistofish hardware in a form that can be widely deployed by non-technical users.

ACKNOWLEDGMENTS

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