UNIVERSITY OF CRETE
COMPUTER SCIENCE DEPARTMENT

COURSE CS-564 (OPTIONAL)
ADVANCED TOPICS
IN HUMAN – COMPUTER INTERACTION

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Recent and emerging interaction techniques: Touch and Gesture Interaction

Touch Interaction

Introduction

- Hands have an impressive ability to perform different kinds of manipulation tasks:
  - **from** working with miniature details
  - **to** lifting heavy objects
- The excellent performance of the hand in natural contexts is based on **the efficiency of the interaction** between **sensors** and **muscles** in the hand and the environment

Touch Sensing

- The foundation for all touch interaction is **touch sensing**
  - i.e., technologies that capture human touch and gestures
- This includes sensing touch using:
  - cameras or arrays of optical elements
  - laser rangefinders
  - resistance and pressure sensors
  - acoustics
  - etc.
- **Touchscreens** are built on top of these technologies

Touchscreens (1/2)

- Touchscreens are displays where the position of contact with the screen can be detected
  - Interaction is achieved either through **pointed physical objects** (e.g., pens) or **fingers**
- A touchscreen behaves as a two dimensional planar smart skin
  - Wherever it is touched, some virtual object can be activated
- The interaction paradigm is easily **customizable** to accommodate a range of applications and users

Touchscreens (2/2)

- They share some **characteristics** that make them ideal for many workplaces and public spaces:
  - Easy to learn
  - Durable
  - Require no additional work space
  - No moving parts
- Today they are used routinely in many **applications** and many **devices** such as:
  - point of sales terminals
  - mobile devices
  - games consoles
  - vehicle navigation systems
  - information kiosks

Multi-touch Technology

- Multi-touch technology allows multiple users to operate **simultaneously**
- Various technologies have been introduced to develop multi-touch capable devices
- These techniques can be classified into **two categories**
  - **Computer Vision-Based**
    - Purely Vision-Based
      - Everywhere Display [Pinhanez ‘03]
    - Vision- and Optical- Based
      - Microsoft Surface
  - **Sensor-Based**
    - iPhone
    - SmartSkin [Rekimoto ‘02]
    - Diamond Touch [Dietz & Leigh ‘01]

Purely Vision-Based Systems

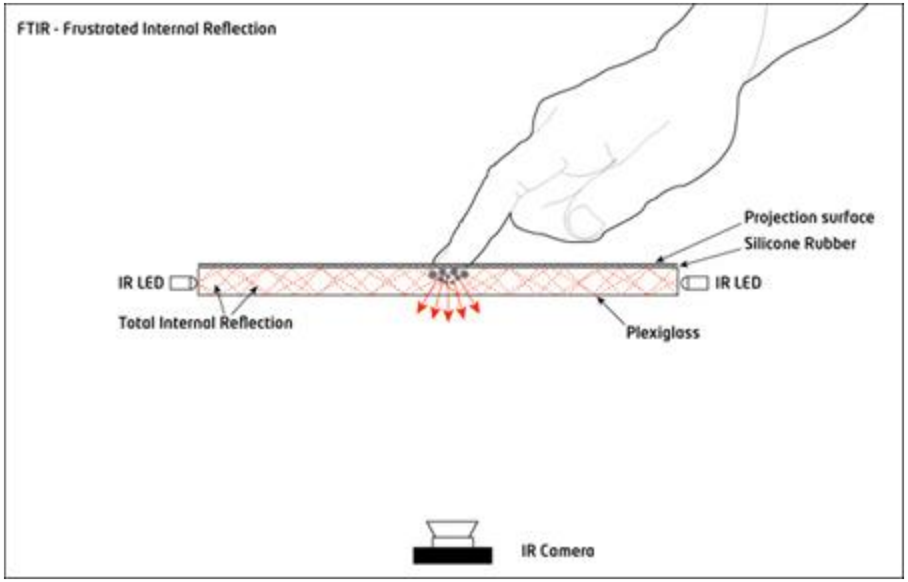
- Due to the decreasing cost and improved performance of computers, computer vision technology has been **greatly improved**
  - This enables the processing of real-time, and high-speed video signals
  - and is sufficient to meet the real-time interaction and human-computer interaction requirements
- Touches and their positions are identified through **image processing** techniques
- This type of multi-touch systems are **highly portable**
  - They can be used on any flat surface without the need for a dedicated display device
- However, the flexibility of pure vision systems comes at the cost of **precision**

Vision- and Optical- Based Systems (1/2)

- Devices based on computer vision and optical Multi-touch technology:
  - have good scalability
  - have a relatively low cost
  - but they have a larger volume
- There are two kinds of computer vision and optical-based Multi-touch systems:
  - Frustrated Total Internal Reflection (FTIR)
  - Diffused Illumination (DI)

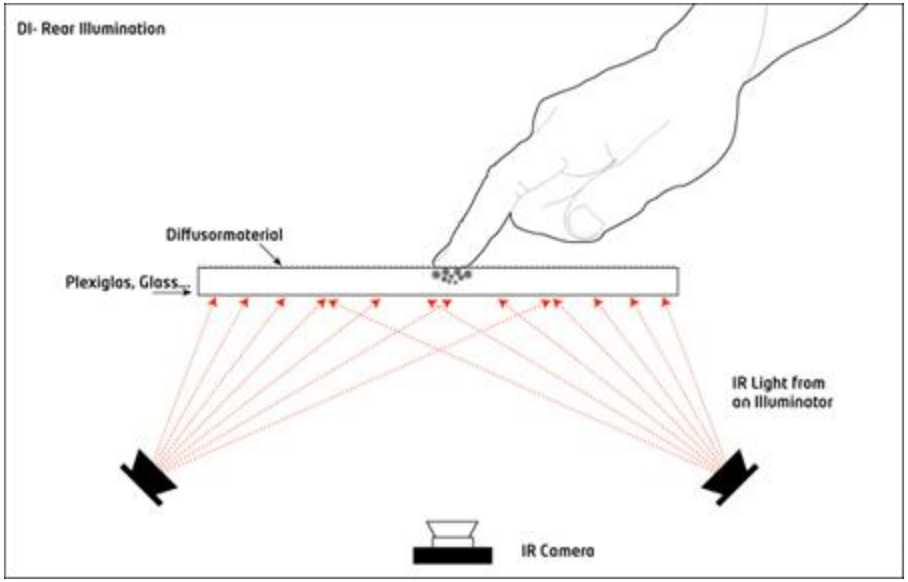
Vision- and Optical- Based Systems (2/2)

Frustrated Total Internal Reflection (FTIR)

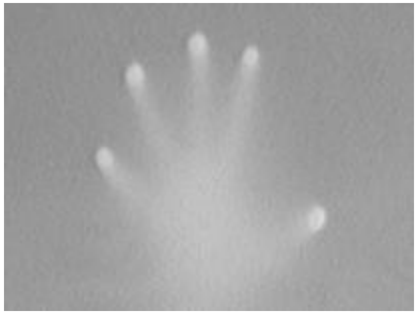


Beams of LED totally reflect within an acrylic medium and when occluded by a finger the scattered light reveals its position

Diffused Illumination (DI)

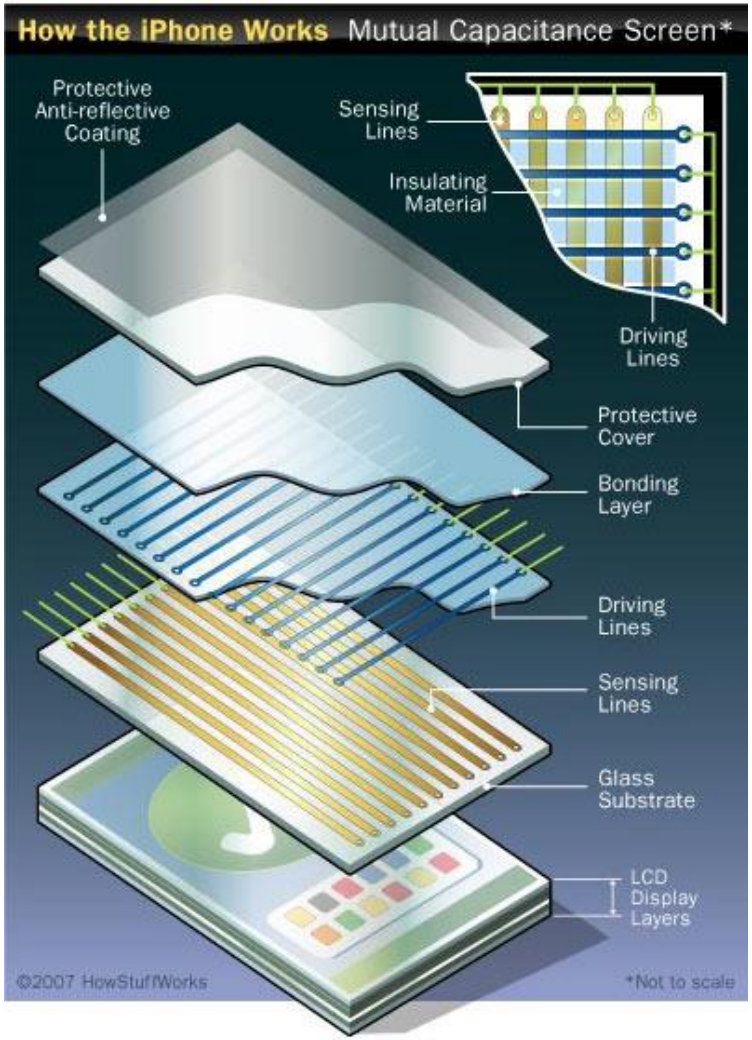


Infrared light shines a surface, a finger reflects more light upon touch thus revealing its position



Sensor-Based Systems

- Many Multi-Touch Devices based on sensor technology can simultaneously **detect multiple touch points**
- Unlike some of the computer-vision-based systems, sensor based systems are almost **impossible to build from off-the-shelf components**
- The **cost** is prohibitively **high**, and the environment **temperature** and **humidity** will affect the system performance
- However, because the sensor can be integrated in the surface, it can be used for mobile phones, PDAs and other small-screen handheld devices



The Key Technology of Multi-touch

- Multi-touch technology can be simply divided into two parts:
  - **Hardware**: serves to complete the information collection
  - **Software**: serves to complete the analysis of information which are finally converted into specific user commands
- Multi-touch technology should include the following components:
  - Multi-touch Hardware Platform
    - Each platform may have its own advantages and disadvantages
  - Accuracy of Selection
    - Precision has great significance on how to accurately track and locate contacts to achieve the freedom of gesture interaction
  - Identification Technology
    - Existing Multi-touch technology detects the contact without carrying information of users
    - The technology that can now identify the user's identity is Diamond Touch technology (which can identify up to four users)
  - Bimanual Interactive Technology
    - A more natural interaction process
    - Two-handed interaction techniques increase parallelism by using both hands of the user

Tangible and Haptic Interaction

Overview

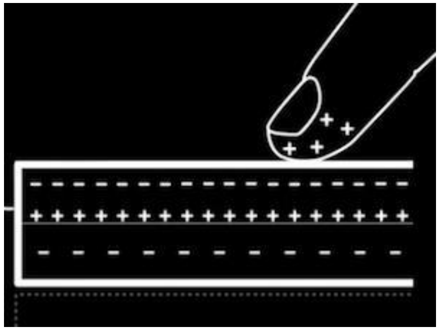
- When touch is described as a skin sense, it is often considered as a passive receiver of stimulation from the environment
- In opposition to this view, a hand can be regarded as a perceptual system which relies on exploration to collect information, and active touch is in many contexts considered to be superior to passive touch
- To stress the importance of activity, the sense is often called ***"active touch"*** or ***"haptics"***
  - The use of the latter two terms is not consistent in the literature
- Sometimes haptics provides more advanced information than vision, for instance concerning the weight of objects and the texture and hardness of surfaces

Haptic Interaction

- Most **devices today** are still in the **stone age of haptics**—they can intelligently vibrate to communicate different things to the user—but that's about it
- While effective, this basic system is **very one dimensional**, in that the entire phone vibrates instead of just the key that you're pressing
- The next generation of haptics aims to make the tactile experience much more nuanced and useful, both on devices and in the air above them

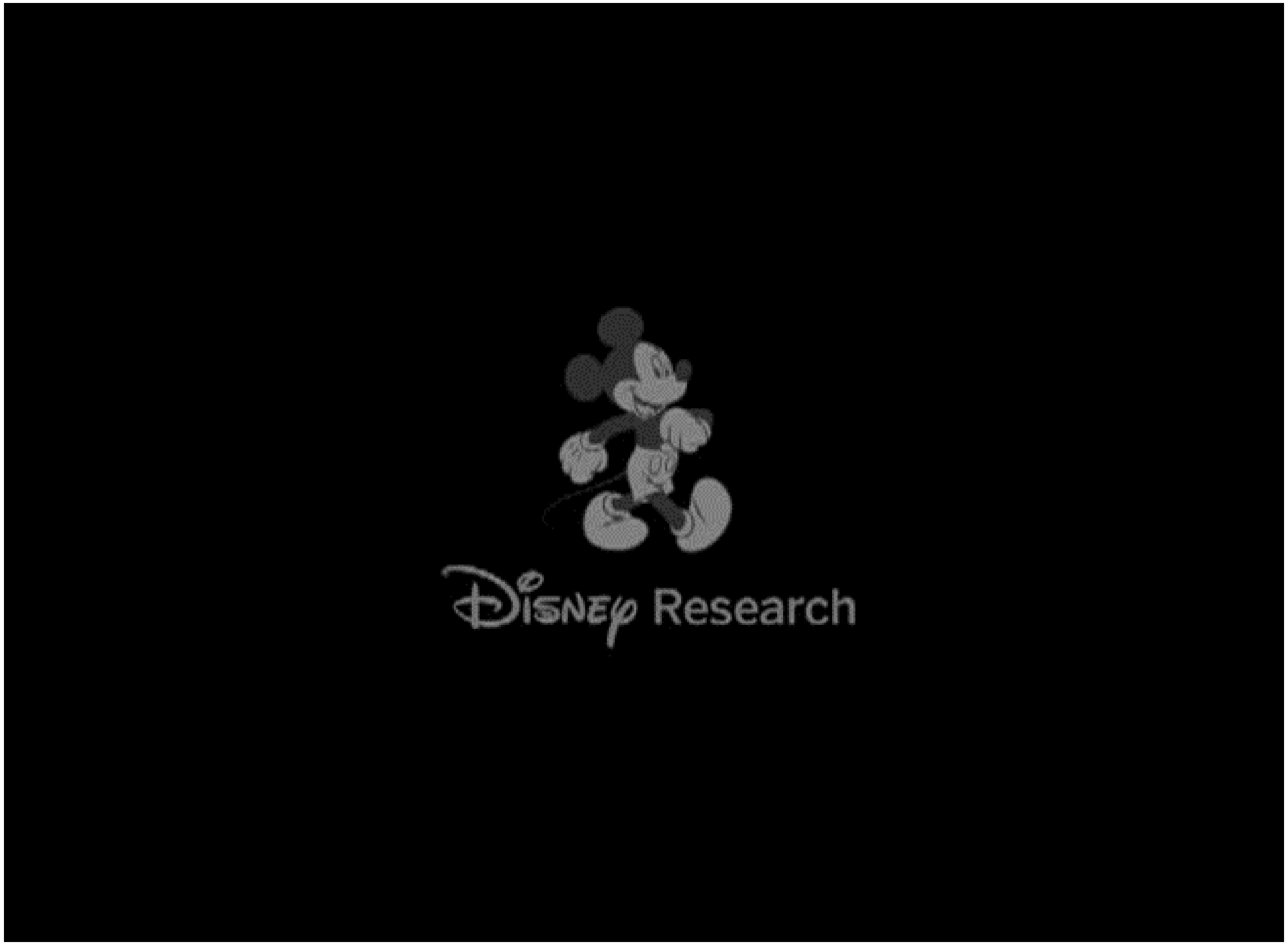
Disney Research Tactile Display

- Disney Research presented an algorithm that is able to **translate 3D information** in an image or video directly **into tactile sensations** on a special haptic display
- The **display** itself stays **perfectly smooth**, and instead modulates the friction at your fingertips to **trick you into feeling** like there's texture under them
- The display creates the illusion of friction using another Disney Research technology from several years ago called TeslaTouch, which uses **oscillating electric charges** to dynamically adjust the friction between your finger and the touch panel



Disney research videos (1/2)

- Tactile rendering of 3D features on Touch Surfaces



Disney research videos (2/2)

- Tesla Touch Technology

UltraHaptics

- UltraHaptics, from the University of Bristol's Interaction and Graphics research group, **does away with tactile displays** entirely, and brings **touch interaction into the air**
- A transducer array **projects** carefully calculated waves of **ultrasonic sound into the air**, which you can't see, hear, or feel
- At certain points, however, the waves come into focus and intensify substantially, displacing the air at those points and **creating a pressure difference that you *can* feel**
- The system can create **multiple pressure points** in different locations **at the same time**, and can even endow individual points with **distinct tactile properties**

UltraHaptics video

UltraHaptics:

multi-point mid-air haptic
feedback for touch surfaces

Tangible Interfaces

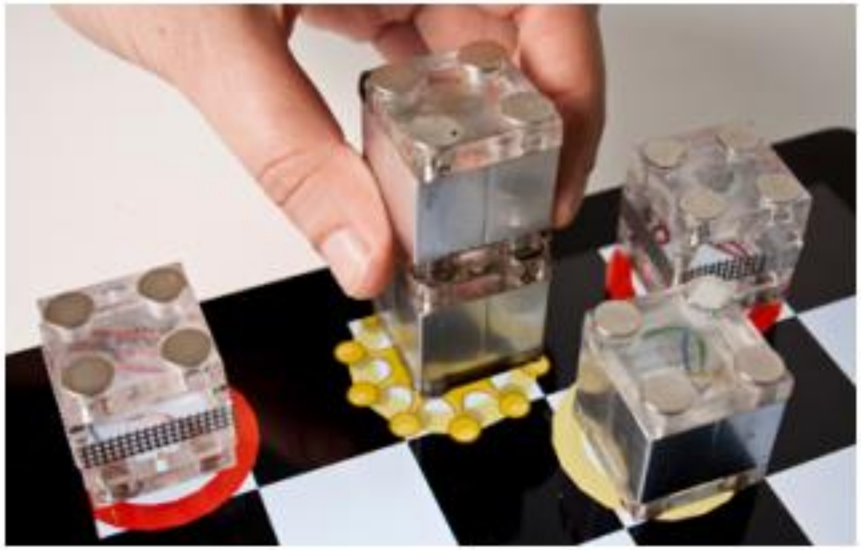
- A Tangible User Interface (TUI) is a user interface that **augments the real physical world** by connecting digital information to **everyday physical objects** and environments
  - They allow users to quite literally grasp data with their hands
  - They often function as both input and output devices
- Tangible Interfaces draw upon the human urge to be active and creative with one's hands
- They can be realized by attaching micro sensors and actuators to physical objects

Application Domains

- Dominant application areas for TUIs seem to be:
  - Learning
  - Support of planning and problem solving
  - Programming and simulation tools
  - Support of information visualization and exploration
  - Entertainment
  - Play
  - Performance and music
  - Social communication

CapStones and ZebraWidgets

- Chan et al. [2012] use stackable gaming pieces and tangible widgets with moving parts to interact with an underlying Touchscreen



Enabling a game of tangible checkers, the touchscreen distinguishes a stack of two CapStones from the single CapStones surrounding it

(a) A single Zebra Dial allows users to adjust the brightness of the underlying image.

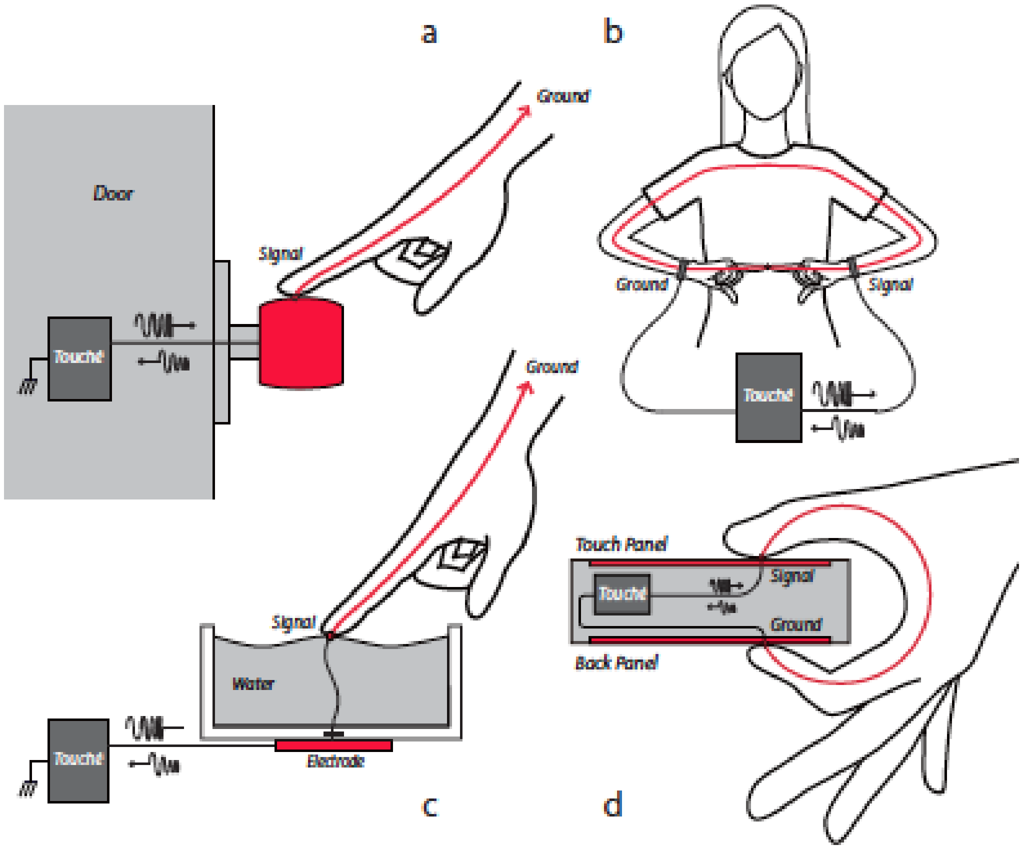
(b) Placing a second Zebra Dial on top, allows adjusting brightness and contrast

The Touché Approach (1/3)

- Touché proposes a **novel technique** that can:
  - detect touch events
  - recognize complex configurations of the human hands and body
- Uses the conductive properties of the human body to detect:
  - how the user is touching the object
  - how the user is connected to the ground
  - the current configuration of the human body and individual body properties
- As a user touches different objects or parts of their body, signals flow through slightly different paths and denote various messages

The Touché Approach (2/3)

- The user interacts with an object that is attached to a Touché sensor board via a single wire
- If the object itself is conductive, the wire can be attached directly to it
- Otherwise, a single electrode has to be embedded into the object and the wire attached to this electrode



The Touché Approach (3/3)

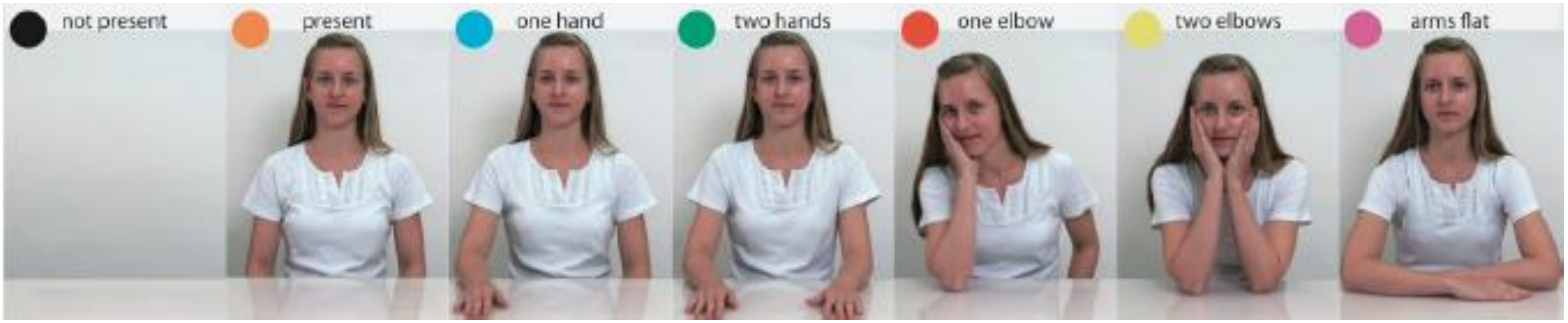
- Example Touché Applications
  - Making everyday objects touch gesture sensitive
  - Sensing human bimanual hand gestures
  - Sensing human body configuration (e.g., pose)
  - Enhancing traditional touch interfaces
  - Sensing interaction with unusual materials (e.g., liquids)

Touché: Making objects touch and grasp sensitive

- If analogue or digital objects can be made aware of **how they are being touched**, held or manipulated, they could configure themselves in meaningful and productive ways
- Touché offers a lightweight, non-invasive sensing approach that makes it very easy to add touch and gesture sensitivity to everyday objects
- **Example** - A smart doorknob that can sense how a user is touching it could have many useful features
  - closing a door with a tight grasp could lock it
  - closing it with a pinch might set a user's away message, e.g., "back in five minutes"
  - a sequence of grasps could constitute a "grasp password" that would allow an authorized user to unlock the door

Touché: Body Configuration Sensing

- Touché can be used to sense the configuration of the entire human body
- **Example 1** - a door could sense:
  - if a person is simply standing next to it
  - if they have raised their arm to knock on it
  - If they are pushing the door
  - or if they are leaning against it
- **Example 2** - a chair or a table could sense the posture of a seated person:
  - reclined or leaning forward
  - arms on the armrests or not
  - one or two arms operating on the surface



Touché: Enhancing Touchscreen Interaction

- Touché brings new and rich interaction dimensions to conventional touch surfaces by **enhancing touch** with sensed **hand posture**
- **Example -** Touché could sense the configuration of:
  - fingers holding a device
    - if they are closed into a fist or held open
    - whether a single finger is touching, all five fingers, or the entire palm
  - the part of the hand touching the device
    - fingertips or knuckles

Touché: On-Body Gesture Sensing

- Unlike inanimate physical objects, the human body is highly variable and uncontrolled, making it a particularly challenging "**input device**"
- Touché takes advantage of the conductive properties of the body and uses the skin as a touch sensitive surface while being **minimally invasive**
  - Electrodes can be worn like a wristwatch

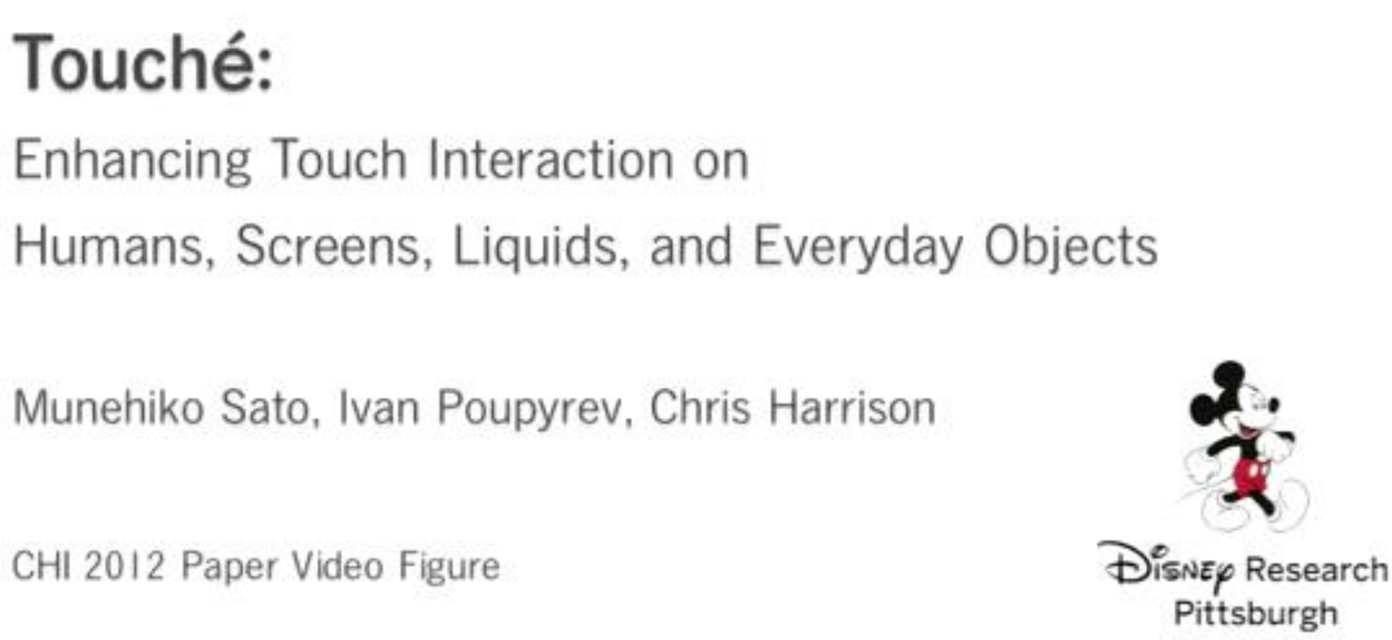
Touché: Sensing Gestures in Liquids

- By interacting with water, we do not mean using touch screens under water, but **touching the water itself**
- Touché can distinguish between a user **touching the water's surface** and **dipping their finger into it**
  - by placing an electrode on the bottom of the water vessel

Touché: Video

[Touché: Enhancing Touch Interaction on Humans, Screens, Liquids, and Everyday Objects]

http://www.youtube.com/watch?v=uanM3YGflVw



Gestures

Definition

"A gesture is a motion of the body that contains information. Waving goodbye is a gesture. Pressing a key on a keyboard is not a gesture because the motion of a finger on its way to hitting a key is neither observed nor significant. All that matters is which key was pressed."

[*Kurtenbach and Hulteen (1990)*]

"Any physical movement that a digital system can sense and respond to without the aid of a traditional pointing device such as a mouse or stylus. A wave, a head nod, a touch, a toe tap, and even a raised eyebrow can be a gesture."

[*Dan Saffer – Designing Gestural Interfaces (2009)*]

The role of gesture in communication

- Gesture plays an important role in **pre-linguistic communication** for babies
- As well as aids **cognition** and fully **linguistic communication** for adults
  - People use gesture to conceptually plan speech production
  - and to communicate thoughts that are not easily verbalized
- Gesture also plays a helpful role for the speaker
  - Gesturing has been shown to lighten cognitive load for both adults and children
- Systems that constraint gestural abilities (e.g,. having your hands stuck on a keyboard) are likely to hinder the user’s thinking and communication

Gesture Classification

- Several studies have dealt with the classification of gestures, examining the role of gestures on their own, and along with speech as a representational format or as a means for displaying thoughts not conveyed in speech

Gesture	Description	Example
Beat	Small baton like movements	*A short beat marking an important point of a conversation*
Cohesive	Used to tie together thematically related but temporally separated portions of discourse	*Hand gestures during a politician’s speech, e.g., when highlighting a series of points*
Deictic	Aspects of the discourse are spatialized or located in the physical space in front of the narrator	*Put that there*
Emblematic / Symbolic	Gestures that have a specific single meaning within each culture	*The American V-for-victory*
Iconic / pantomimic	Some feature of the action or event being described is depicted	*Would you like to go [fishing] tomorrow?, accompanied by a gesture of throwing the fishing line to the water*
Metaphoric	The represented concept has no physical form	*The meeting went [on and on], accompanied by a rolling motion of the hand*

Human Based Gesture Vocabulary (1/2)

- Gesture research shows that there is **no** such thing as a **universal gesture vocabulary**
  - so a good gesture vocabulary may only match one specific application and user group
- The gesture vocabulary must be **tailored** for the specific **task** and contain gestures:
  - Easy to perform and remember
  - Intuitive
  - Metaphorically and iconically logical towards functionality
  - Ergonomic; not physically stressing when used often
- The system should be able to recognize gestures unambiguously

Human Based Gesture Vocabulary (2/2)

- Biomechanics and ergonomics tell about **constraints** in postures and the usage of the gestures, such as avoiding to stay in static positions, and moving joints too far from their neutral positions
- There are constraining relationships between individual joints within fingers and between neighboring fingers
  - These constraints are different in people
- The ergonomics show that it is important to make the recognition algorithms **tolerant to de-stressing movements**, which allows the user to avoid staying fixed in e.g. a static “residue” or “pointing” gesture
- **Tolerance for deviations** in gestures is desirable when implementing gesture interfaces
  - Because of varying hand shapes and posture performance

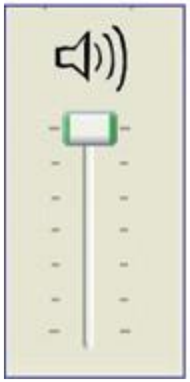
Image Schemas

- Image schemas are **knowledge about the world** that is expected of a typical user
- **Everyone develops image schemas** starting from their earliest interactions with the world as babies
- They are developed **based on experiences with the physical world** and they allow people to apply general concepts to multiple scenarios
  - Up-Down us an excellent example of an image schema
  - Up-Down is intuitively applied to many concepts like quantity or volume

Primary Metaphors

MORE IS UP

LESS IS DOWN



- **Primary metaphors** are the relationships between the image schema and the abstract concepts
- When designing natural gestures, primary metaphors should be leveraged whenever possible to express abstract concepts within the application
  - the primary metaphor **MORE IS UP – LESS IS DOWN** can be found in a vertical sliding gesture for controlling the volume of speakers
  - when we walk along a path, waypoints in front of us will be reached at a later time from now. This pervasive experience grounds the metaphor **THE FUTURE IS IN FRONT – THE PAST IS BEHIND**
  - familiarity tends to co-occur with physical closeness, forming the metaphor **FAMILIAR IS NEAR – UNFAMILIAR IS FAR**

Procedure to Finding Gestures

- Nielsen et al (2004), presented some **important issues** in choosing the set of gestures for an interface **from a user-centred view** such as the learning rate, ergonomics, and intuition
- A procedure was proposed for selecting appropriate gestures:

A. **Find the Functions**
   - Find the functions needed by the application and which the gestures will have to communicate

B. **User Tests – Collect Gestures from User Domain**
   - The goal is to find the gestures that represent the functions found in step A
   - This is done through experiments with people by taking them through scenarios under camera surveillance where they communicate the above functions

C. **Analysis – Extract Gesture Vocabulary**
   - The video recorded data is evaluated to extract the gestures that the testees used in their interaction

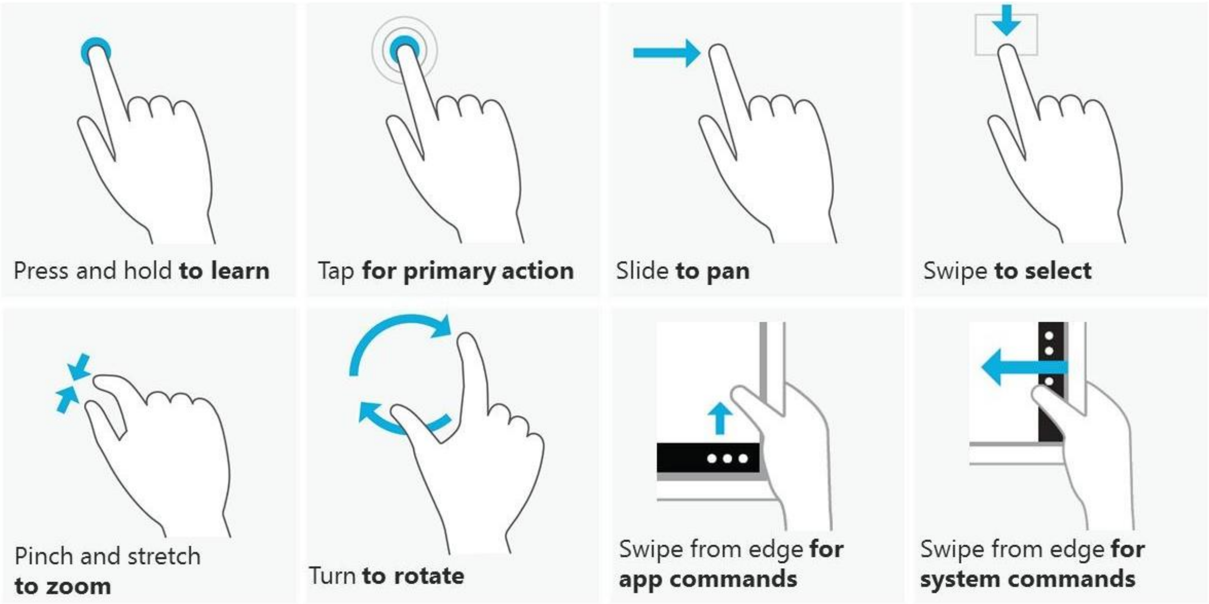
D. **Test – Benchmark the Chosen Gesture Vocabulary**
   - Test the resulting gesture vocabulary

Gesture Interfaces Categories

1. Gestures **on a touch display** or **pad**
   - as in the iPad or an ATM
   - also known as TUI (touch user interfaces)
2. Gestures **through a controller**
   - such as the Wiimote
3. Gestures identified by a **vision-based system**
   - such as the Kinect
   - also known as NUI (natural interaction interfaces)

Touchscreen gestures

- Interfaces manipulated by gestures performed by the finger or hand on a touchscreen or touchpad
  - Most common class of gesture interfaces
  - Point of Sales systems (POS) and kiosks are common public applications
- Multi-touch systems
  - Introduced to the mass market by Apple through MacBook’s MagicPad and made popular through the iPhone/iPod Touch mobile devices



iOS 7 Gesture Interaction Guidelines

- **Avoid associating different actions with the standard gestures**
  - Unless your app is a game, redefining the meaning of a standard gesture may confuse people and make your app harder to use
- **Avoid creating custom gestures that invoke the same actions as the standard gestures**
  - People are used to the behavior of the standard gestures, and they don’t appreciate being expected to learn different ways to do the same thing
- **Use complex gestures as shortcuts to expedite a task, not as the only way to perform it**
  - As much as possible, always give users a simple, straightforward way to perform an action, even if it means an extra tap or two. Simple gestures let users focus on the experience and the content, not the interaction
- **In general, avoid defining new gestures unless your app is a game**
  - In games and other immersive apps, custom gestures can be a fun part of the experience. But in apps that help people do things that are important to them, it’s best to use standard gestures because people don’t have to make an effort to discover them or remember them
- Always bear in mind that nonstandard gestures aren’t discoverable and should rarely, if ever, be the only way to perform an action

Vision-based gesture interfaces

- Interfaces that are operated through gestures **captured by** one or more **cameras**
- **Examples** include the Gestix system (see figure) or Sign Language Interfaces

Gestix Gestural Interface

- Such interfaces may often be a **subset** of **Perceptual Interfaces**
  - Multimodal Interfaces that track one or more of the following: speech, expressions, body, head or eye movements, gestures

Example: the Gestix Gestural Interface

- **Gestix** is a sterile gesture interface for users, such as doctors/surgeons, to browse medical images in a dynamic medical environment
- A **vision-based** gesture capture system interprets user's gestures in real-time to **navigate** through and **manipulate** an image and data visualization environment
- Dynamic navigation gestures are translated to commands based on their relative positions on the screen
- A state machine switches from **navigation gestures** to others such as **zoom** and **rotate**

Gestix video

[Innovative Technology: Hand Gesture system]() available at: http://www.youtube.com/watch?v=gSyjFLBsIHg

Applications

Apart from the devices mentioned:

- Sign Language Interfaces
- Remote device operation through gestures
  - The Clapper
    - a sound activated electrical switch
    - first mass market gestural interface
  - TV zapping through hand motions
  - PowerPoint Presentations
  - Public restrooms (faucets, toilet paper dispensers, lights)
- Gaming (Wii, Arcades)

Why use them (1/3)

- **More natural** interactions
  - Human beings are physical creatures; they like to interact directly with objects
  - Interactive gestures allow users to interact naturally with digital objects in a physical way, like they do with physical objects
- **Less cumbersome** or visible **hardware**
  - With many gestural systems**, the usual hardware** of a keyboard and a mouse **isn’t necessary**: a touchscreen or other sensors allow users to perform actions without this hardware
  - This benefit allows for gestural interfaces to be put in places where a traditional computer configuration would be impractical or out of place, such as in retail stores, museums, airports, and other public spaces

Why use them (2/3)

- Eyes-free
  - Performed without having to watch the screen closely
- Silent interaction
  - Less obtrusive than e.g., voice input
- More flexibility
  - As opposed to fixed, physical buttons, **a touchscreen**, like all digital displays, **can change at will**, allowing for many different configurations depending on functionality requirements
  - Thus, a very small screen (such as those on most consumer electronics devices or appliances) can change buttons as needed
  - This can have usability issues, but the ability to have many controls in a small space can be a huge asset for designers
  - With **non-touchscreen gestures**, **the sky is the limit, space-wise**. One small sensor, which can be nearly invisible, can detect enough input to control the system. No physical controls or even a screen are required

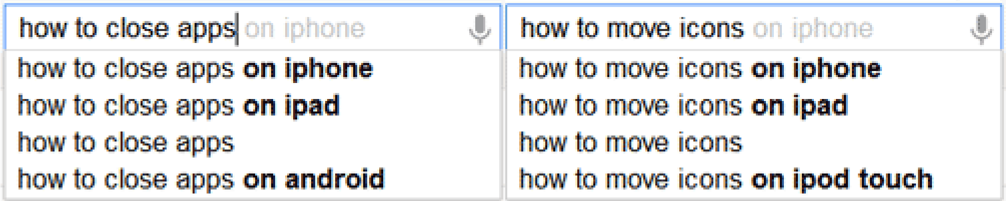
Why use them (3/3)

- **More nuance**
  - Keyboards, mice, trackballs, styli, and other input devices, although excellent for many situations, are simply not as able to convey as much subtlety as the human body
  - A raised eyebrow, a wagging finger, or crossed arms can deliver a wealth of meaning in addition to controlling a tool. Gestural systems **have not begun to completely tap** the wide emotional palette of humans that they can, and likely **will, eventually exploit**
- **More fun**
  - You can design a game in which users press a button and an on-screen avatar swings a tennis racket
  - But it is simply **more entertaining**—for both players and observers — **to mimic swinging** a tennis racket physically and see the action mirrored on-screen
  - Gestural systems encourage play and exploration of a system by providing **a more hands-on** (sometimes literally) **experience**

Challenges: Discoverability

- Similarly to command-line interfaces, gesture interfaces **do not offer clues** as to what the gestures actually are (memorization vs. GUI recognition)
  - **GUIs offer verbs** as commands in buttons (“delete”, “apply**”). Gestures are the verbs** themselves
- **Some** gestures are becoming **mainstream** and are fairly obvious to discover, such as
  - pinch and expand for zoom, flick through lists, two-finger rotation, etc.
- Others are impossible to discover alone

Frequent searches on Google reveal the problem



Challenges: No common vocabulary

- Not all gesture interfaces use the same gestures for the same actions
  - One reason is **patents**, which is still a grey area
  - **Technology is young** and there is **no standard** way of doing things
  - The problem of discoverability means developers seek new approaches in the quest for an optimal, natural solution
- This is **not** an area for **product differentiation**. This is an area that requires **standardization**, **predictability**, and **consistency** with user expectations.

Challenges: Vision-based interfaces

- The challenges are similar to those of other vision-based interfaces (such as eye-tracking or head-pose)
  - Poor lighting conditions
  - Camera specifications of depth and angle
  - Demanding processing
  - Identifying similar gestures
  - Accuracy

Reasons NOT to have a Gestural Interface (1/3)

- **Heavy data input**
  - Although some users adapt to touchscreen keyboards easily, a keyboard is decidedly faster for most people to use when they are entering text or numbers
- **Inappropriate for context**
  - The environment can be non-conducive to a gestural interface in any number of situations, either due to **privacy** reasons or simply to **avoid embarrassing the** system's **users**
  - Designers need to take into account the probable environment of use and determine what, if any, kind of gesture will work in that environment

Reasons NOT to have a Gestural Interface (2/3)

- **Reliance on the physical**
  - Gestural interfaces **can be more physically demanding** than a keyboard/screen
  - The **broader** and more **physical** the gesture is (such as a kick), the more likely that some people **won't be able to perform** the gesture due to age, infirmity, or simply environmental conditions
    - E.g. pressing touchscreen buttons in winter gloves is difficult
  - The **inverse is also true**: the subtler and smaller the movement, the less likely everyone will be able to perform it
  - The keyboard on the iPhone, for instance, is entirely too small and delicate to be used by anyone whose fingers are large or otherwise not nimble

Reasons NOT to have a Gestural Interface (3/3)

- **Reliance on the visual**
  - Many gestural interfaces use visual feedback alone to indicate that an action has taken place (such as a button being pressed)
  - In addition, most touchscreens and many gestural systems in general rely entirely on visual displays with little to **no haptic affordances or feedback**
  - There is often **no physical feeling that a button has been pressed**, for instance. If your users are visually impaired (as most adults over a certain age are) a gestural interface may not be appropriate

- This problem may actually have a solution soon

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The End

Questions?