Using Capacitive Sensors for New Exertion Interfaces

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Abstract
Capacitive sensors are proximity/touch sensors with a simple principle of operation but complex behavior. Their intrinsic properties make them apt for novel exertion interfaces. Some possible uses include input devices for beat-em-up games, gesture interfaces or enhanced play objects. CapToolKit, an open-source capacitive sensing toolkit makes prototyping novel exertion interfaces easy.

Keywords
Capacitive sensing, exertion, games, sensors, input devices

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

Introduction
Exertion interfaces [1] offer a fun, healthy way to interact with a computer and/or other humans. They often have different design requirements than conventional user interfaces. Capacitive sensors are versatile, robust, and powerful. Incorporating these sensors in exertion interfaces may enrich the user experience they provide.

About Capacitive Sensing

Capacitive sensors allow measuring the distance between an electrode and other objects. The electrode creates an electric field that is disturbed by objects passing through it. The amount of disturbance is determined by the electric properties of the object and its distance to the electrode. The range of such a sensor can be from micrometers to a couple of meters, depending on sensor design and electrode size. The resolution can be up to a few nanometers, but generally rapidly decreases with distance between electrode and object. Up to a distance of 10 centimeter, millimeter resolution is easily achievable. For a more detailed explanation of sensor working principle and limitations, please see [4].

Prototyping with CapToolKit

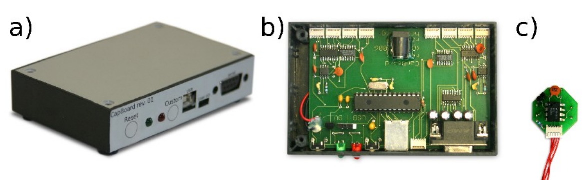

Figure 1. CapBoard (a,b) is the sensor platform in CapToolKit. Up to eight small sensors (c) can be read out via USB or TCP.

We developed a toolkit for prototyping capacitive sensing applications. The toolkit has been placed under an open-source license (GPL). It is available at *www.capsense.org* (new version to be uploaded soon). CapToolKit offers an easy and cheap way to attach up to eight capacitive sensors to a PC via USB. Applications can read the sensor data either directly from the USB interface or via a USB-to-TCP bridge.

Capacitive Sensing for User Interfaces

Capacitive sensors allow tracking almost arbitrary objects. For 3D tracking at least three sensors have to be employed. Various researchers (we, too [3]) have experimented with tracking hands using capacitive sensors. While the idea of controlling a computer just by waving ones hand around is fascinating, actual results are not. With capacitive sensors, changes in the environment can not easily be distinguished from intentional user input. For example, if another person stands near a sensor, she also distorts the electric field, masking the users intentional distortion of the field. Due to many influencing factors, it is very difficult to determine the absolute position of an object from sensor readings.
The principles of capacitive sensing have been known for over 80 years now. Several scientists and companies have presented prototypes or even products of capacitive gesture trackers. However, the only working solutions "in the wild" have to severely limit interaction possibilities to counter the problems mentioned.

Capacitive Sensing for Exertion Interfaces

Capacitive sensors may not be the hardware of choice for classic human-computer interfaces. Due to some unique properties, they are a very promising option for exertion interfaces, especially game controllers:

High Robustness

Capacitive sensors have no moving or fragile parts. The sensor itself is a small circuit board, the electrode is usually a sturdy metal plate. Thus they can be incorporated into installments or play objects.

Variable Sensor Characteristics

Capacitive sensors are very versatile. Their primary use is for proximity sensing. The sensitivity and direction of the sensor is determined by electrode size, shape and placement. Instead of generating a lot of data (like e.g. a camera) requiring costly post-processing, capacitive sensors just deliver the data you defined by sensor design and placement.

For measuring the force of a punch, a piece of foam can be placed on the electrode. The stronger the punch, the farther the foam is compressed, and the closer the user's fist gets to the electrode. The sensor measures the remaining distance between fist and electrode.

They can even be used to measure capacitive coupling between human body and ground, detecting a user's footsteps [2].

Friendly but Challenging Behavior

Capacitive sensors generate low-complexity data. A user can quickly grasp the correlation between his movements and sensor output. Thus the barrier to entry of such an interface can be very low. However, the many influencing factors determining a sensor reading also introduce high complexity. While a new user may quickly learn the basic usage of such an input device, she needs lots of time in order to master the device. Accidental observations or attempts to fudge the device may open up entirely new game tactics. For example, a user may learn from which direction to approach a sensor in order to remain undetected – or effect a higher sensor reading. Requiring extra effort in order to master a game corresponds with many 'real' exertion interfaces, like bats and balls.

The aforementioned properties of capacitive sensors make them highly apt for exertion interface designs. Some examples for such interfaces spring to mind: sturdy, foam-covered sensor bars, which the user has to hit at the right places in order to destroy enemies attacking his avatar on the computer screen. Balls may determine, if they are held by one or more persons, or lying on the ground. An enhanced version of 'Dance Dance Revolution' could not only track feet movement, but the whole body.

Current Status

We are currently improving CapToolKit and brainstorming ideas for interesting game controllers. A game controller prototype using capacitive sensors will be built and evaluated in late 2007 / early 2008.

Citations

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