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

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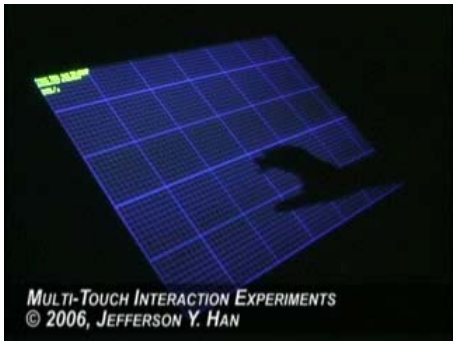
Single-Touch Interfaces

- One finger at a time
- One user at a time
- Examples:
  - ATM
  - Point-of-Sale
  - Restaurant Ordering Systems

Multi-Touch Interfaces

- Multiple simultaneous points of contact
- Inherently Multi-User
  - Interactive Walls
  - Tabletops
- Just coming to the market
  - Perspective Pixel
  - Microsoft Surface

Multi-Touch Video



Multi-Touch Interaction Experiments
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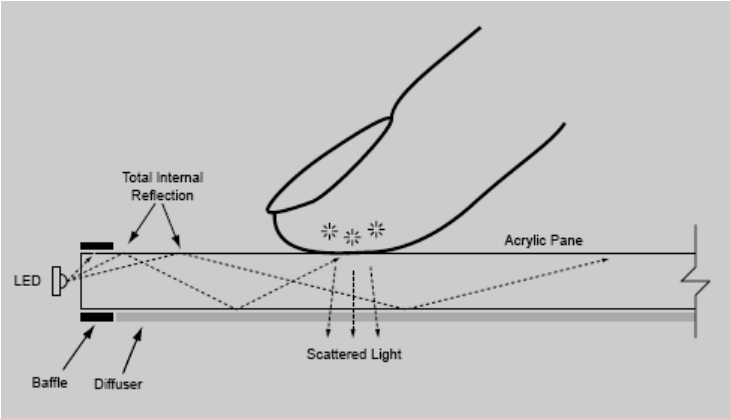
Frustrated Total Internal Reflection

- When light encounters an interface to a medium with a lower index of refraction (e.g. glass to air), the light becomes refracted.
- The extent of refraction depends on the angle of incidence, and beyond a certain *critical* angle, it undergoes *total internal reflection (TIR)*.
- Fiber Optic cable is a common technology that employs TIR.
- However, another material at the interface can *frustrate* this TIR, causing the light to escape the waveguide there instead.

Frustrated Total Internal Reflection



Implementation – Primary Components

- Acrylic Sheet (1/4" or thicker)
- Infra-Red LEDs
- IR-Detecting Camera (modified webcam)
- Projector
- Diffuser (projection surface overlay)
- Frame with Light Baffles
- Computer

Why this Approach?

- Inexpensive
  - My prototype is at $542 (not including the $2,300 projector, computer, or miscellaneous tools and "workbench" materials).
- Scalable Size
  - From handheld to full wall displays.
- Relatively simple to construct

Downsides to this Approach

- Space Behind Projection Surface Required
  - Rear-Projection
  - Camera
- Can Be Mitigated By:
  - Short-Throw Projector
  - Multiple Cameras
- Doesn't tell you what finger (or what user) produced the contact.
- Doesn't provide "hover" information (might not be a downside).

Practical Concerns (1)

- Placing the diffuser behind the acrylic causes disparity between the display and interaction surfaces.
- Mitigation:
  - Make the diffuser the interaction surface by placing it on top of the acrylic (has consequences).

Practical Concerns (2)

- Oils and Sweat will contaminate the acrylic.
- Mitigation:
  - Make the diffuser the interaction surface by placing it on top of the acrylic (has consequences).

Practical Concerns (3)

- Dry skin, directly against acrylic, generates weaker blobs.
- Why?
  - Tiny air gaps exist between your finger and the surface. Moisture provides better coupling.
- Mitigation:
  - Press Harder
  - Moisten Skin
  - Use a compliant surface (e.g. silicone) between the acrylic and the diffuser.

Practical Concerns (4)

- Modern projectors have a 2:1 throw ratio (2 feet of distance for every 1foot of diagonal display)
- Mitigation:
  - Fold the image using mirrors (I couldn't make this work well).
  - Use a short throw projector (expensive).

Practical Concerns (5)

- Modern projectors typically display horizontally, and have cooling systems designed for this orientation.
- Mitigation:
  - Use mirrors to angle the image upward – tabletop displays – not applicable for wall displays).

Practical Concerns (6)

- Need baffles on the front of the surface to reduce "backlighting" of your hand or body as it draws near the surface. This is caused from IR light "leaking" from the edges of the acrylic.
- Baffles on the underside of the acrylic are necessary to eliminate "hot spots".

Practical Concerns (7)

- Mounting camera and projector – especially a concern for portability and quickly recalibrating the setup.

Practical Concerns (8)

- Software – Free/Open Source software has a (not completely unjustified) reputation of being poorly constructed.
- TouchLib – I think this is a decent start – but is very rough around the edges.

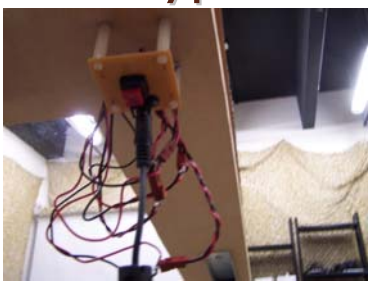
Practical Concerns (9)

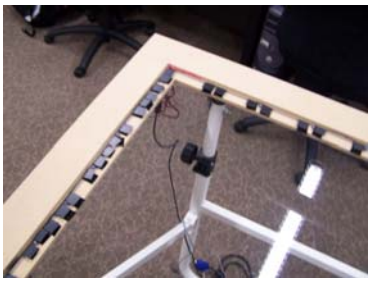
- The least expensive camera option (webcam – which is also the most easily accessed via software) filters IR light and allows visible light. We want to reverse this – allow IR light and filter visible light.
- The webcam has to be opened, and the IR filter removed. Then the webcam has to be fitted with a visible light filter.
- Problems:
  - Hard (or impossible) to open some webcams.
  - Some webcam IR filters are painted on.
  - Materials for visible light filter:
    - Exposed film negative
    - Floppy disk
    - Trash bag (multiple ply)
    - Bona-fide, commercial IR-pass filter

Prototype




Prototype



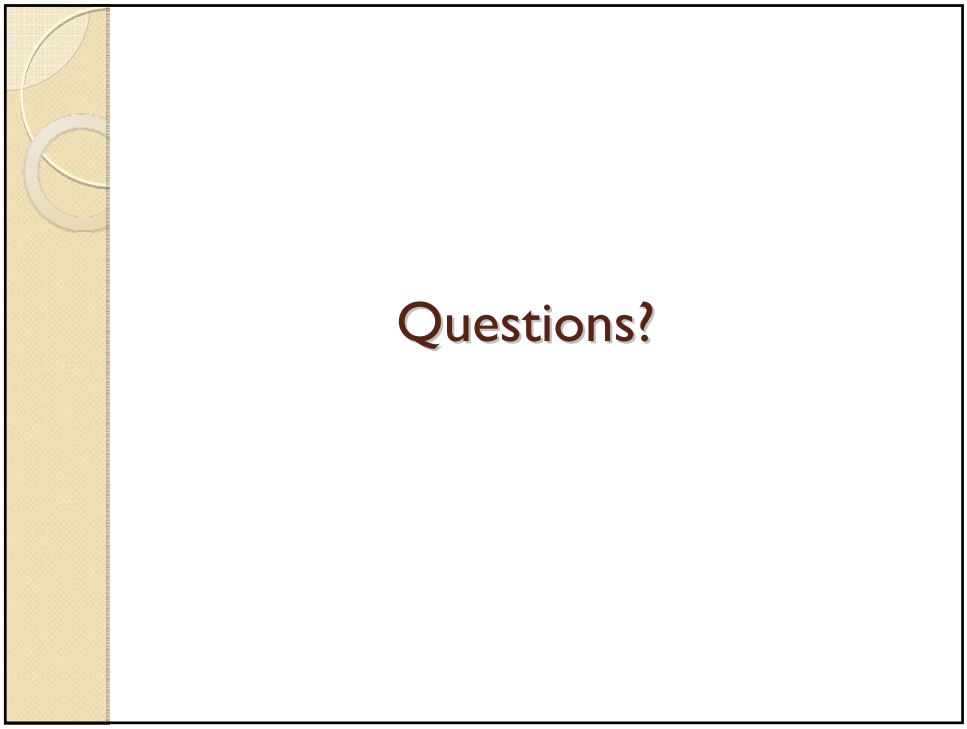



Prototype – Parts List

- 24”x36”x3/8” Acrylic Sheet
- Drafting Table
- 30”x42”x3/4” MDF Sheet
- 32 Osram SFH485 880nm IR LEDs – 4 sets wired in parallel of 8 LEDs wired in series
- 12v AC/DC power supply
- Microsoft LifeCam VX-6000 (71degree wide-angle lens, 1.3MP max resolution, up to 30fps,USB 2.0)
- Rosco Gray Rear-Projection Screen
- 3M DMS-700 Short-Throw Projector
- Silicone Rubber (Sort-A Clear 40)
- Misc. Cables/Resistors/Switches/Hardware
- Mirror

Other Applications

- Tangible Interfaces
  - Cell Phones
  - Credit Cards
  - MP3 Players
  - Anything with a fiducial/bar code on the bottom or it
- Biometric Sensing (e.g. finger/palm prints)
- Requires Visible-Light Camera(s)


Questions?