# Rainbowfish: Visual Feedback on Gesture-Recognizing Surfaces

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## Abstract
In recent years, gesture-based interaction methods are supported by a wide variety of devices, such as capacitive trackpads and capacitive 3D gesture recognition systems. Capacitive interaction systems are often integrated into laptops, but can also be installed ubiquitously under any kind of non-conductive surface - for example under a table. When interacting with such proximity-sensing surfaces, users often face the challenge that the affordances are often not directly apparent. Moreover, most devices have no ability to provide feedback, which is often only displayed on a complementary screen, not in the area in which the interaction takes place. In order to solve these problems, we present an approach which combines a semi-transparent capacitive proximity-sensing surface with an LED array. The LEDs are used to visually indicate possible gestural movements and provide feedback on the current interaction status.

## Author Keywords
capacitive proximity sensing; gesture recognition; visual feedback; visual feed-forward clues

## ACM Classification Keywords
H.5.2. [Information Interfaces and Presentation]: User Interfaces - Graphical user interfaces; Input devices & strategies

## Introduction

Gesture recognition is widely used to realize natural interaction in various types of user interfaces. The required information about hand and finger movements of a person can be captured by different means - such as cameras, portable accelerometers or capacitive trackpads. Capacitive sensing enables to recognize 2D, as well as 3D, object positions. A sensor usually consists of one or more sensing electrodes connected to a measurement circuit. Depending on the electrode size, a capacitive sensor is capable of detecting the presence of a human hand within typical distances of 30 cm [3]. By employing more than one sensor, it is possible to determine the 3D-position of a human hand or other body parts [1]. Besides using capacitive sensors for interacting with a computer, they were used to recognize the way in which a user touches an object [2]. Stationary installed capacitive sensors enable to recognize activities, for example playing cards above a table [4].

The affordances of capacitive interaction systems are often not visible. For example, a touch pad affords touching, but it is not clear why and when a user should use two fingers for scrolling in a document. When extending the interaction space from 2 dimensions to 3 dimensions, even more questions and problems arise. As interaction with capacitive sensors is limited by a certain distance to the electrodes, the interaction barriers are also not apparent to the users. Questions like '*When is my hand being detected?*' and '*Which gestures am I able to perform?*' will arise frequently, especially when users are not familiar with the system. Providing solutions to these challenges becomes more relevant as commercial capacitive 3D gesture recognition systems became available over the past couple of years[1].

[1]e.g. Microchip GestIC - www.microchip.com/gestic/

**Figure 1:** Rainbowfish is a capacitive gesture recognition system providing interactive feedback and feed-forward clues.

For these reasons, we developed Rainbowfish, a novel capacitive gesture recognition system which is shown in Figure 1. The central contribution of our work is the device's ability to present visual feedback and feed-forward clues on its surface. Therefore, it may visualize the position of a human hand or give hints on the context-dependent gestures a user is able to perform. Rainbowfish is capable of detecting a human hand within a proximity of 15 cm.

## Technical Implementation

The goal of our implementation was to build an interface that can be controlled by hand movements. It can be used for both computer-based applications and ubiquitous interaction with the environment. Especially when interacting with intelligent environments, gesture-recognizing surfaces embedded into everyday objects can be a low-cost alternative to many camera-based methods.

The final design has a surface with a 16:10 proportion (400 mm x 250 mm) and contains 12 transparent electrodes, each connected to a custom-built capacitive proximity sensor. Furthermore, an LED grid was integrated, illuminating the device's acrylic glass surface. A mainboard controls Rainbowfish and acts as a gateway to a computer. All electronic components are embedded into a custom-made and 3D-printed frame structure, as shown in Figure 2. The transparent electrodes are made of Indium-Tin-Oxide (ITO), a material widely used for touch screens. ITO has a very good surface conductivity and light transmittance, and is thus also a suitable material for capacitive proximity measurements.

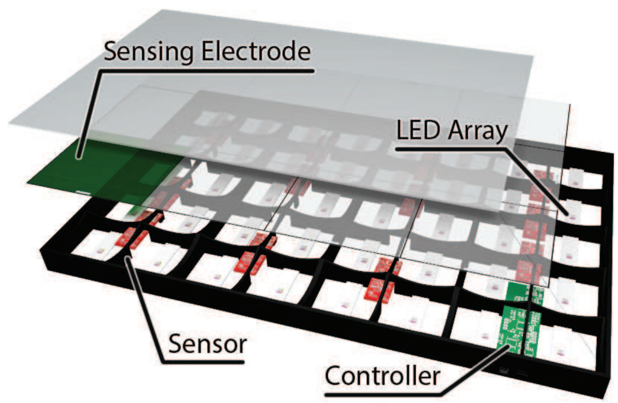


**Figure 2:** The gesture recognition device consists of four main components depicted in the figure.

The capacitance measurements are conducted in loading mode [3], which means that each electrode builds up an electric field to objects in its surroundings. The measured capacitance increases when an object approaches the electrode. An electrode can be easily shielded by placing a second electrode with the same potential below the first one. This reduces external influences on the measurement, for example created by underlying electronic components. Applying a frequency of approximately 600 KHz, the sensors trigger succeeding charge and discharge cycles on the capacitor that is built by the sensing electrode and the approaching object to determine its capacitance. The mainboard polls the 12 sensors by $I^2C$ and allows for obtaining 20 measurements per second and sensor. In order to communicate with a PC, Rainbowfish opens a virtual COM port with a two-way interface: The measurements are sent to the host PC, whereas the PC triggers visualization profiles on the board. Therefore, the application logic on the host determines how the visualization is composed. The lightweight visualization profiles contain either direct drawing instructions or trigger predefined animations.

## Demonstration Setup

The demonstration setup is depicted in Figure 3. It combines a graphical user interface, running an image viewer application, with our gesture recognition device placed in front of a screen. In the first navigation level, an overview with thumbnails of all images is shown. It is possible to scroll through the images by moving the hand to the left or right-hand corners of the device. The corresponding regions are illuminated by a purple color on Rainbowfish's surface. An image can be chosen by having the cursor linger above the desired picture for three seconds. Parallel to the progress bar on the screen, the recognized hand position visualized on the surface fades from blue to green. When an image is selected, the whole surface of the Rainbowfish lights up shortly in green to signal successful input. Similar to that, all gestures recognized successfully are indicated by a green lighting. Once an image is selected and has been enlarged, it is possible to browse through pictures using swipe gestures. Additional to the direct visual feedback on the hand position, a feed-forward animation visualizes that swipe gestures can be executed in this view.

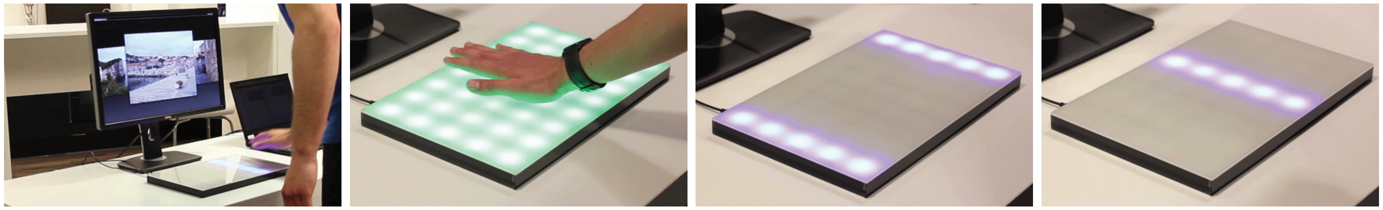

**Figure 3:** In the demonstration setup, an image viewer is controlled with gestures (image 1). When a gesture was recognized successfully, the device will light up in green (image 2). Forward clues are given by statically illuminating active regions (image 3) or animating swipe gestures with bars that move over the surface (image 4).

## Discussion & Future Work

Based upon our implementation, we conducted a user study with 20 persons. It revealed that the feed-forward animations, as well as the visual feedback, helps new users in controlling the image viewer. Using feed-forward animations, gestures can be learned more easily. On the contrary, many experienced users do not take the visual animations into account after being familiarized with the system. Many test persons mentioned, the visual feedback had some positive influences on their intrinsic motivation to interact with the system. Even while experiencing problems, they felt more confident and motivated to use the system. Therefore, we believe that interaction designers, as well as people interested in sensing modalities for HCI, will benefit from our demonstration and interesting discussions will arise.

In the future, we plan to increase Rainbowfish's interaction space from 15 cm to distances of 30 cm in order to support recognizing three-dimensional gestures. At this point, the visualization concepts have to be revised to include more meaningful information about the recognized object distance. Although our approach has been realized within a device that is able to recognize hands, we would like to transfer the concept to traditional capacitive trackpads. Aside from computer-centered interaction, we already use the presented technology as a low-cost gesture recognition system for home automation, for example as a gesture-controllable door opener with interactive feed-forward clues and feedback.

## References


[1] Grosse-Puppendahl, T., Braun, A., Kamieth, F., and Kuijper, A. Swiss-cheese extended: an object recognition method for ubiquitous interfaces based on capacitive proximity sensing. In *CHI '13* (2013), 1401–1410.

[2] Sato, M., Poupyrev, I., and Harrison, C. Touché: enhancing touch interaction on humans, screens, liquids, and everyday objects. In *CHI '12* (2012), 483–492.

[3] Smith, J. R., Gershenfeld, N., and Benton, S. A. *Electric Field Imaging*. PhD thesis, Massachusetts Institute of Technology, 1999.

[4] Wimmer, R., Kranz, M., Boring, S., and Schmidt, A. A capacitive sensing toolkit for pervasive activity detection and recognition. In *PerCom '07* (2007), 171–180.