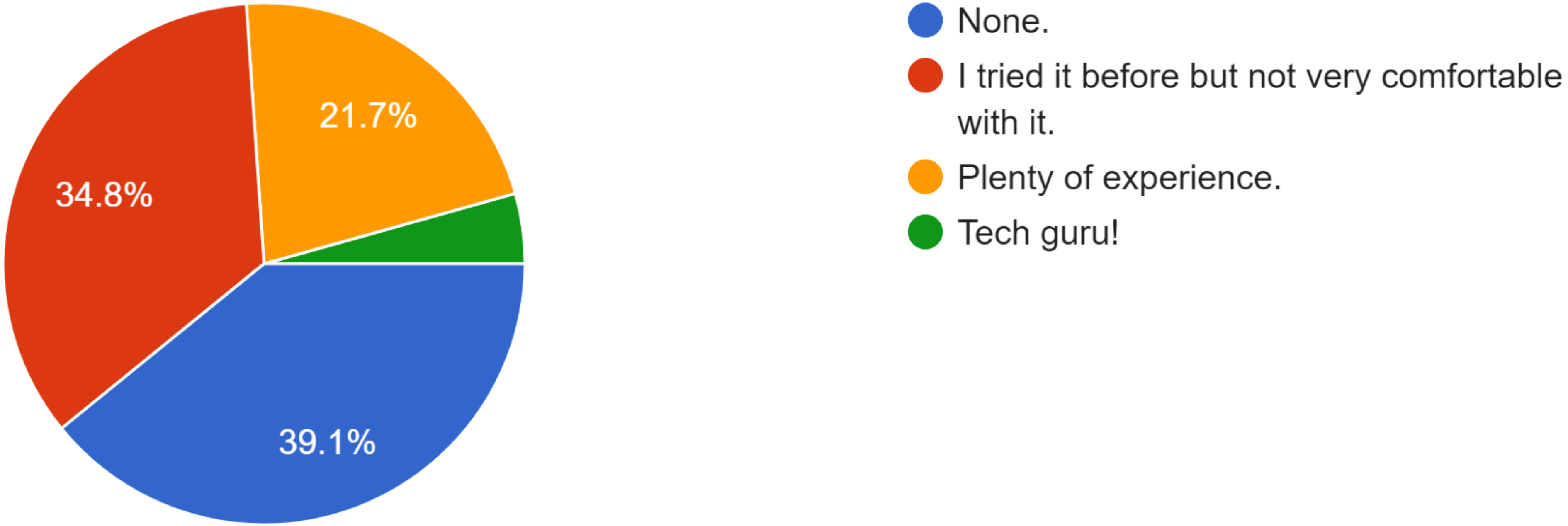
Survey overview

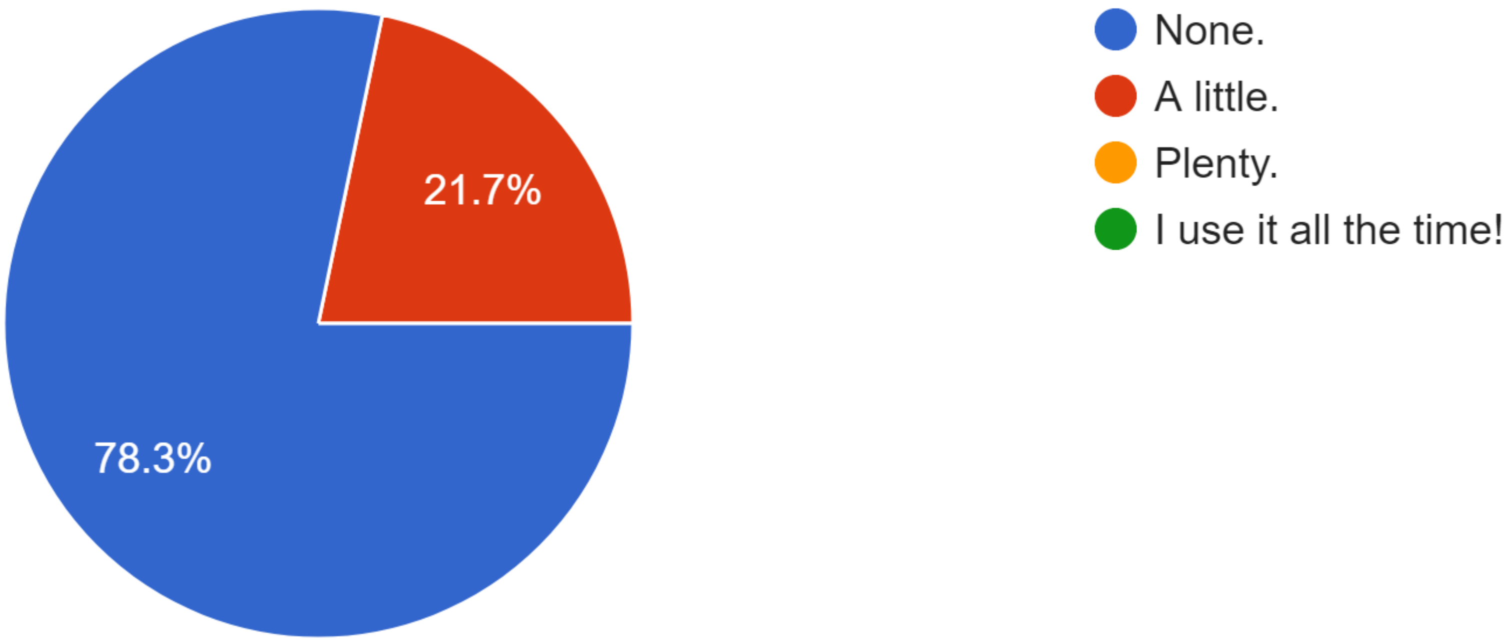
Microcontroller skills (say Arduino/Raspberry Pi)

23 responses



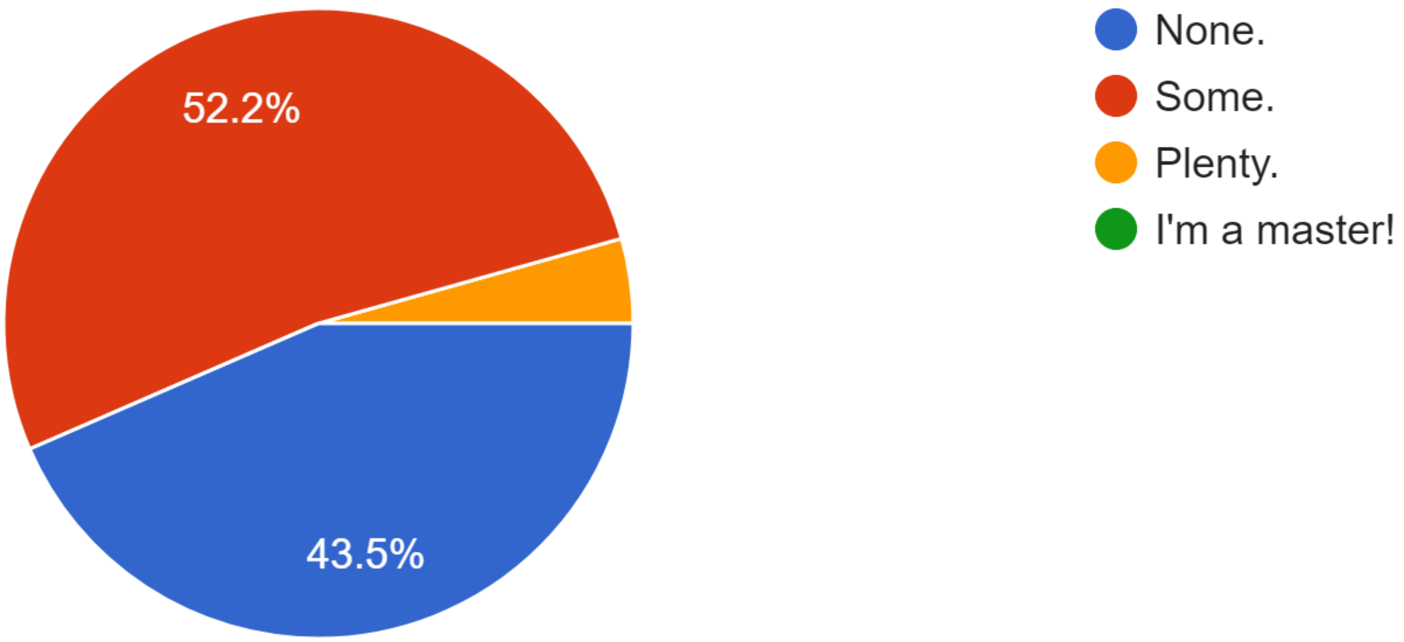
Laser cutter experience?

23 responses



3D modeling experience?

23 responses



What do you want to learn from this course?

I want to learn to build projects and have most time spent on building

I want to learn a possible research question between visualization and physical computing. (e.g.: accessibility, creativity, etc) If possible, I hope to submit a workshop paper or any other small written outcome to a venue after the class.

How to run user study

Course requirement

Learn basics of HCI and understand if anyway I can incorporate with my area of research

I want to learn a possible research question between visualization and physical computing. (e.g.: accessibility, creativity, etc) If possible, I hope to submit a workshop paper or any other small written outcome to a venue after the class.

I want to learn a possible research question between visualization and physical computing. (e.g.: accessibility, creativity, etc) If possible, I hope to submit a workshop paper or any other small written outcome to a venue after the class.

How tech around me works and how I can apply them to software engineering consepts.
And broaden my understanding in general.

I want to do something cool

I wish to learn fabrication techniques such as 3d modelling/printing, laser cutting as well as ongoing interactive tech used in HCI domain

I would like to have more hardware and robotics skills. I also have limited exposure to HCI but find it very interesting and generally want to be more exposed to the content area.

Concerns that you would like to share with me?

I am a little concerned that this class may take up a little to much time relative to my research.

I am a little concerned that this class may take up a little to much time relative to my research.

I'm concerned that I don't have much of engineering background.

I do not have any experience with coding with hardware, so I am a bit worried about the projects and the mini robot climbing competition.

Time limit to complete a project

It looks like the workload of the course is heavy.

Sources for ordering project related components.

Sparkfun.com (a great starting point to buy various electronic components)
Adafruit.com (another great website as a "one-stop" shopping site)
Pololu.com (especially good for all kinds of motors)
Hobbyking.com (another website for shopping motors, especially drone-related motors such as servo/brushless motors)
Robotshop.com (Motors + robot-related hardware)
Mcmaster.com (screws, pipe, foam sheet, acrylics, etc)
Amazon.com (this one you know for sure)
Ebay.com (you may find some very interesting items that are not easy to find in the US ->; warning can be delayed!)

Multi-touch Technology

Huaishu Peng | UMD CS | Fall 2023


How would you BUILD a
multi-touch devices?
JEFFHAN


How will you track the finger?
With what hardware?
JEFFHAN

1 min brainstorming

Draw some **sketches?**

There are lots of different

Type of technologies

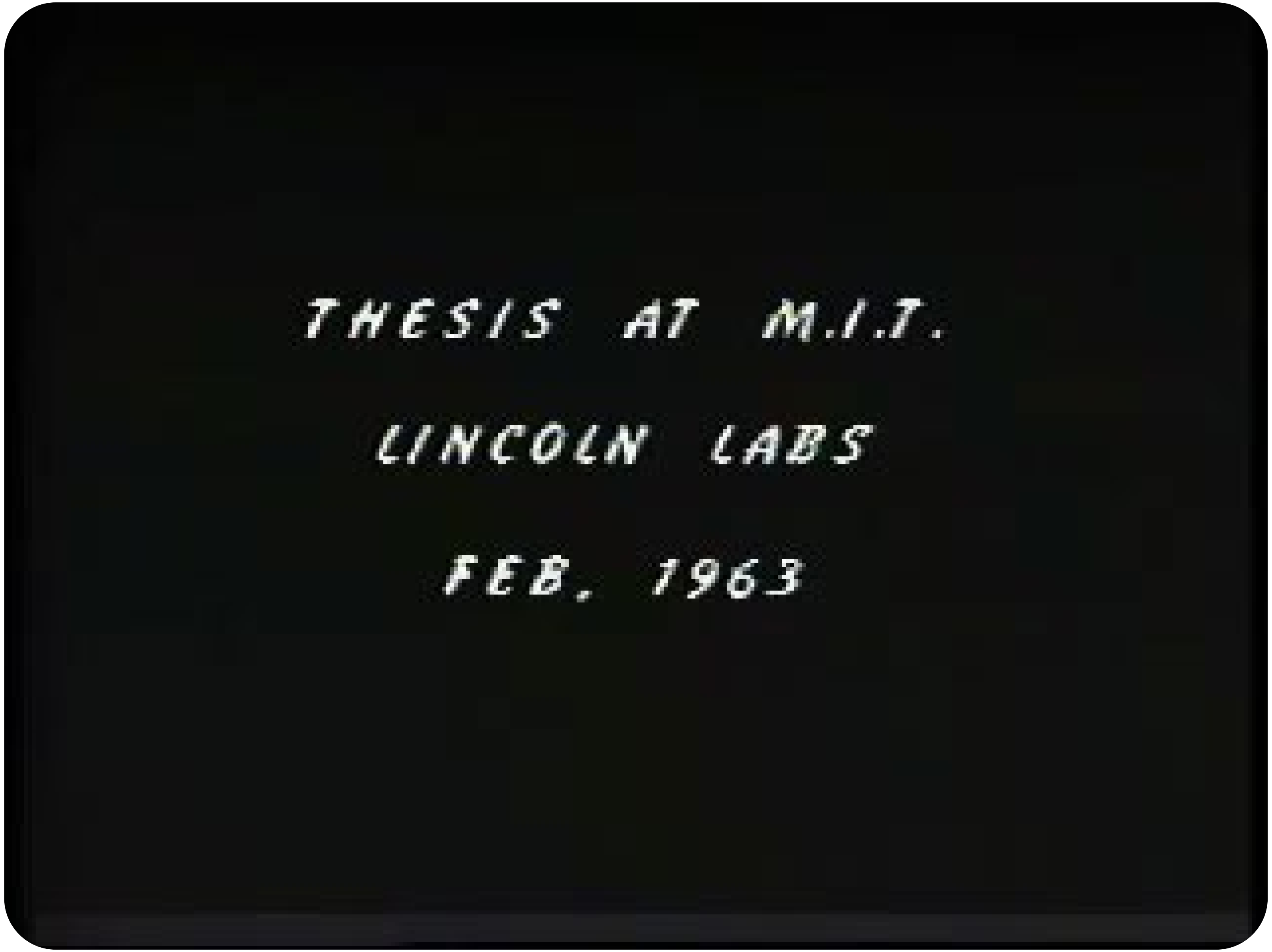
Camera-based
Resistive
Capacitive …

Let’s review the **history** again…

Steve Jobs, 2007:
“And we have invented
a new technology
called multi-touch,
which is phenomenal.
[0:33:33]

1986: Sensor Frame (McAvinney)

but there is **tech close to multi-touch**
that actually was invented even earlier…



Ivan Sutherland Demos Sketchpad, **1963** we have come a long way since then…

30 years later, multi-touch has reached the consumer market…

and then there’s still stuff
that **hasn’t reached the consumer market yet**

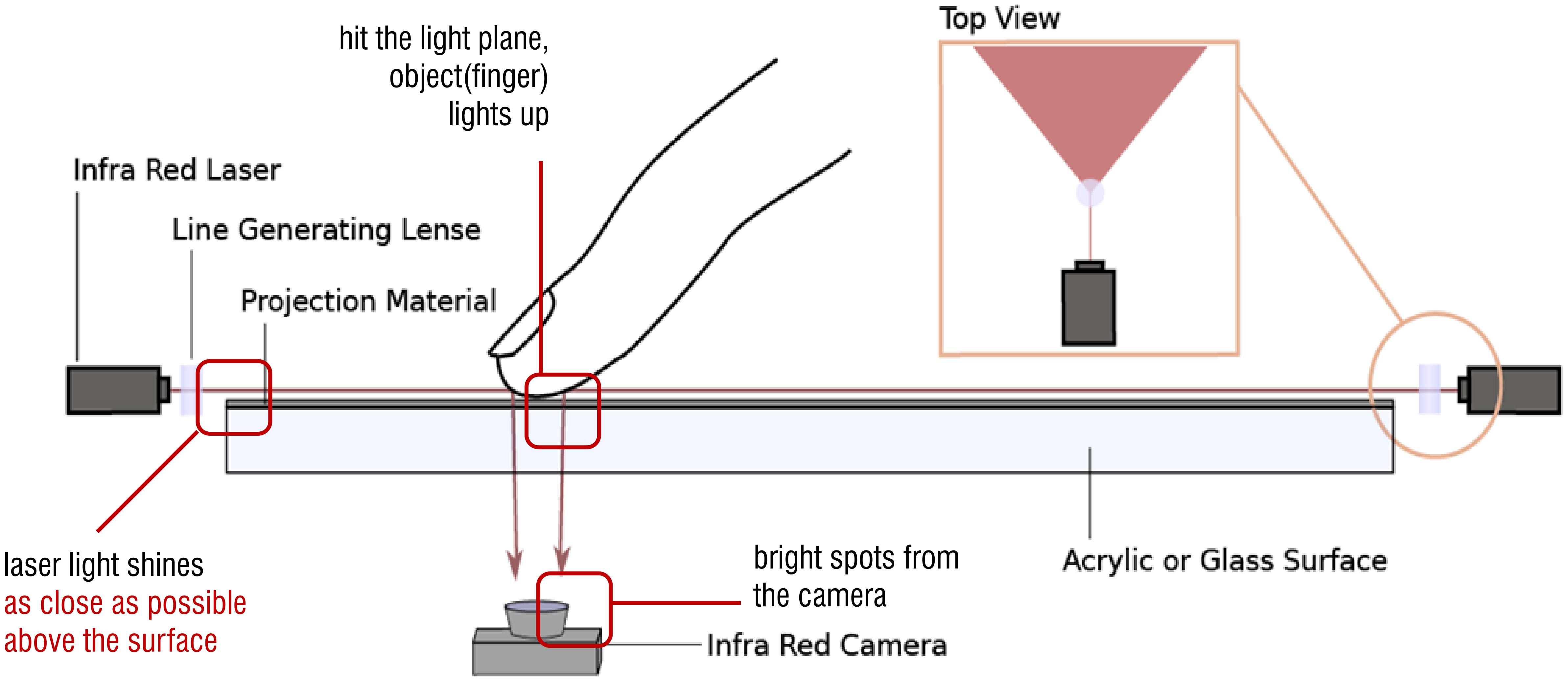
1991: Pierre Wellner, Digital Desk

multi-touch:
engineering principles

camera based multi-touch technology

#1 - Laser Light Plane (LLP)

LLP - Laser Light Plane



How does this recognize touch?

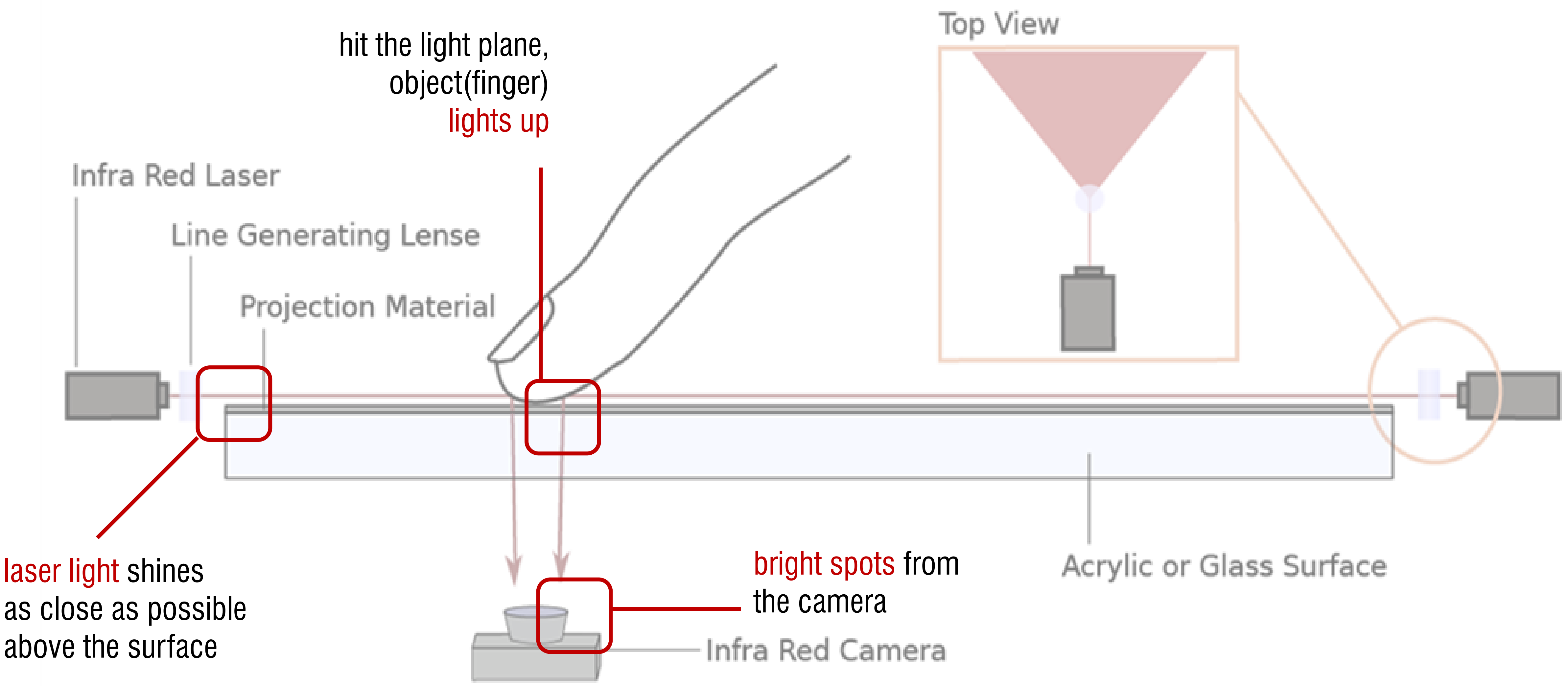
30s brainstorming

http://sethsandler.com/multitouch/llp/

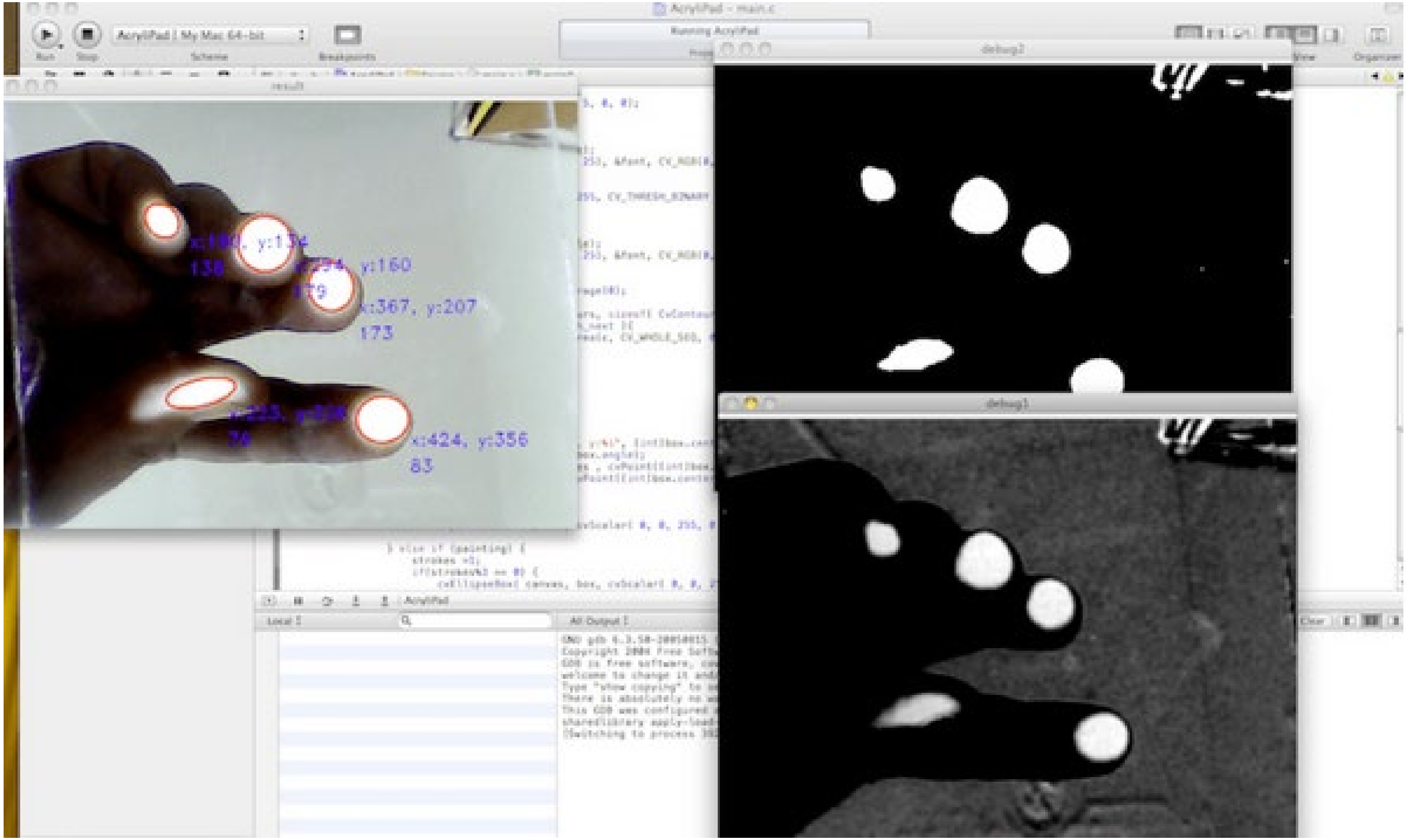
http://www.youtube.com/watch?v=-GcmDOH8ebw

https://www.youtube.com/watch?v=mliHstoD4iU

LLP - Laser Light Plane



http://sethsandler.com/multitouch/llp/



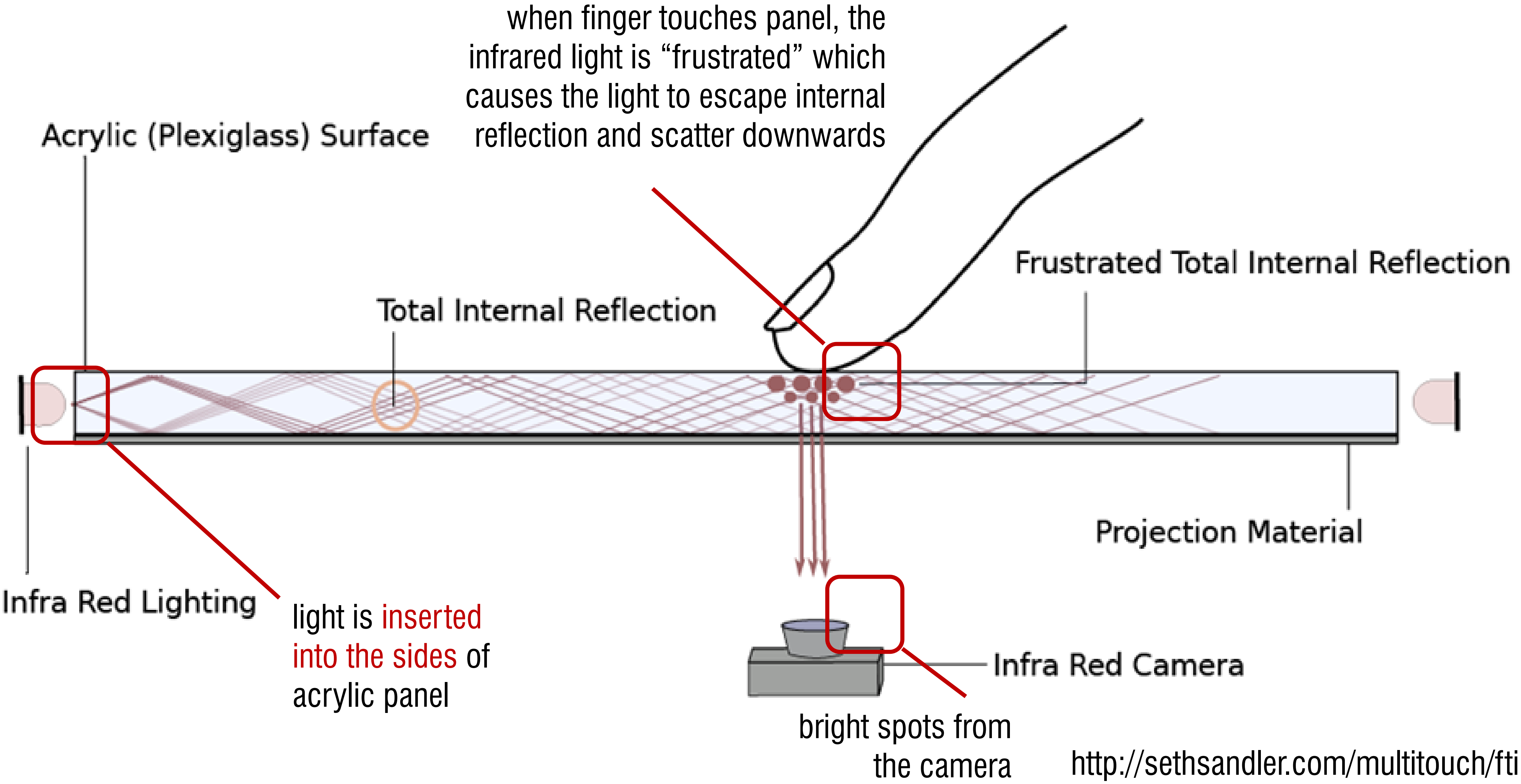
easy to do computer vision tracking based on this

camera based multi-touch technology

#2 - frustrated total internal reflection

total internal reflection

FTIR - Frustrated Total Internal Reflection



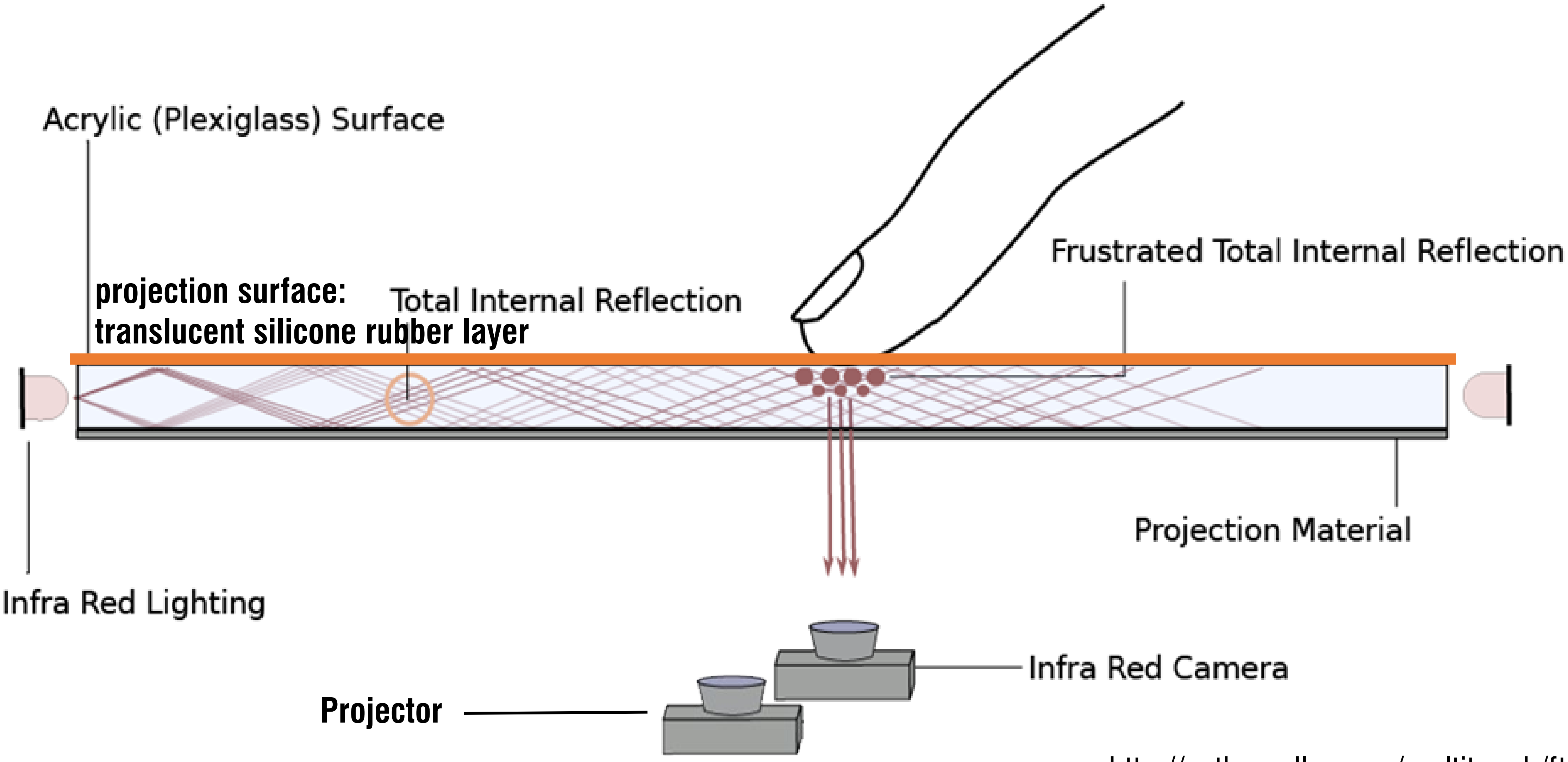
http://sethsandler.com/multitouch/ftir/

camera based multi-touch technology

#2 - frustrated total internal reflection
- combine with projector

since acrylic is transparent, you cannot directly project on it
add a projection surface allows to display an image

FTIR - Frustrated Total Internal Reflection



http://sethsandler.com/multitouch/ftir/


JEFFHAN

Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection

Jefferson Y. Han
Media Research Laboratory
New York University
719 Broadway. New York, NY 10003
E-mail: jhan@mrl.nyu.edu

Figure 1: Simple examples of multi-touch interaction using our FTIR technique

ABSTRACT
This paper describes a simple, inexpensive, and scalable technique for enabling high-resolution multi-touch sensing on rear-projected interactive surfaces based on *frustrated total internal reflection.* We review previous applications of this phenomenon to sensing, provide implementation details, discuss results from our initial prototype, and outline future directions.

ACM Classification: H.5.2 [**User Interfaces**]: Input Devices and Strategies

General Terms: Human Factors

Keywords: multi-touch, touch, tactile, frustrated total internal reflection

We present a simple technique for robust multi-touch sensing at a minimum of engineering effort and expense. It is based on *frustrated total internal reflection (FTIR)*, a phenomenon familiar to both the biometric and robot sensing communities. It acquires true touch image information at high spatial and temporal resolutions, is scalable to large installations, and is well suited for use with rear-projection. It is not the aim of this paper to explore the multi-touch interaction techniques that this system enables, but rather to make the technology readily available to those who wish to do so.

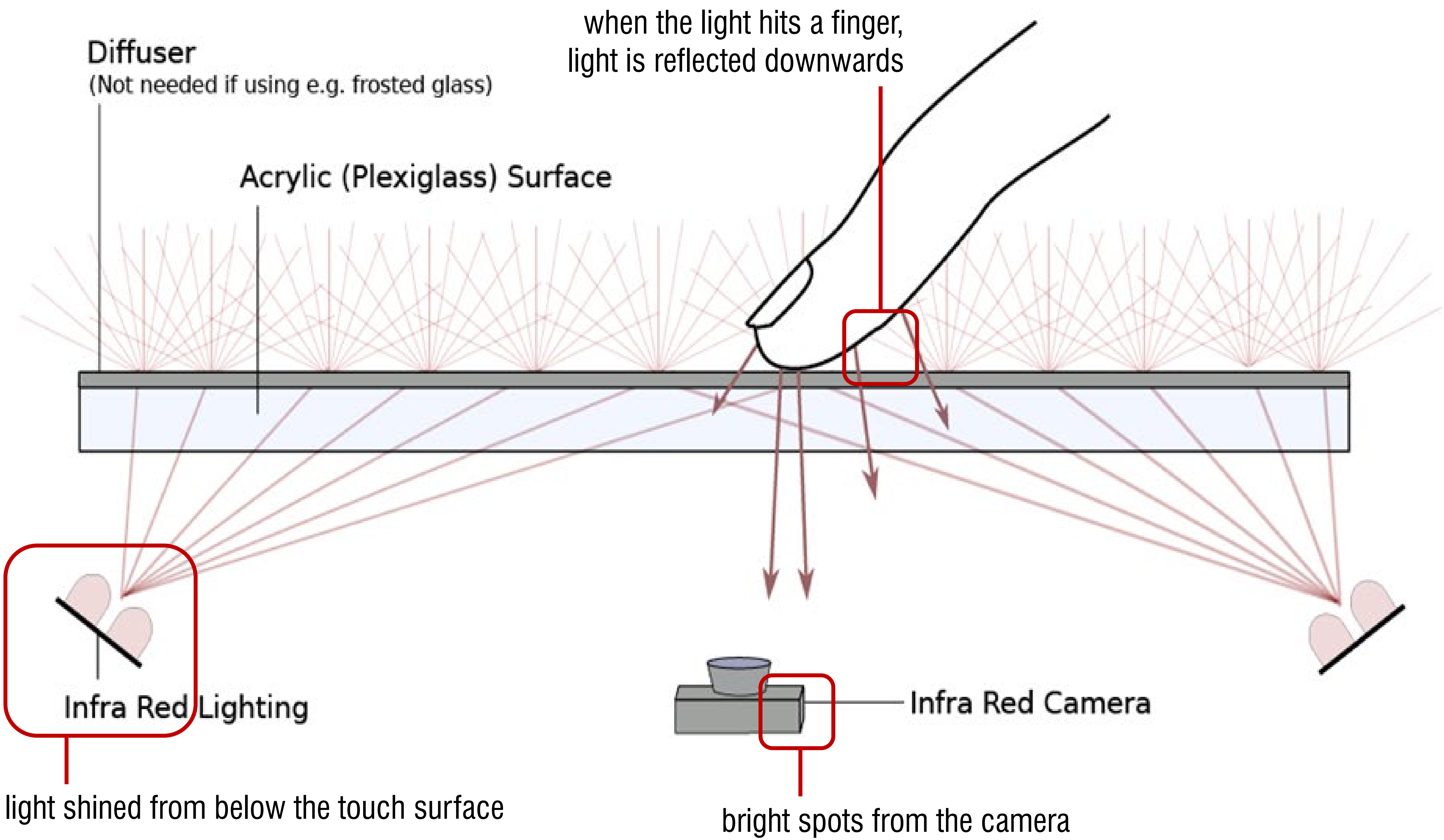
RELATED WORK
A straightforward approach to multi-touch sensing is to simply utilize a plurality of discrete sensors, making an individual connection to each sensor as in the *Tactex MTC Express* [20]. They can also be arranged in a matrix configuration with

UIST 2005 paper (lasting impact award)

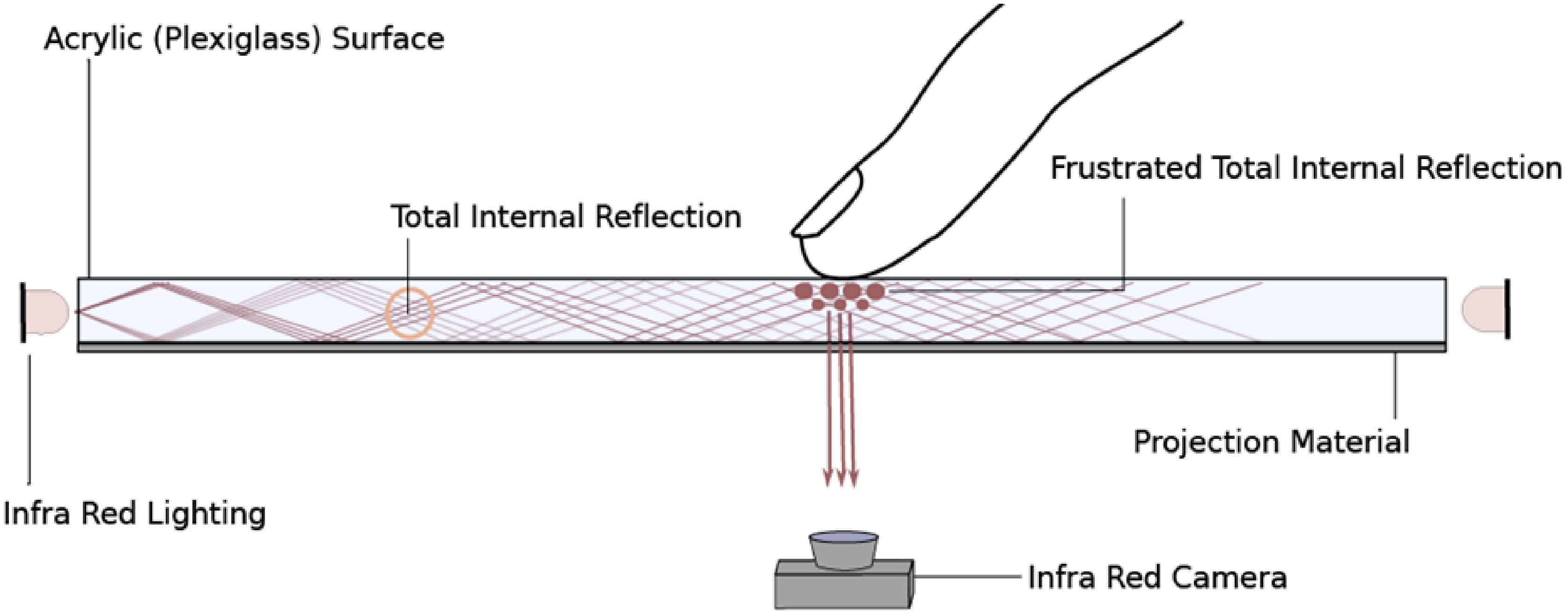
camera based multi-touch technology

#3 - rear diffused illumination (rear DI)

RDI - Rear Diffused Illumination

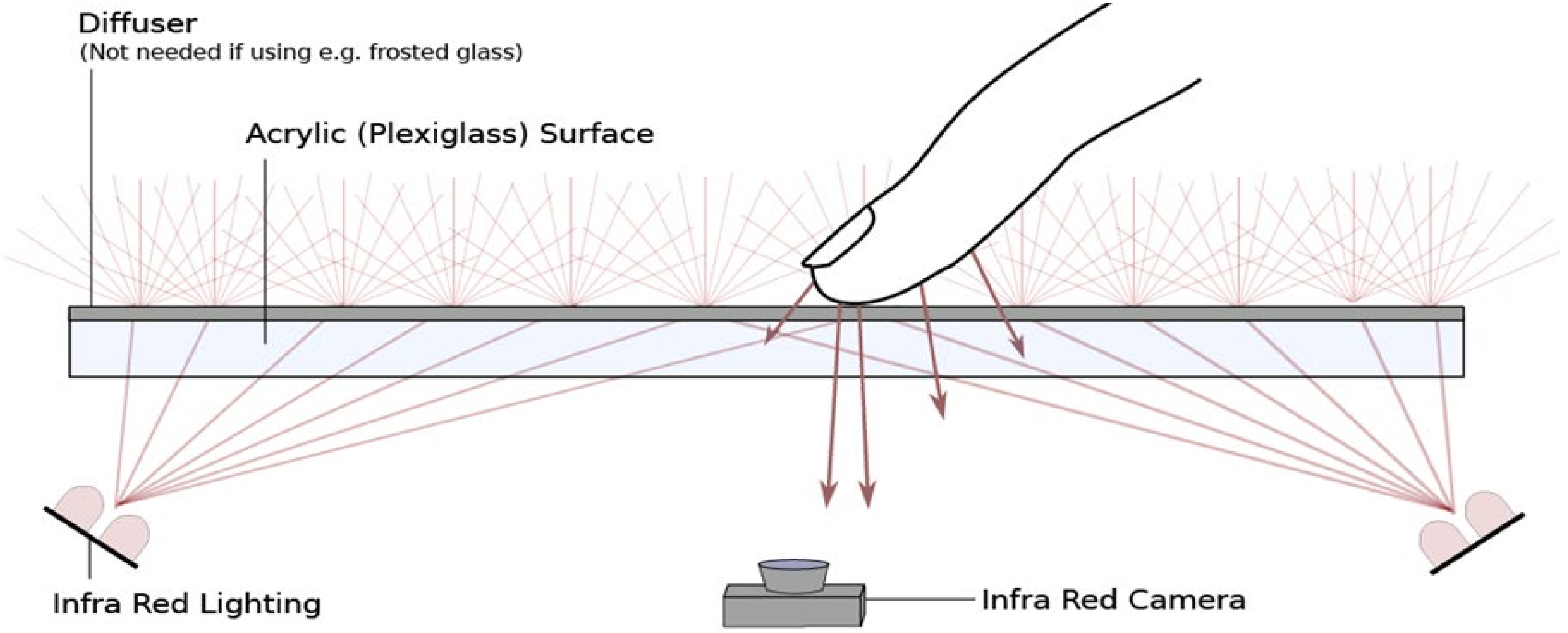


#2 - frustrated total internal reflection

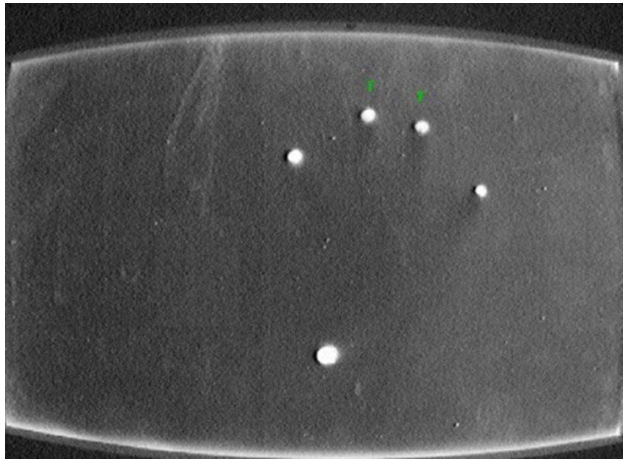


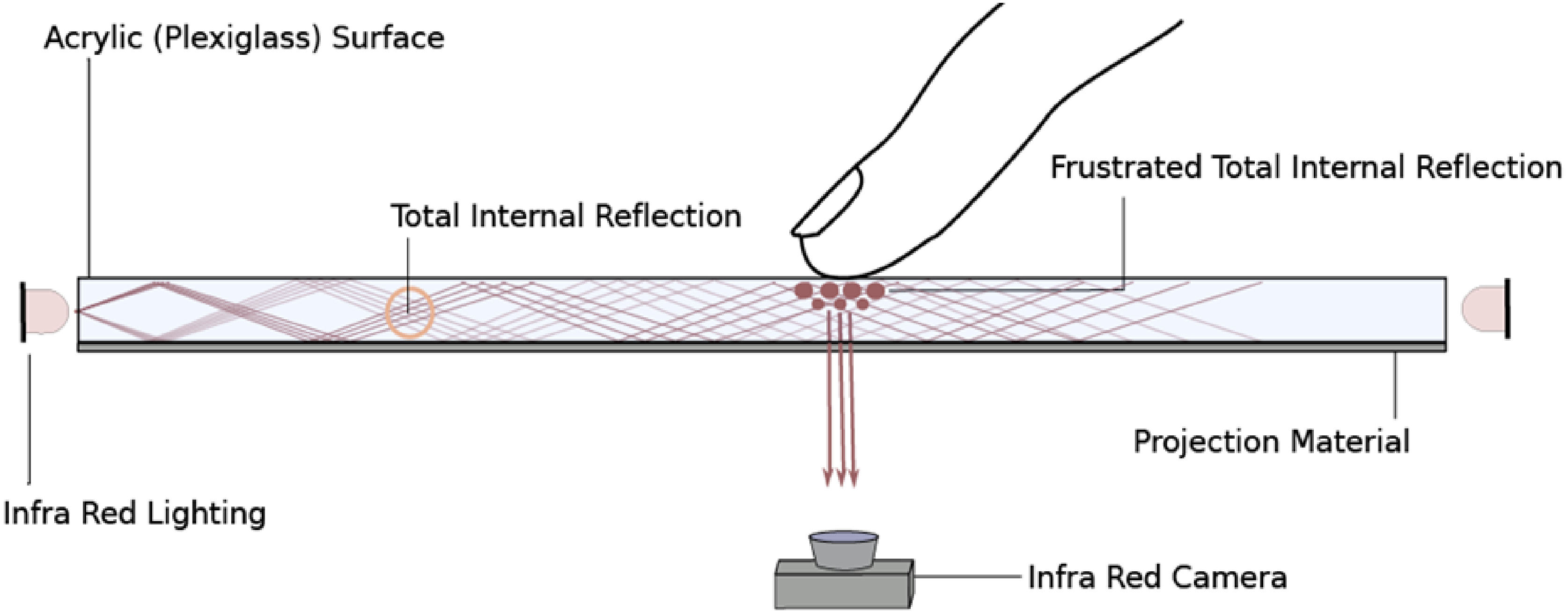
Any difference then?

#3 - rear diffused illumination (rear DI)



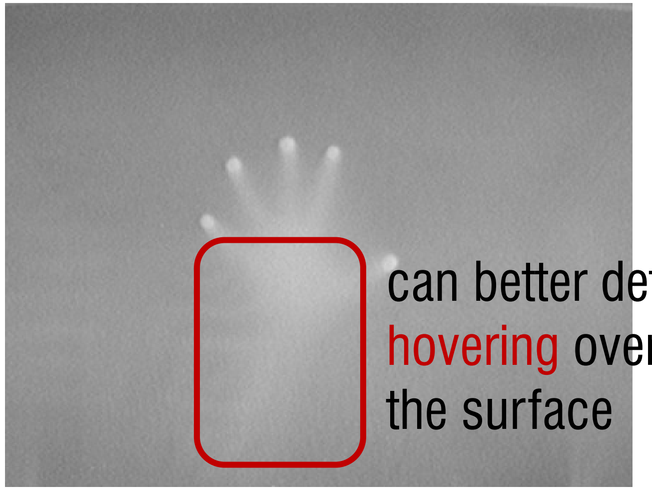
#2 - frustrated total internal reflection



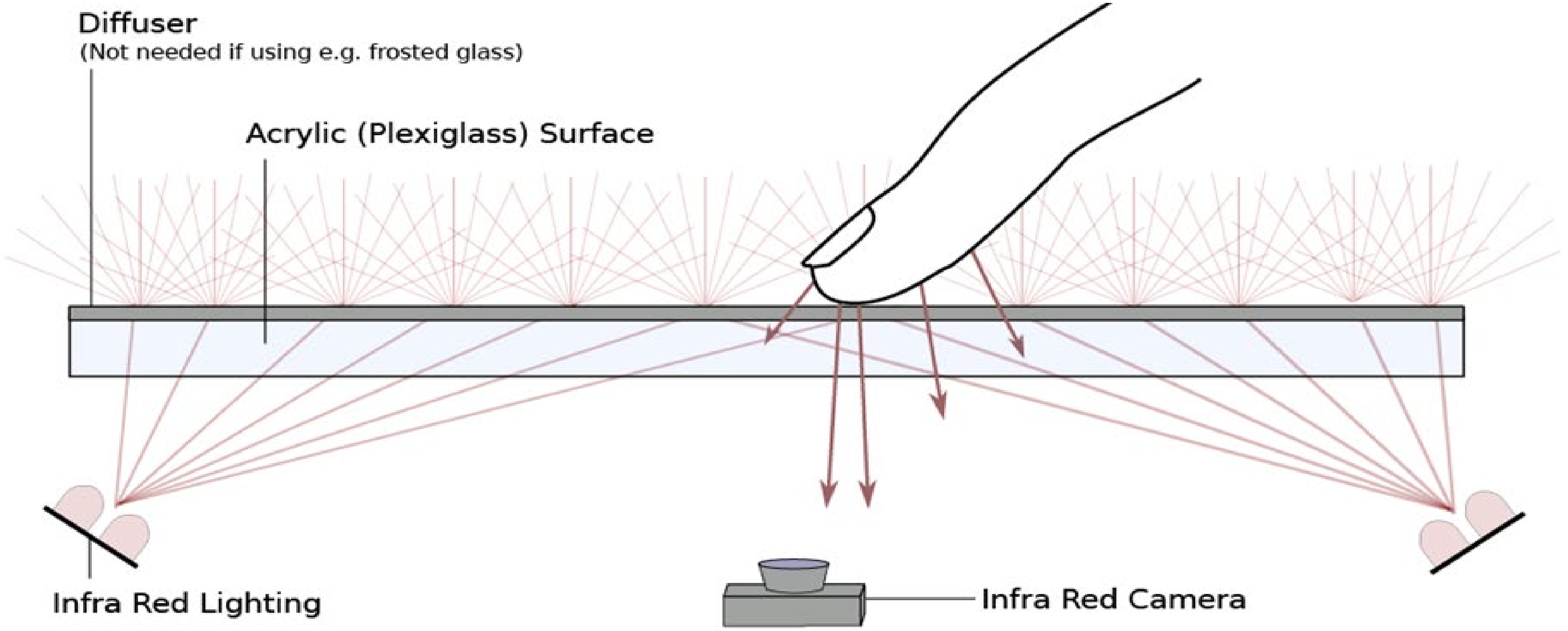


Any difference then?

#3 - rear diffused illumination (rear DI)



can better detect hovering over the surface



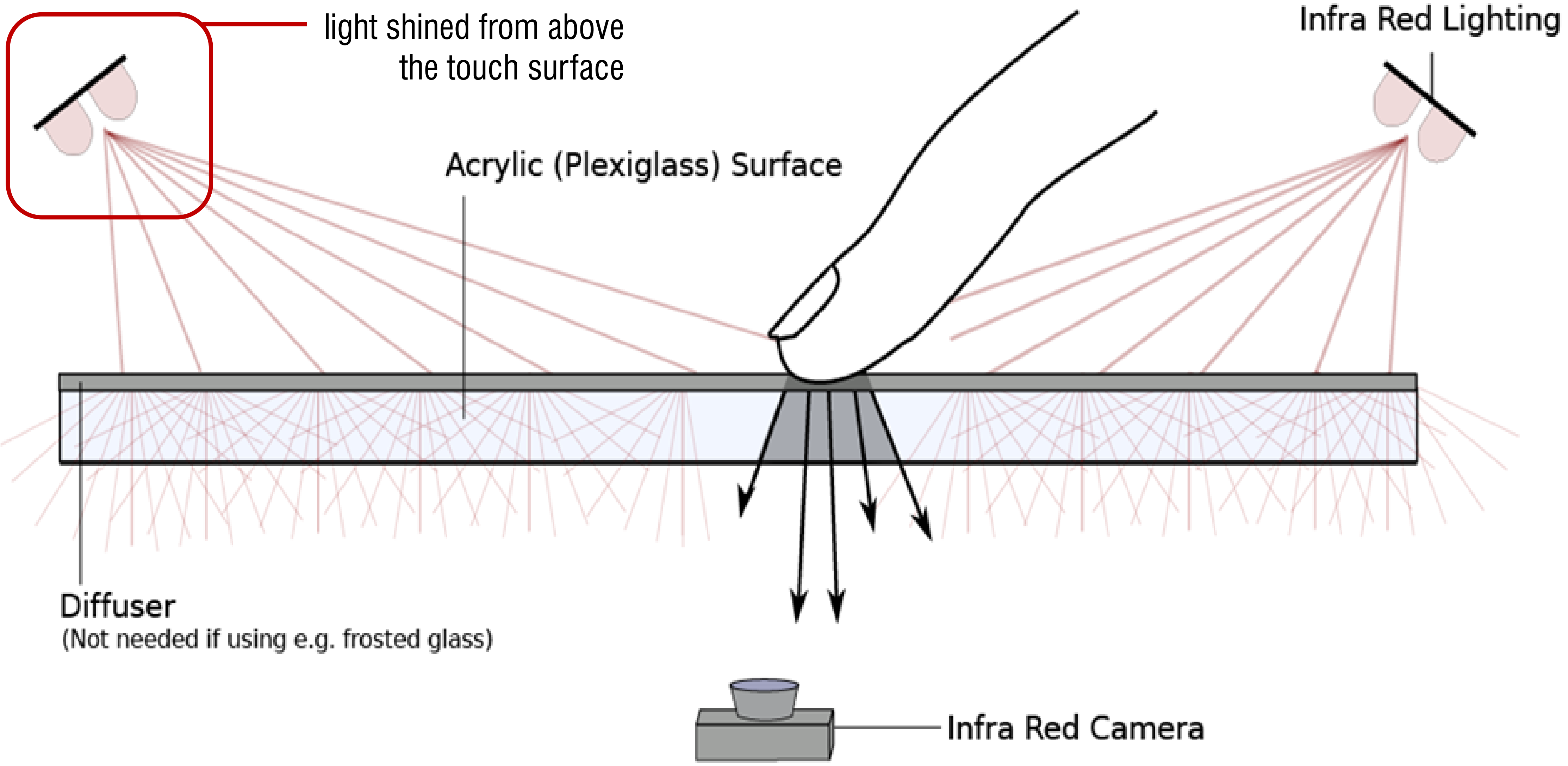
camera based multi-touch technology

#3 - rear diffused illumination (rear DI)

camera based multi-touch technology

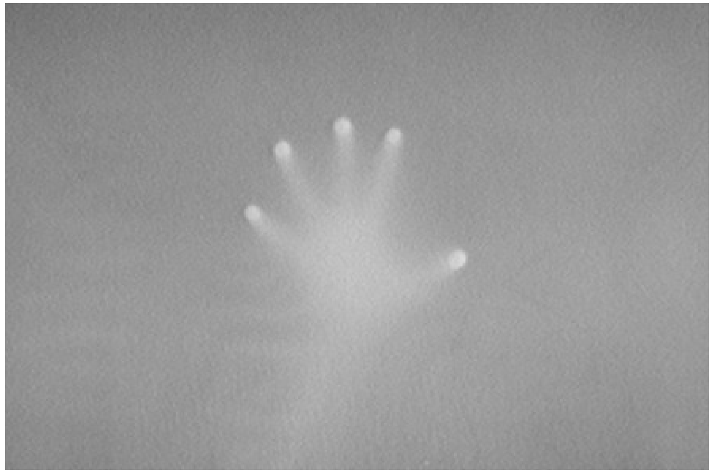
#4 - front diffused illumination (front DI)

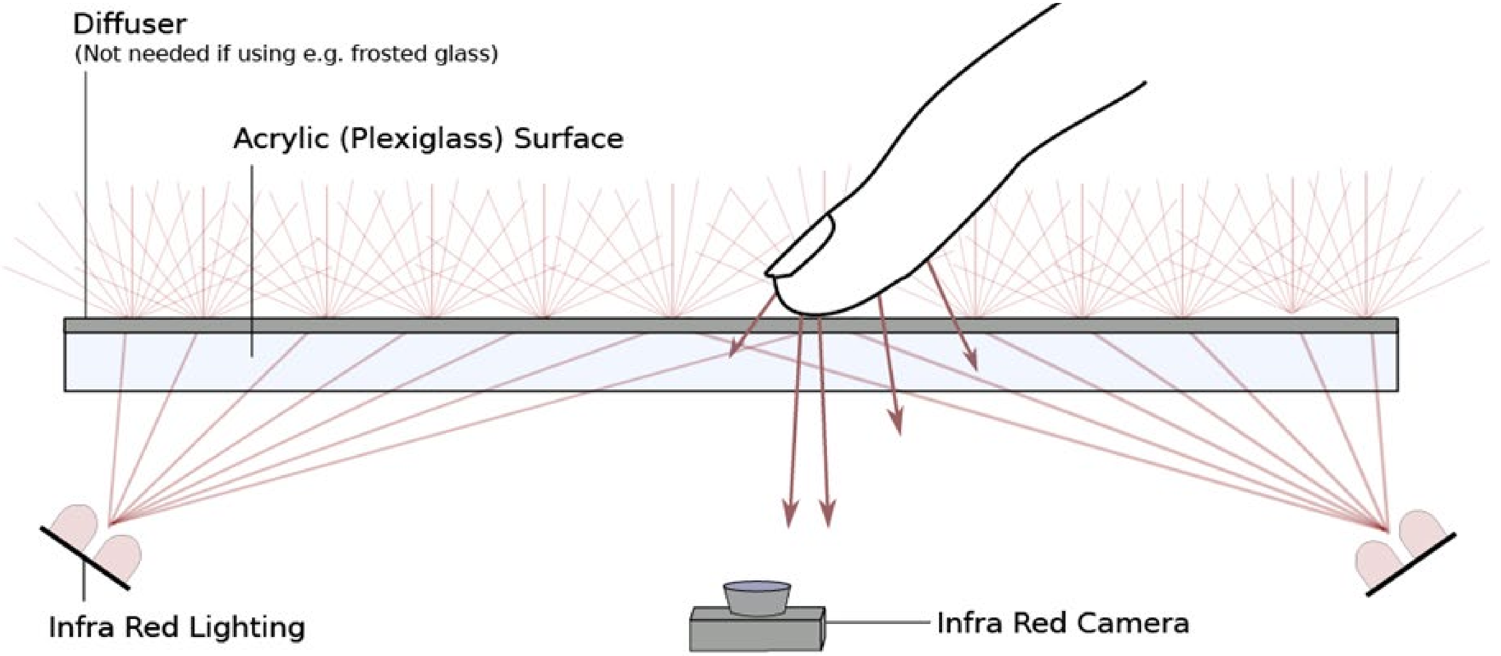
FDI - Front Diffused Illumination



http://sethsandler.com/multitouch/frontdi/

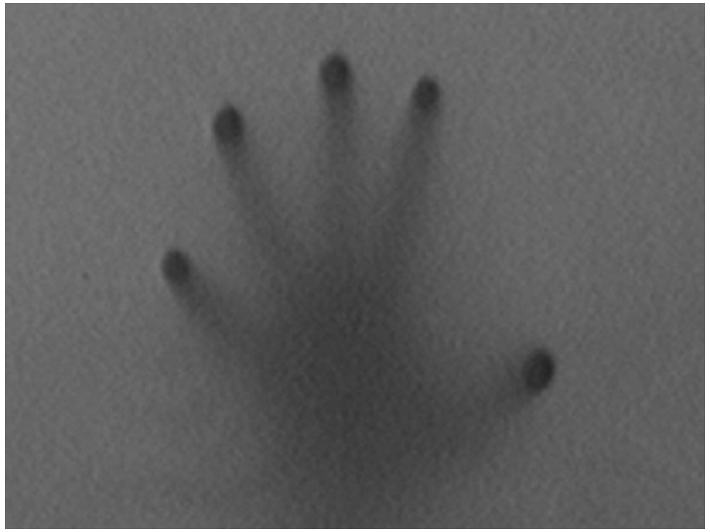
#3 - rear diffused illumination (rear DI)

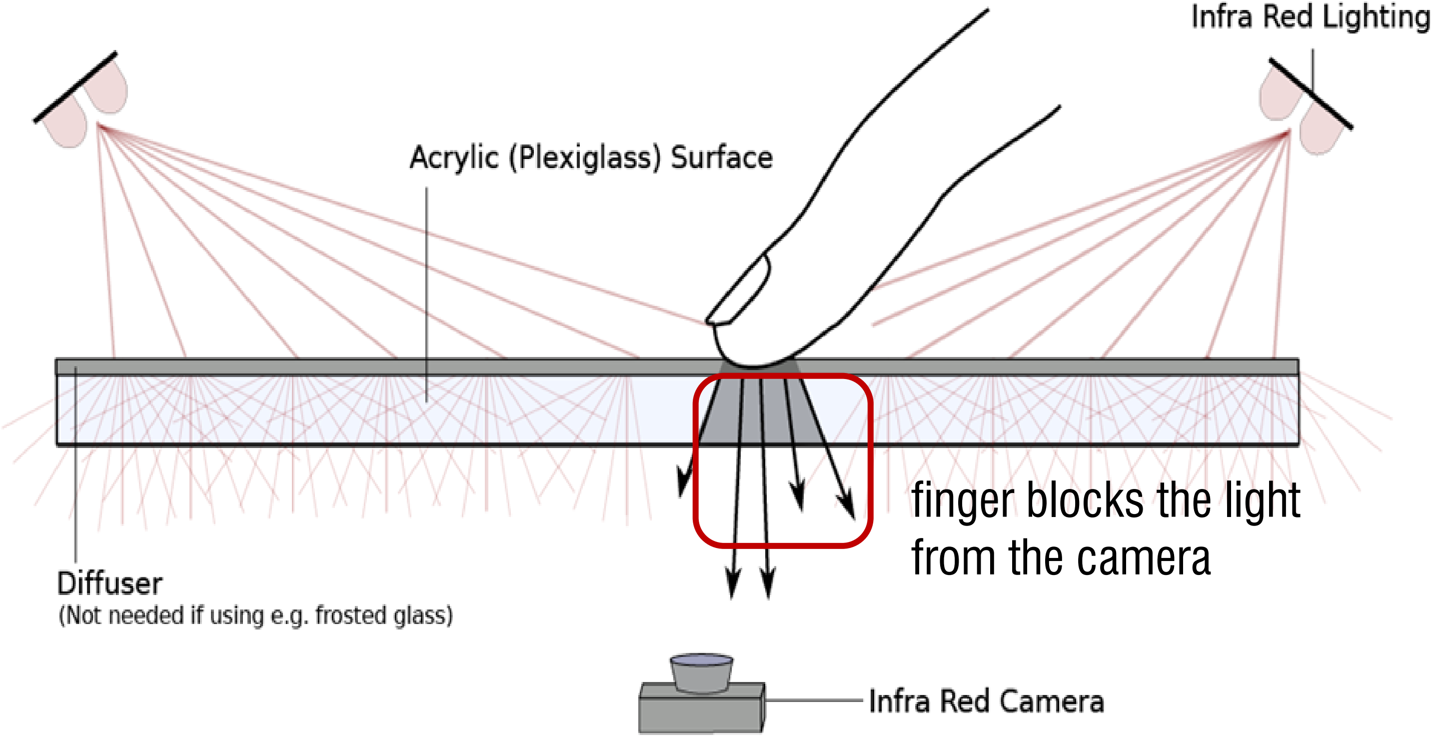




Comparison?

#4 - front diffused illumination (front DI)





http://www.youtube.com/watch?v=vLAzlNB0QQY

How to build one by yourself

MTBiggie by Seth Sandler, 2011

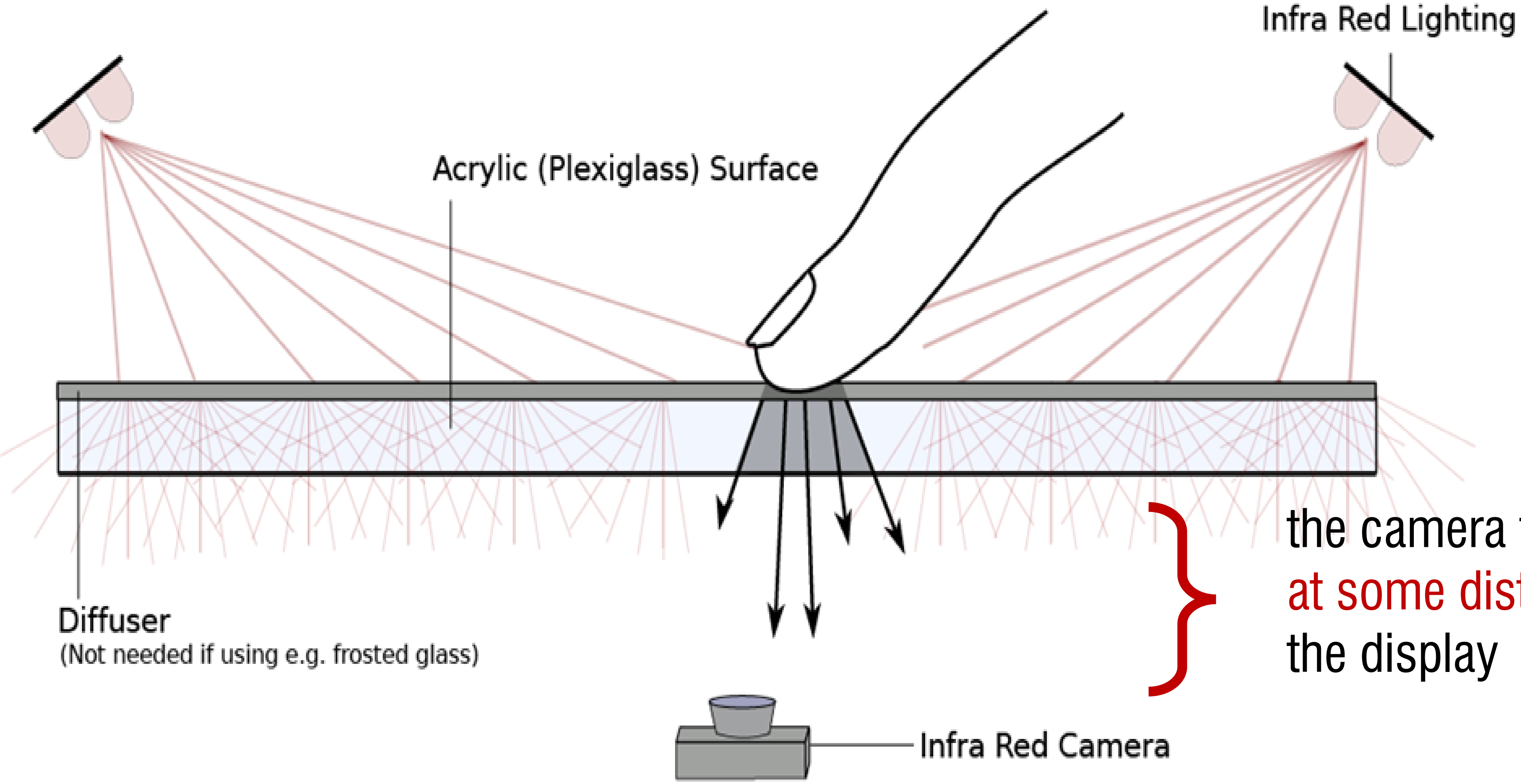
camera based multi-touch technology

#1 - laser Light Plane (LLP)
#2 - frustrated total internal reflection (FTIR)
#3 - rear diffused illumination (rear DI)
#4 - front diffused illumination (front DI)

A light source
A way to break the light
A cam to capture the spot/shadow

What are the limitations of camera based multi-touch technique?

What are the limitations of camera based multi-touch technique?

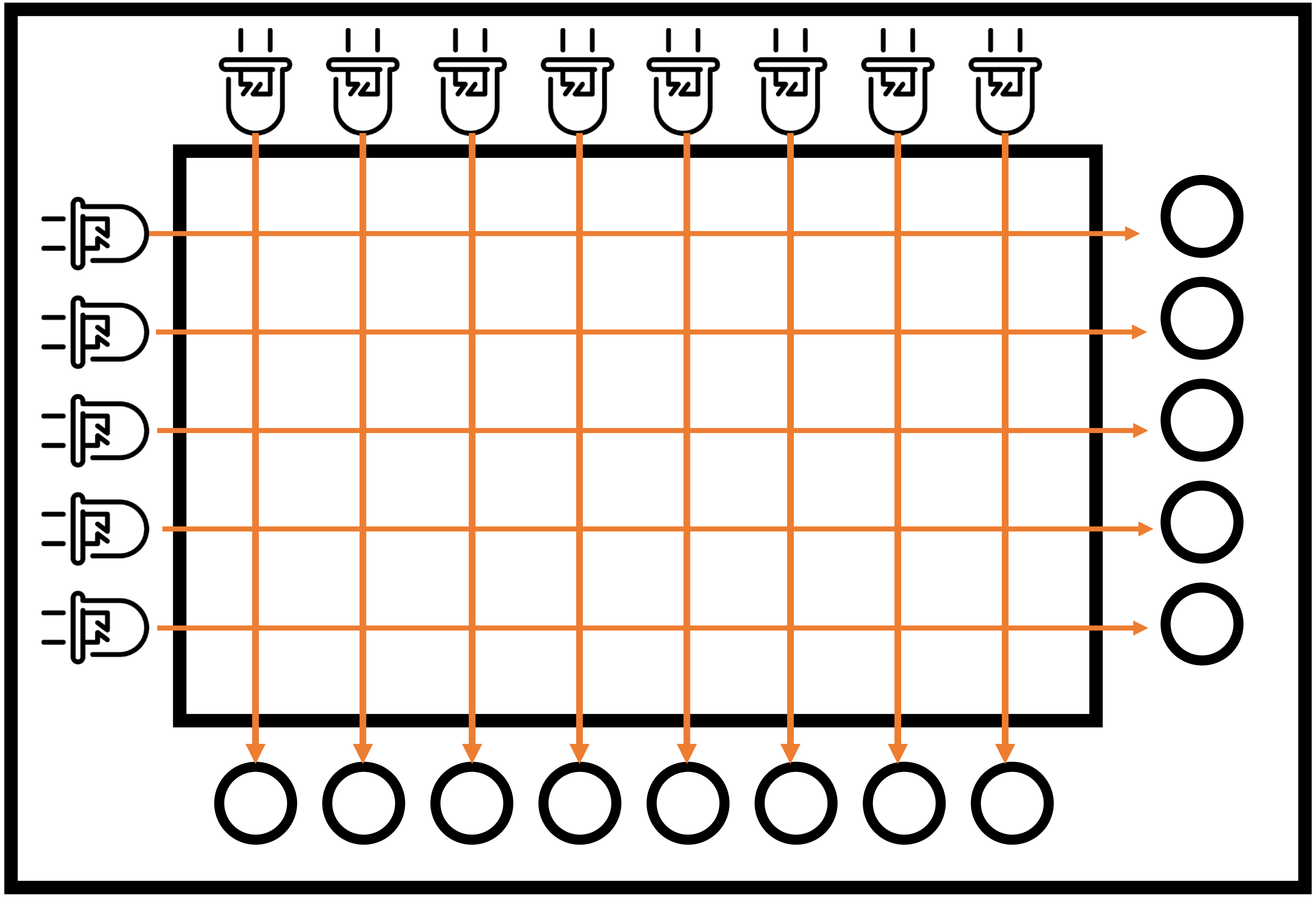


the camera to be placed at some distance from the display

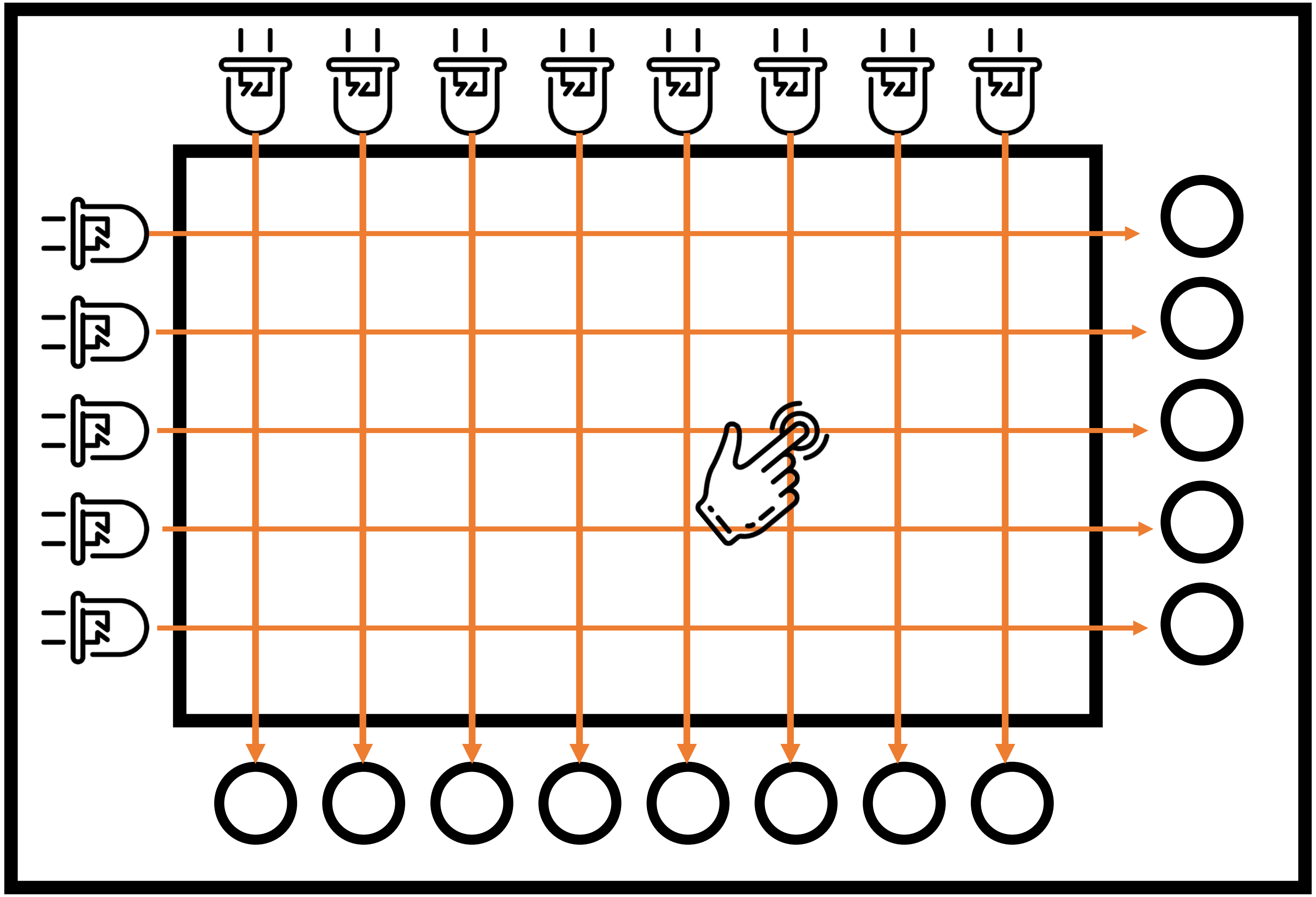
Put the sensor not to the bottom of the display
but to the side of it

infrared touch panels (ITP)

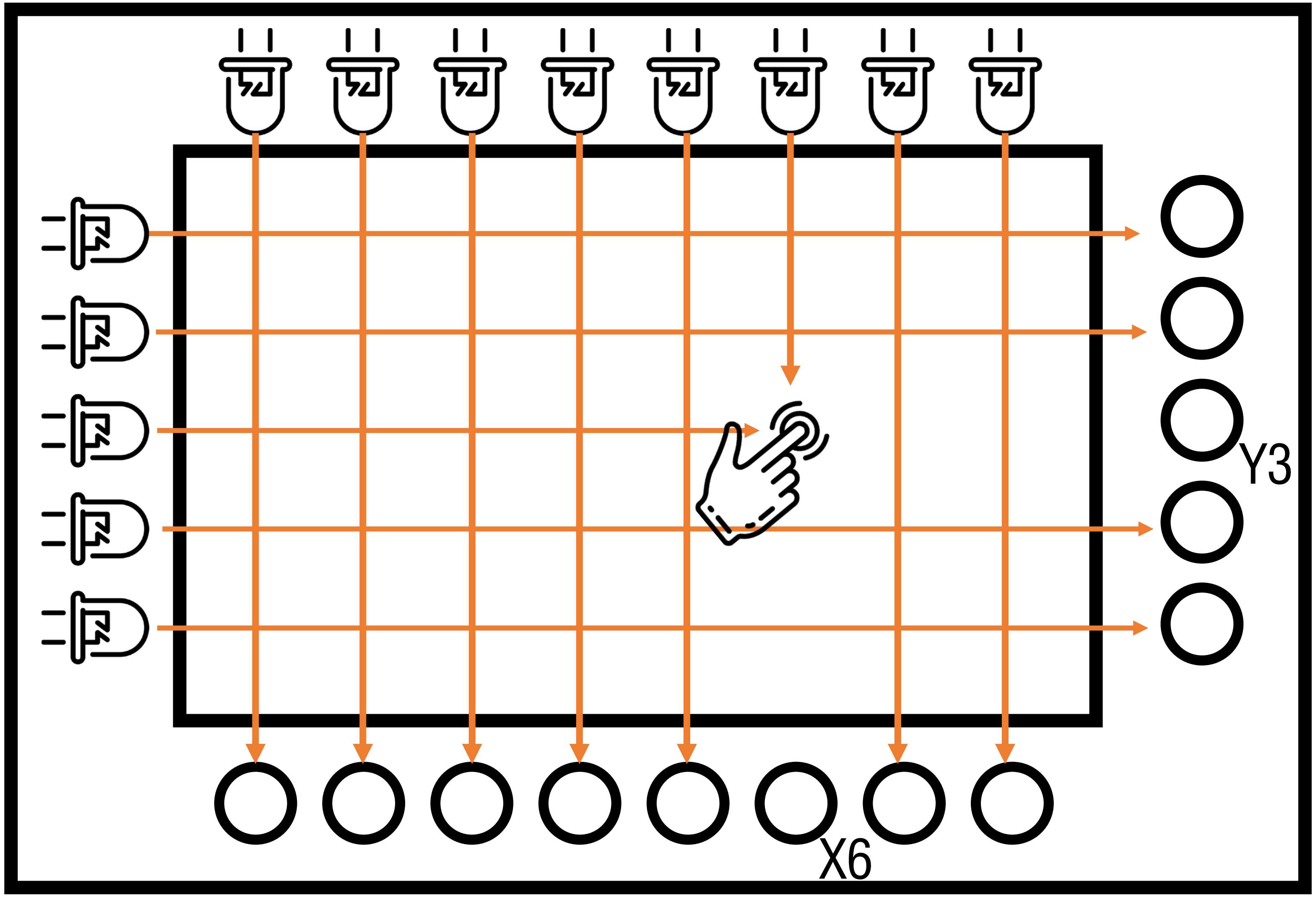
infrared touch panels (ITP)



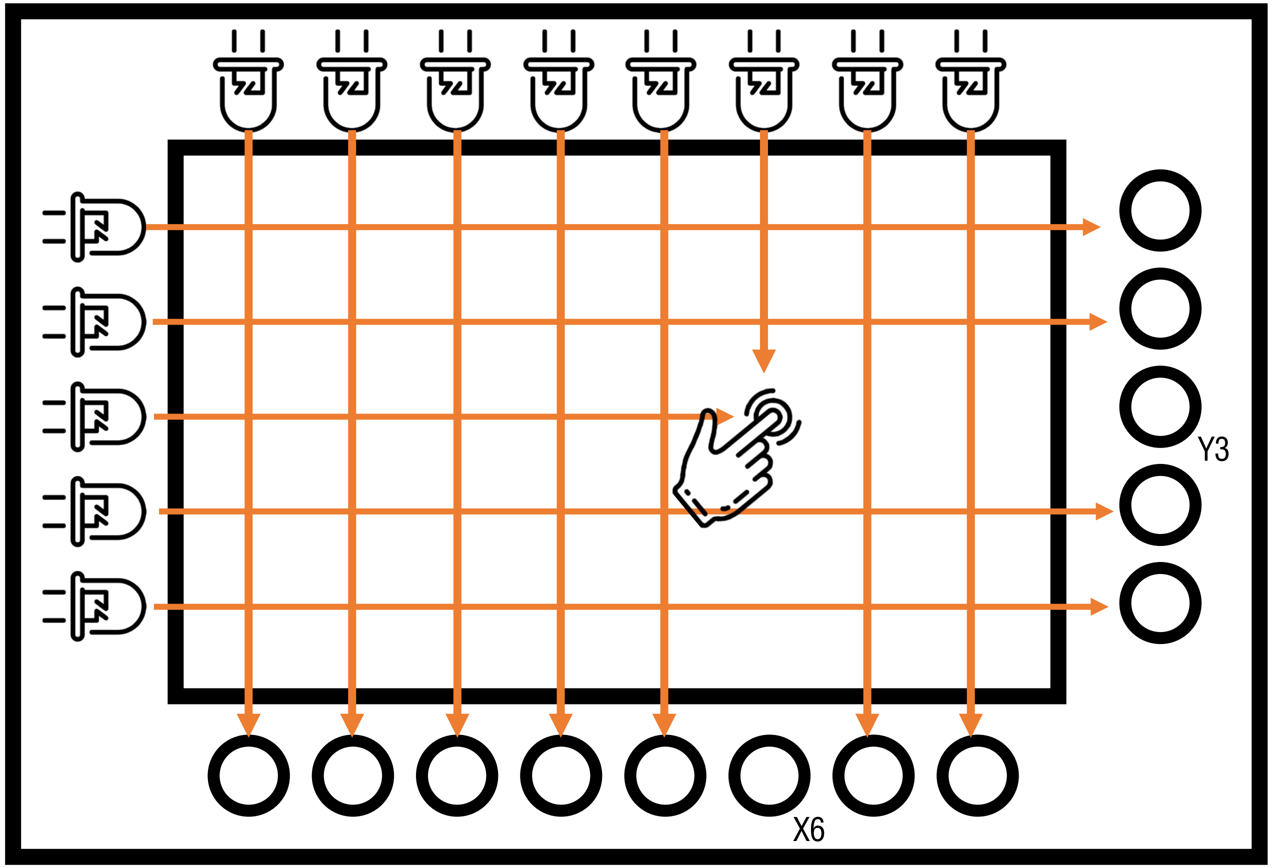
infrared touch panels (ITP)



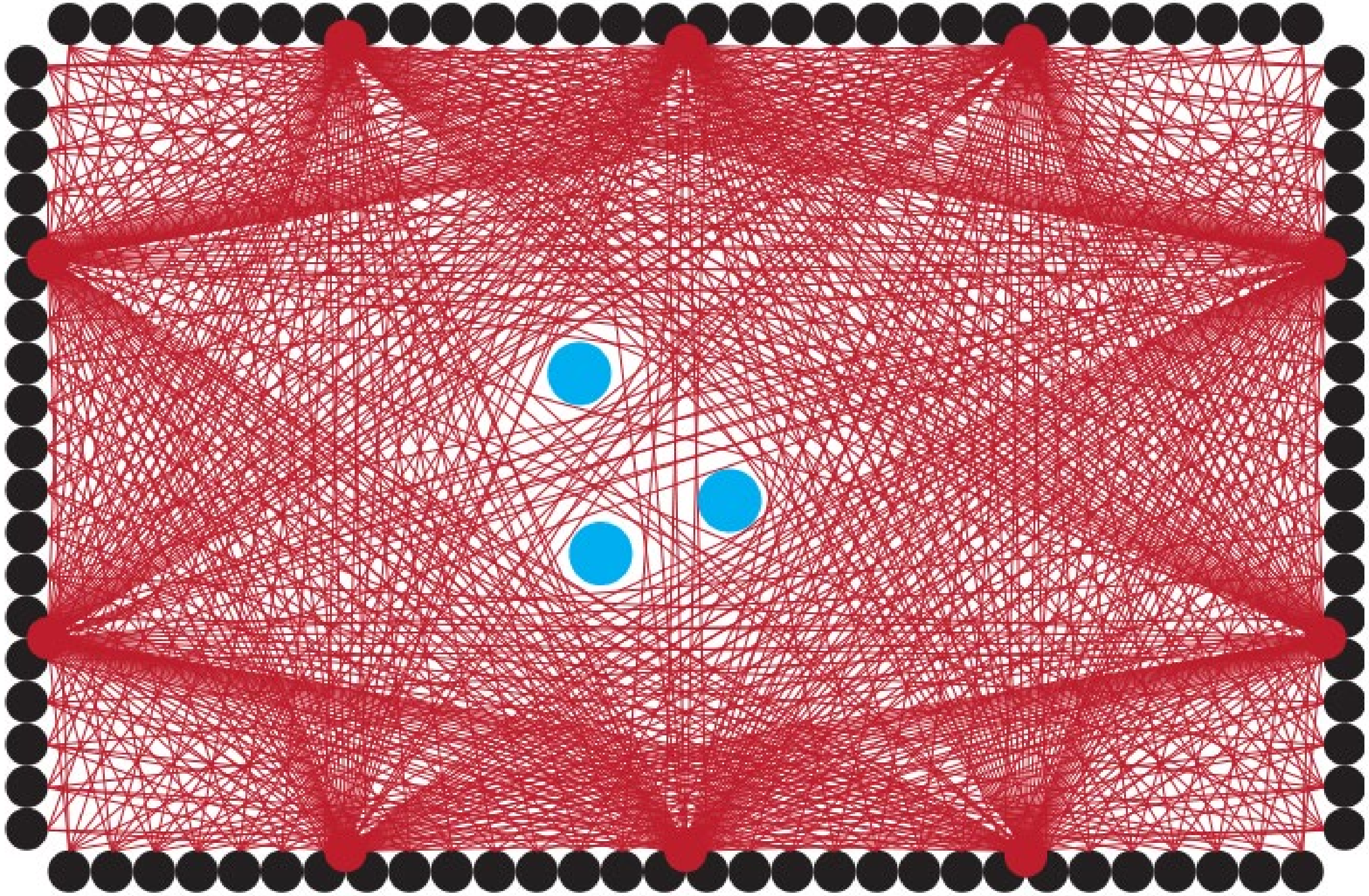
infrared touch panels (ITP)



infrared touch panels (ITP)



infrared LEDs and **light sensors**
placed in a grid on bezel
LEDs transmit light to light sensors on the other side
anything that disrupts light, will register as touch



ZeroTouch: An Optical Multi-Touch and Free-Air Interaction Architecture

Jon Moeller, Andruid Kerne
Interface Ecology Lab @ TAMU CSE
jmoeller@gmail.com, andruid@ecologylab.net

ABSTRACT
ZeroTouch (ZT) is a unique optical sensing technique and architecture that allows precision sensing of hands, fingers, and other objects within a constrained 2-dimensional plane. ZeroTouch provides tracking at 80 Hz, and up to 30 concurrent touch points. Integration with LCDs is trivial. While designed for multi-touch sensing, ZT enables other new modalities, such as pen+touch and free-air interaction. In this paper, we contextualize ZT innovations with a review of other flat-panel sensing technologies. We present the modular sensing architecture behind ZT, and examine early diverse uses of ZT sensing.

Author Keywords
Multi-touch; ZeroTouch; Free-Air; Interaction; Sensing

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces—*Input Devices*

General Terms
Design, Experimentation

INTRODUCTION
Flat-panel multi-touch technologies are slowly but surely scaling to larger and larger screen-sizes. What was once predominantly the domain of bulky vision-based camera/projector multi-touch systems is now being rapidly encroached upon by more space-efficient technologies, albeit at higher relative cost/screen area.

Recent developments in large-area flat-panel multi-touch sensing have used optical technologies. Whether by incorporation of optical sensors in the display itself, or by surrounding a display with optical sensors and transmitters, optical technologies are able to scale to large screen sizes.

Capacitive sensing technologies have recently scaled to large displays, enabling high-precision multi-touch at a scale once the sole realm of vision-based sensing. However, capacitive requires factory integration, and thus is unsuitable for integration with the large contingent of non-multi-touch displays already in the world.

There are a number of technologies that enable multi-touch interaction on non-interactive displays in the market today, and the majority of these employ optical-based touch sensing. Some use cameras and computer vision techniques, and some use optical sensors and emitters to detect touch.

In this paper, we detail ZeroTouch (ZT), a hardware/software architecture for multi-touch sensing [16]. ZeroTouch is a flat-panel optical multitouch technology using a linear array of modulated light receivers which surround the periphery of a display to detect touch. It is designed with a modular architecture. A complete sensor is built from a number of smaller sensing modules, allowing a full sensor to be built at any practical size.

First, we present an overview of flat-panel optical multi-touch techniques, and position ZeroTouch amidst the multi-touch sensing landscape. Next, we go deeper into the technology of ZT, describing its modular architecture, sensing technique, and temporal and spatial resolution characteristics of the sensor. Finally, we develop application areas of ZT with case studies. We wrap up with a discussion and implications for the technology.

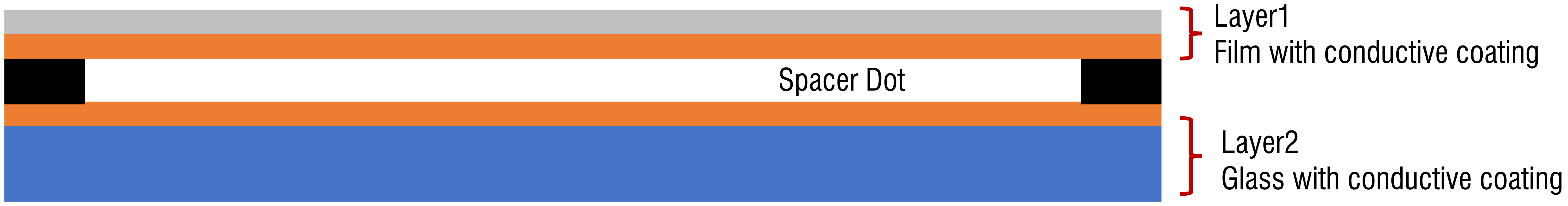
OPTICAL FLAT-PANEL SENSING TECHNOLOGIES
There are a few techniques for optical flat-panel sensing, some which sense from the sides, and some which sense directly behind or within the display itself. We will discuss some issues common to all forms of optoelectronic sensing, develop an overview of prior optoelectronic techniques, and situate ZT among them.

Common Issues in Optoelectronic Sensing
Among the wide variety of techniques for optoelectronic touch sensing, most suffer from a few common problems which can interfere with a system's success. Ambient light sensitivity is perhaps the most important noise factor in optoelectronic multi-touch systems, followed by active light interference.

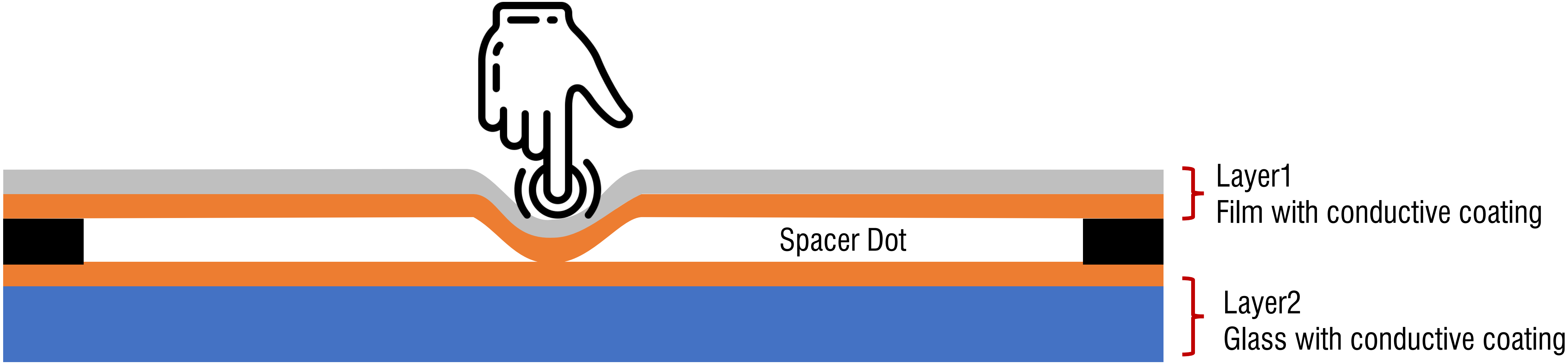
CHI 2012
Moeller et.al. from TAMU

infrared touch panels (ITP)
resistive touch panels (RTP)

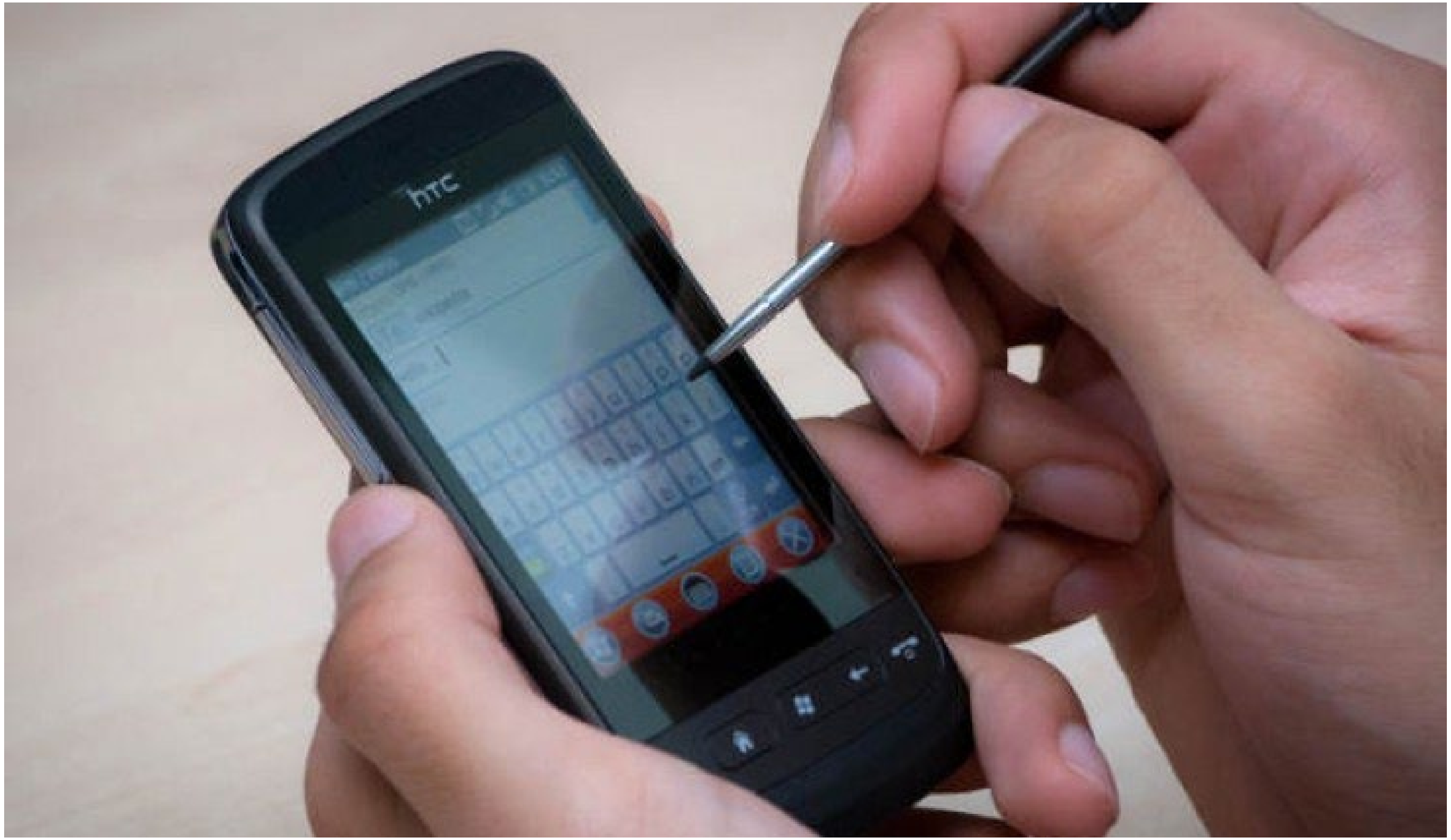
resistive touch panels (RTP)



resistive touch panels (RTP)

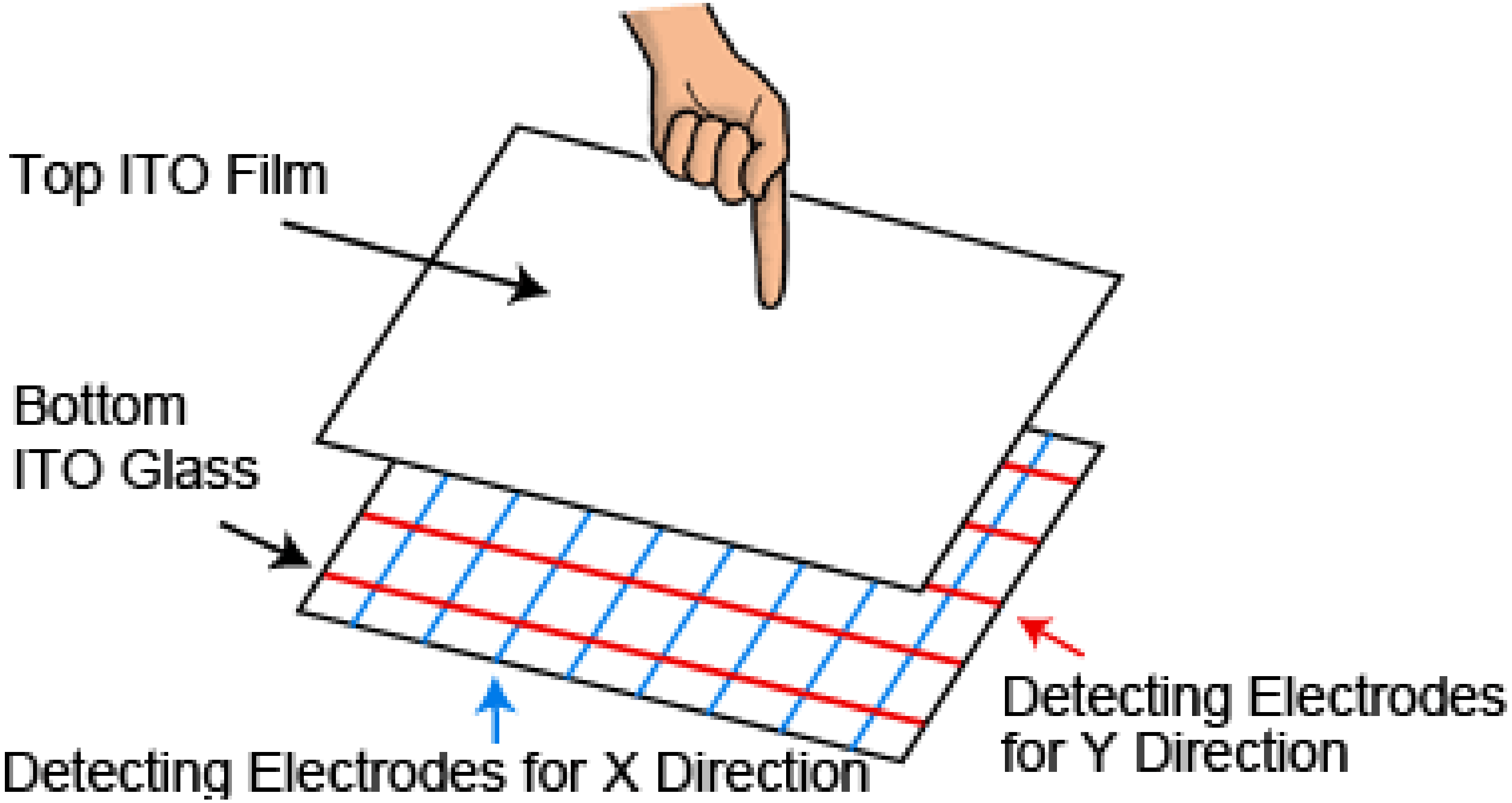


when the top sheet gets pressed by a finger, the pressed point
makes contact with the bottom sheet
electricity now get conducted at the contact point




eat: drink details
ABSOLUT-CRAN-LIME

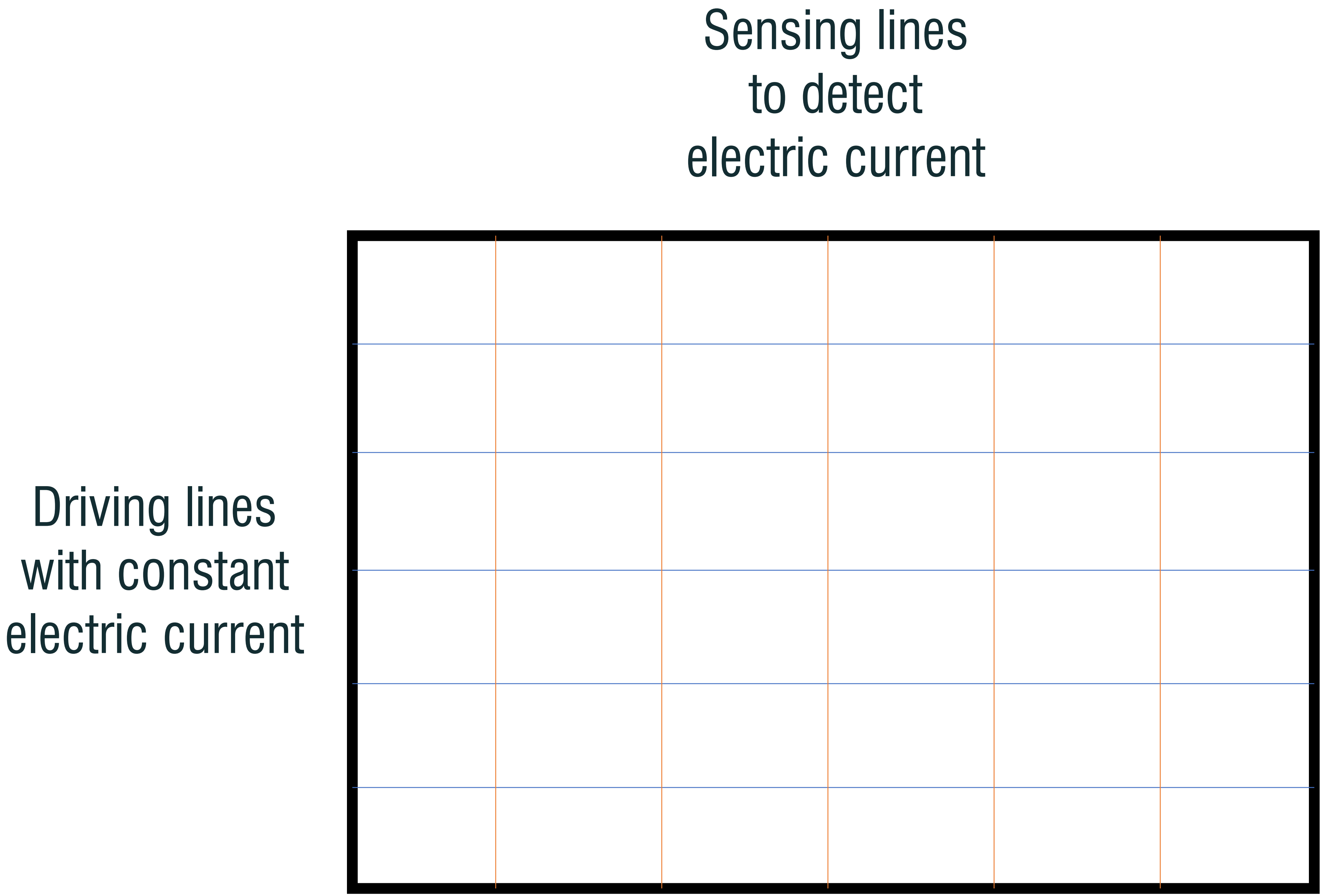
Sensing principle?

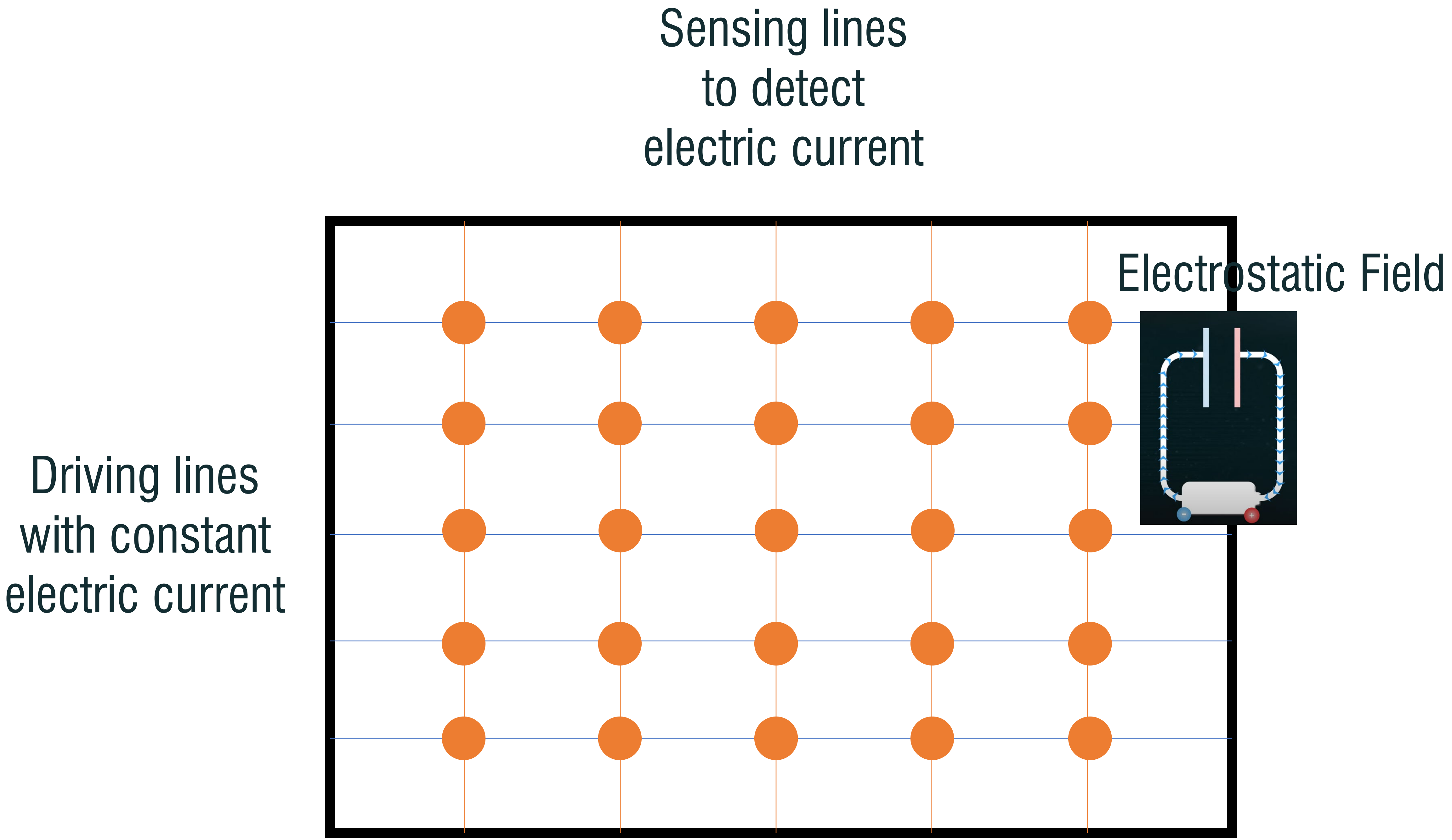


https://www.dmccoltd.com/english/products/fivewire.asp

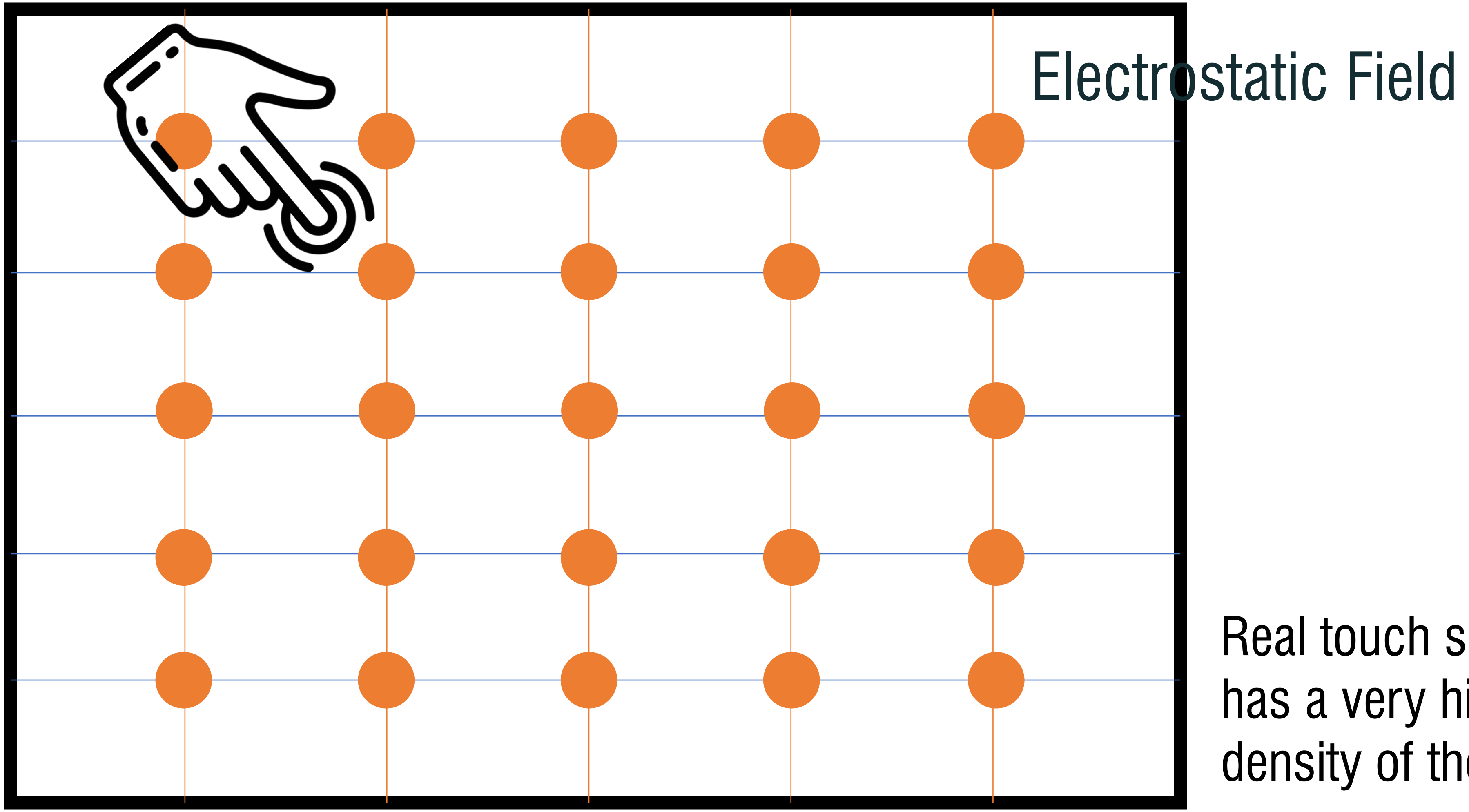
infrared touch panels (ITP)
resistive touch panels (RTP)
capacitive touch screens

capacitive
touch screens


Sensing lines
to detect
electric current
Driving lines
with constant
electric current

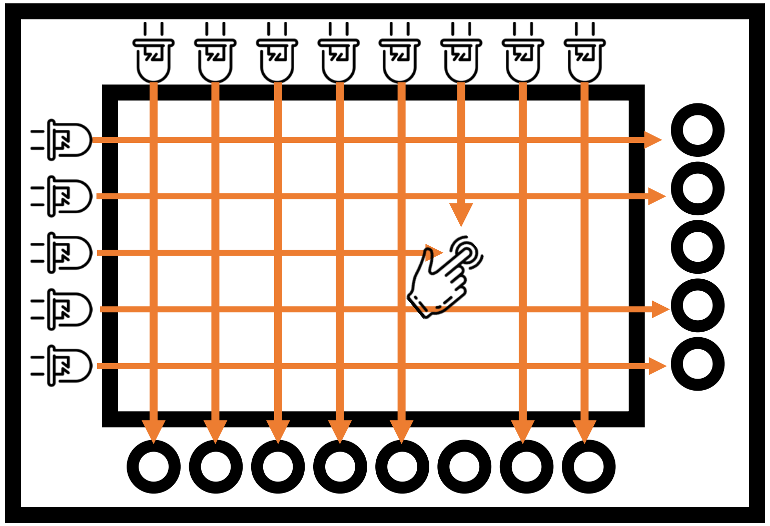

Sensing lines
to detect
electric current
Electrostatic Field
Driving lines
with constant
electric current

Human body has a natural capacitance
distorting the electrostatic field
at the contact point

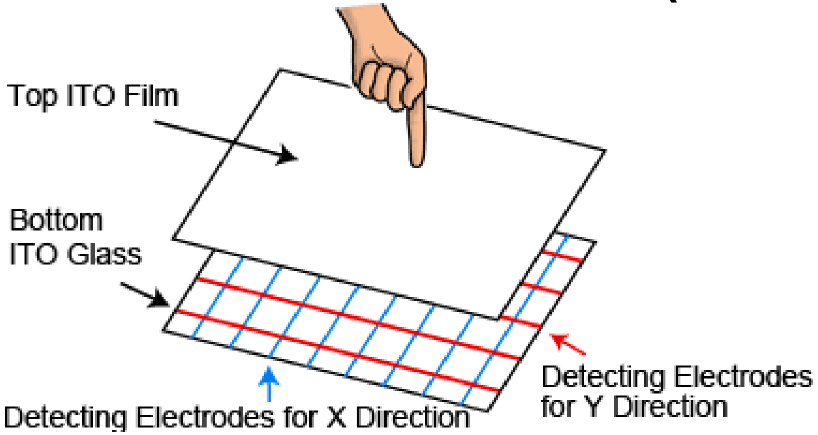


Real touch screen
has a very high
density of the grid

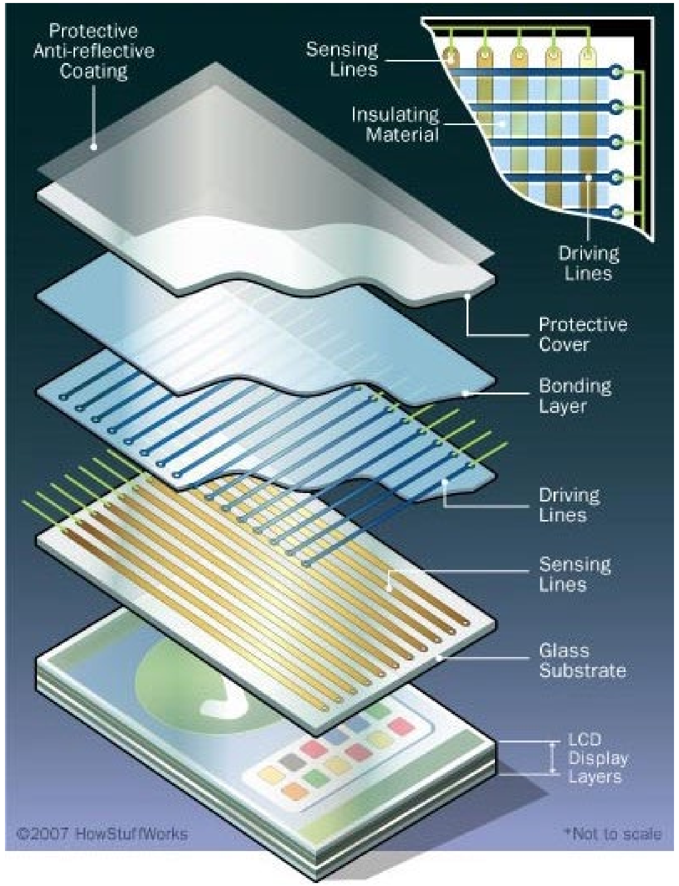
infrared touch panels (ITP)



resistive touch panels (RTP)

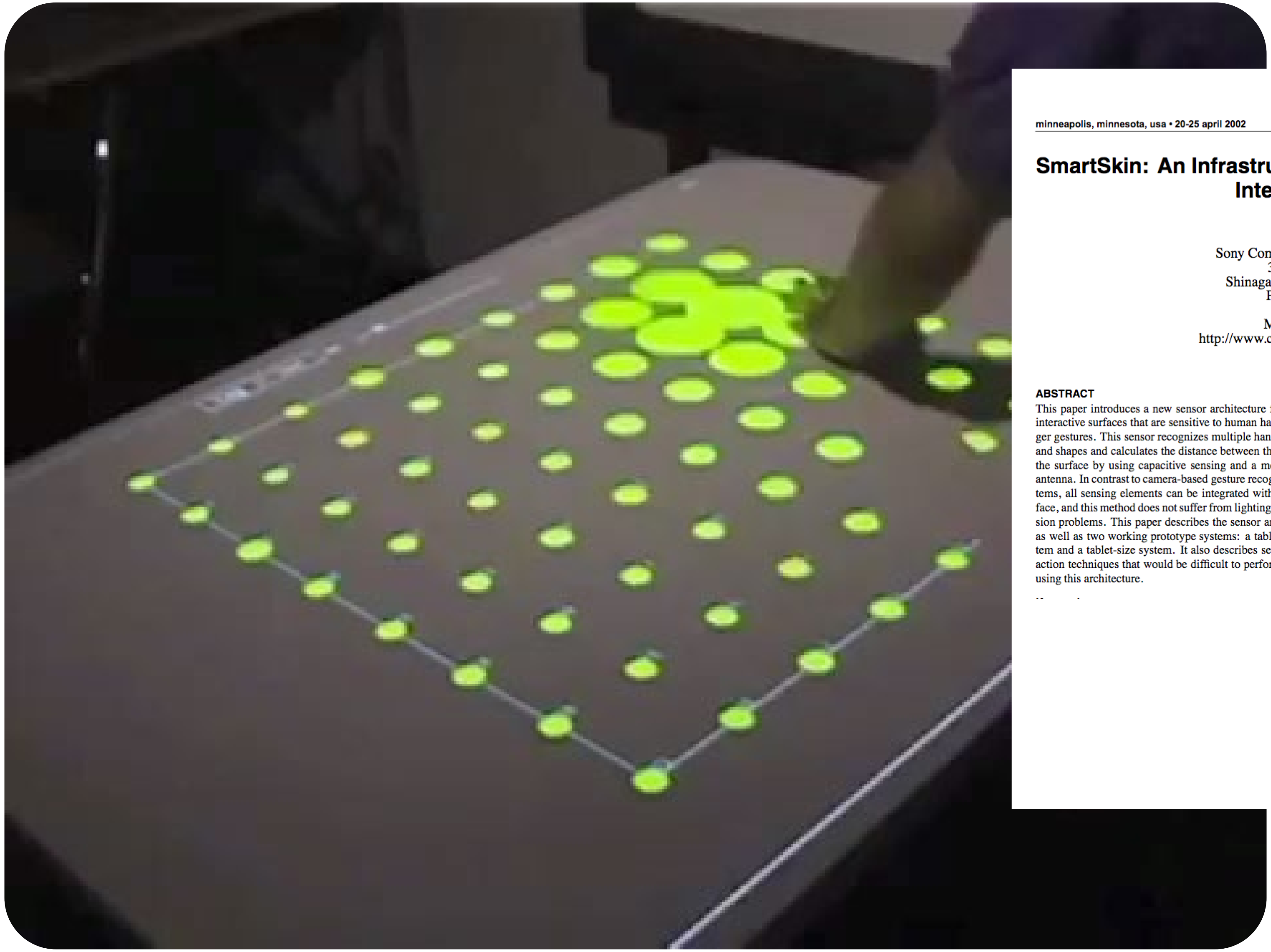


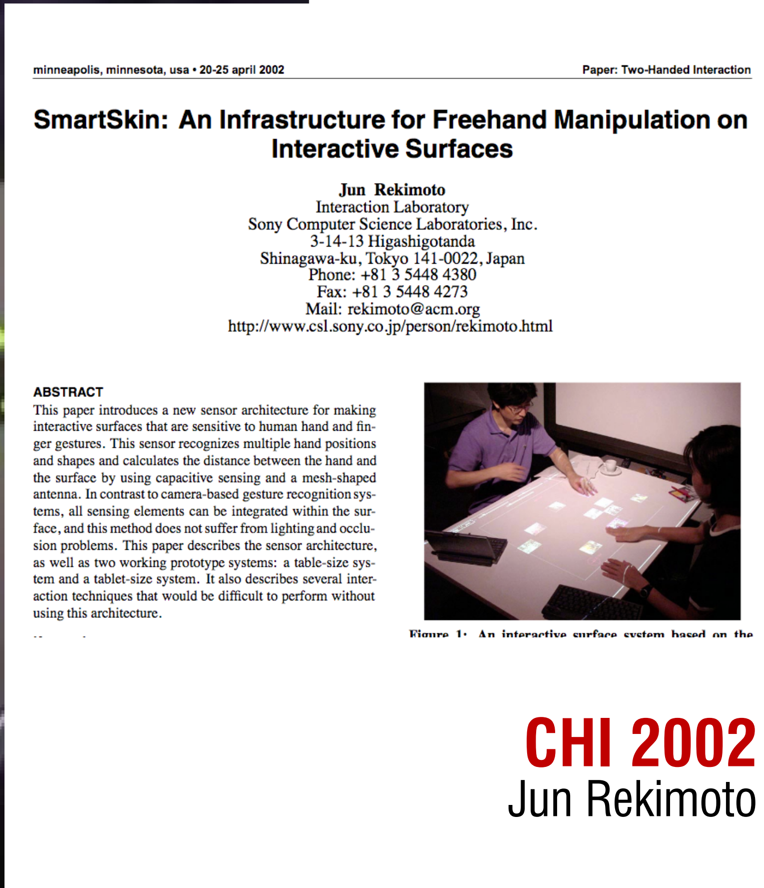
capacitive touch screens



http://www.sky-technology.eu/en/displays/touch-screens/projected-capacitive-touch-screens-how-they-work.html

same principle





SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces

Jun Rekimoto
Interaction Laboratory
Sony Computer Science Laboratories, Inc.
3-14-13 Higashigotanda
Shinagawa-ku, Tokyo 141-0022, Japan
Phone: +81 3 5448 4380
Fax: +81 3 5448 4273
Mail: rekimoto@acm.org
http://www.csl.sony.co.jp/person/rekimoto.html

ABSTRACT
This paper introduces a new sensor architecture for making interactive surfaces that are sensitive to human hand and finger gestures. This sensor recognizes multiple hand positions and shapes and calculates the distance between the hand and the surface by using capacitive sensing and a mesh-shaped antenna. In contrast to camera-based gesture recognition systems, all sensing elements can be integrated within the surface, and this method does not suffer from lighting and occlusion problems. This paper describes the sensor architecture, as well as two working prototype systems: a table-size system and a tablet-size system. It also describes several interaction techniques that would be difficult to perform without using this architecture.

Figure 1: An interactive surface system based on the

CHI 2002
Jun Rekimoto

DiamondTouch: A Multi-User Touch Technology

Paul Dietz and *Darren Leigh*
Mitsubishi Electric Research Laboratories
201 Broadway
Cambridge, MA 02139 USA
+1-617-621-7500
{dietz,leigh}@merl.com

ABSTRACT
A technique for creating a touch-sensitive input device is proposed which allows multiple, simultaneous users to interact in an intuitive fashion. Touch location information is determined independently for each user, allowing each touch on a common surface to be associated with a particular user. The surface generates location dependent, modulated electric fields which are capacitively coupled through the users to receivers installed in the work environment. We describe the design of these systems and their applications. Finally, we present results we have obtained with a small prototype device.

KEYWORDS: DiamondTouch, multi-user, touch, collaborative input, single display groupware

INTRODUCTION
DiamondTouch is a multi-user touch technology for tabletop front-projected displays. It enables several different people to use the same touch-surface simultaneously without interfering with each other, or being affected by foreign objects.

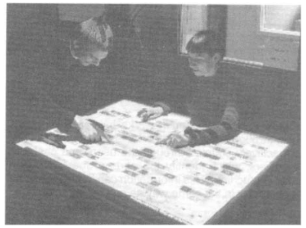


Figure 1: The collaborative work environment for Human-Guided Simple Search.

ity. Keeping track of many mice is nearly impossible. This leaves users physically pointing at their virtual pointers to

UIST 2001
Dietz et.al.

Learn the technologies behind multi-touch screen

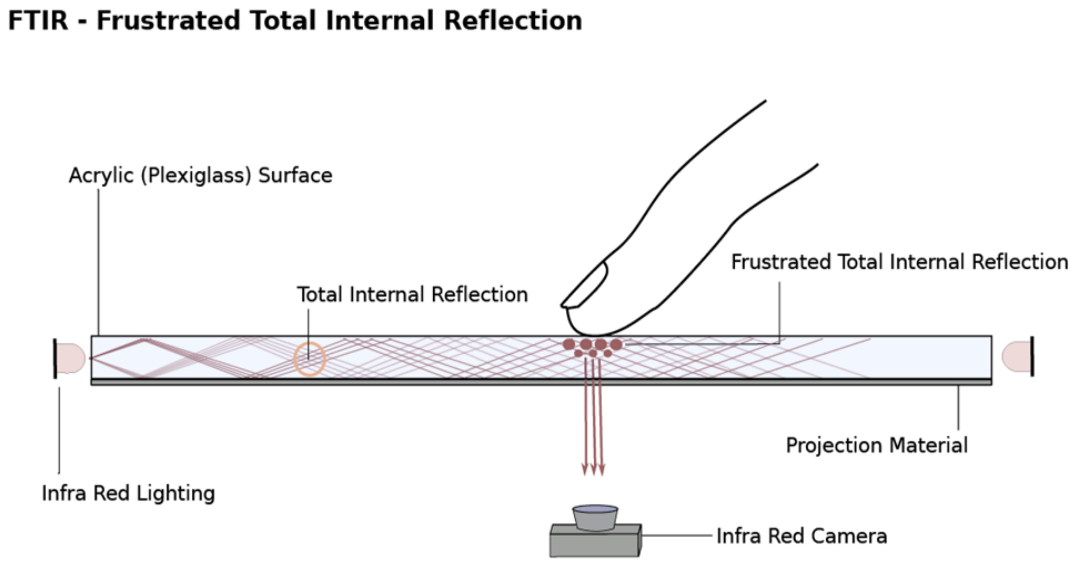
Camera-based | Resistive | Capacitive | …

Recap

technologies behind multi-touch screen

Camera-based | Resistive | Capacitive | …

#1 - laser Light Plane (LLP)
#2 - frustrated total internal reflection (FTIR)
#3 - rear diffused illumination (rear DI)
#4 - front diffused illumination (front DI)



Recap

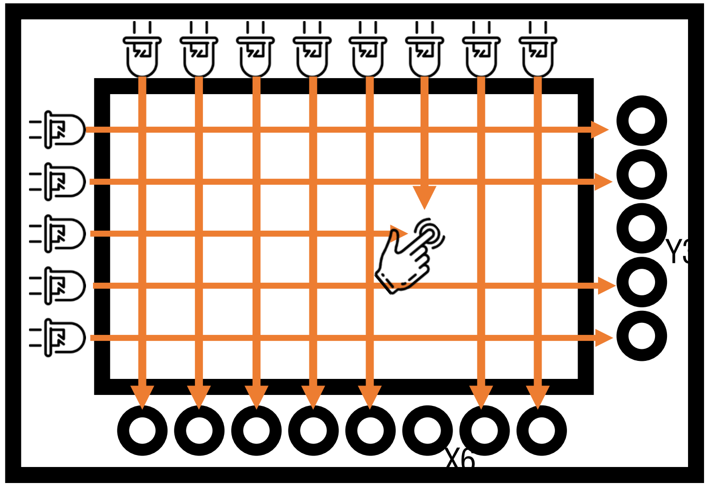
technologies behind multi-touch screen

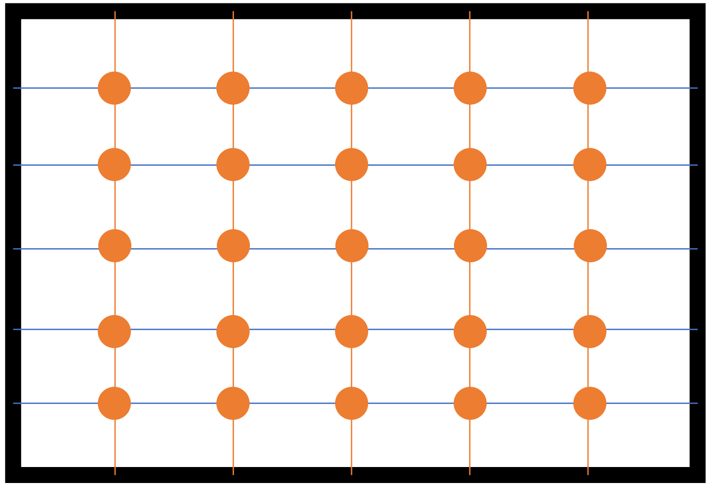
Camera-based | Resistive | Capacitive | …

Recap

technologies behind multi-touch screen

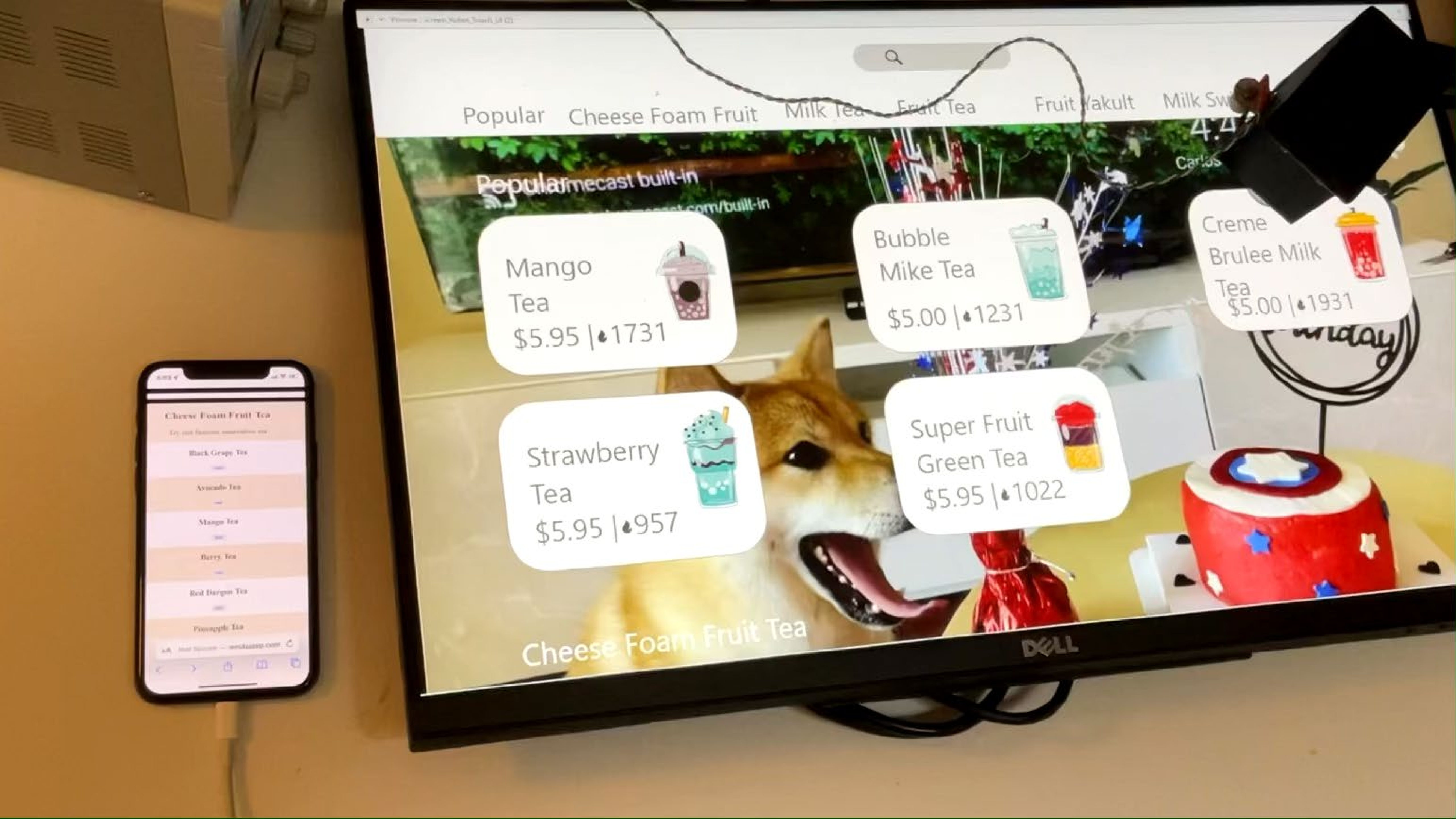
Camera-based | Resistive | Capacitive | …





We have seen touchscreen devices almost everywhere nowadays replacing physical buttons

What can we do for people who cannot benefit from it?



Popular
Cheese Foam Fruit
Milk Tea
Fruit Tea
Fruit Yakult
Mango Tea
$5.95 | 1731
Bubble Mike Tea
$5.00 | 1231
Creme Brulee Milk Tea
$5.00 | 1931
Strawberry Tea
$5.95 | 957
Super Fruit Green Tea
$5.95 | 1022
Cheese Foam Fruit Tea
DELL

BrushLens

Hardware Interaction Proxies for Accessible Touchscreen Interface Actuation

Chen Liang, Yasha Iravantchi, Thomas Krolikowski, Ruijie Geng
Alanson Sample, Anhong Guo

UNIVERSITY OF MICHIGAN

BrushLens: Hardware Interaction Proxies for Accessible Touchscreen Interface Actuation

Chen Liang, University of Michigan, Ann Arbor, MI, USA, clumich@umich.edu
Yasha Iravantchi, University of Michigan, Ann Arbor, MI, USA, yiravan@umich.edu
Thomas Krolikowski, University of Michigan, Ann Arbor, MI, USA, tkroliko@umich.edu
Ruijie Geng, University of Michigan, Ann Arbor, MI, USA, gengr@umich.edu
Alanson Sample, University of Michigan, Ann Arbor, MI, USA, apsample@umich.edu
Anhong Guo, University of Michigan, Ann Arbor, MI, USA, anhong@umich.edu

Figure 1: Touchscreen devices are widely adopted but not always accessible, such as restaurant kiosks (1). Assumptions about users' visual and motor abilities (2) to perceive visual information, locate, navigate, interpret interface layout, and precisely perform pre-defined gestures do not always hold, making devices inaccessible for some users. We propose BrushLens, a hardware phone case (3) that is equipped with an array of touchscreen actuators (4). It acts as a hardware interaction proxy that perceives, locates, and actuates touchscreen on behalf of users (5), and allows users to interpret and give interaction intentions through the accessible interface running on their personal devices. This allows users to "Brush" on the interface (6) while the actuators constantly monitor their positions through camera and sensor input, and perform a touch gesture directly if any of them is on top of the target button, making inaccessible devices accessible for people with diverse abilities.

ABSTRACT

Touchscreen devices, designed with an assumed range of user abilities and interaction patterns, often present challenges for individuals with diverse abilities to operate independently. Prior efforts to improve accessibility through tools or algorithms necessitated alterations to touchscreen hardware or software, making them inapplicable for the large number of existing legacy devices. In this paper, we introduce BrushLens, a hardware interaction proxy that performs physical interactions on behalf of users while allowing them to continue utilizing accessible interfaces, such as screenreaders and assistive touch on smartphones, for interface exploration and command input. BrushLens maintains an interface model for accurate target localization and utilizes exchangeable actuators for physical actuation across a variety of device types, effectively reducing user workload and minimizing the risk of mistouch. Our evaluations reveal that BrushLens lowers the mistouch rate and empowers visually and motor impaired users to interact with otherwise inaccessible physical touchscreens more effectively.

UIST '23, October 29–November 01, 2023, San Francisco, CA, USA

ACM ISBN 979-8-4007-0132-0/23/10...$15.00
https://doi.org/10.1145/3586183.3606730

KEYWORDS

Touchscreen appliances, accessibility, interaction proxy, computer vision, touch actuation

ACM Reference Format:
Chen Liang, Yasha Iravantchi, Thomas Krolikowski, Ruijie Geng, Alanson Sample, and Anhong Guo. 2023. BrushLens: Hardware Interaction Proxies for Accessible Touchscreen Interface Actuation. In *The 36th Annual ACM Symposium on User Interface Software and Technology (UIST '23), October 29–November 01, 2023, San Francisco, CA, USA.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3586183.3606730

1 INTRODUCTION

Touchscreen devices have become ubiquitous in everyday life, playing a critical role in performing various everyday tasks. From flight check-in kiosks to food ordering systems, interacting with these devices independently has become essential in various usage scenarios. However, despite their widespread adoption, such devices are often designed with assumptions about users' abilities and interaction patterns, making them less accessible to completely inaccessible for users with diverse abilities. Individuals with visual impairments may have difficulty perceiving the necessary information to operate these touchscreens, and the risk of triggering unintended actions

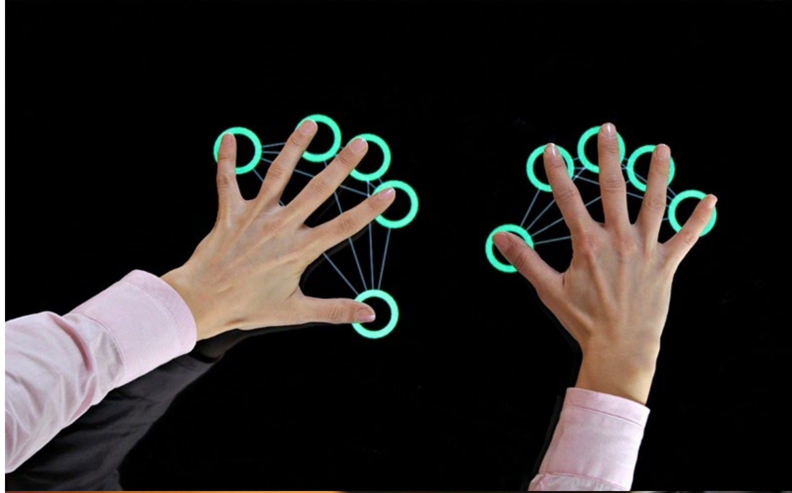
UIST 2023

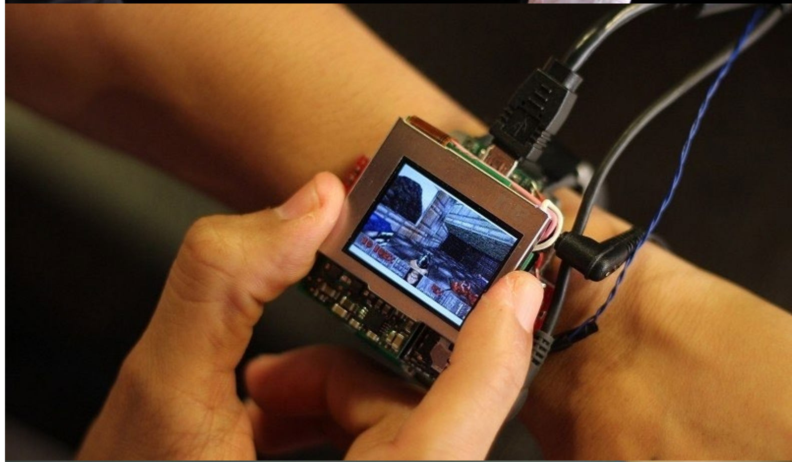
Liang et.al.

Learn

- Varies interactive technologies
- Technologies behind the scene

Wed: Milestone 1 presentation





Special thanks to Prof. Stefanie Mueller for the material

Optional readings

DiamondTouch: A Multi-User Touch Technology

Paul Dietz and *Darren Leigh*
Mitsubishi Electric Research Laboratories
201 Broadway
Cambridge, MA 02139 USA
+1-617-621-7500
{dietz,leigh}@merl.com

ABSTRACT

A technique for creating a touch-sensitive input device is proposed which allows multiple, simultaneous users to interact in an intuitive fashion. Touch location information is determined independently for each user, allowing each touch on a common surface to be associated with a particular user. The surface generates location dependent, modulated electric fields which are capacitively coupled through the users to receivers installed in the work environment. We describe the design of these systems and their applications. Finally, we present results we have obtained with a small prototype device.

KEYWORDS: DiamondTouch, multi-user, touch, collaborative input, single display groupware

INTRODUCTION

DiamondTouch is a multi-user touch technology for tabletop front-projected displays. It enables several different people to use the same touch-surface simultaneously without interfering with each other, or being affected by foreign objects. It also allows the computer to identify which person is touching where.

During the course of research on Human-Guided Simple Search [1] some of our colleagues have constructed a collaborative workspace in which multiple users work on the same data set. The environment consists of a ceiling-mounted video projector displaying onto a white table around which the users sit. A single wireless mouse is passed around as different users take the initiative. Our colleagues proposed that the collaboration would be improved if the users could independently and simultaneously interact with the table, and considered using multiple mice.

The use of multiple mice in a collaborative environment is particularly problematic. It can be challenging for users to keep track of one pointer on a large surface with lots of activ-

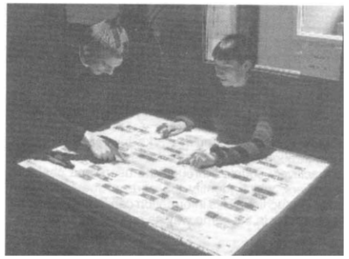


Figure 1: The collaborative work environment for Human-Guided Simple Search.

ity. Keeping track of many mice is nearly impossible. This leaves users physically pointing at their virtual pointers to tell other users where they are. Also, relying on a separate physical device keeps us from utilizing the natural human tendencies of reaching, touching and grasping.[1]

Using a large touch-screen as the table surface would seem to be an answer, but existing touch technologies were inadequate. Most allow only a single touch and do not identify users. While schemes have been developed where users take turns [3], we wanted the interaction to be simultaneous and spontaneous.

Unlike electronic whiteboards or other vertical touch systems, the tabletop nature of our display creates a problem: people tend to put things on tables. With a pressure-sensitive surface, foreign objects create spurious touch-points causing single touch systems to malfunction.

Optimally, we would like a multi-user touch surface to have the following characteristics:

[1] Plus see the discussion in [2] for advantages of touch ta[illegible]

UIST 2001

Dietz et.al.

StateLens: A Reverse Engineering Solution for Making Existing Dynamic Touchscreens Accessible

Anhong Guo, Junhan Kong, Michael Rivera, Frank F. Xu, Jeffrey P. Bigham
Human-Computer Interaction Institute, Carnegie Mellon University, Pittsburgh, PA, USA
{anhongg, jbigham}@cs.cmu.edu, {junhank, mlrivera, fangzhex}@andrew.cmu.edu

ABSTRACT

Blind people frequently encounter inaccessible dynamic touchscreens in their everyday lives that are difficult, frustrating, and often impossible to use independently. Touchscreens are often the only way to control everything from coffee machines and payment terminals, to subway ticket machines and in-flight entertainment systems. Interacting with dynamic touchscreens is difficult non-visually because the visual user interfaces change, interactions often occur over multiple different screens, and it is easy to accidentally trigger interface actions while exploring the screen. To solve these problems, we introduce *StateLens* — a three-part reverse engineering solution that makes existing dynamic touchscreens accessible. First, StateLens reverse engineers the underlying state diagrams of existing interfaces using point-of-view videos found online or taken by users using a hybrid crowd-computer vision pipeline. Second, using the state diagrams, StateLens automatically generates conversational agents to guide blind users through specifying the tasks that the interface can perform, allowing the StateLens iOS application to provide interactive guidance and feedback so that blind users can access the interface. Finally, a set of 3D-printed accessories enable blind people to explore capacitive touchscreens without the risk of triggering accidental touches on the interface. Our technical evaluation shows that StateLens can accurately reconstruct interfaces from stationary, hand-held, and web videos; and, a user study of the complete system demonstrates that StateLens successfully enables blind users to access otherwise inaccessible dynamic touchscreens.

Author Keywords

Reverse engineering; dynamic interfaces; touchscreen appliances; accessibility; crowdsourcing; computer vision; conversational agents.

CCS Concepts

•**Human-centered computing** → **Interactive systems and tools; Accessibility technologies;**

INTRODUCTION

Inaccessible touchscreen interfaces in the world represent a long-standing and frustrating problem for people who are

UIST '19, October 20-23, 2019, New Orleans, LA, USA
© 2019 Association of Computing Machinery.
ACM ISBN 978-1-4503-6816-2/19/10 ...$15.00.
http://dx.doi.org/10.1145/3332165.3347873

Figure 1. StateLens is a system that enables blind users to interact with touchscreen devices in the real world by *(i)* reverse engineering a structured model of the underlying interface, and *(ii)* using the model to provide interactive conversational and audio guidance to the user about how to use it. A set of 3D-printed accessories enable capacitive touchscreens to be used non-visually by preventing accidental touches on the interface.

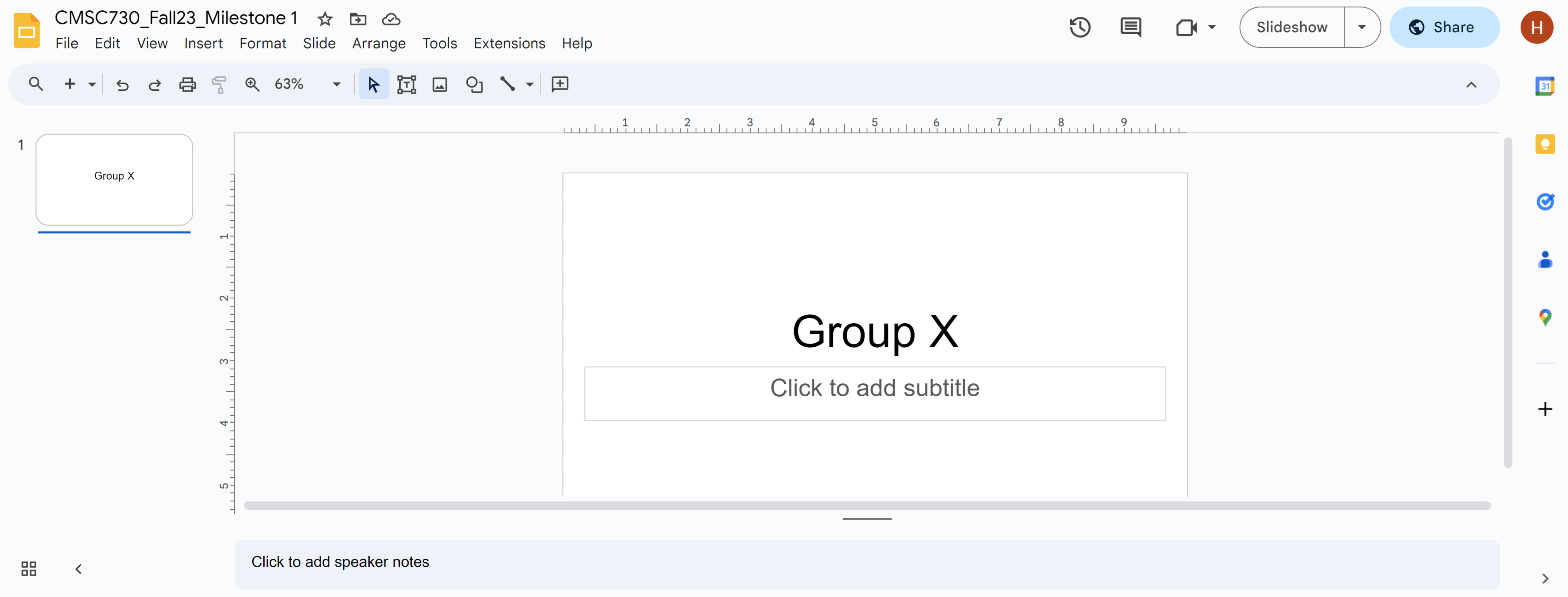
blind. Imagine sitting down for a 12-hour flight only to realize that the entertainment center on the seatback in front of you can only be controlled by its inaccessible touchscreen; imagine checking out at the grocery store and being required to tell the cashier your pin number out loud because the checkout kiosk is an inaccessible touchscreen; and, imagine not being able to independently make yourself a coffee at your workplace because the fancy new coffee machine is controlled only by an inaccessible touchscreen. Such frustrating accessibility problems are commonplace and pervasive.

Making touchscreen interfaces accessible has been a long-standing challenge in accessibility [14, 17, 30], and some current platforms are quite accessible (*e.g.*, iOS). Solving all of the challenges represented by the combination of difficult issues for public touchscreen devices has remained elusive: *(i)* touchscreens are inherently visual so a blind person cannot read what they say or identify user interface components, *(ii)* a blind person cannot touch the touchscreen to explore without the risk of accidentally triggering something they did not intend, and, *(iii)* a blind person does not have the option to choose a different touchscreen platform that would be more accessible and cannot get access to the software or hardware to make it work better. This paper is about enabling blind people to use the touchscreens they encounter *in-the-wild*, despite the fact that nothing about how these systems are designed is intended for their use.

Most prior work on making touchscreens ac[illegible] sumed access to change or add to the touchscreen hardware or software. For example, physical buttons were added to the

UIST 2019

Guo et.al.



Link: https://shorturl.at/dTVY1