Multi-touch Sensing and Interactive Tabletops

LMU München, Medieninformatik, Otmar Hilliges,
Instrumented Environments, WS 2008/09

Interactive Surfaces

- Multi-user face-to-face collaboration
- Direct-touch interaction with digital content
- Natural and physical quality

Topics Today

- Multitouch History and Status Quo
- Approaches and Solutions
  - Hardware
  - Software
- Current Research @ LMU


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12:34 PM
SMS
Text
Tuesday
9
Calendar
Photos
Camera
Calculator
Stocks
280
Maps
73°
Weather
Notes
Clock
Settings
Phone
Mail
Web
iPod


social &
economic shifts

New?

[Lee, S., Buxton, W. , Smith, K.C. 1985]

[Krueger, 1983]

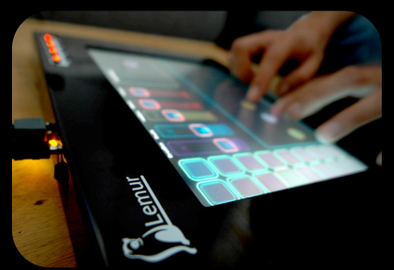
[Buxton, W. 1994]

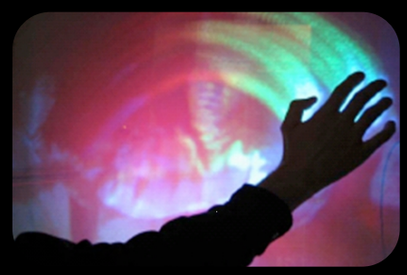
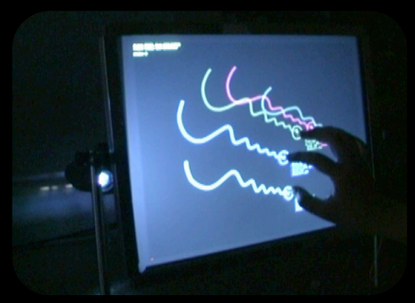
25+ Years of Research

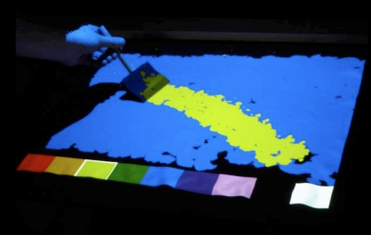
Approaches & Solutions

- Embedded sensors
  - Capacitive
  - Resistive
  - Optical
- Camera Infrared
  - FTIR
  - Diffuse Illumination
- Others





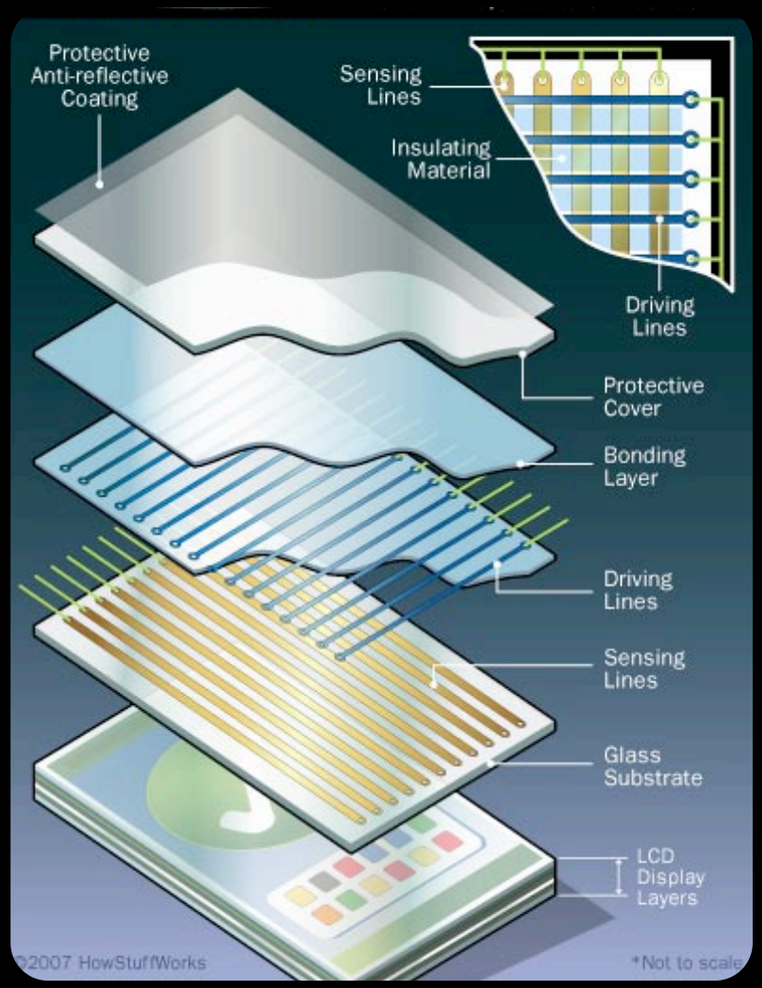



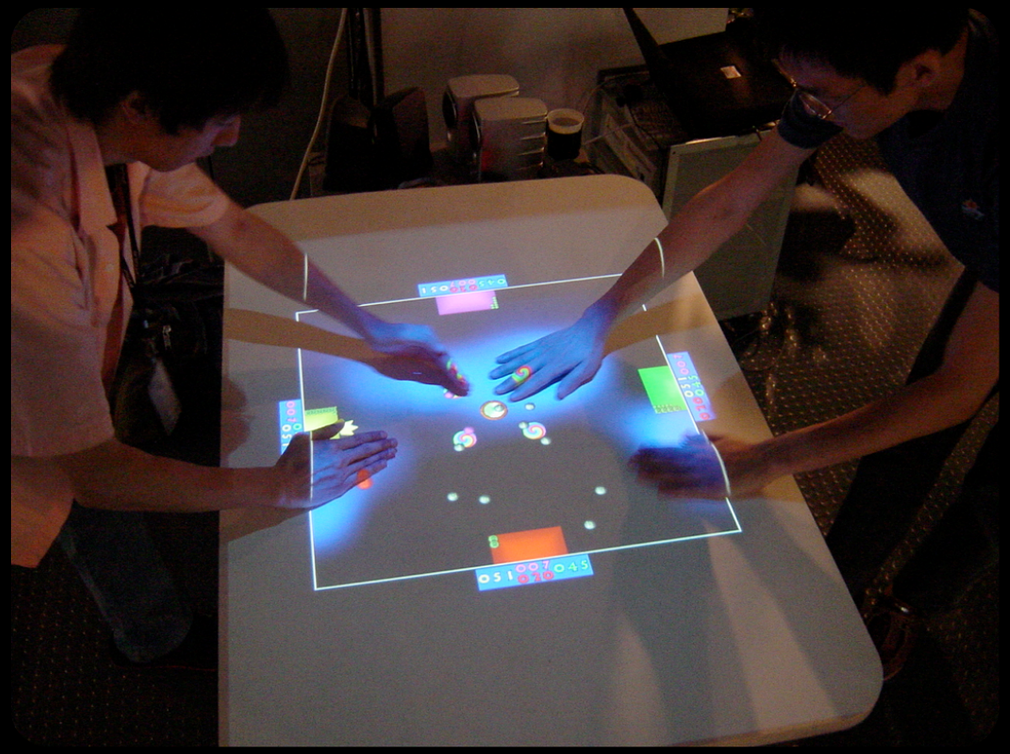
Capacitive Sensing

- Layer of conductive material holds charge
- Finger depressing surface changes amount of charge
- MT requires grid of driving and sensing lanes
- OR individual electrodes embedded in one layer

[Dietz Leigh'01]

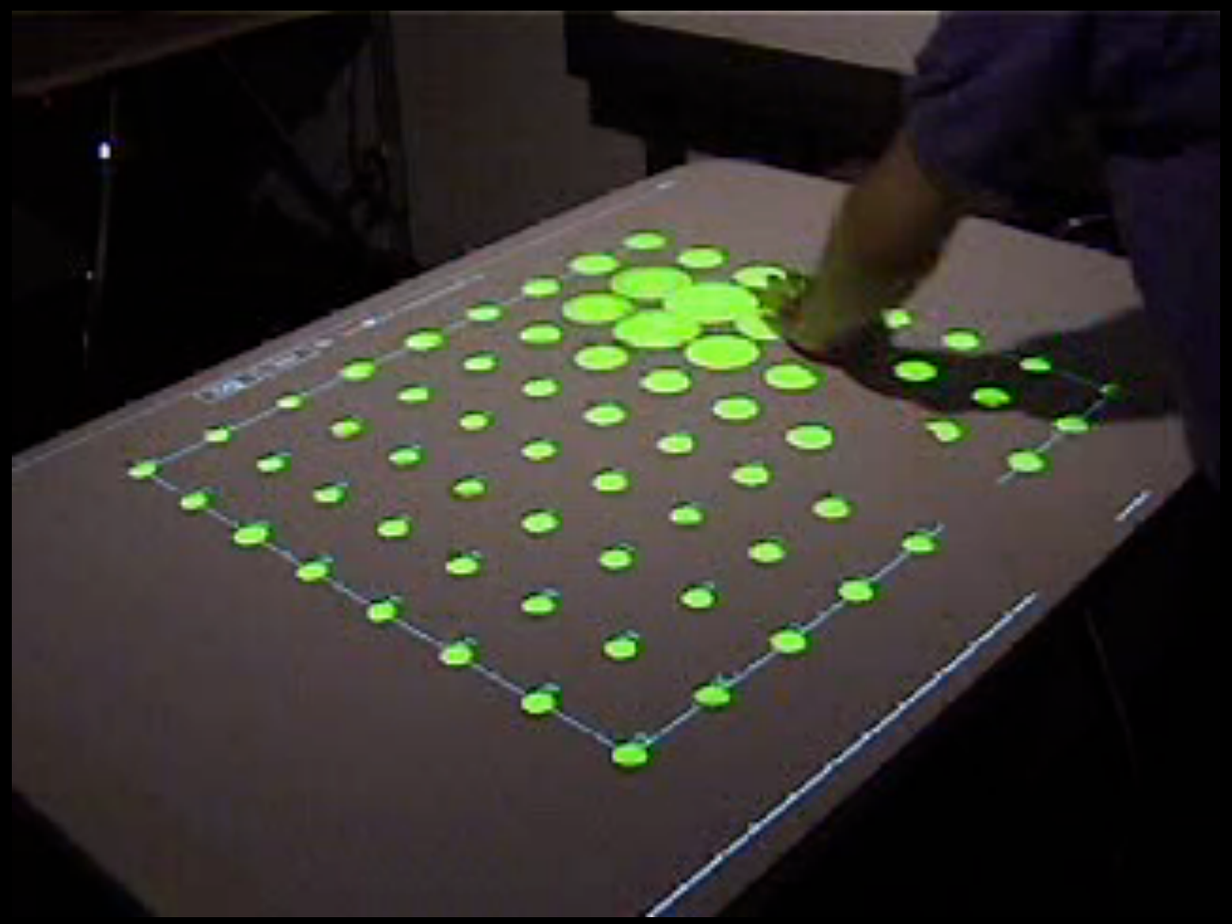
[Rekimoto'02]





[Jun Rekimoto, SmartSkin, CHI 2002]

Smartskin Video



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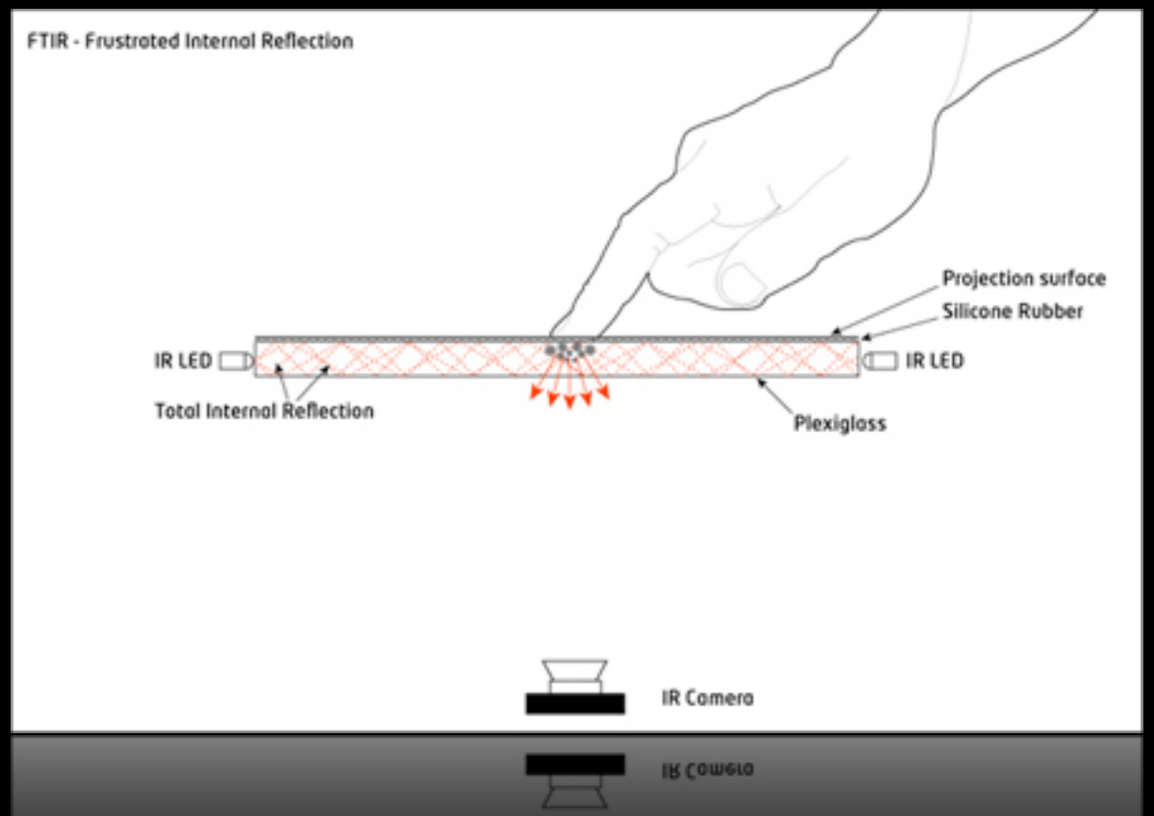
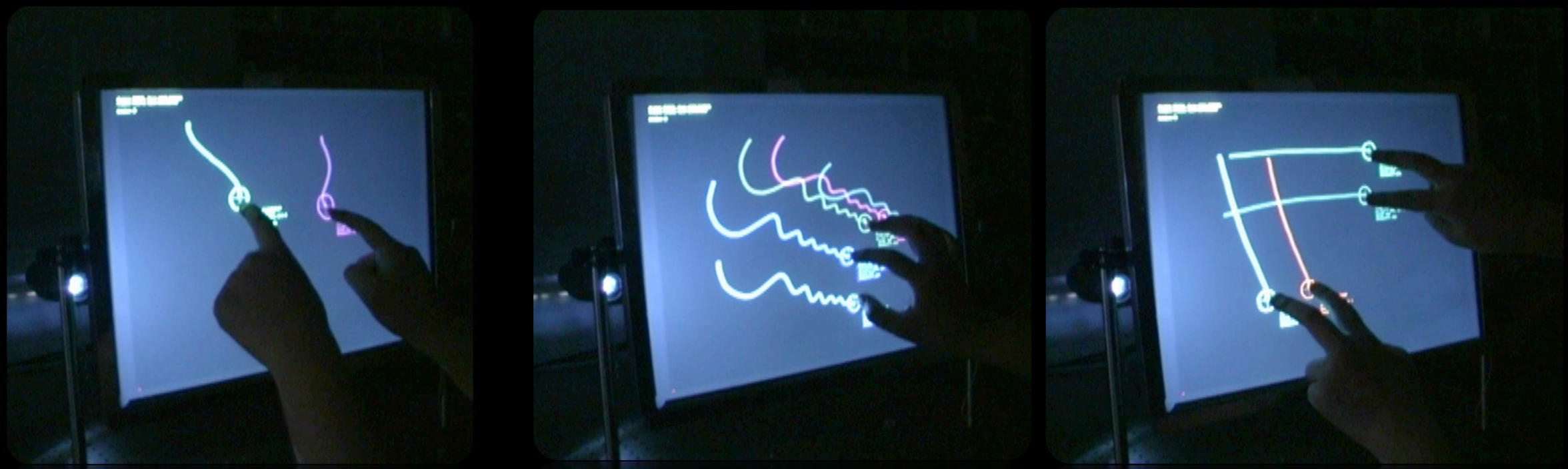
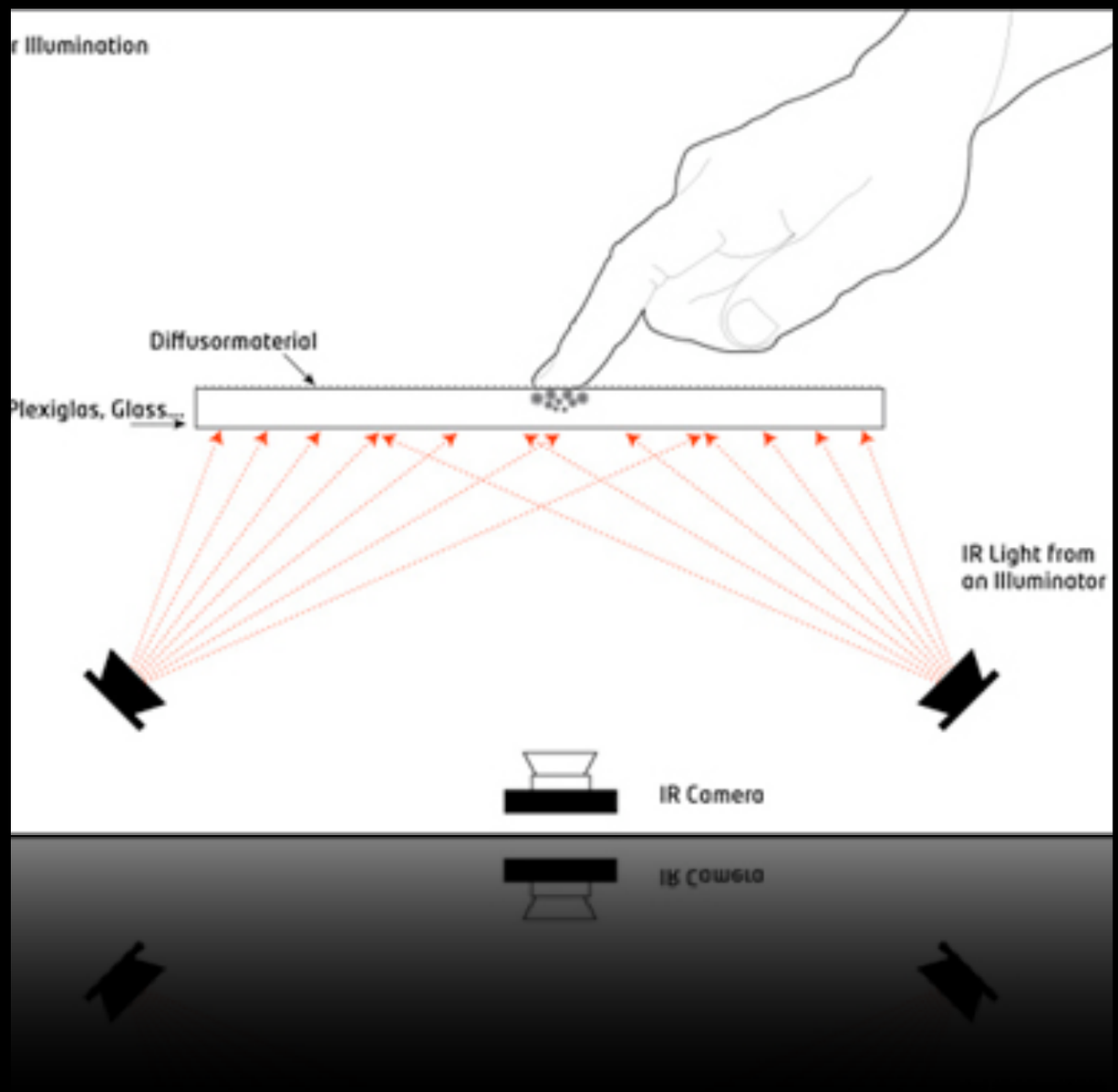


http://iad.projects.zhdk.ch/multitouch/

Optical Sensing - FTIR



[Han, J.Y. UIST 2005]



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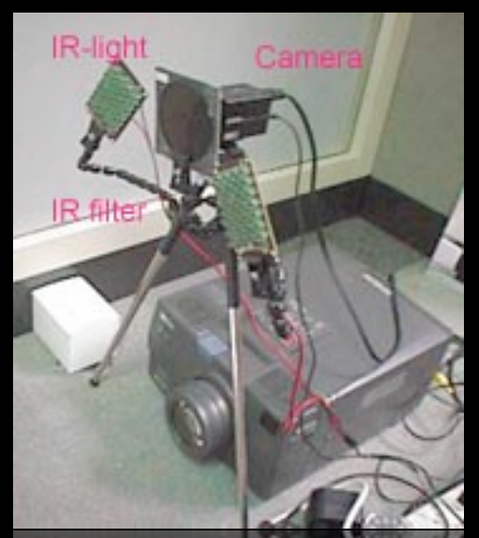
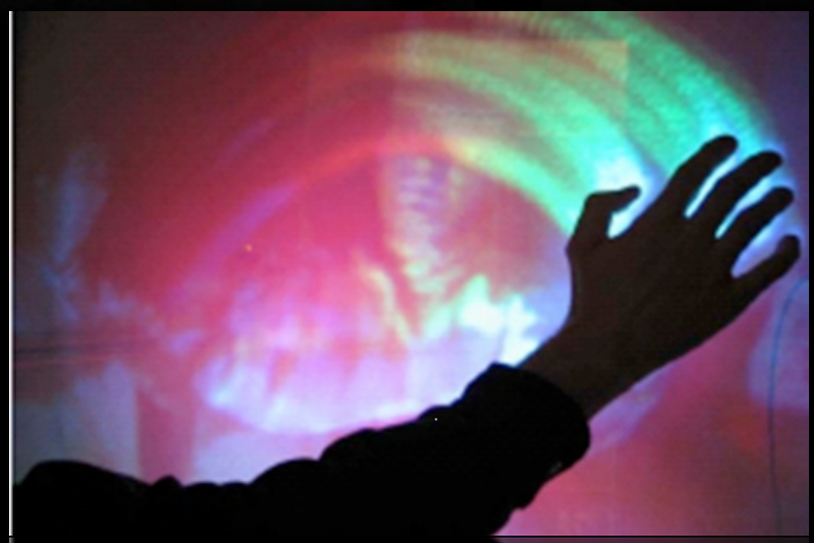
Optical Sensing - DI



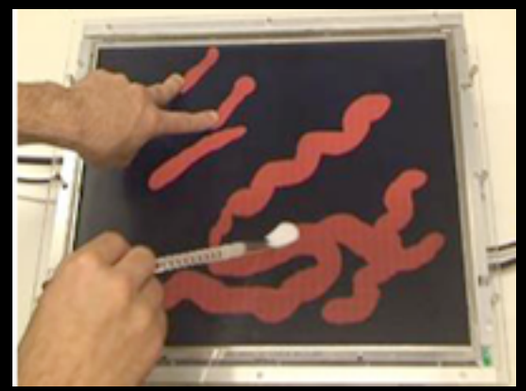
[Jun Rekimoto, HoloWall, UIST 1997]

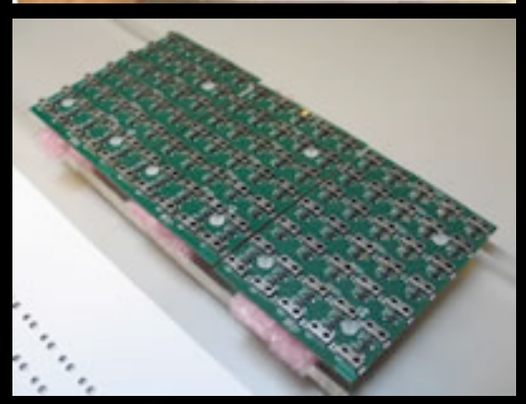


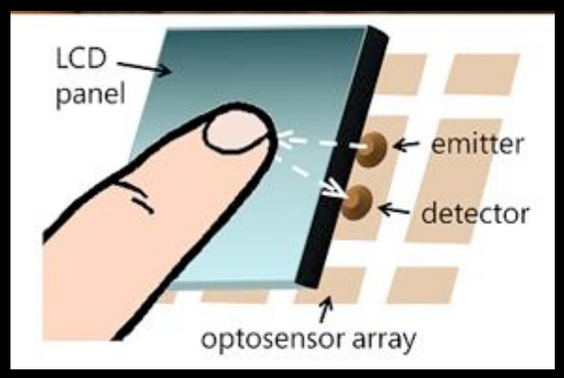
[Andy Wilson, TouchLight, ICMI 2004]

[Jorda, S., ReacTable, ICMI ICMC2005]

Embedded Optical Sensing







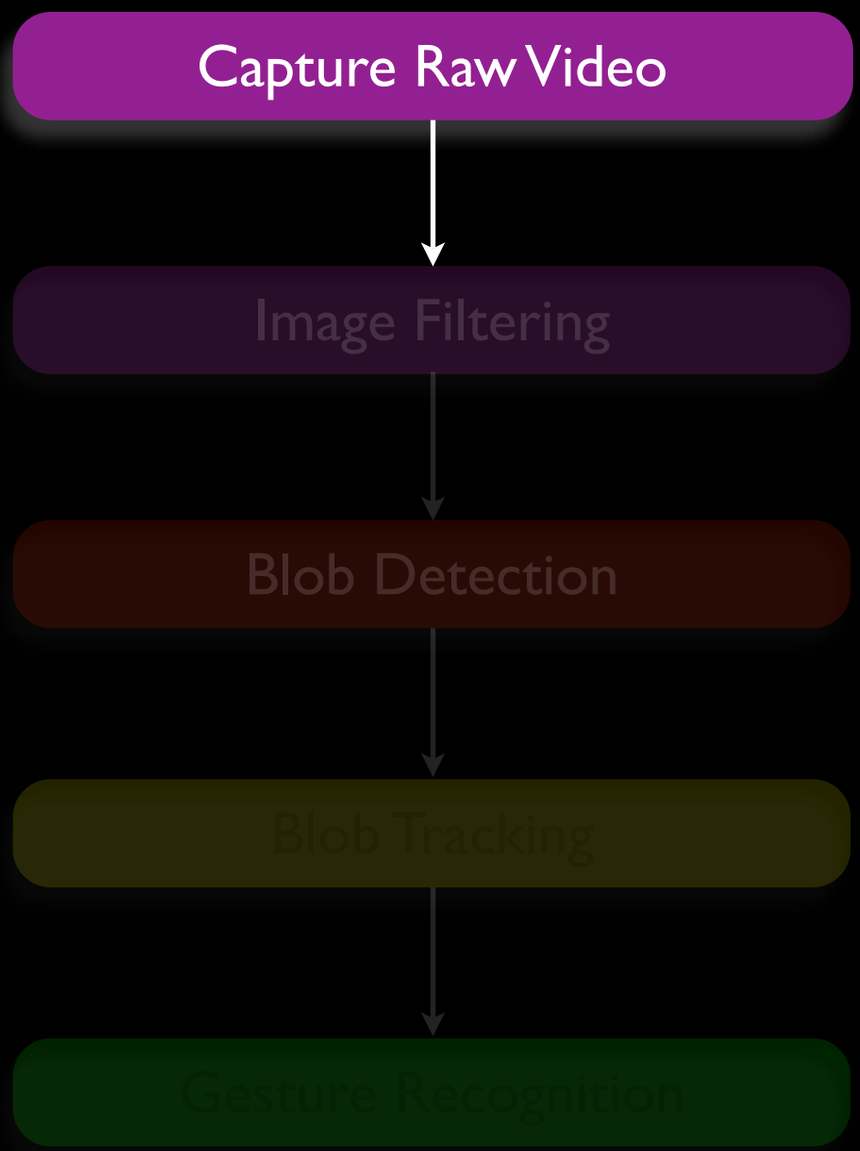
- optical sensing through LCD display
- thin form factor
- embedded IR emitters and detectors

[Hodges et al. UIST'07]

Summary Hardware Approaches

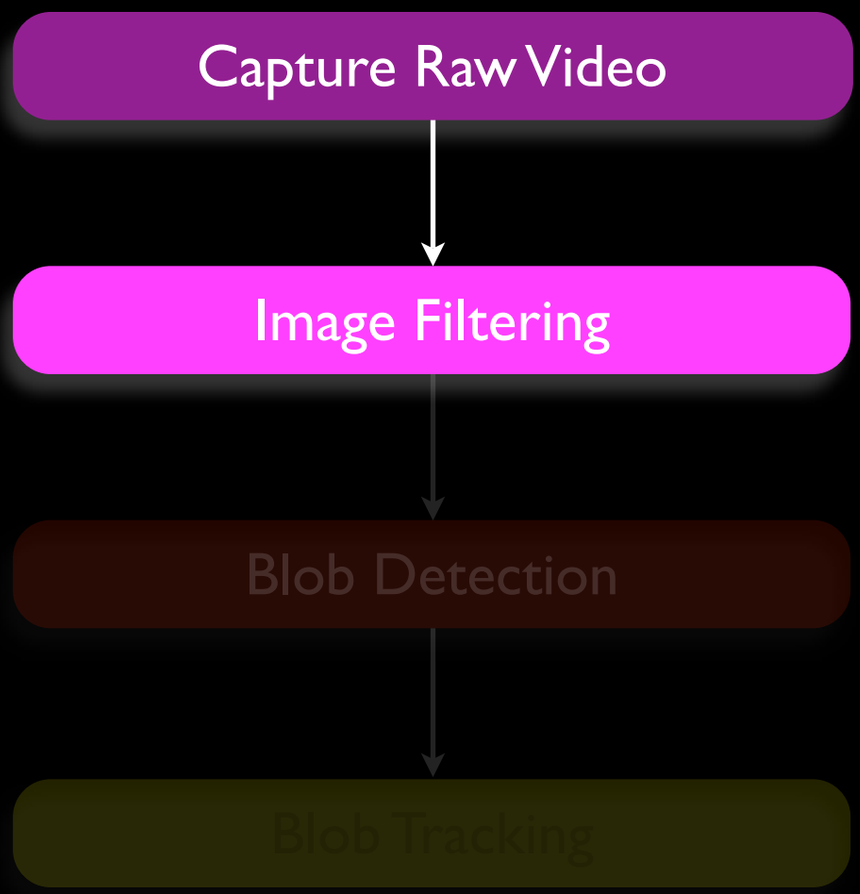
- A raft of different possibilities to sense
  - multiple simultaneous contacts
  - objects
  - objects & fingers
  - rich contour and shape information (object outlines, whole hands)
- Everything is in flux - every approach has different drawbacks & advantages

Software - Basics



Raw Camera Image - DI

Software - Basics



Filtered Image - DI

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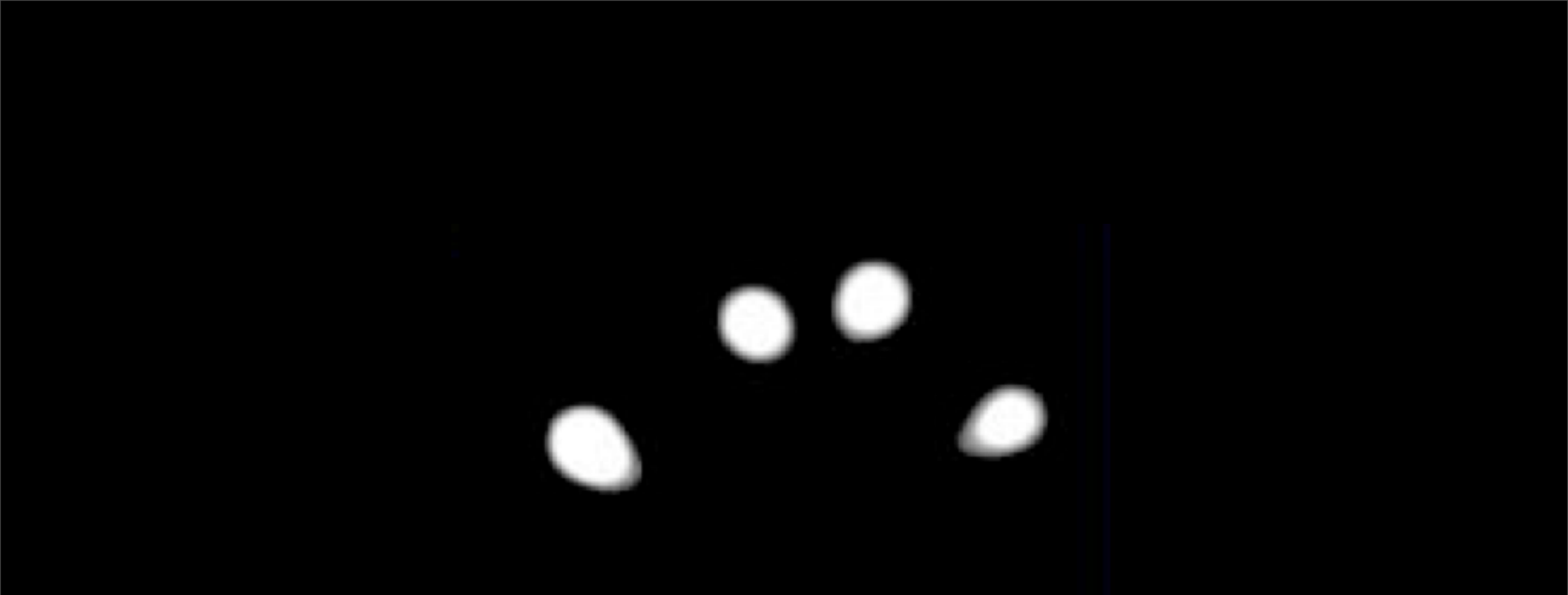

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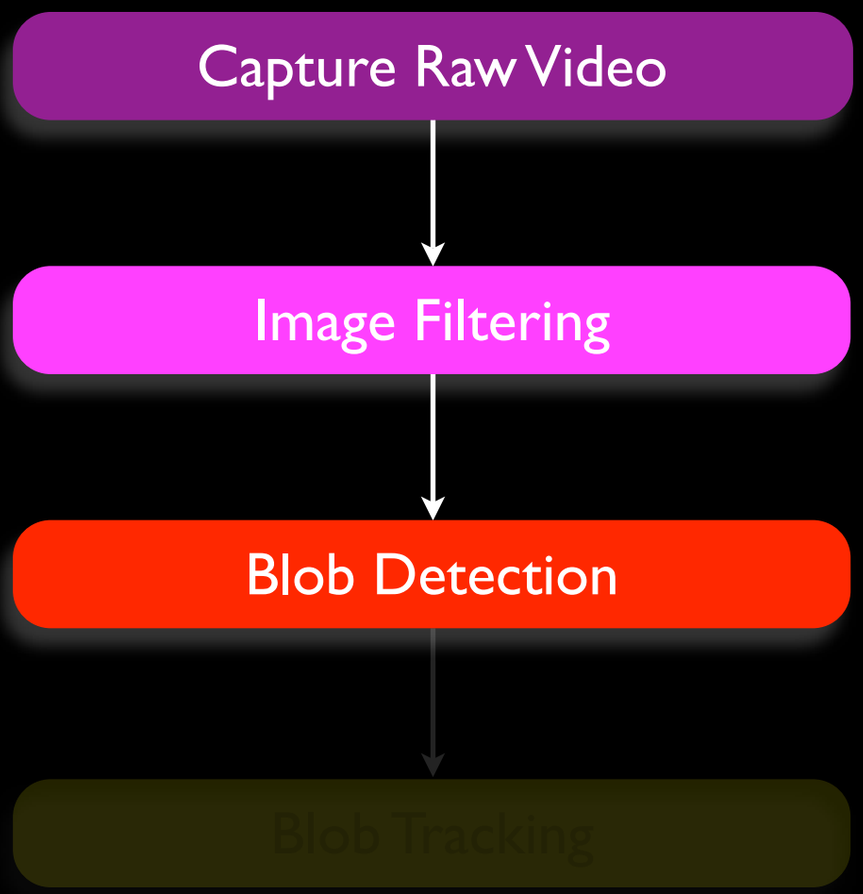
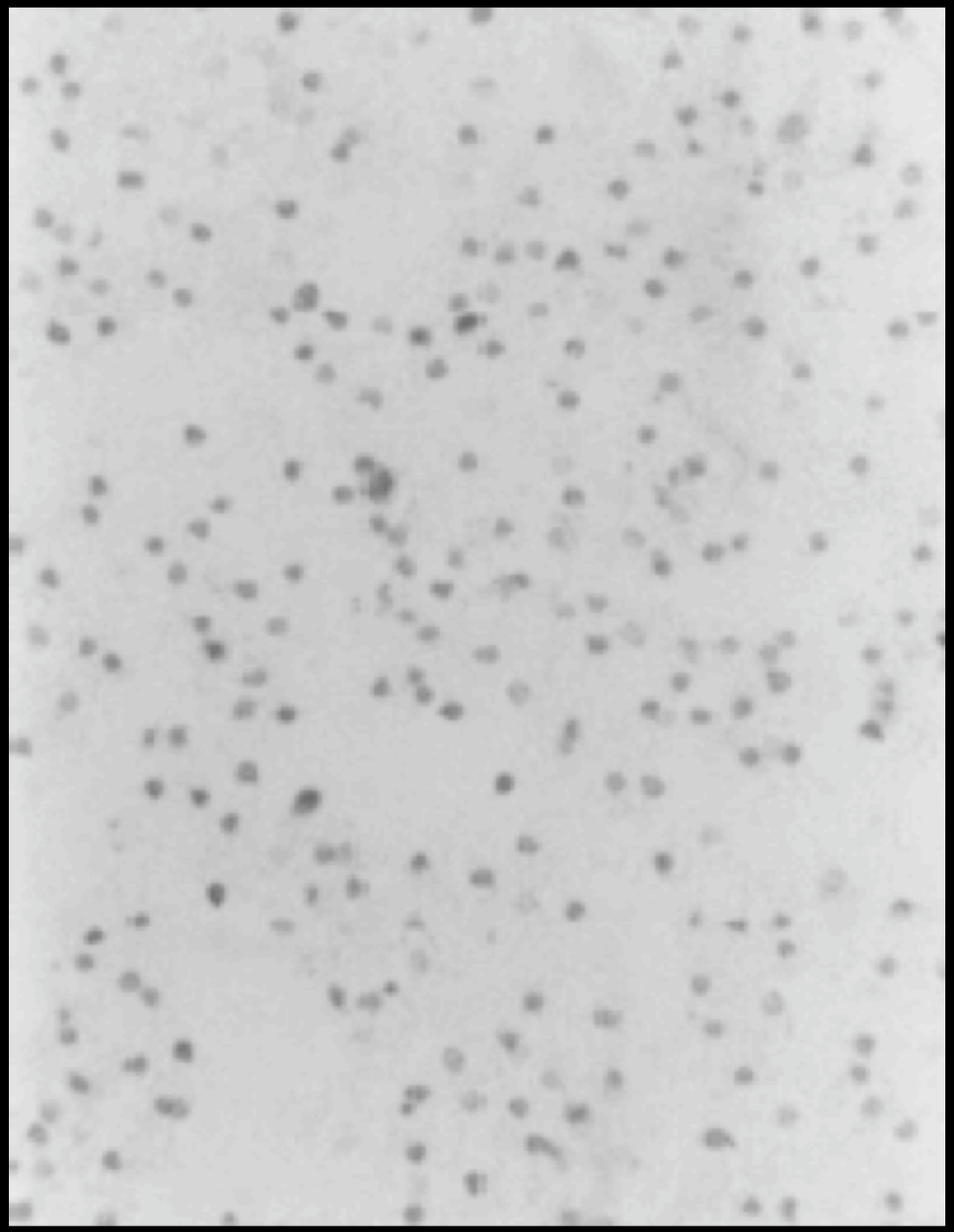


Blob Detection



Connected Component Analysis - Principle

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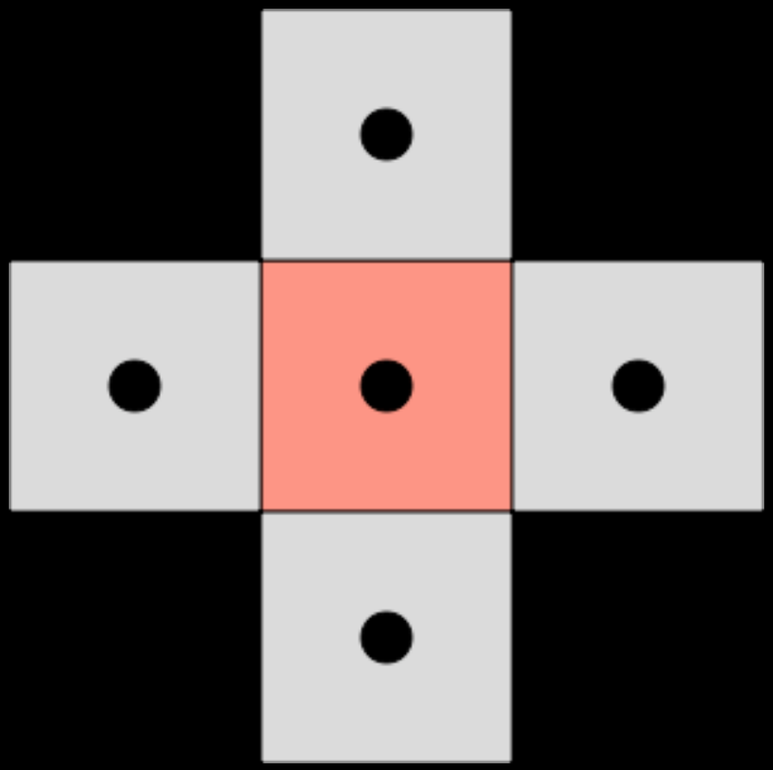
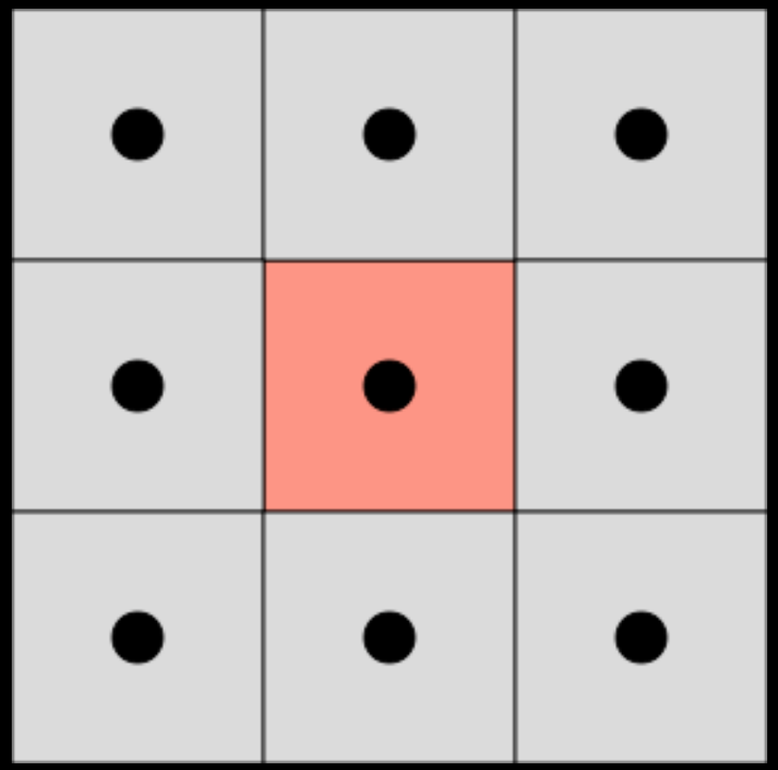
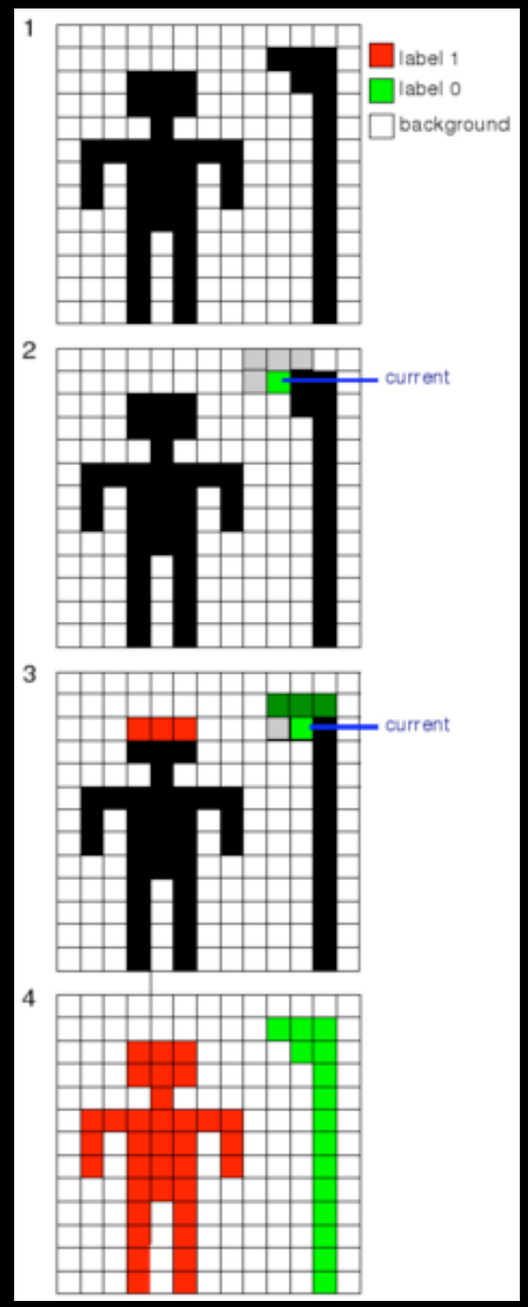


4-Connectivity



8-Connectivity

- Pass I:
  - iterate over image, row - major
  - If not background
    - neighborhood test
    - no neighbors -> new label
    - else -> lowest neighboring label
- Pass II:
  - iterate over image, row - major
  - If not background
    - find equivalent labels
    - relabel



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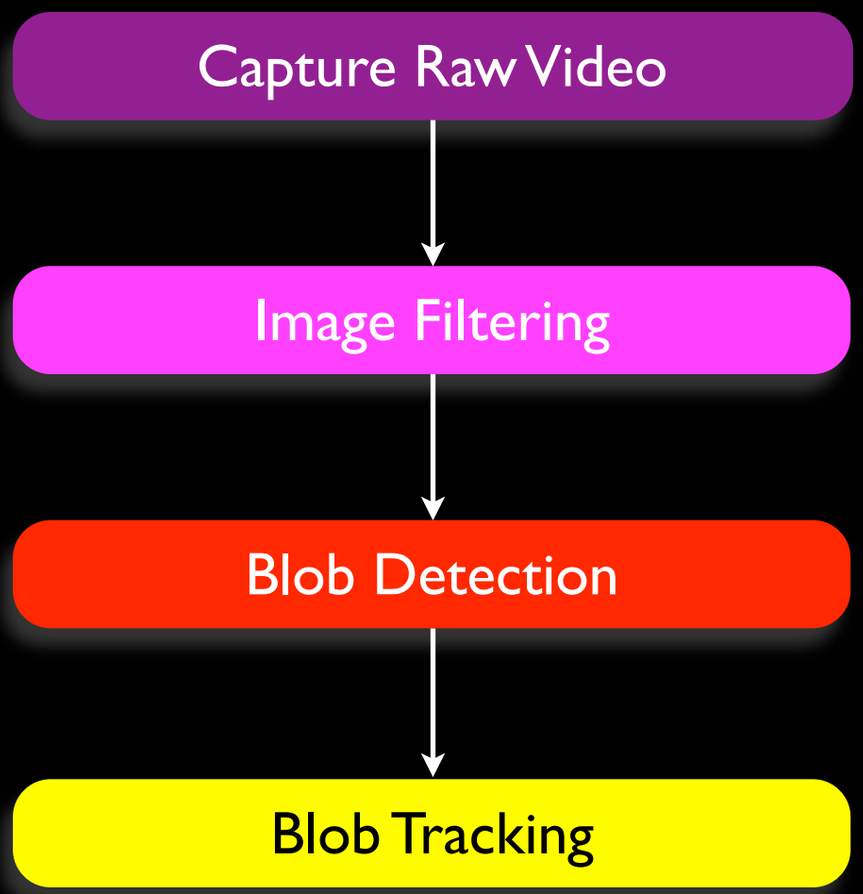

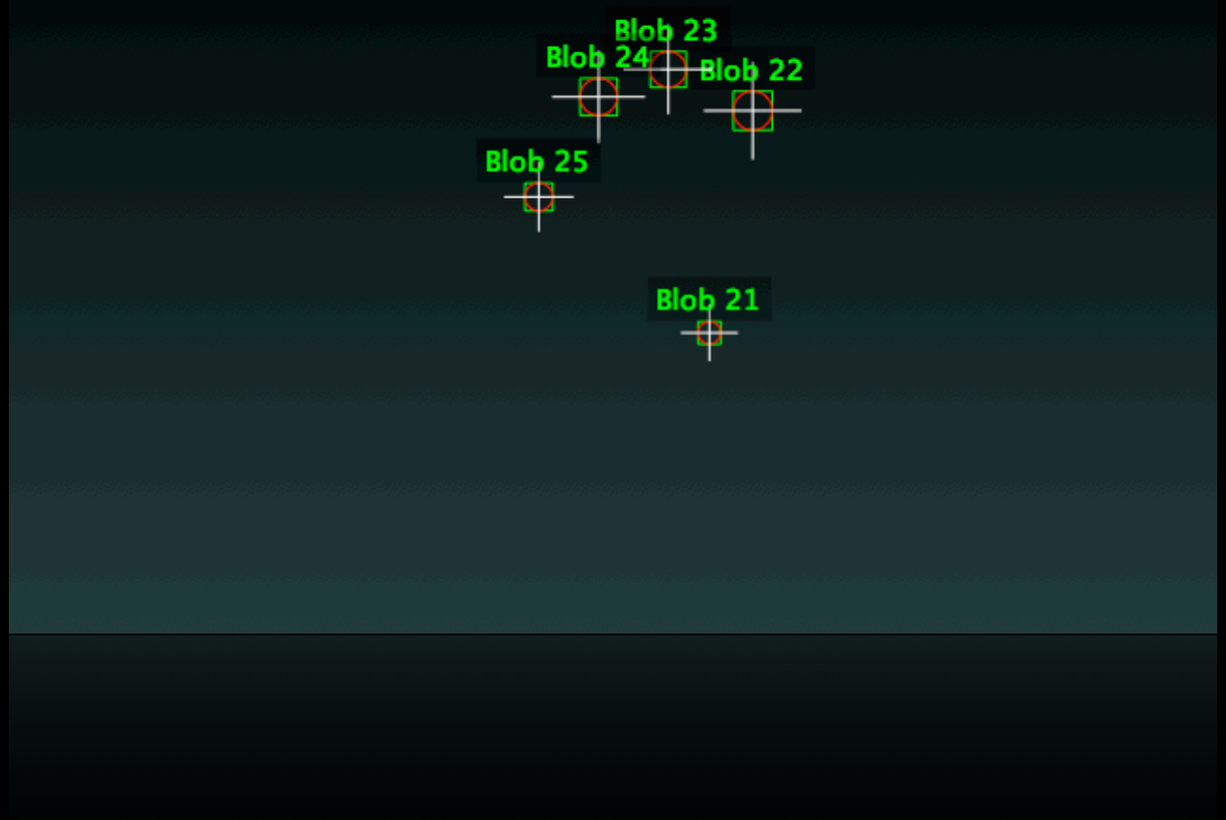

Blob Detection

Blob Tracking Principle

- Detect blobs
- Save blob positions over several frames
- Compare blob positions across frames
  - Use heuristics to identify blobs (euclidean distance)

Problems with Blob Tracking I

- Fingers move
  - blob size changes
  - orientation and major / minor axis change
  - center-of-mass changes rapidly -> jitter in the interface

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- Fingers move
  - blob size changes
  - orientation and major / minor axis change
  - center-of-mass changes rapidly -> jitter in the interface
- Possible Solution:
  - Temporal smoothing (Kalman filtering)
  - Motion prediction (dead reckoning)

Problems with Blob Tracking II

- Hit testing is ambiguous

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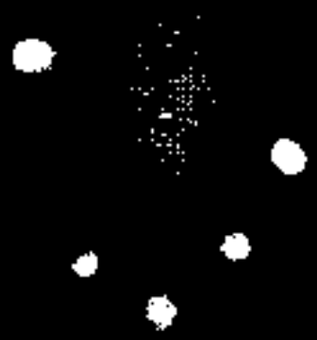

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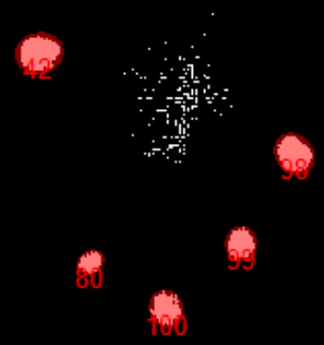

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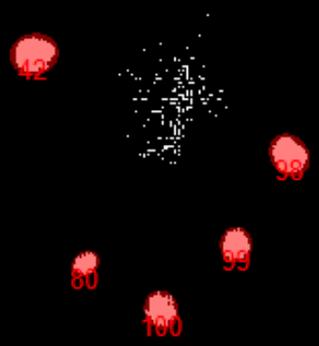

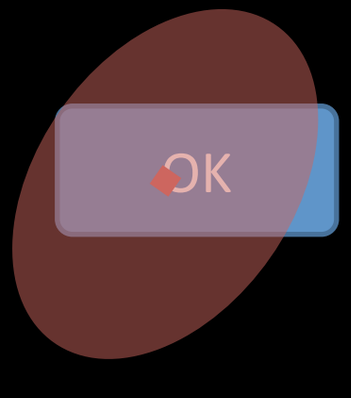

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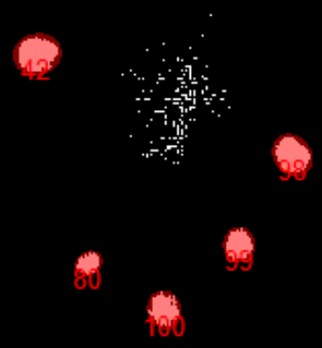

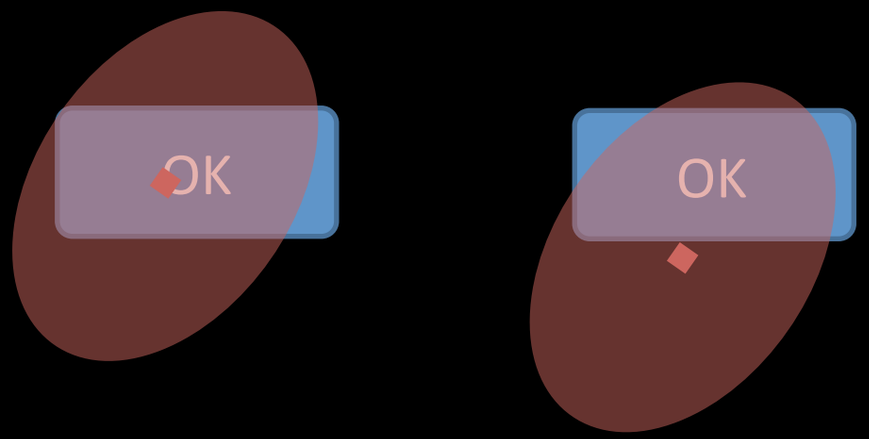

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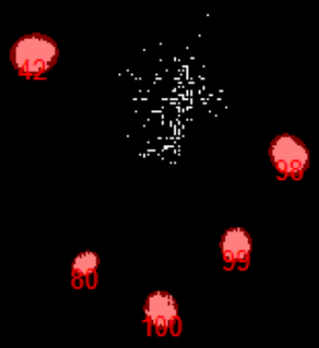
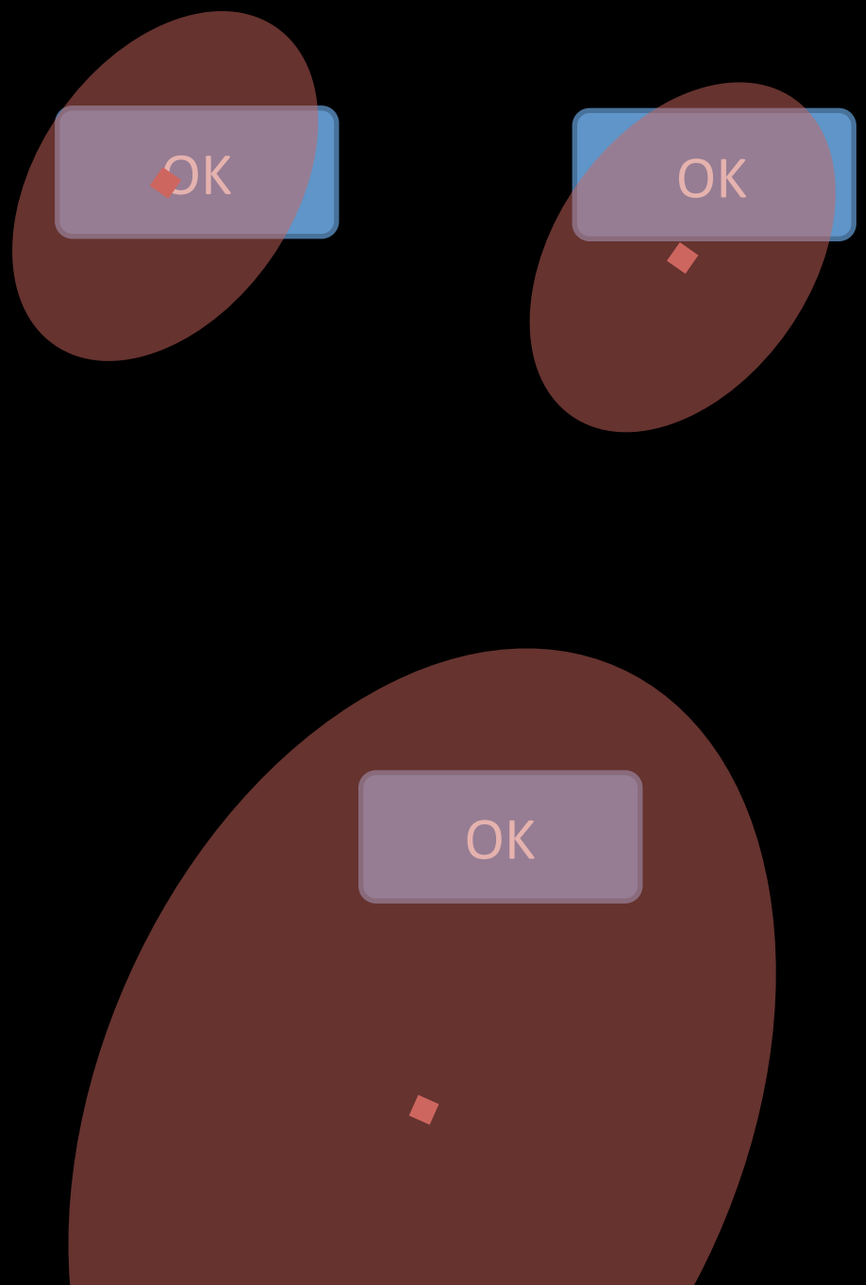
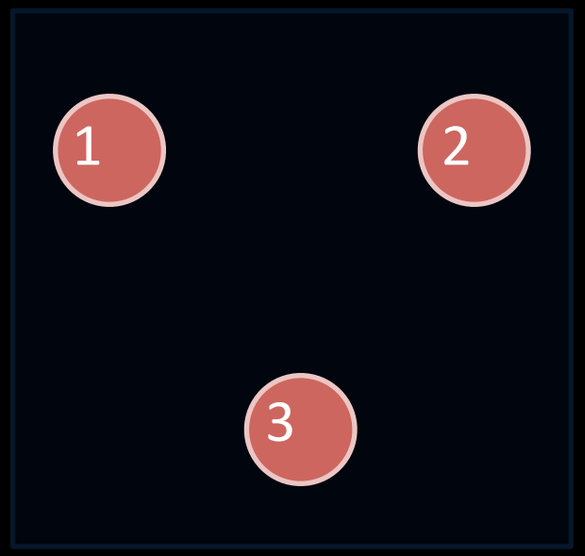




Problems with Blob Tracking II

- Correspondence is a hard problem



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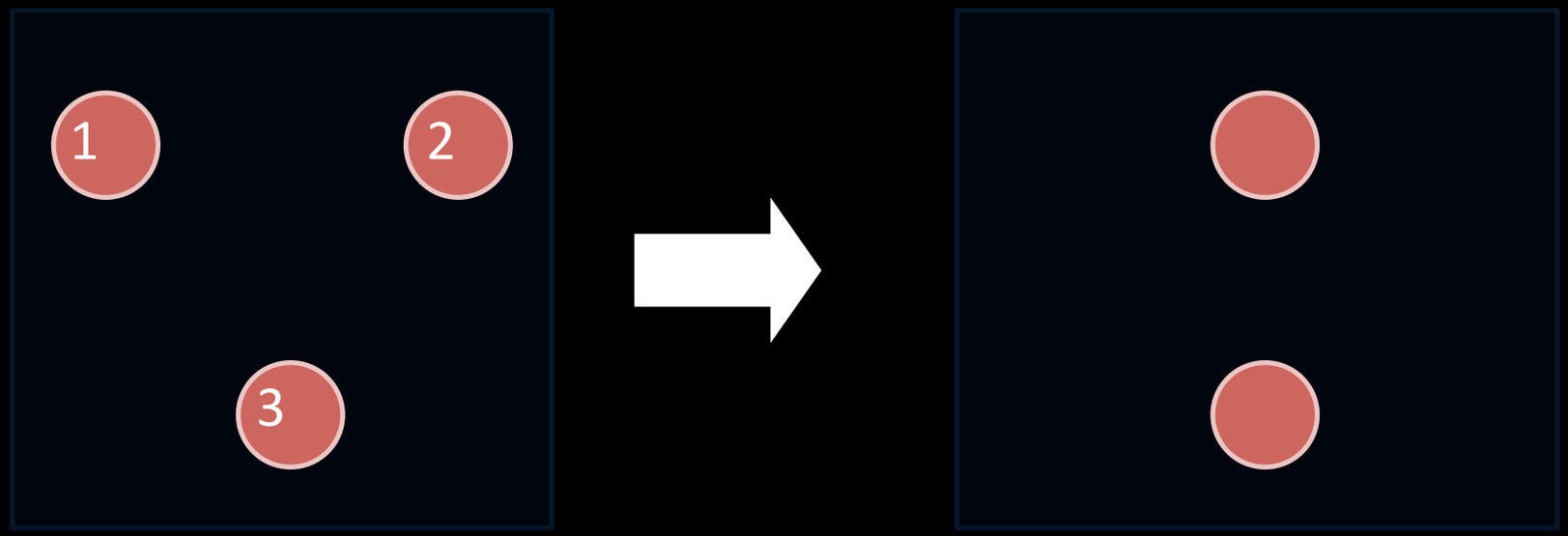

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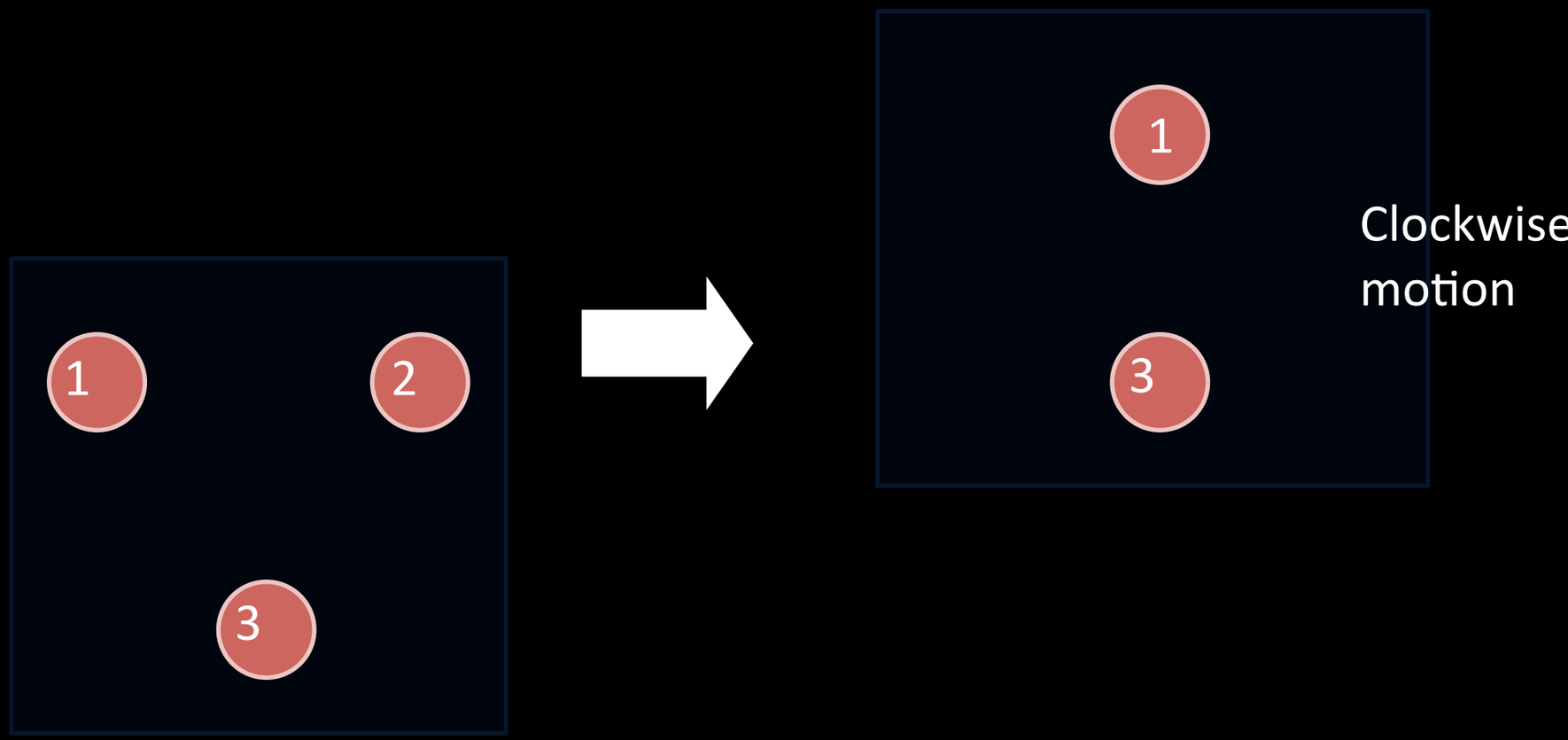

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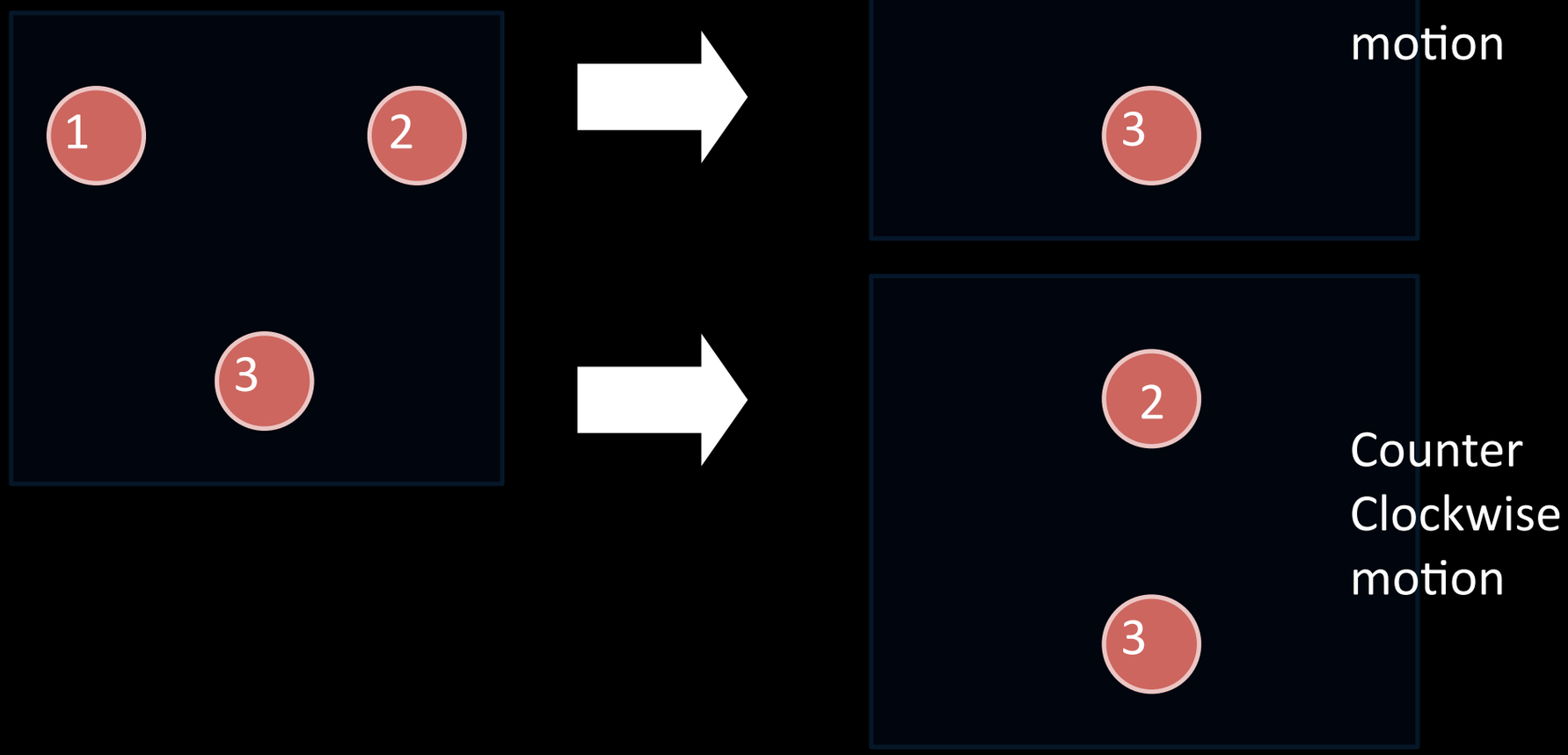

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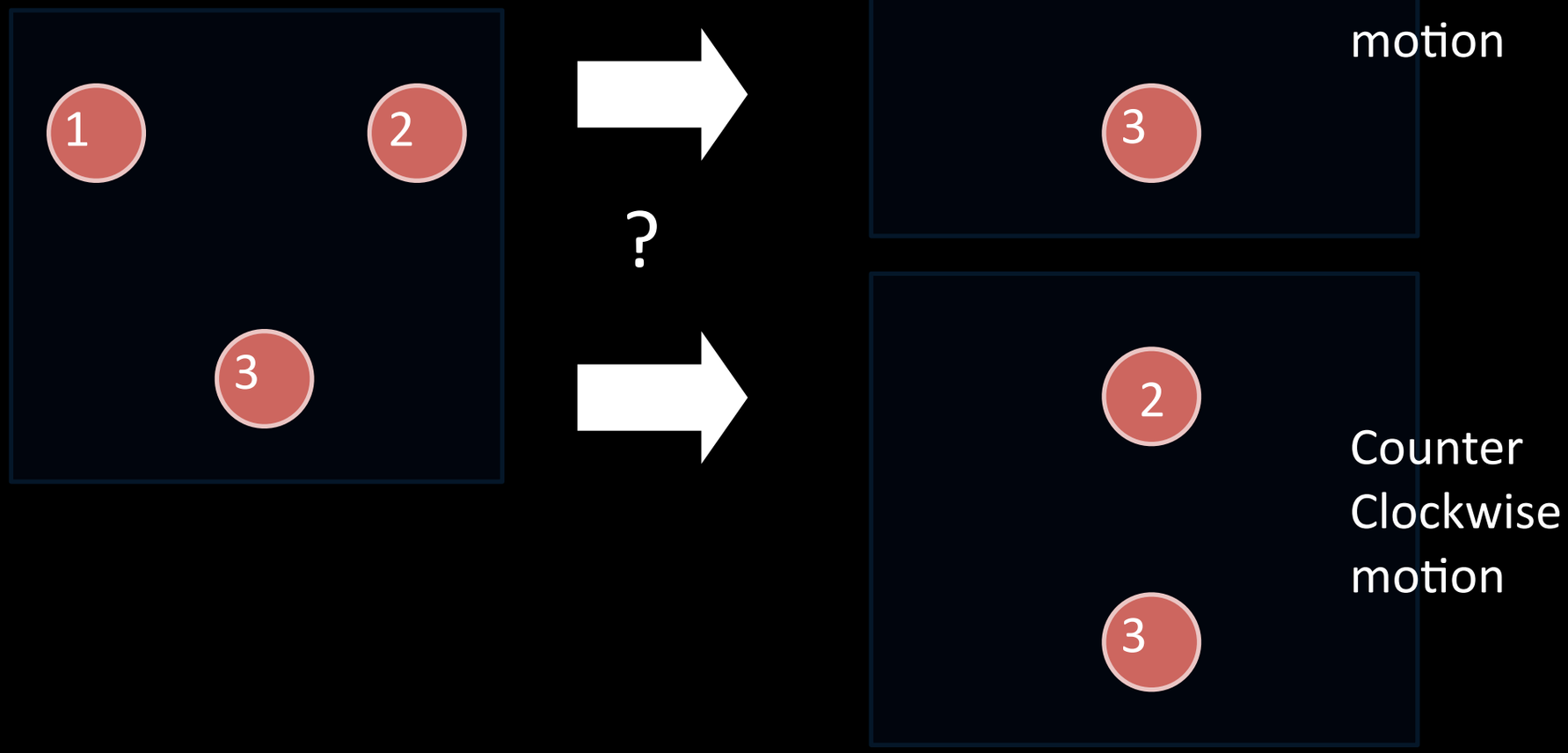

Possible Solution Optical Flow

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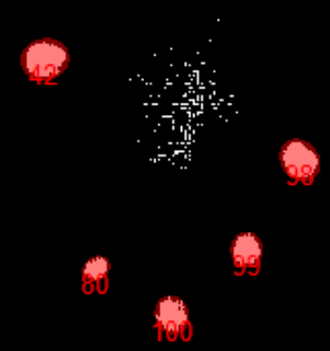

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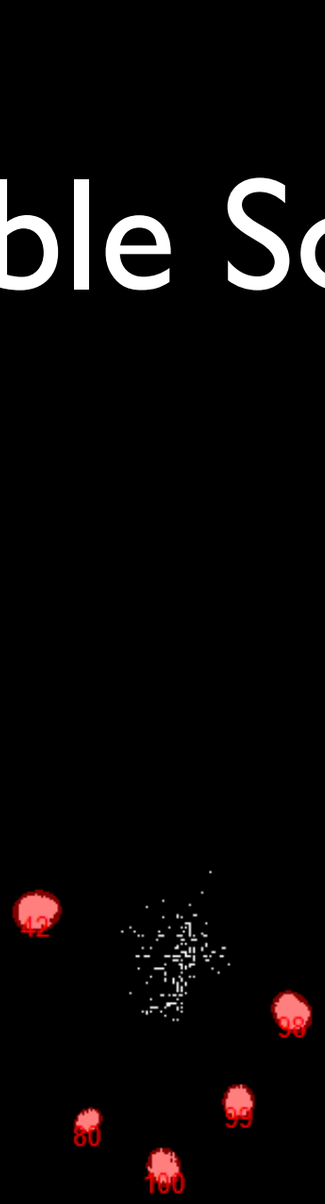

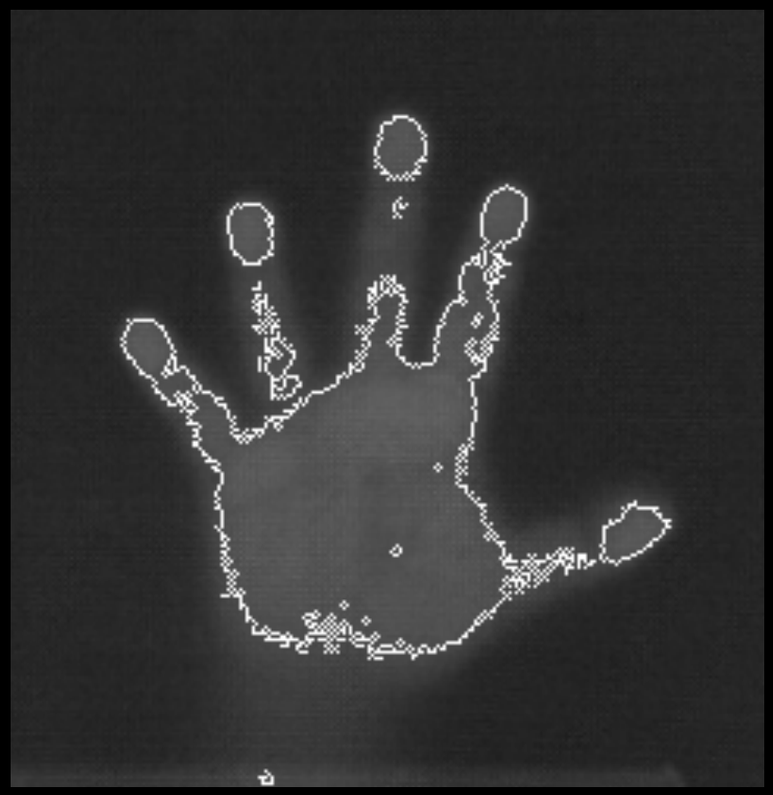

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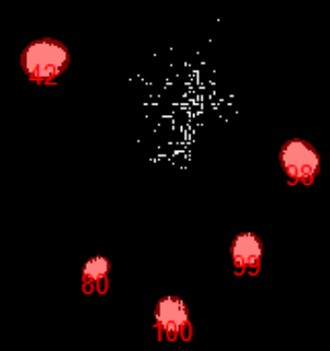

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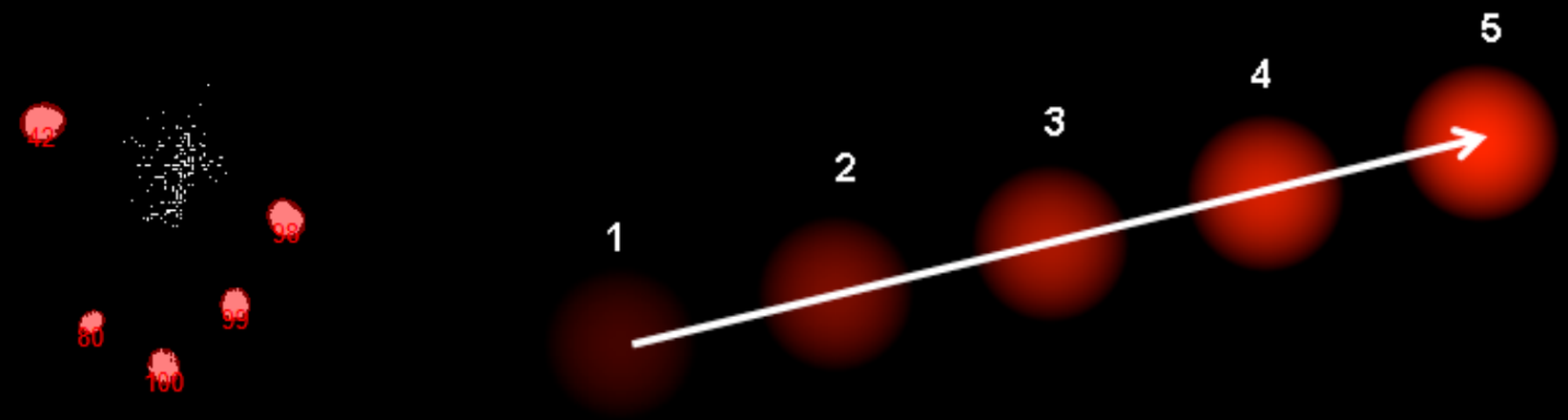

Software Frameworks

- Many open-source / free frameworks available
  - Different capabilities (blobs, objects, fiducials)
  - often extensible (OpenCV)
  - different abstraction layers
    - “multi-cursor” driver
    - source-code library
    - app development framework

Software Frameworks II

- touchlib (www.nuigroup.com) / tbeta (http://tbeta.nuigroup.com/) - Win
- Touché (http://gkaindl.com/software/touche) - Mac OS X
- libavg (http://www.libavg.de/) - Linux / Mac OS X
- OpenTouch (http://code.google.com/p/opentouch/)
- MPX (http://wearables.unisa.edu.au/mpx/) - multi-point X-Server *nux
- Reactivision (http://mtg.upf.edu/reactable/?software) - SW driving Reactable

Applications?

Multi - Touch Applications

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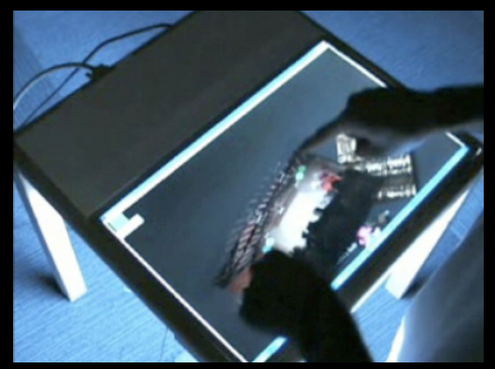

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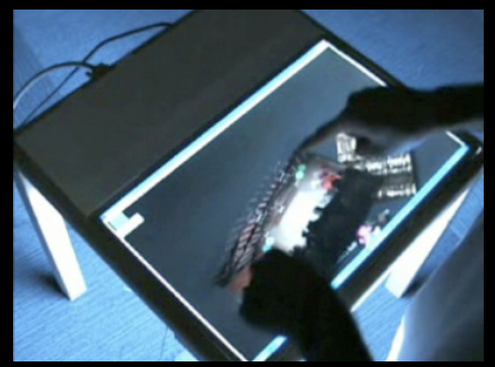

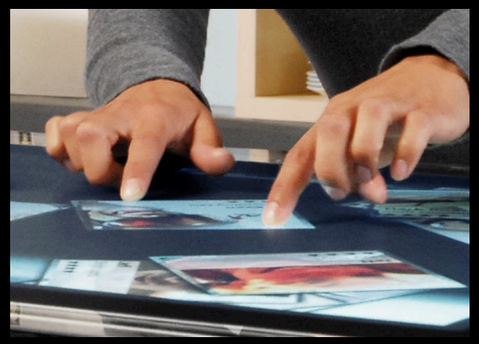

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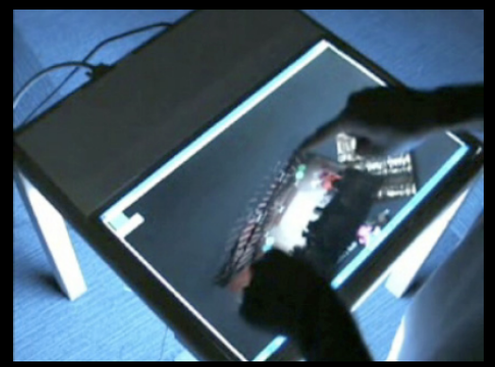

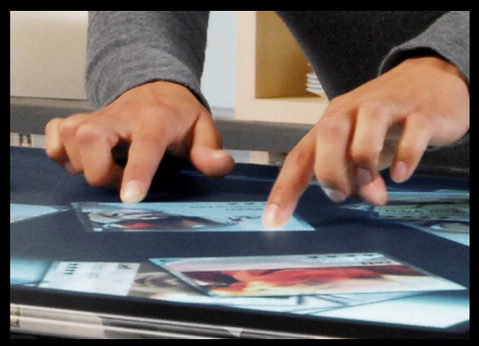

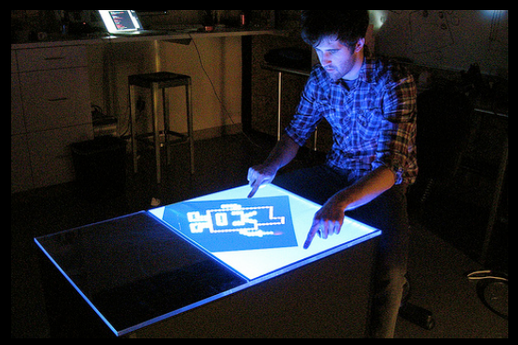

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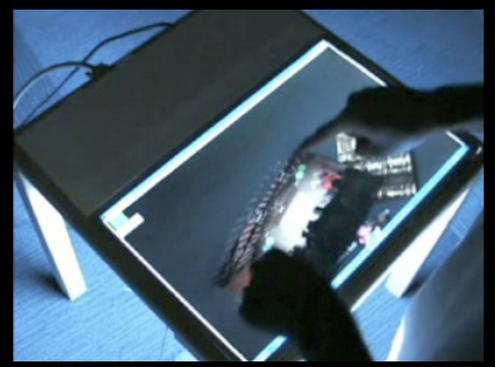
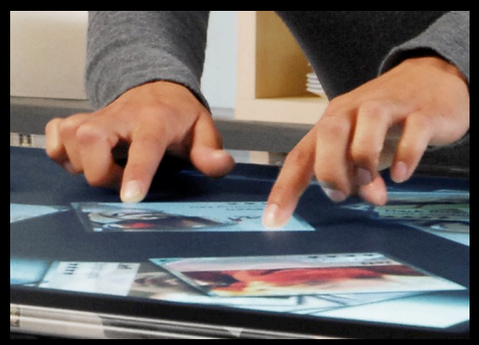
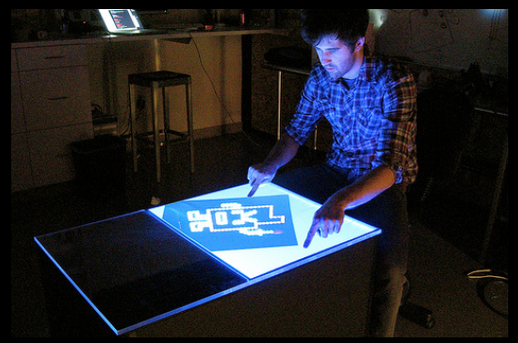
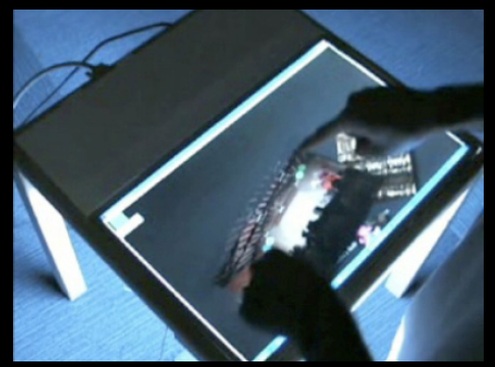
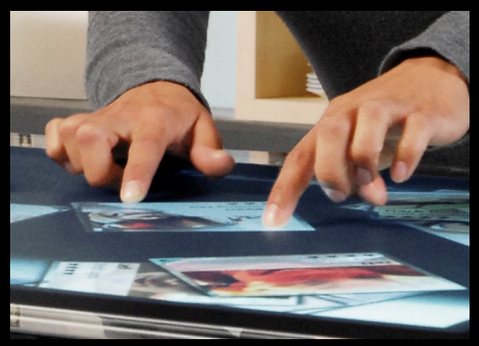


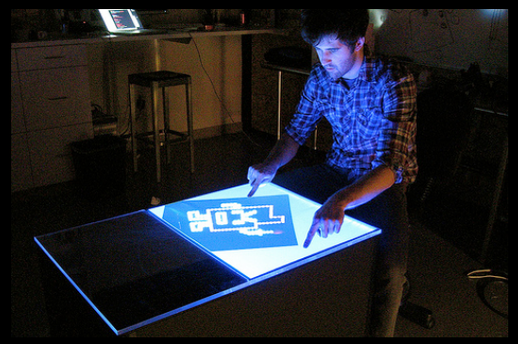




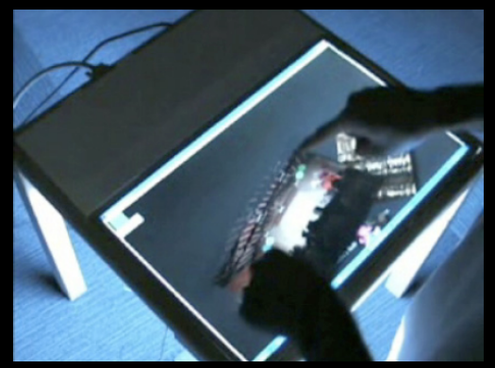
Multi - Touch Applications

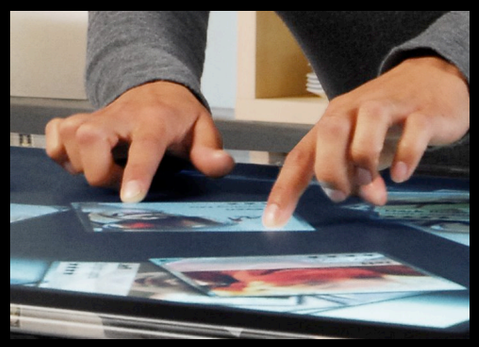


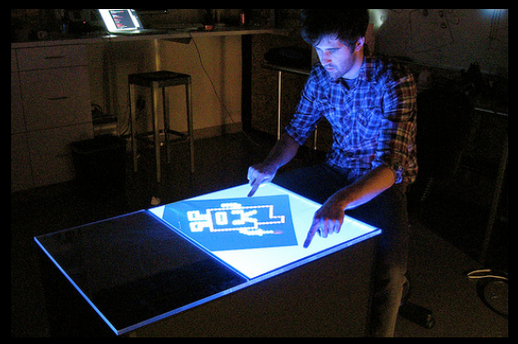




Multi - Touch Applications







Applications?

-

OK maybe not (yet)!

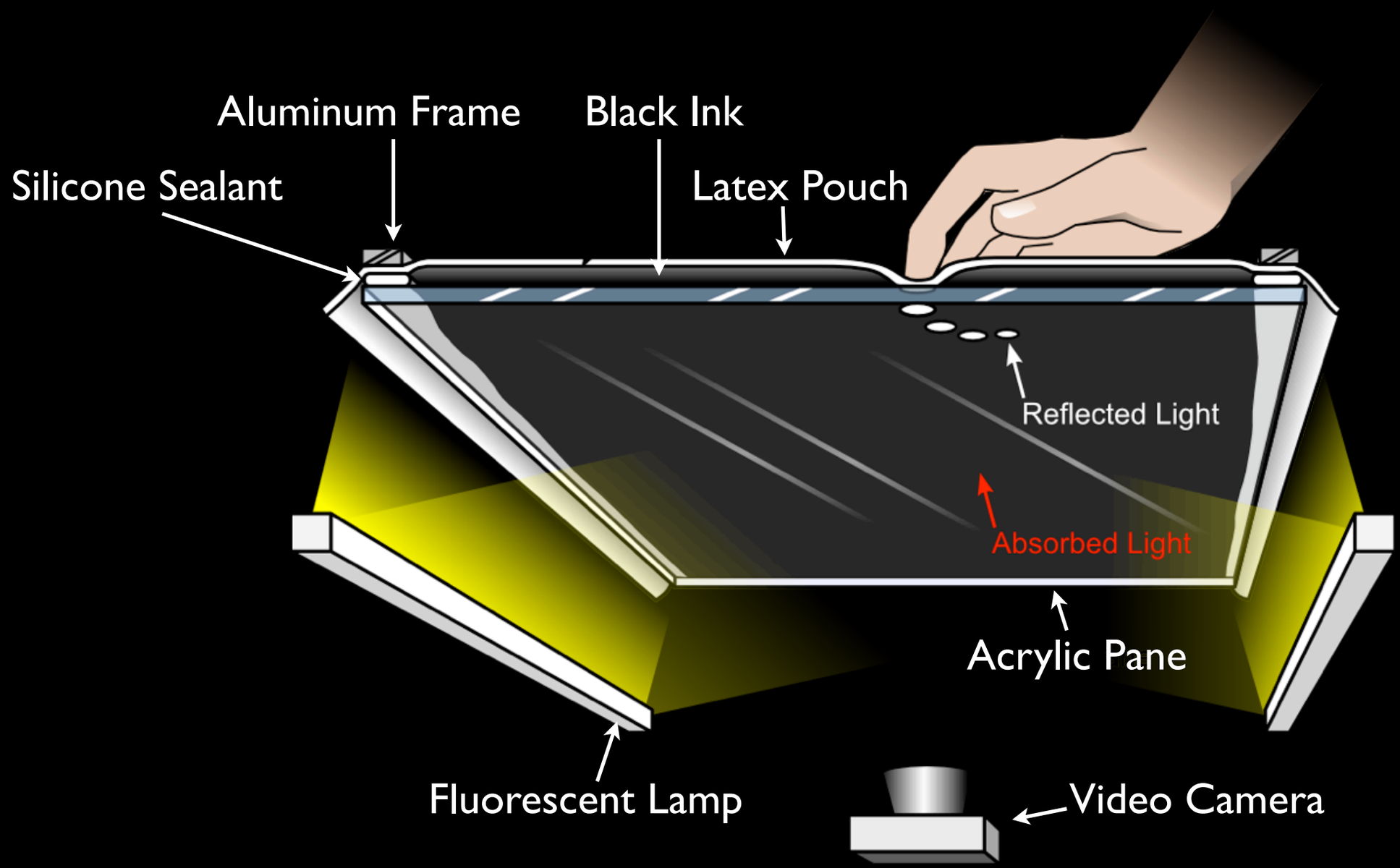
Current Research

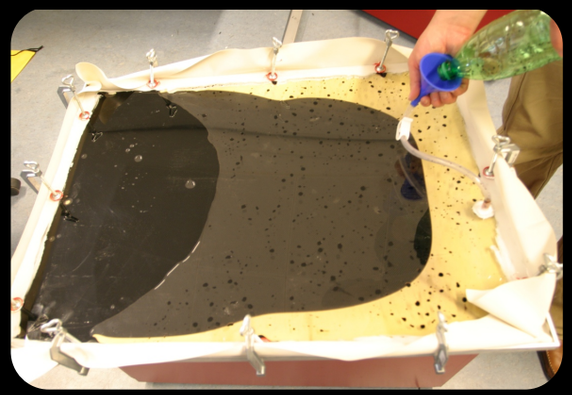
- Multi touch interaction is a hot research topic (conferences to watch: UIST, (CHI), tabletop)

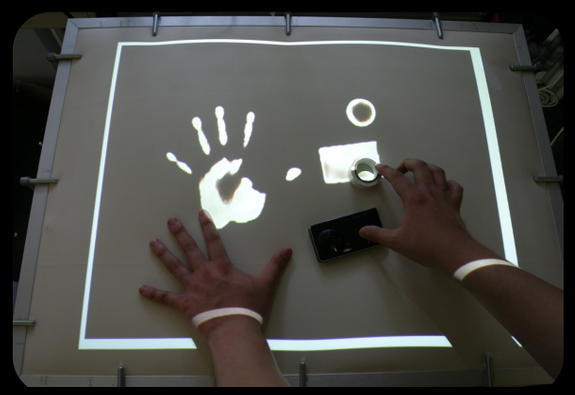
- Also here at LMU
  - Three interactive tables
  - Large interactive wall
  - Many projects and publications

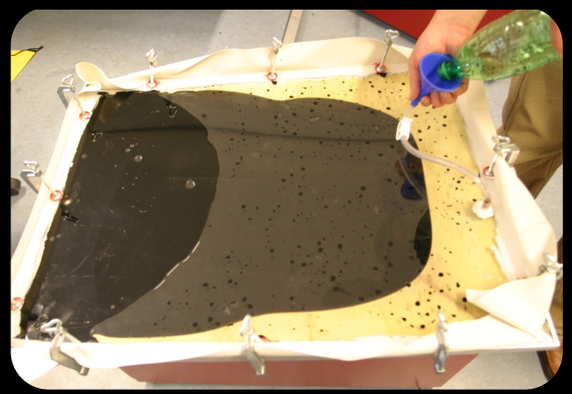
- Different approach to building interactive surfaces
- Multiple fingertips
- Whole hands and objects
- Distinct signal and user experience

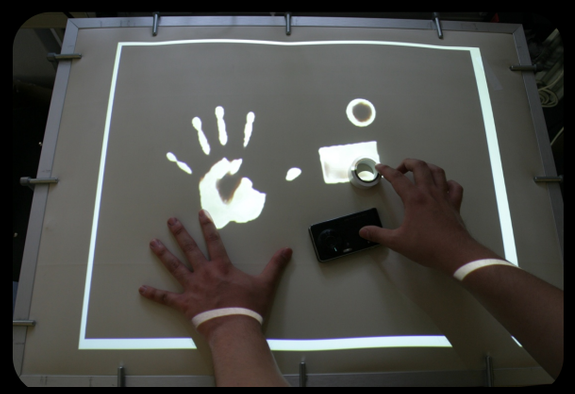
Liquid Displacement Sensing
-
Overview



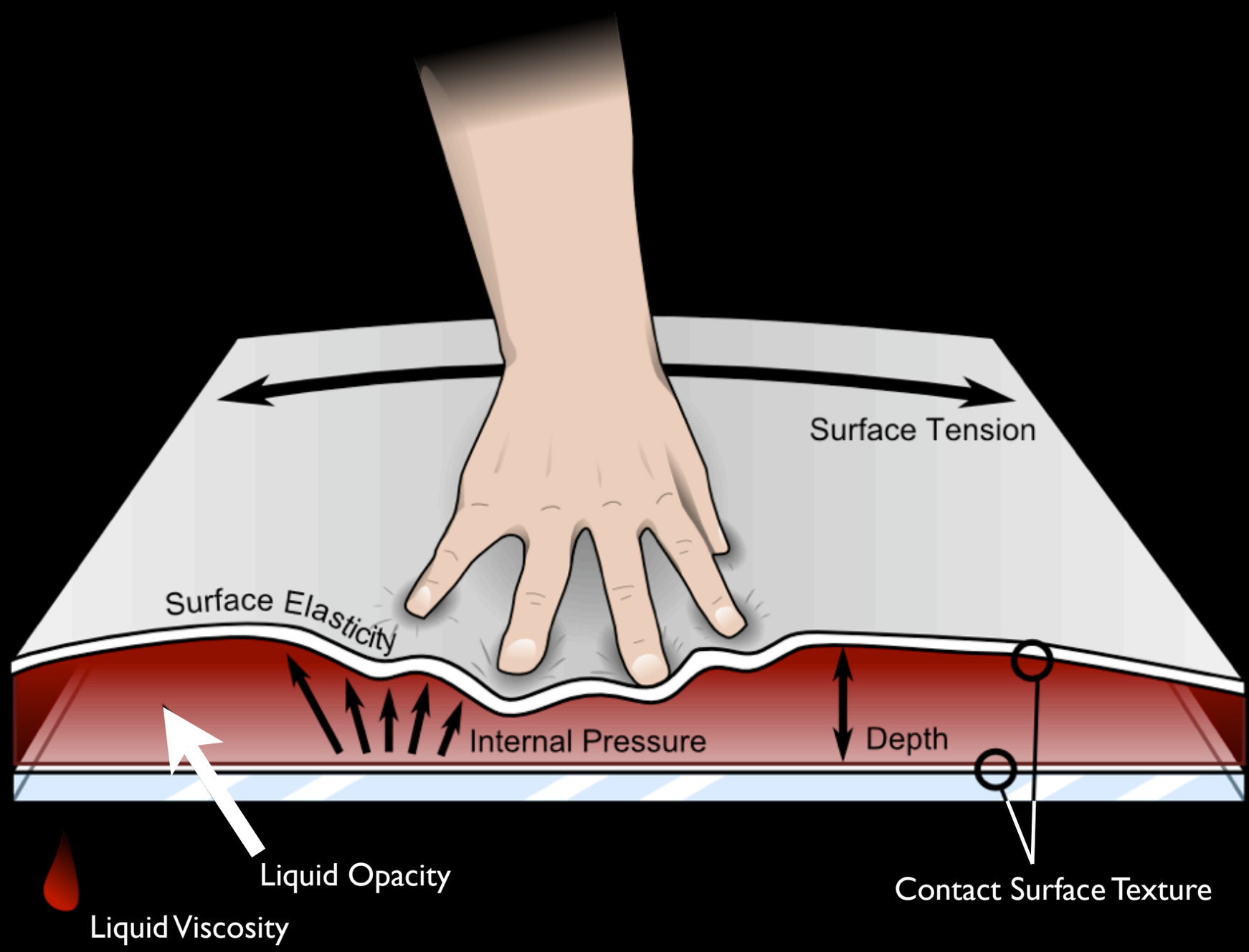








Liquid Displacement Sensing
-
Material Properties



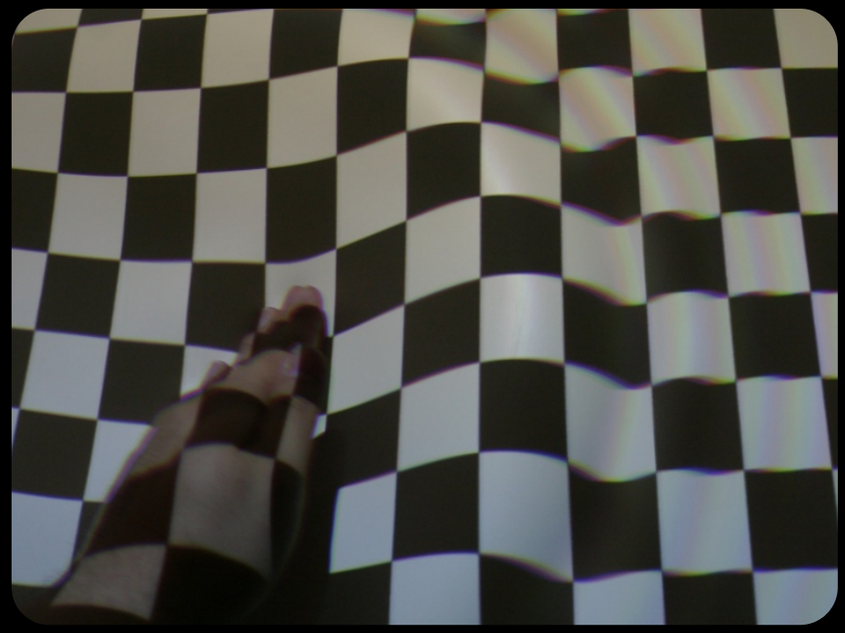
Material Elasticity

too thick & rigid

appropriate thickness

Material Elasticity

rippling effect



distortion caused by ripples

Surface Tension

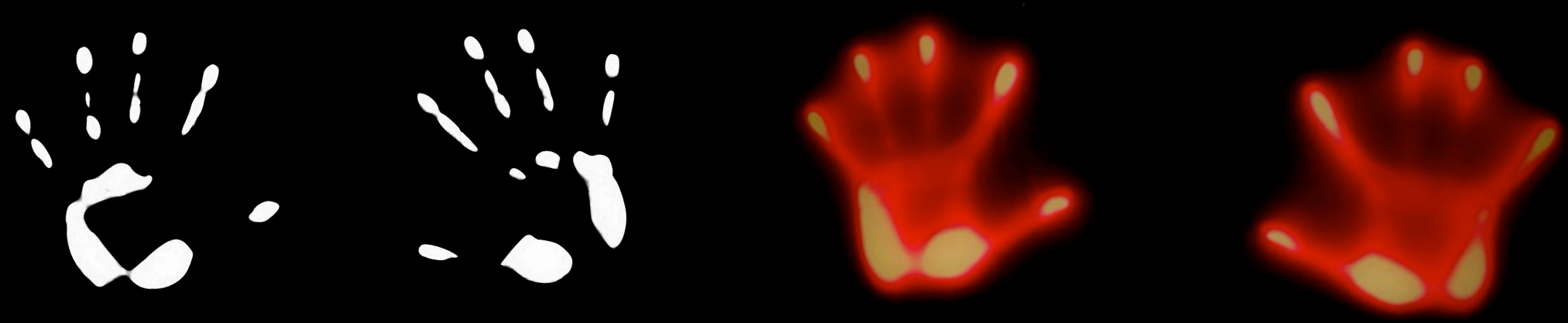
Surface Tension

Pouch Pressure

- Internal Pressure can reduce rippling effect and motion blur
- Air-gap between ink and surface
- Reduces deformation hysteresis
- Suppresses waves within the liquid

Liquid Volume and Tint

- Liquid tint & opacity
  - Black liquid provides high contrast
  - Colored & transparent liquids allow for pressure sensing
- Increased volume enables depth estimation

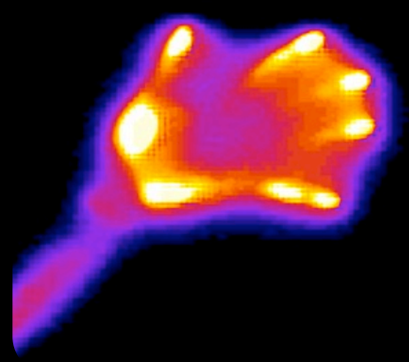


Liquid Volume

Liquid Volume

Raw Sensor Data -
No Image Processing Applied

Pressure Sensitivity:
Different Colors and Opacity of Dyes
Increased Liquid Volume



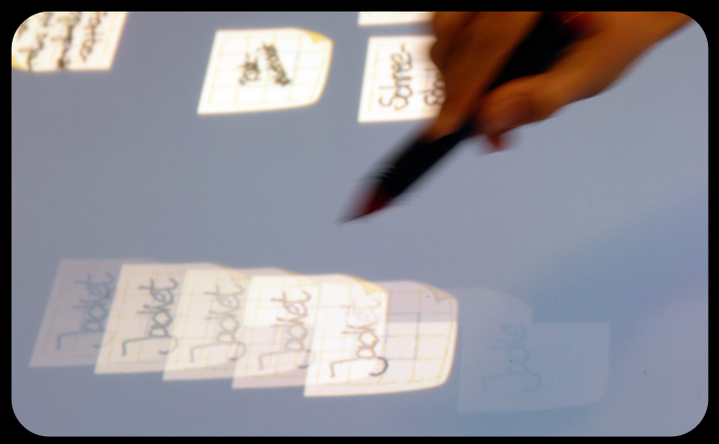
Conclusion

- New approach for rapid prototyping of multi-touch and object sensing surfaces
- Recognition of shapes and outlines of objects
- Circumvents IR illumination problem
- Pressure and (some) height sensing possible

Future Work

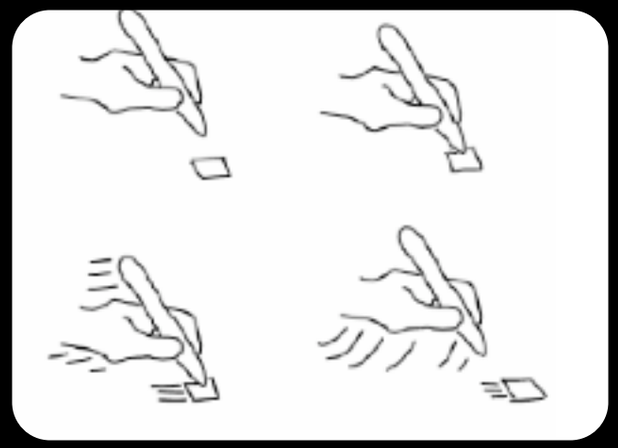
- Top projection increases size
- Works only for horizontal surfaces
- Applications that exploit specifics of the signal

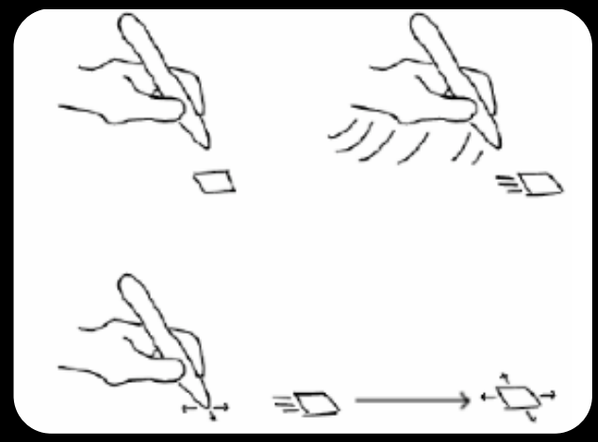
Pseudo-Physicality



- Many interaction techniques mimic physical behavior
- Two categories:
  - giving objects momentum
  - or physical extend

Related Work - Superflick





[Reetz GI‘06]

Related Work - Data Mountain

[Robertson UIST'98]

Related Work - Bumptop

[Agarawala CHI‘06]

Related Work - Bumptop

Document
Movement

[Agarawala CHI‘06]

Related Work - Bumptop

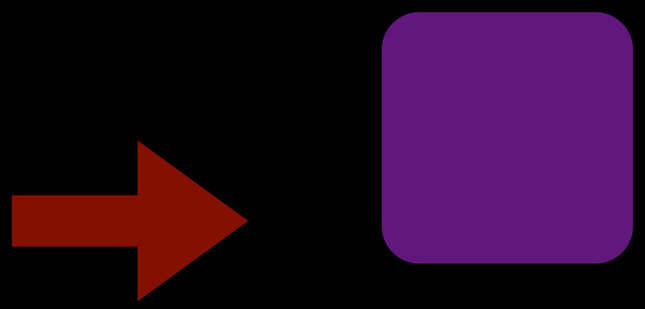
[Agarawala CHI‘06]

Our Approach – Design Goals

- Simple way of modeling multi-touch input in physics enabled applications.
- (Re) creation of basic tabletop interactions
- Instead of a myriad of gesture based commands:
  - Let the physics solver do the heavy lifting

Approach I: Forces

- Object state is influenced by the exertion of forces
- Calculating forces and applying them is the most physics friendly way to move objects



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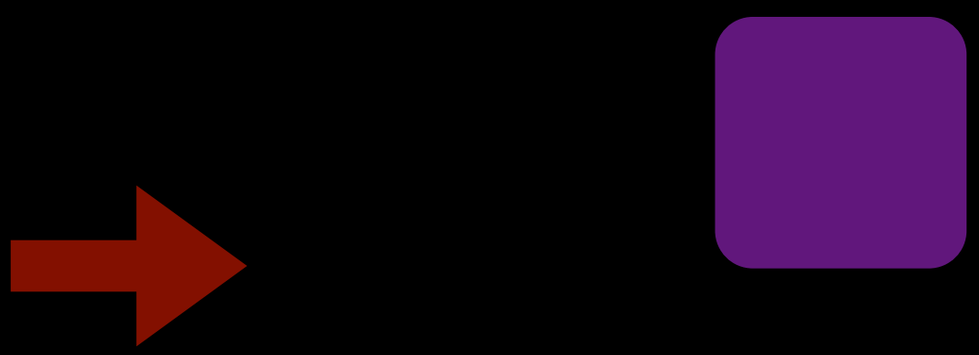
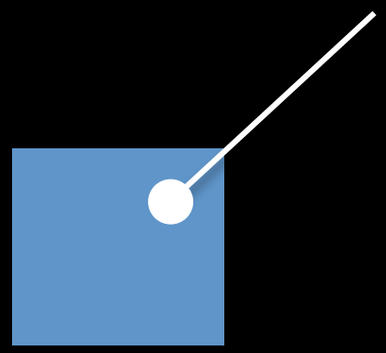


Forces - Problems

- Direct force calculation is not accurate
- Other forces present in the system
  - Gravity
  - Collisions
- Internal forces are hidden to the programmer
  - Air resistance
  - Friction

Approach II: Joints

- Joint(s) virtual rope
- Useful to implement drag'n'drop



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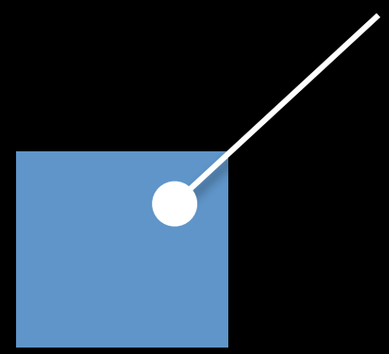

Joints - Problems

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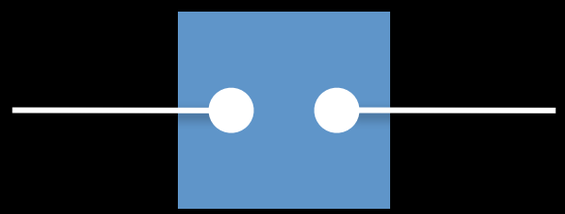

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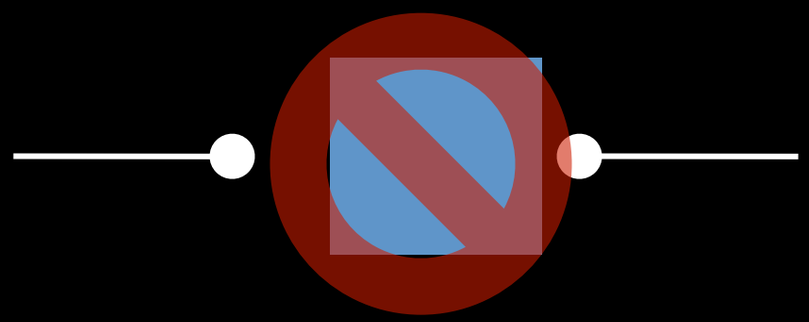
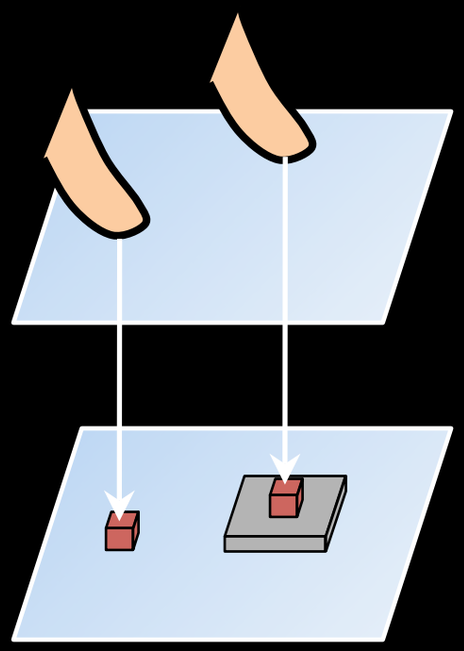
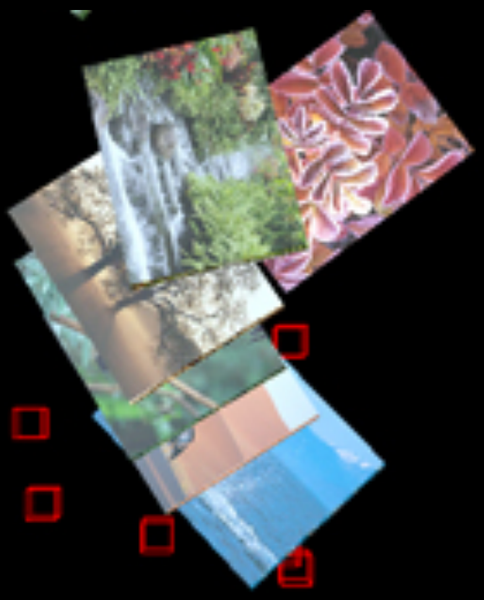


Approach III: Proxy Objects



- Special objects introduced into the simulation per contact point
- Incarnation of fingertips in the virtual world
- Collide with other objects and push them aside.



Leveraging Collision Forces

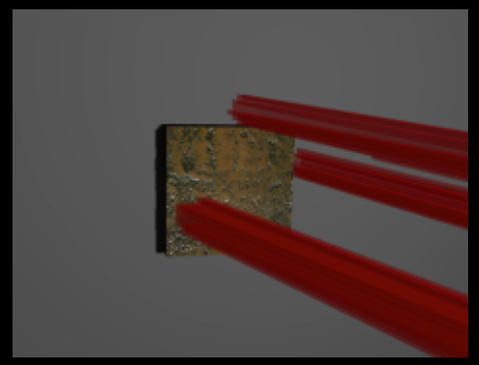
Leveraging Collision Forces

Leveraging Friction Forces

Leveraging Friction Forces

Particle Proxies

- Idea: model contact shape with many proxy objects (particles)
- Collisions obey shape of the contact (e.g., flat or side of the hand)
- Distribution of forces is modeled more accurately (e.g., conforms to 3D shape)



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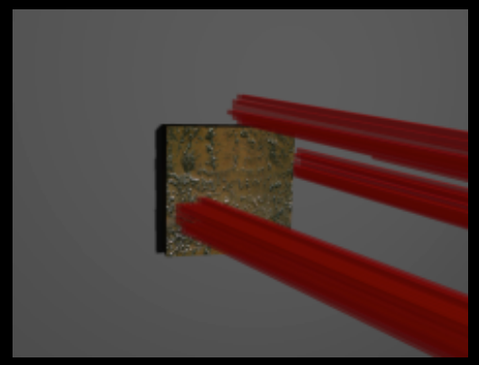
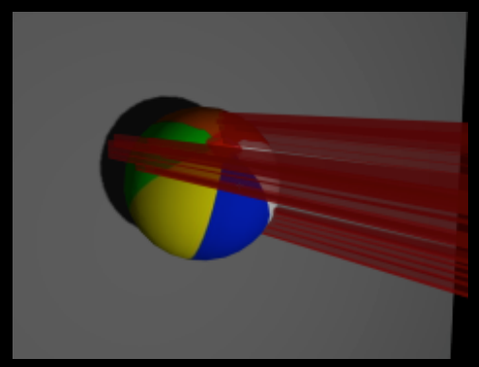
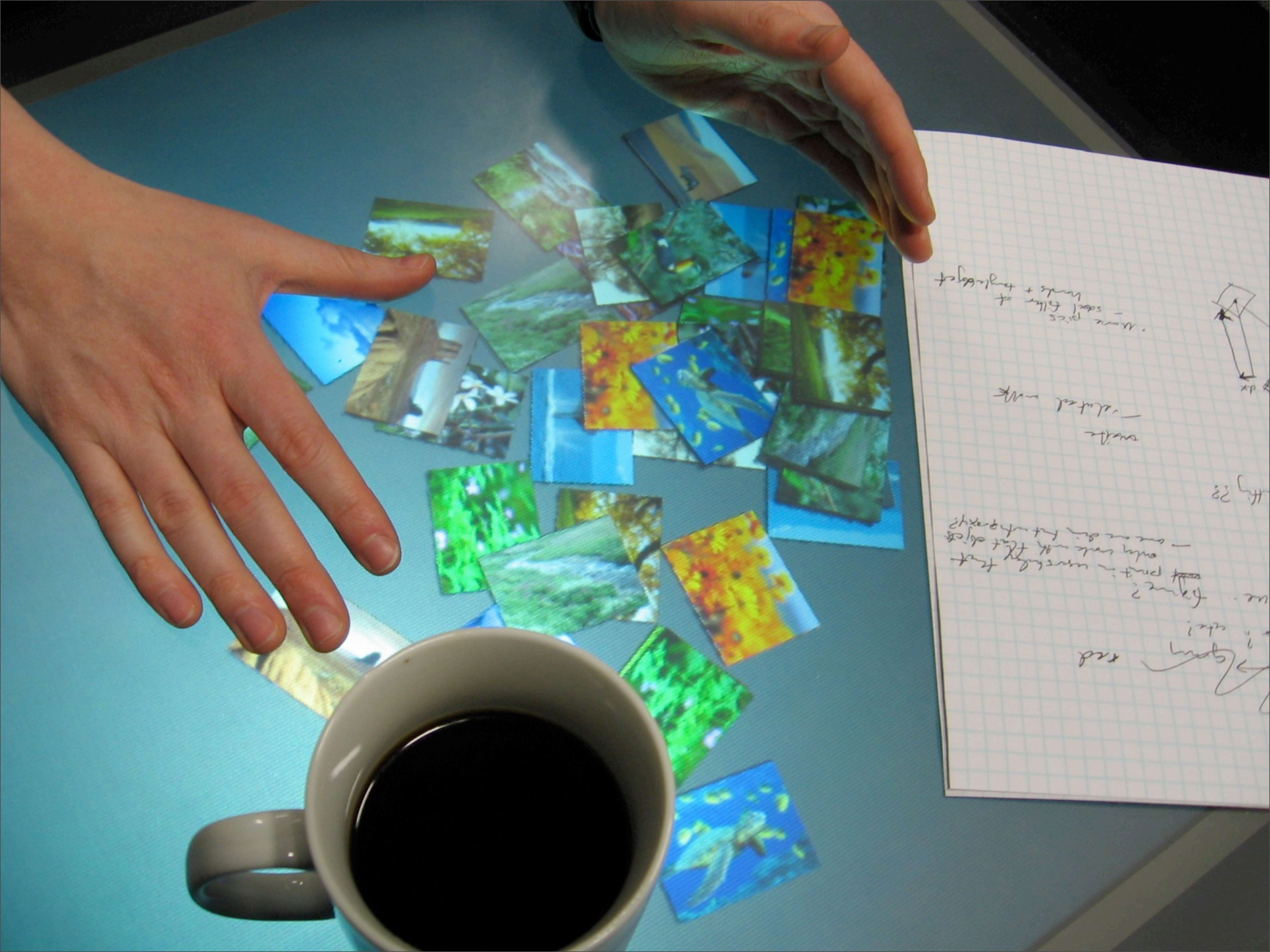
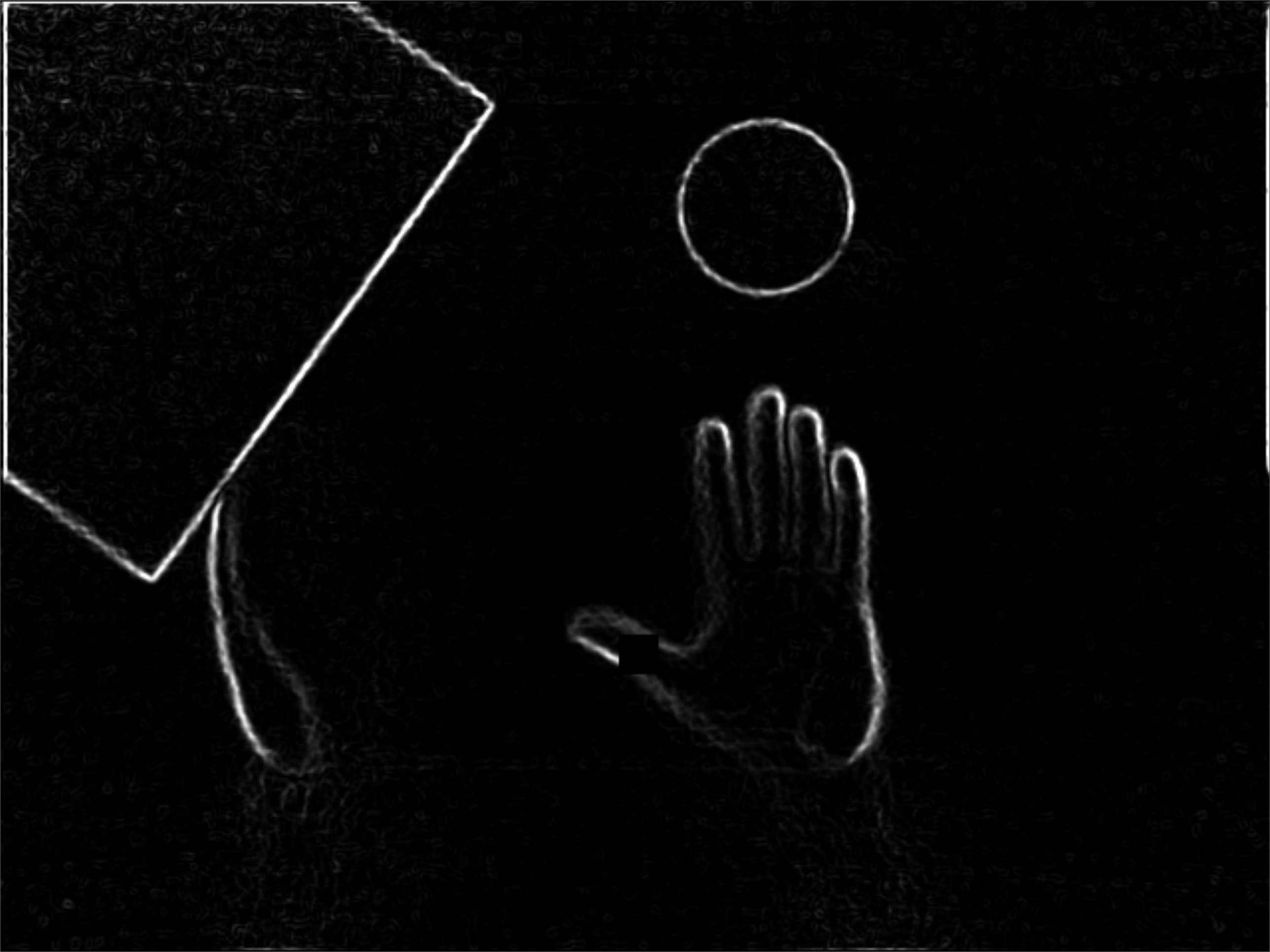
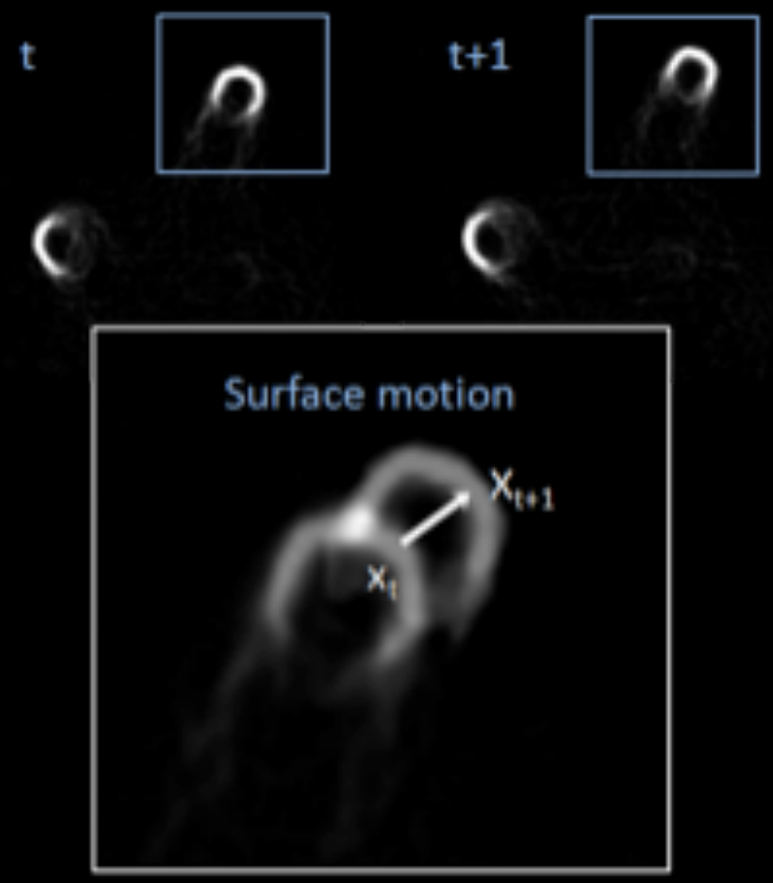


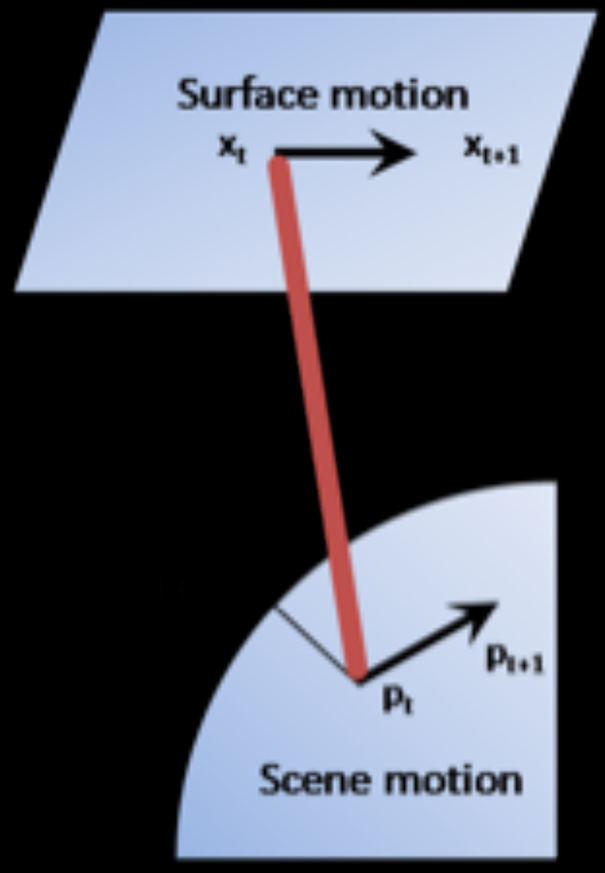






From Tracking to Flow





Bringing Physics to the Surface

Limitations

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- How to go beyond physics?
    - What about the ubiquitous two-finger zoom?!
    - Can we make anything besides games?
    - Lack of physical feedback

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- How to go beyond physics?
    - What about the ubiquitous two-finger zoom?!
    - Can we make anything besides games?
    - Lack of physical feedback

- Interacting in 3D
    - Picking up objects is tricky
    - Depth-sensing cameras may help

Questions? - Thank You!

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