DIY IR Sensors for Augmenting Objects and Human Skin

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ABSTRACT

Interaction designers require simple methods of creating ad-hoc sensors for prototyping interactive objects. Methods of creating custom sensing solutions commonly include various capacitive and resistive techniques. Near-infrared (IR) sensing solutions can be used as an alternative to these established methods. There are many situations in which IR sensors may be a preferred method of input, such as grasp detection and touch interactions on the skin. In this paper we outline the general approach for designing IR sensors and discuss the design and applications of two custom sensors.

Author Keywords

IR-sensing, multi-touch, on-body touch sensing

ACM Classification Keywords

H.5.2 [User Interfaces]: Input Devices and Strategies, Prototyping

INTRODUCTION

Trends in HCI such as tangibles, organic user interfaces and wearable computing have led to an increasing amount of devices with non-planer interaction surfaces on objects with arbitrary geometry [7]. Improvements in quality and availability of 3D printing technology allow us to create such objects at whim. When exploring the interactive potential of such arbitrary objects, we are limited by the available sensing technologies. Commercial sensors usually are designed around a flat PCB base and come in specific discrete sizes; most likely they will not fit an arbitrarily shaped object.

A solution to this problem is creating special purpose sensors designed to specifically accommodate the form factor of the prototype at hand. Examples of such approaches are resistive solutions such as Holman's TactileTape [6] and Resigraph [5] as well as capacitive solutions demonstrated by Olberding et al. [8].

These methods support sensors of arbitrary size and shape, however, they provide little to no expressivity in terms of dynamics: approach behavior, pressure, etc. Capacitive sensors are further limited by certain environmental factors. DIY capacitive sensors, for example, perform very poorly in combination with E Paper technology or when used directly on the skin. Capacitive and resistive touch solutions also require access to the interaction surface, either in the form of an overlay or a substrate directly underneath the interaction surface.

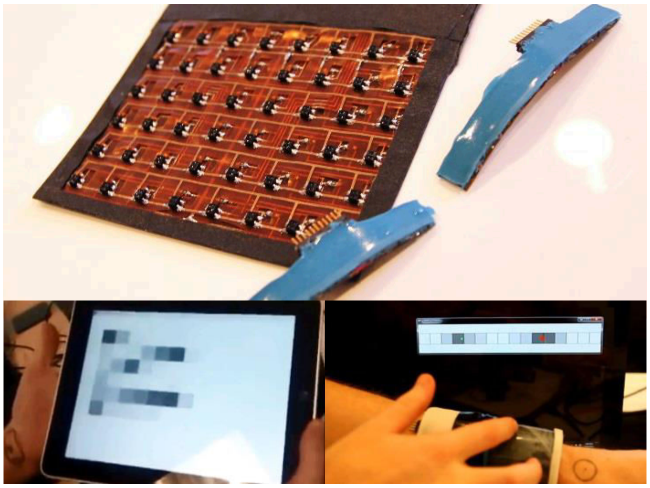

Figure 1 – Volumetric sensor (square array & bottom left) for sensing hand position in 3 dimensions; projected 2D sensor for touch interactions on the wrist (blue strips & bottom right).

Like capacitive or resistive touch solutions, near-infrared (IR) sensors (Figure 1) can be manufactured in arbitrary configurations. IR sensors however do not have any of the previously mentioned drawbacks of resistive or capacitive DIY solutions. IR sensors can be used for sensing touch, pressure and, acting as proximity sensors, can also sense the approaching finger in mid-air. This makes them well suited for sensing expressive, dynamic interactions. IR sensors also do not require access to the interaction surface; instead of acting as an overlay or substrate, they can be projected on a surface from the side. This enables touch interactions using the skin as substrate, for example in the proximity of a wrist watch.

RELATED WORK

Jeff Han presented prototypes which use the bidirectional properties of LEDs to create a touch sensor and also demonstrated the use of frustrated total internal reflection [3]. Similar sensors to our approach are used for various other applications, from touch-less interactions in public restrooms to optical pickups in musical instruments [9].

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SideSight, a project by Microsoft research, used this principle for creating a touch interface around a device [2].

IR SENSING

IR Touch sensors consist of two elements: an IR emitter and an IR phototransistor (Figure 2). If an object comes within the proximity of the emitter, light is reflected back, allowing a measurable voltage to propagate through the phototransistor. Such a system can also measure finger-pressure, as the flesh of the finger changes its IR reflectivity with pressure. Different materials reflect IR in different intensities. If the distance between the sensor and the material is known, this can be used for object identification.

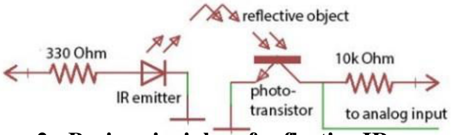

Figure 2 - Basic principles of reflective IR sensors.

We use flexible circuits to enable the sensors to conform to various shapes, while making them as thin and lightweight as possible (Instructions for creating DIY flex-circuits can be found on Instructables [10]). We treat the incoming sensor readings as images and use blob-tracking algorithms for collecting touch and gesture information. The accuracy of the sensors in x & y dimensions depends on the density of its IR-emitter and photo-transistor arrays. The accuracy on the z axis (distance from sensor) depends on distance between emitter and photo-transistor, their viewing angles and strength of IR illumination.

Case Study #1 – Volumetric Sensor Array

We augmented a tablet computer with a sensor consisting of an array of 6 by 8 of these components on a flexible PCB (Figure 1, left). The QRE1113 IR sensor by Fairchild was used, as it contains both emitter and receiver in a package.

This sensor provided the tablet with information of what lay behind it, allowing us to collect touch and grasp information. The sensor could also identify if the tablet was placed on a table and, if placed on a table which was augmented with IR patterns, it could also identify where on the table it was placed. This sensor can also be placed behind an LCD display providing it with multi-touch and gesturing abilities, as demonstrated by Hodges et al. [4].

Case Study #2 – Projected 2D Touch Sensor

We created a one dimensional array of alternating IR emitters and photo-transistors (Figure 1, right & Figure 3). For our emitter we chose the SFH 4045N by Osram. The specific emitter was chosen because of its wavelength (950nm), its relatively small viewing angle (18°) and because it can be mounted at right angles. For the receiving element we chose the PT12-21C/TR8 by Everlight, as it closely matched our emitter's wavelength (940nm), has a wide viewing angle (120°) and can also be mounted at right angles. We found that this setup maximized the resolution of the sensor: the small viewing angle of the emitter reduced the ambient saturation of IR light, while the wide angle of the receiver enabled us to use software interpolation between multiple receivers to enhance precision. We further reduced the incoming ambient IR by encapsulating emitters and phototransistors in non-translucent silicone (Figure 3).

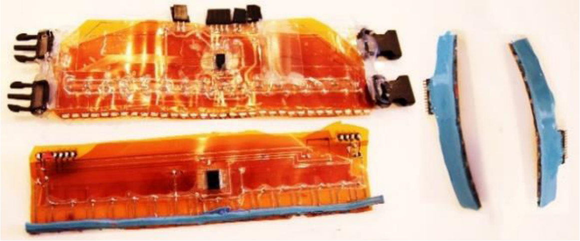

Figure 3 – Prototypes (left) and final version (right) of projected 2D touch sensor for interactions on the wrist.

As this sensor can be projected on the interaction surface, rather than acting as an overlay, we are able to use it to explore bare skin as interaction surface. Because the interaction area is projected, we can also use this sensor for touch sensing on flexible E Paper devices, such as DisplaySkin [1]. This has been a challenge with resistive or capacitive sensors.

Limitations

In laboratory settings and for experiments and evaluations these sensors perform reliably, as ambient IR can usually be controlled. In outdoor situations, IR from sunlight can saturate the phototransistors, potentially reducing the usability of the sensor. A solution to this is taking two consecutive readings: one with active IR illumination and one without. Using the differences between these readings for image processing can enhance the usability of IR sensing in situations with high ambient IR.

REFERENCES

1. Burstyn, J., Strohmeier, P., and Vertegaal, R. DisplaySkin: Exploring Pose-Aware Displays on a Flexible Electrophoretic Wristband. Proc TEI '15
2. Butler, A., Izadi, S., and Hodges, S. SideSight: multi-touch interaction around small devices. Proc. UIST '08
3. Han, J.Y. Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. *UIST'05*
4. Hodges, S., Izadi, S., Butler, A., Rrustemi, A., and Buxton, B. ThinSight : Versatile Multi-touch Sensing for Thin Form-factor Displays. *UIST'07*
5. Holman, D., Fellion, N., and Vertegaal, R. Sensing Touch Using Resistive Graphs. *DIS '14*, 195–198.
6. Holman, D., and Vertegaal, R. TactileTape : Low-Cost Touch Sensing on Curved Surfaces. *UIST'11*
7. Holman, D. and Vertegaal, R. Organic User Interfaces. Communications of the ACM 51, 6 (2008), 48.
8. Olberding, S., Gong, N.-W., Tiab, J., Paradiso, J. A., and Steimle, J. A Cuttable Multi-touch Sensor. *UIST '13*
9. Sokolovskis, J. and Mcpherson, A.P. Optical Measurement of Acoustic Drum Strike Locations. *NIME'15*, 70–73.
10. Strohmeier, P. Yet Another DIY Flex Circuits Tutorial. http://www.instructables.com/id/Yet-Another-DIY-Flex-Circuits-Tutorial/