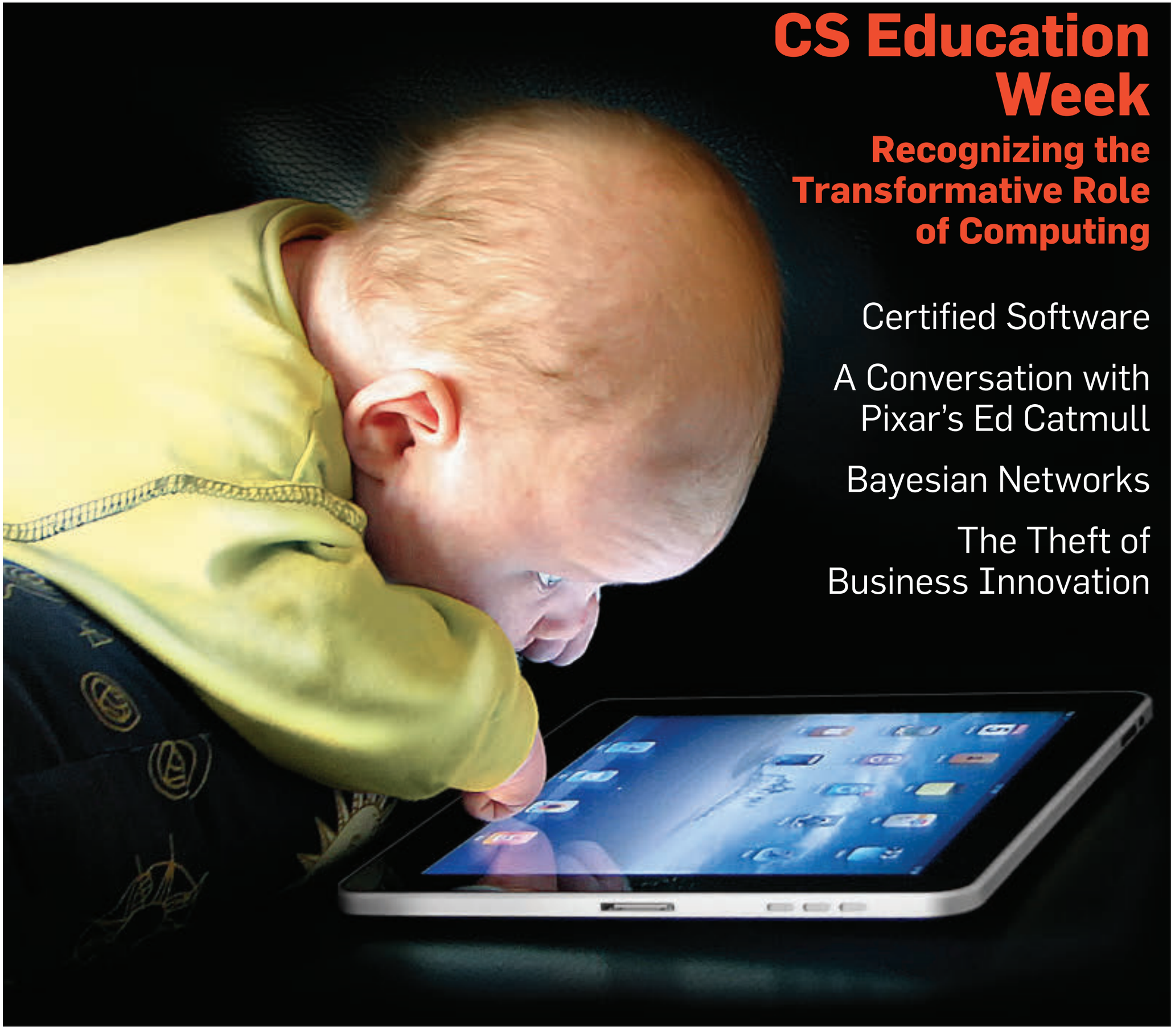
Interaction tactile et multi-points

Sylvain Malacria
http://www.malacria.com/
mailto:sylvain.malacria@inria.fr

ressources: http://malacria.com/teachings/

Diapositives adaptées de Géry Casiez et Gilles Bailly



CS Education Week

Recognizing the Transformative Role of Computing

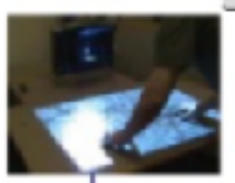
Certified Software

A Conversation with Pixar's Ed Catmull

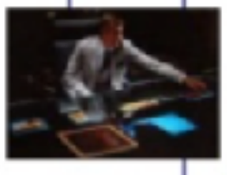
Bayesian Networks

The Theft of Business Innovation

History of Multi-touch interaction



1980 1982 Movie: Tron



1983 HP-150 world's first touchscreen PC

1984 First multi hand display Bell Labs

1985 3D multi-touch sensitive tablet

1991 Pierre Wellner paper on multi touch and pinching motions

1992 Simon - first smartphone With touchscreen

1999 iGesture Pad and TouchStream keyboard by Fingerworks

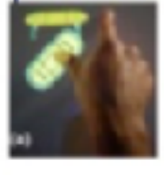
2001 Mitsubishi MERL R&D Lab DiamondTouch

2001 Mixed Reality table of Microsoft Research

2002 Movie: Minority report

2002 Sony labs SmartSkin surface

2003 University of Toronto Multi-finger Multi-hand Multi-user interaction

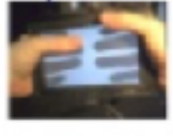


Q1 2006 Jeff Han @TED

2005 Microsoft PlayAnywhere Touch and object detection

2006 NUI Group Foundation NUI Group

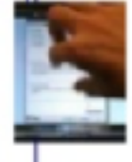
2006 Lucid Touch



Jun 2007 iPhone release

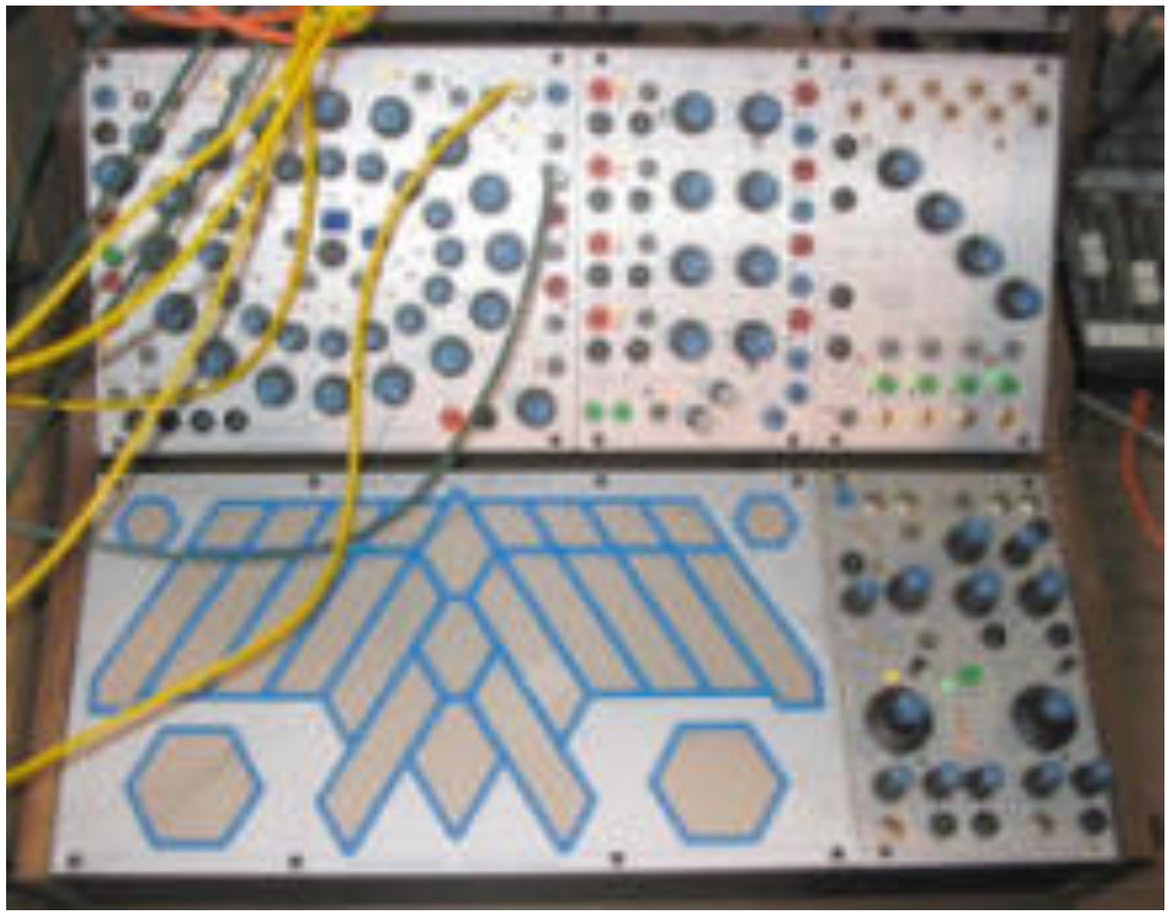
Q3 2008 Microsoft Surface

Q1 2009 Microsoft Windows 7



Q1 2009 SMART table

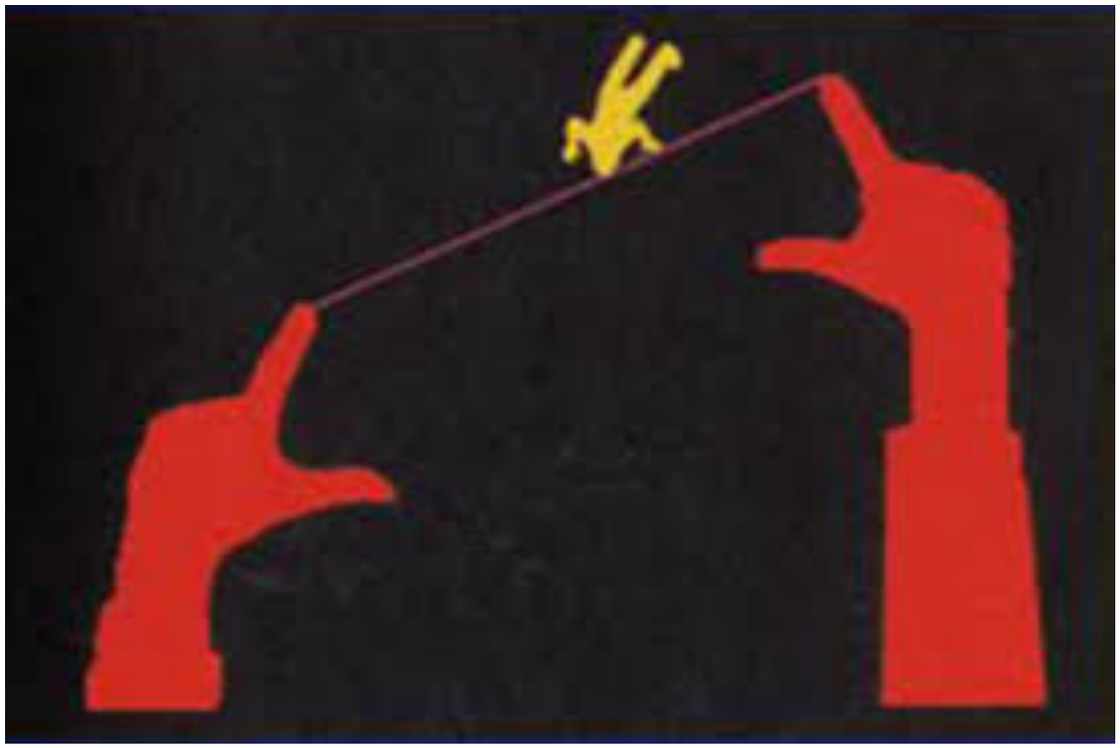
Keyboard

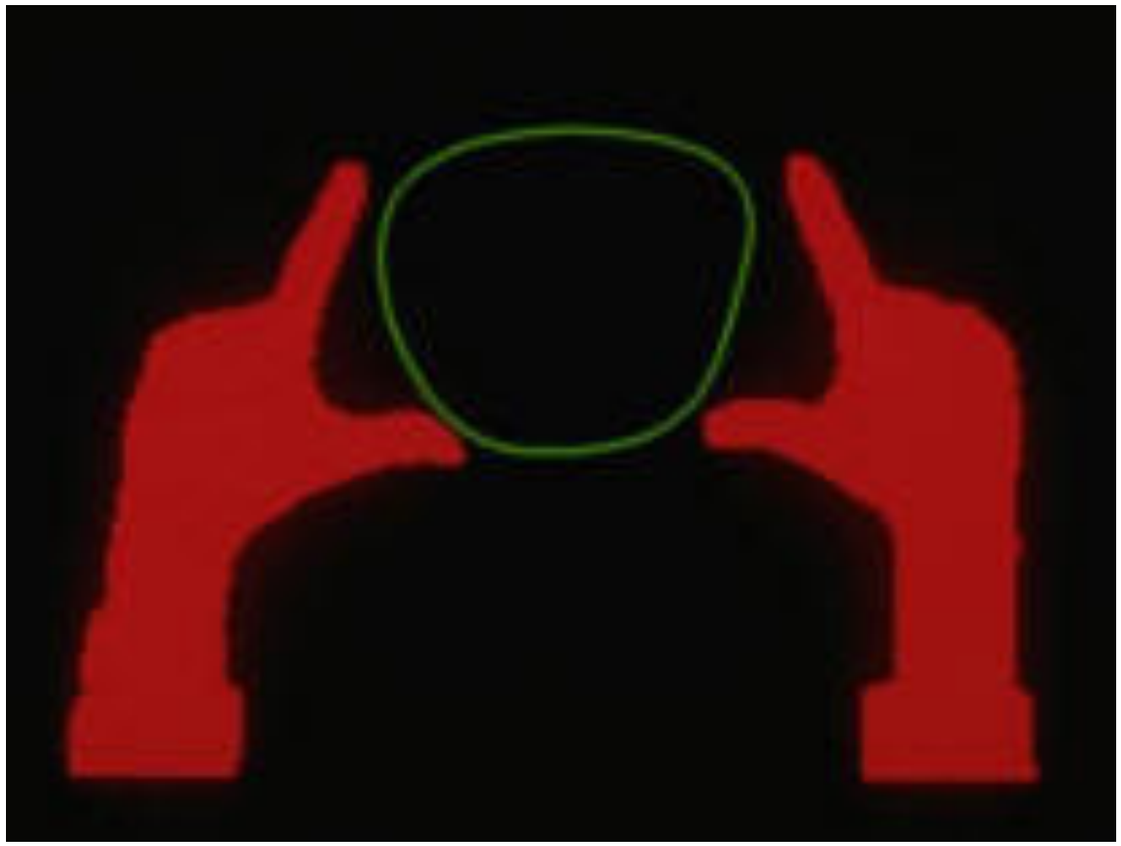


Electronic Touch Sensor

1983

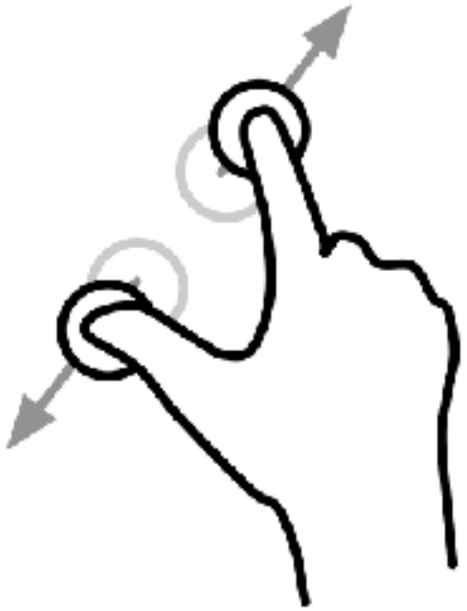
VideoPlace





1985

RST [Krueger et al.]



1985

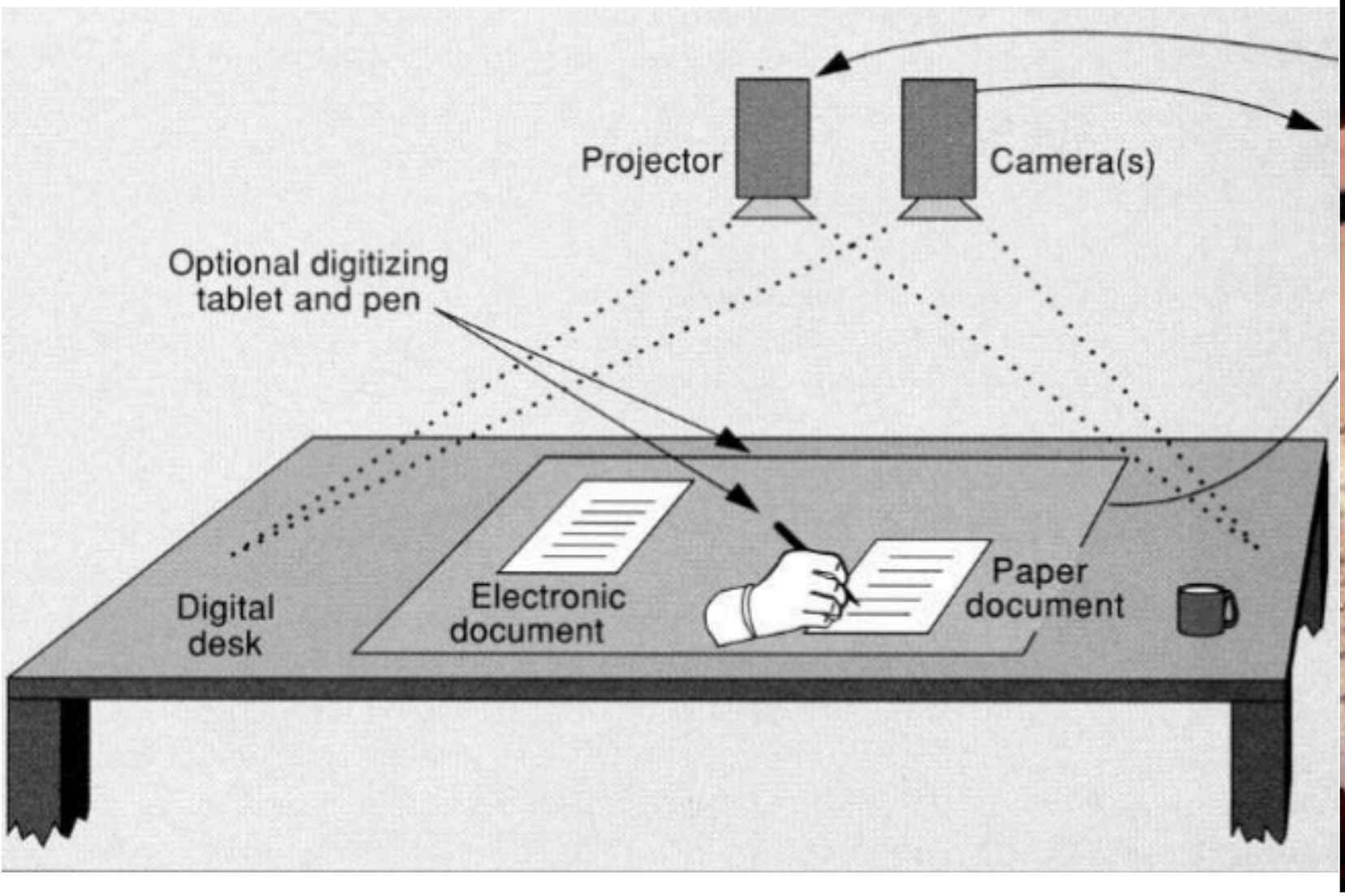
Multitouch Tablet

1985

Multitouch Tablet

1991

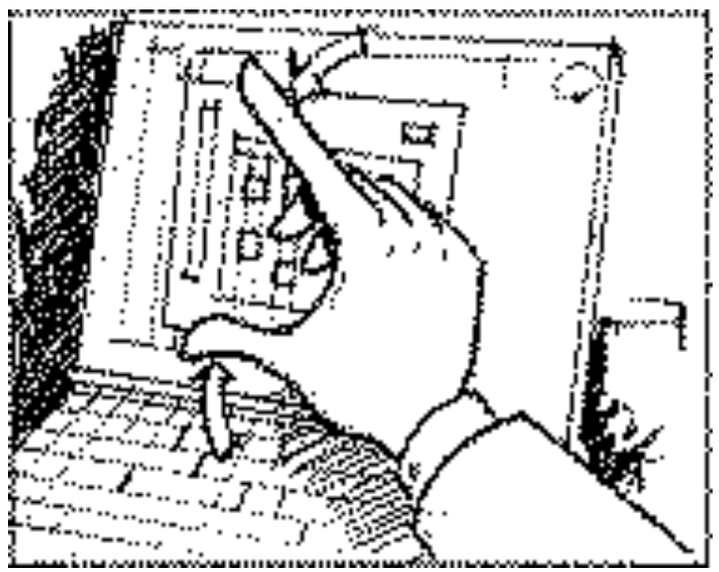
DigitalDesk



1991

Flip Keyboard

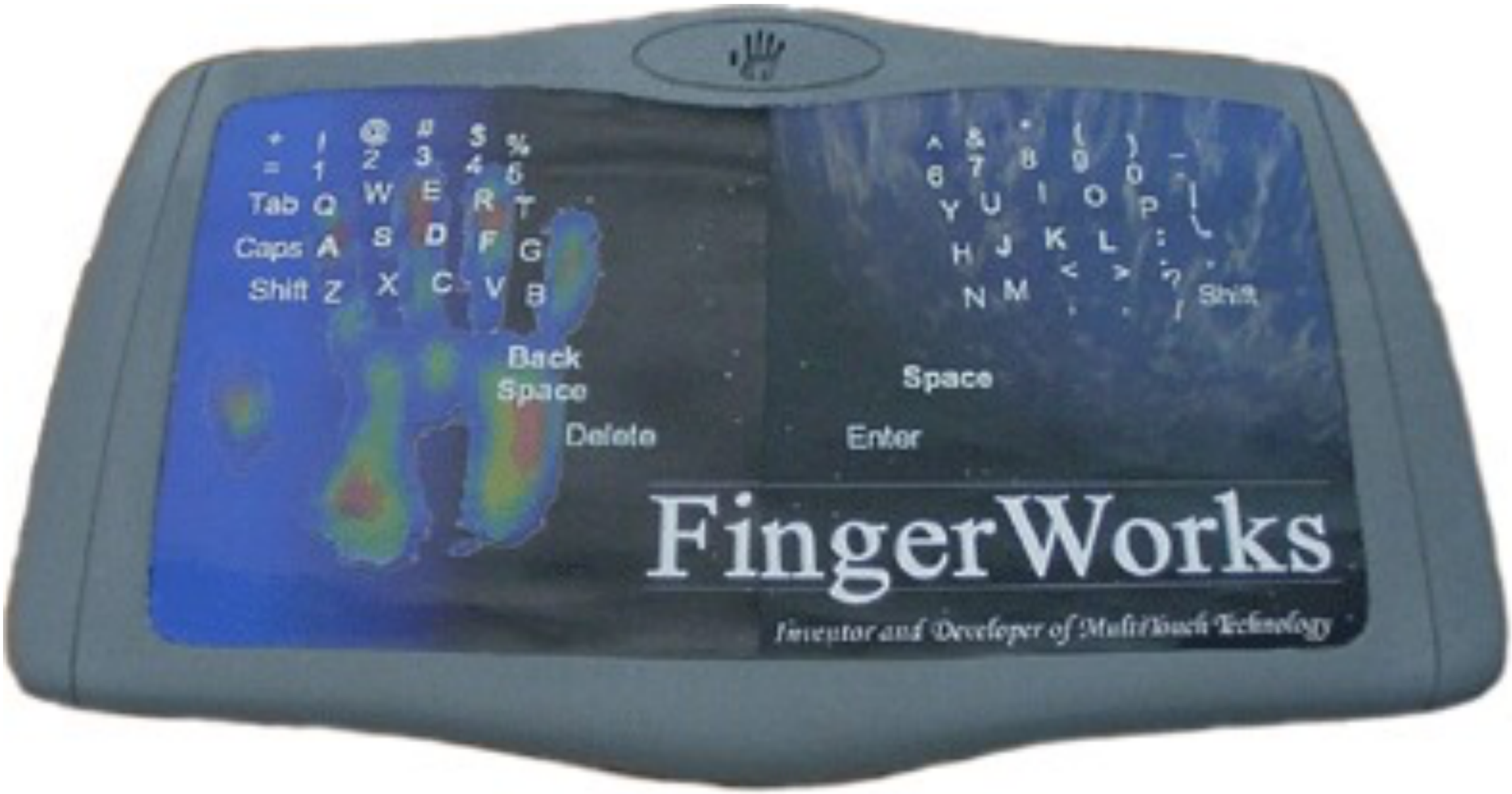
Wacom



Starfire

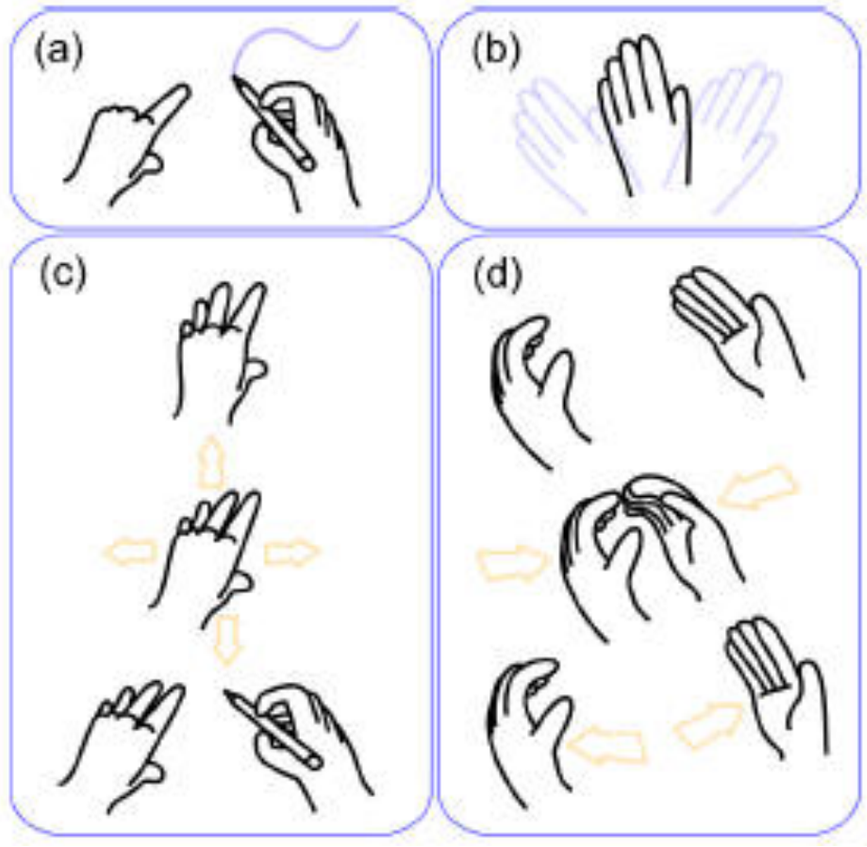
2001

FingerWorks



2001

Diamond Touch



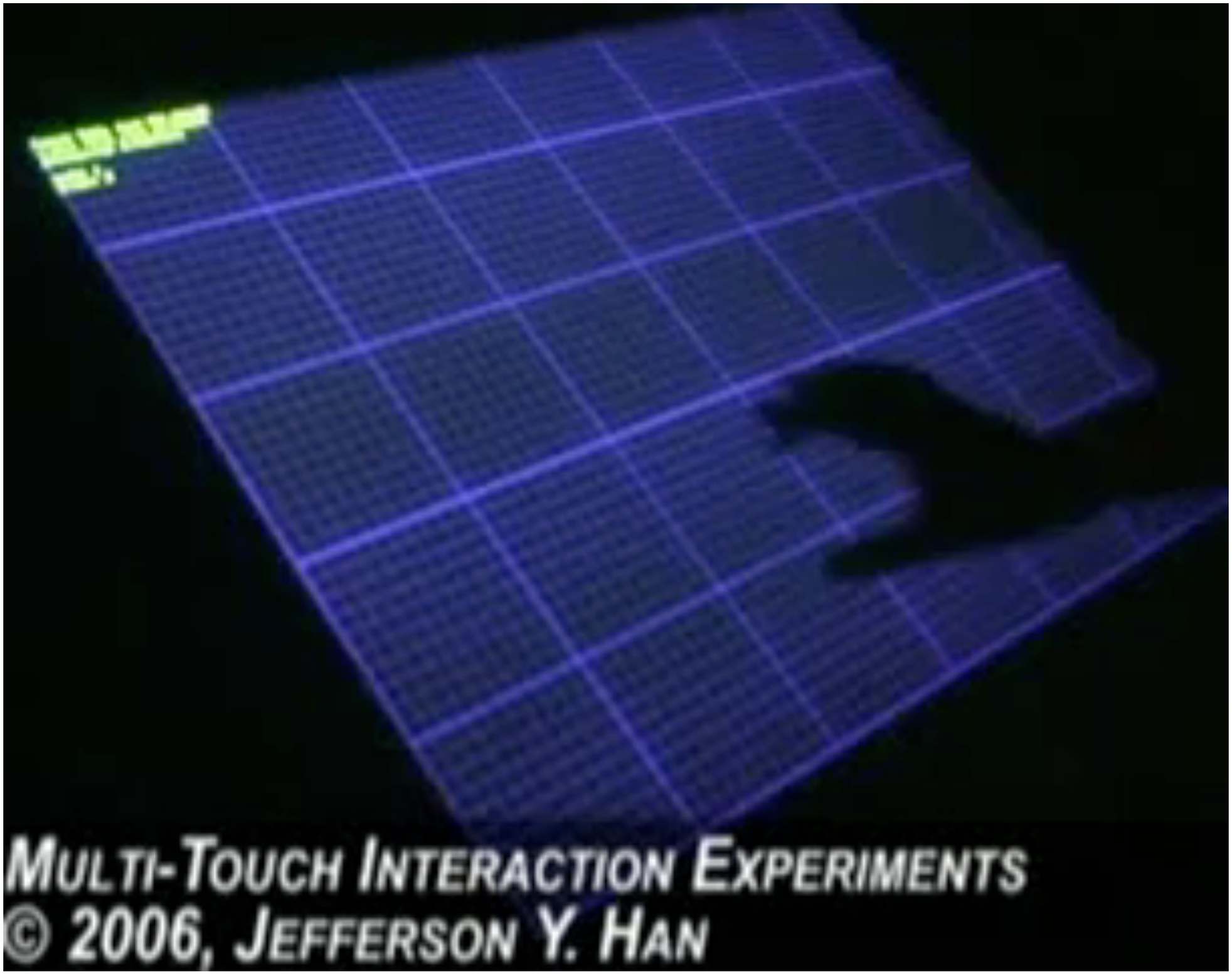
2002

Smartskin

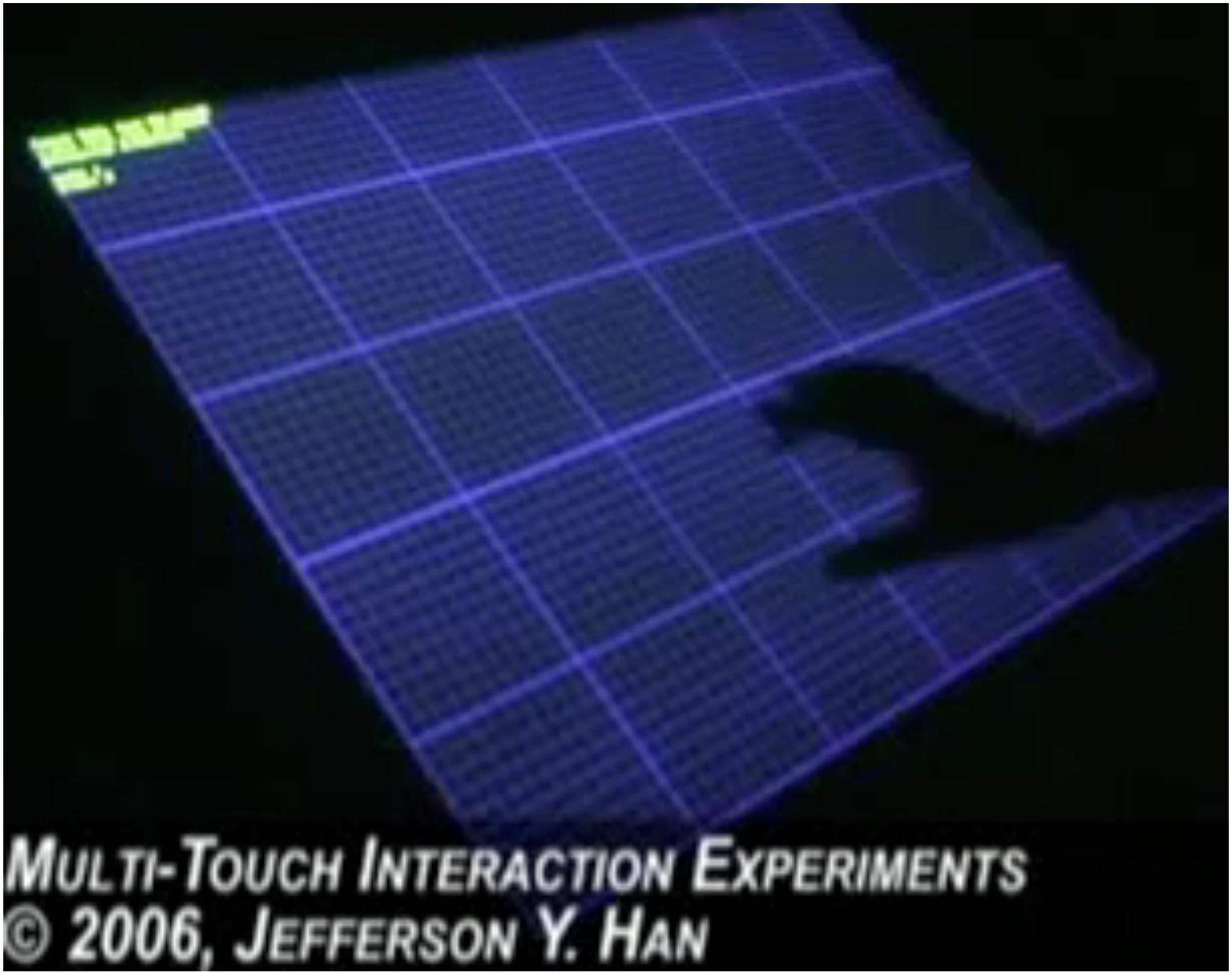
2003

Lemur/Jazz Mutant

2006



2006



2007

iPhone


AT&T
9:42 AM
SMS
Text
Tuesday
9
Calendar
Photos
Camera
YouTube
Stocks
280
Maps
73°
Weather
Clock
Calculator
Notes
Settings
iTunes
Phone
Mail
Safari
iPod

2007

Microsoft Surface

2007

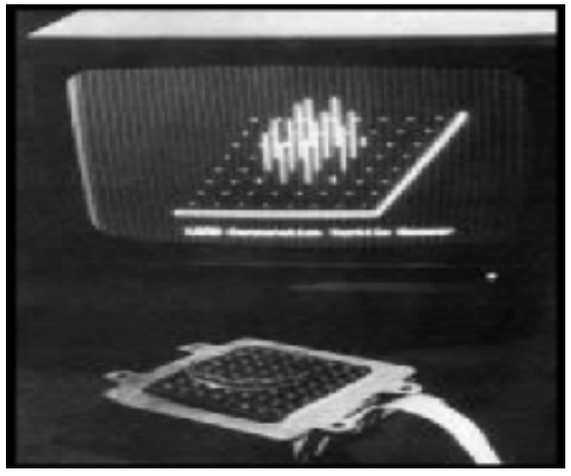
ThinSight

2011

Microsoft Surface 2.0

Technologie

1972
PlatoIV



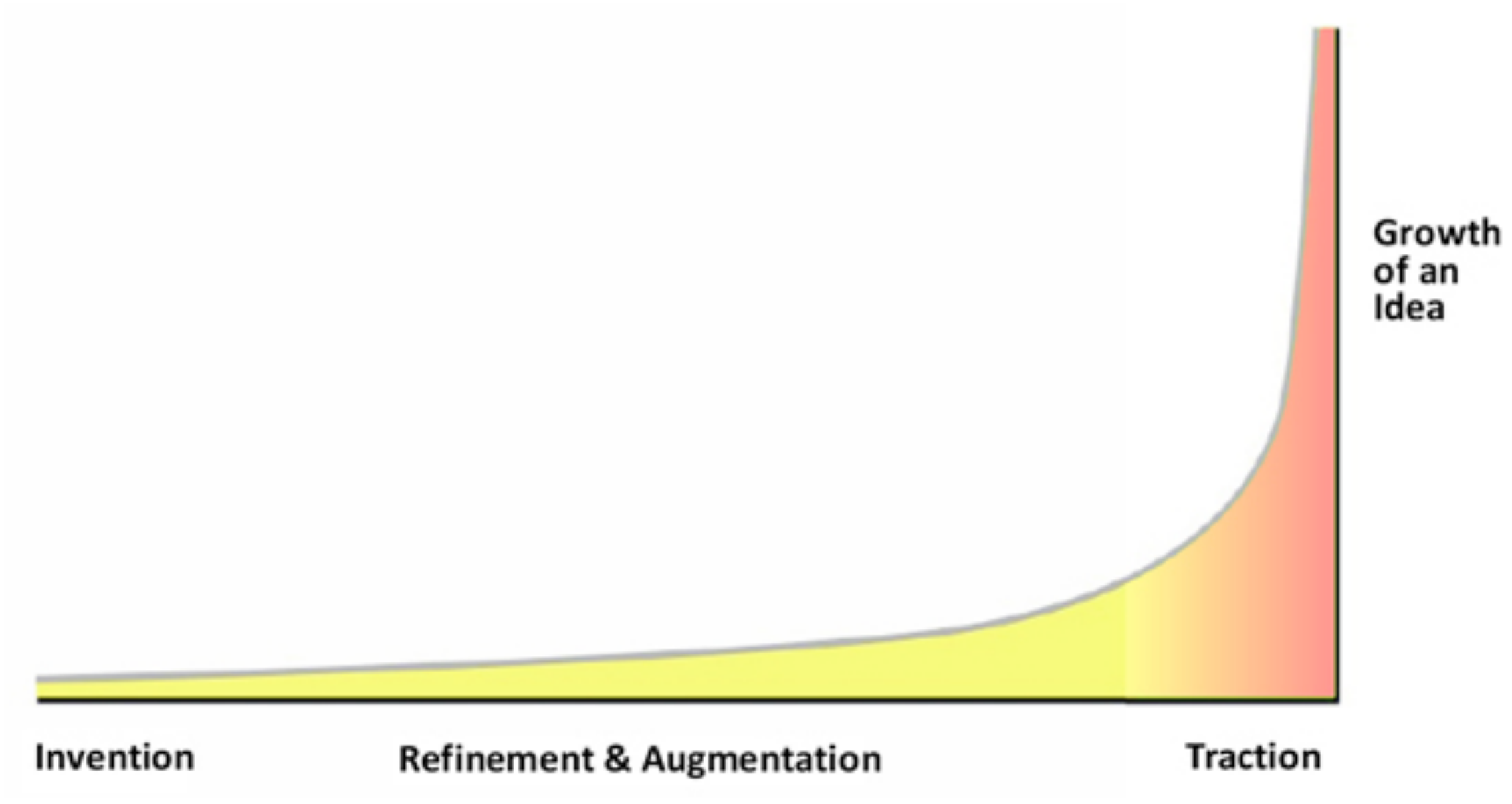
1981

2007
iPhone

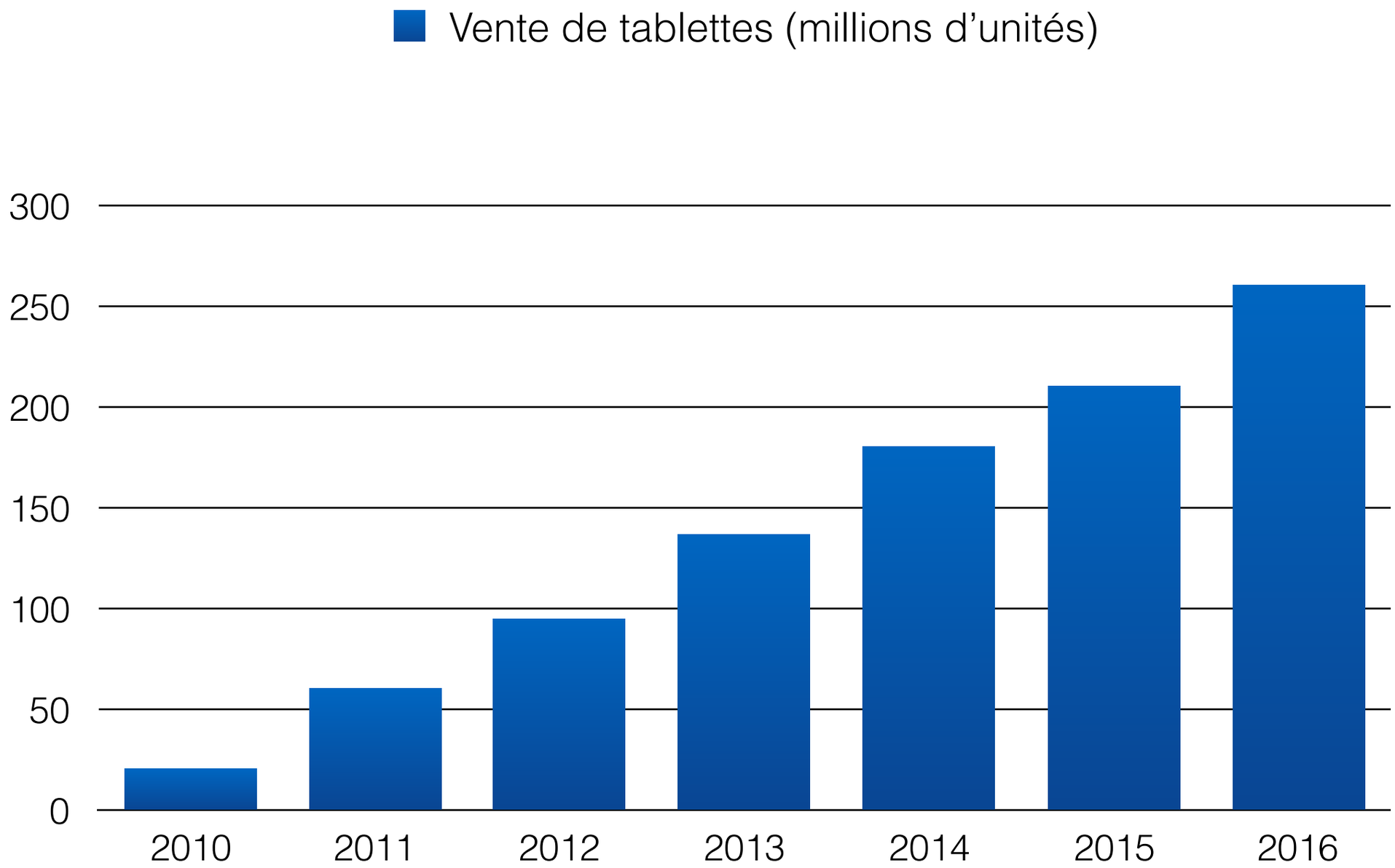
2010
iPad

The long nose of innovation

Bill Buxton



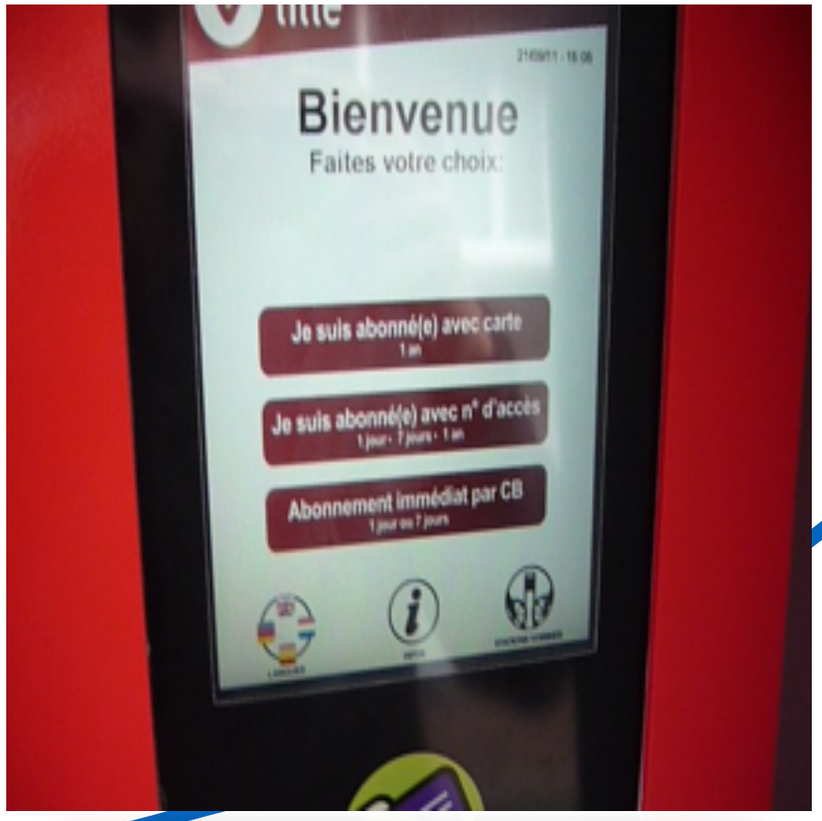
Technologie



Source : Rapport DisplaySearch 2011

Technologie tactile

– Nombre de périphériques tactiles dans les espaces publics



2007 2008 2009 2010 2011 2012

« Everything is best for something and worst for something else. The trick is knowing what is what, for what, when, for whom, where, and most importantly, why. »

–Bill Buxton

Avantages

Barrière d’entrée

Robuste

Plaisir

Sans fil

Multipoint vs souris

Multipoint vs souris

Multipoint vs souris

(2) Degrés de Liberté (DDL) intégrés

Multipoint vs souris

(2) Degrés de Liberté (DDL) intégrés

(1) pointeur

Multipoint vs souris

(2) Degrés de Liberté (DDL) intégrés

(1) pointeur

interaction *indirecte*

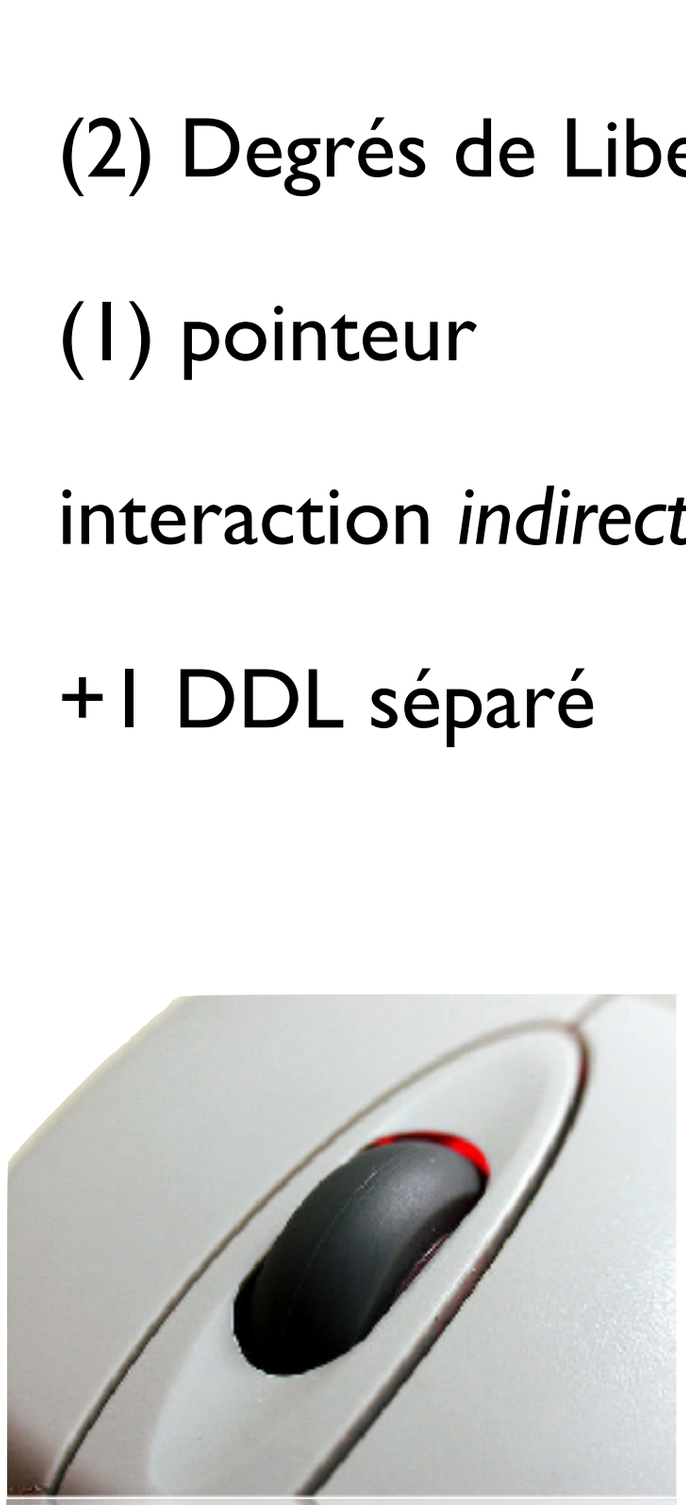
Multipoint vs souris

(2) Degrés de Liberté (DDL) intégrés

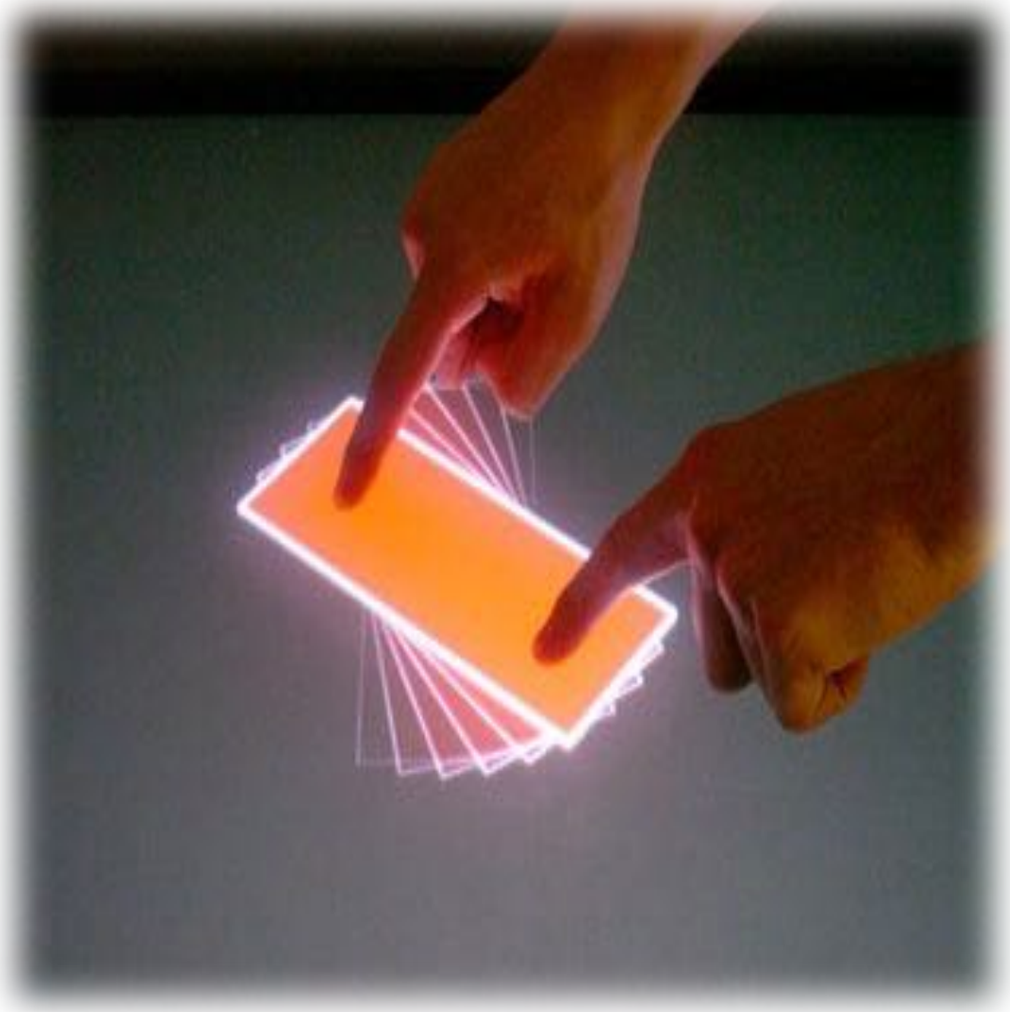
(1) pointeur

interaction *indirecte*

+1 DDL séparé



Directivité

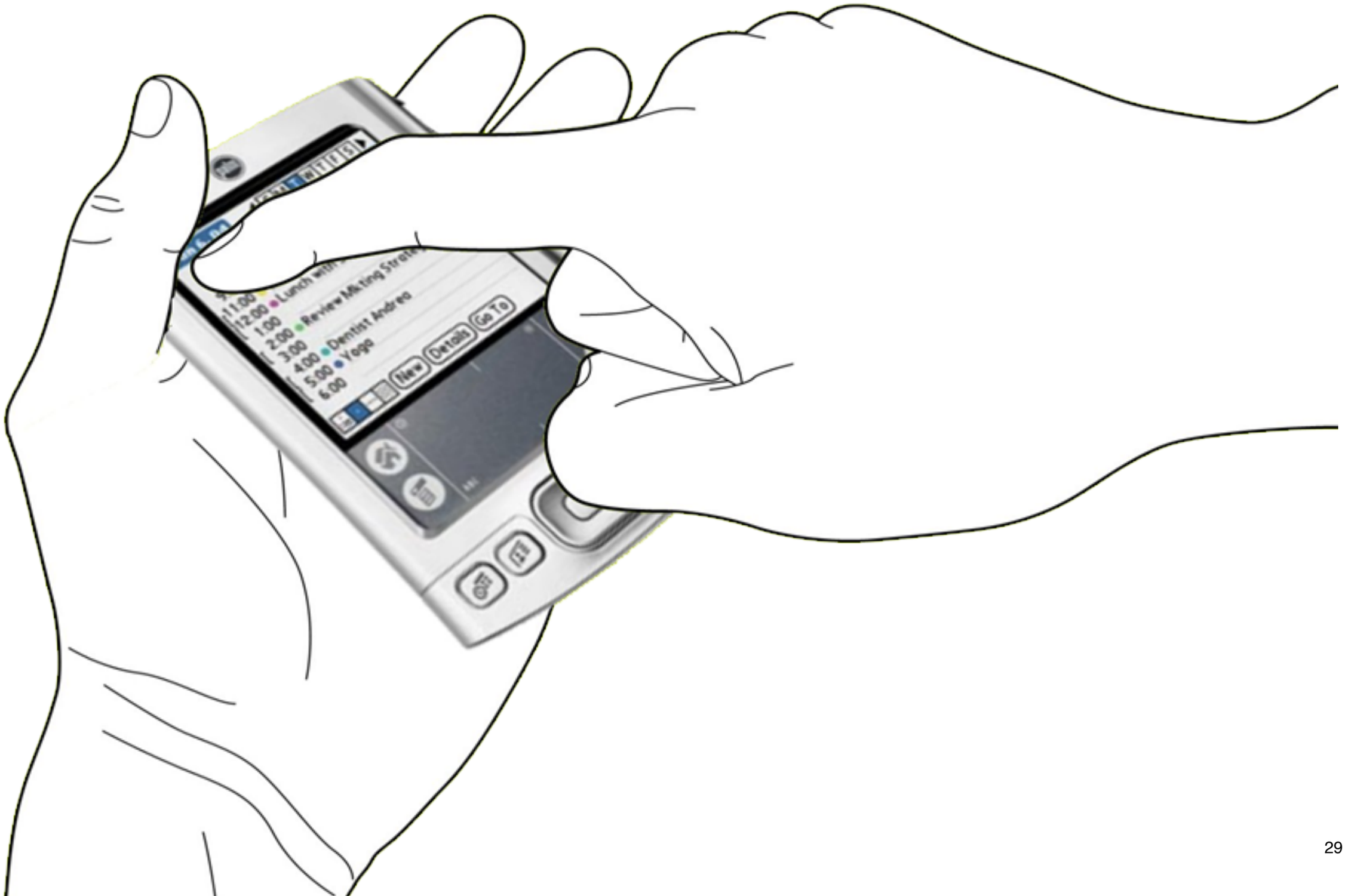


Direct

Indirect

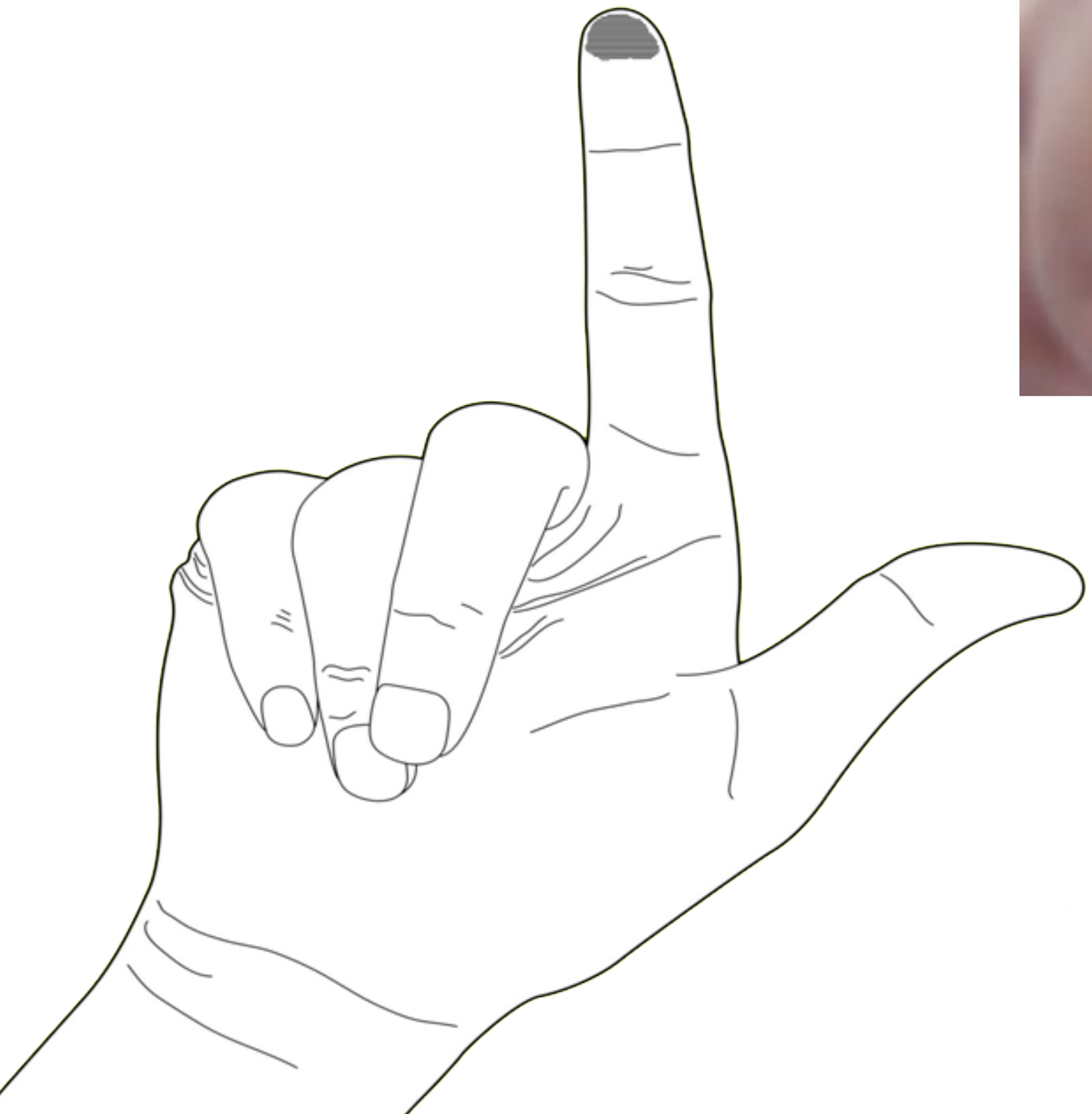
Problems

Fat Finger



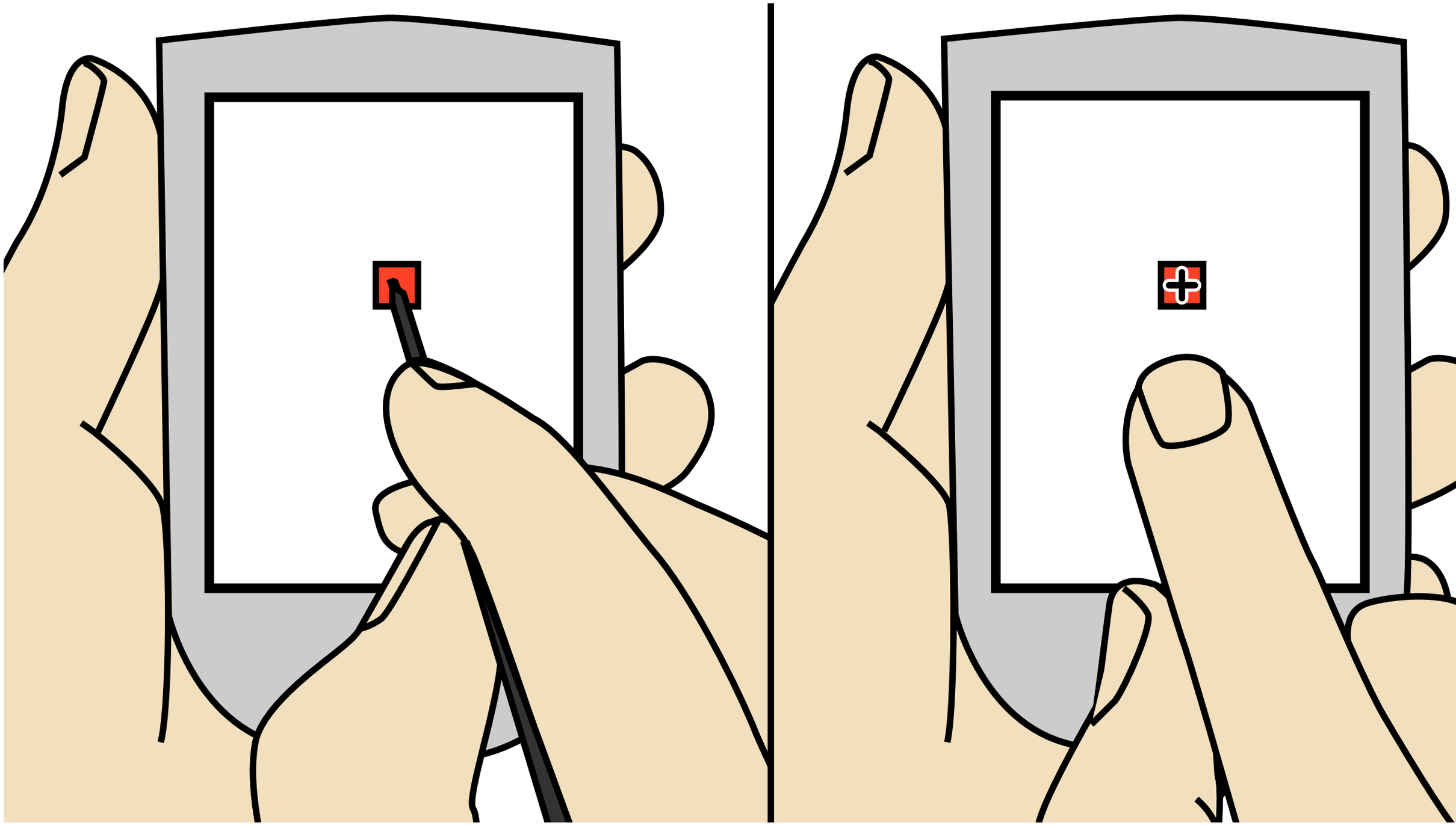
Problems

Fat Finger



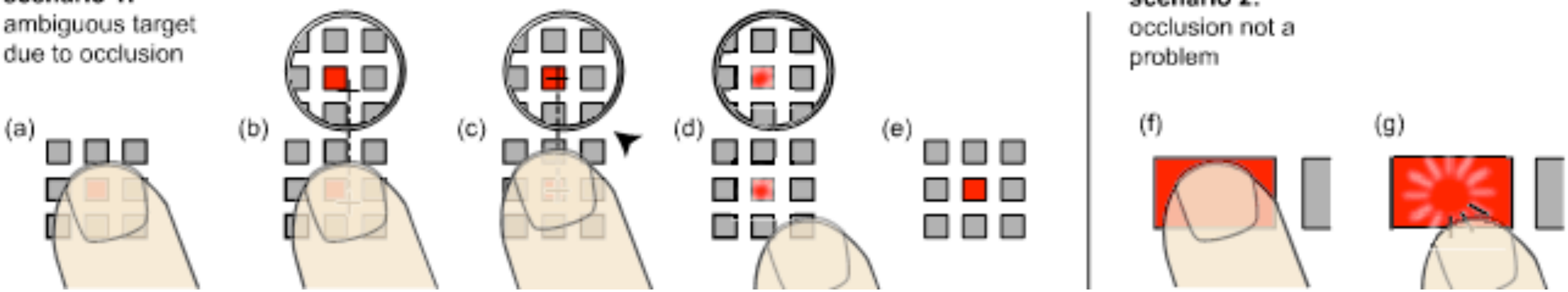
Problems

Precision



Shift

[Vogel et al. 2007]



Shift

[Vogel et al. 2007]

Shift

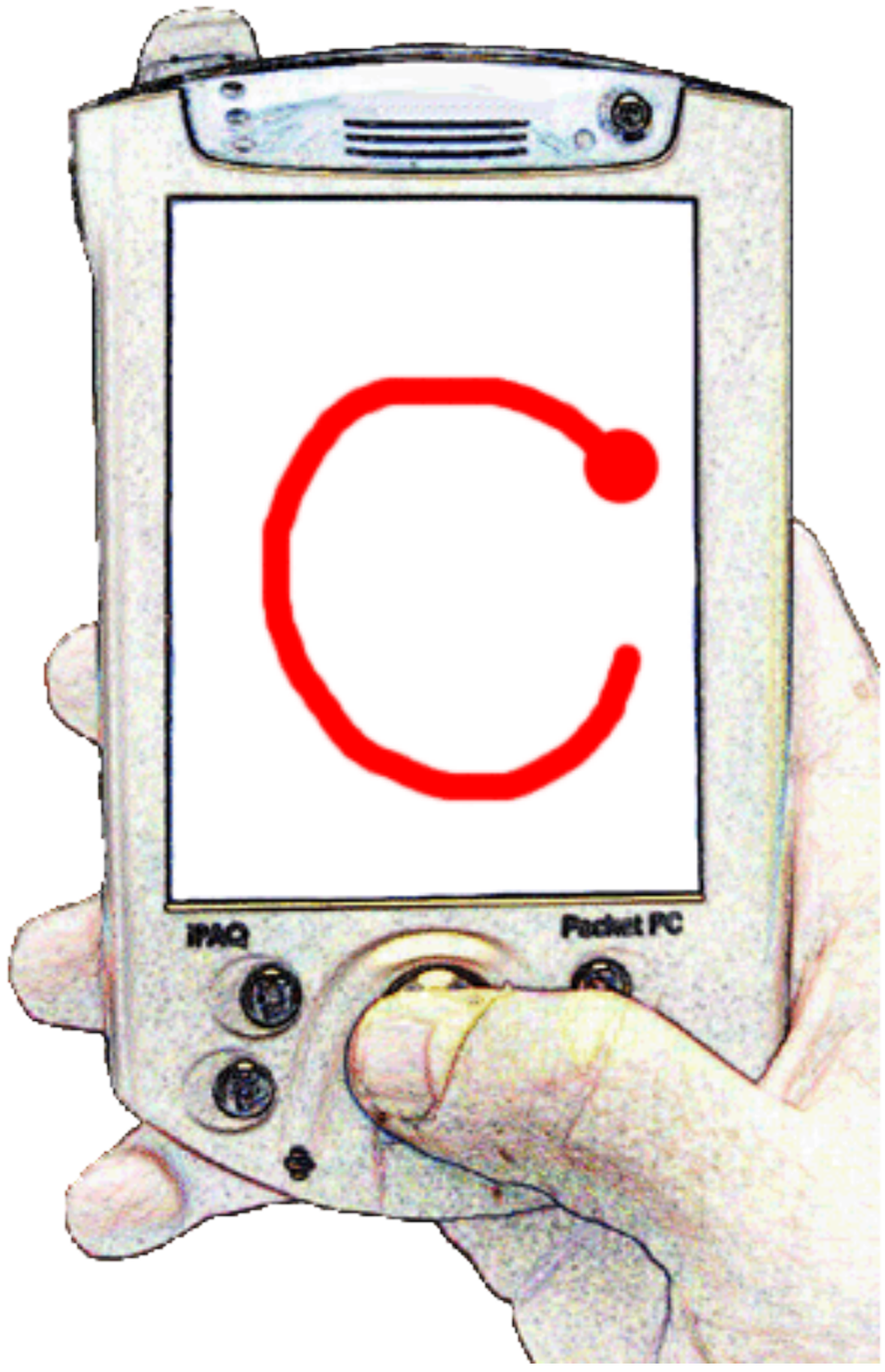
[Vogel et al. 2007]

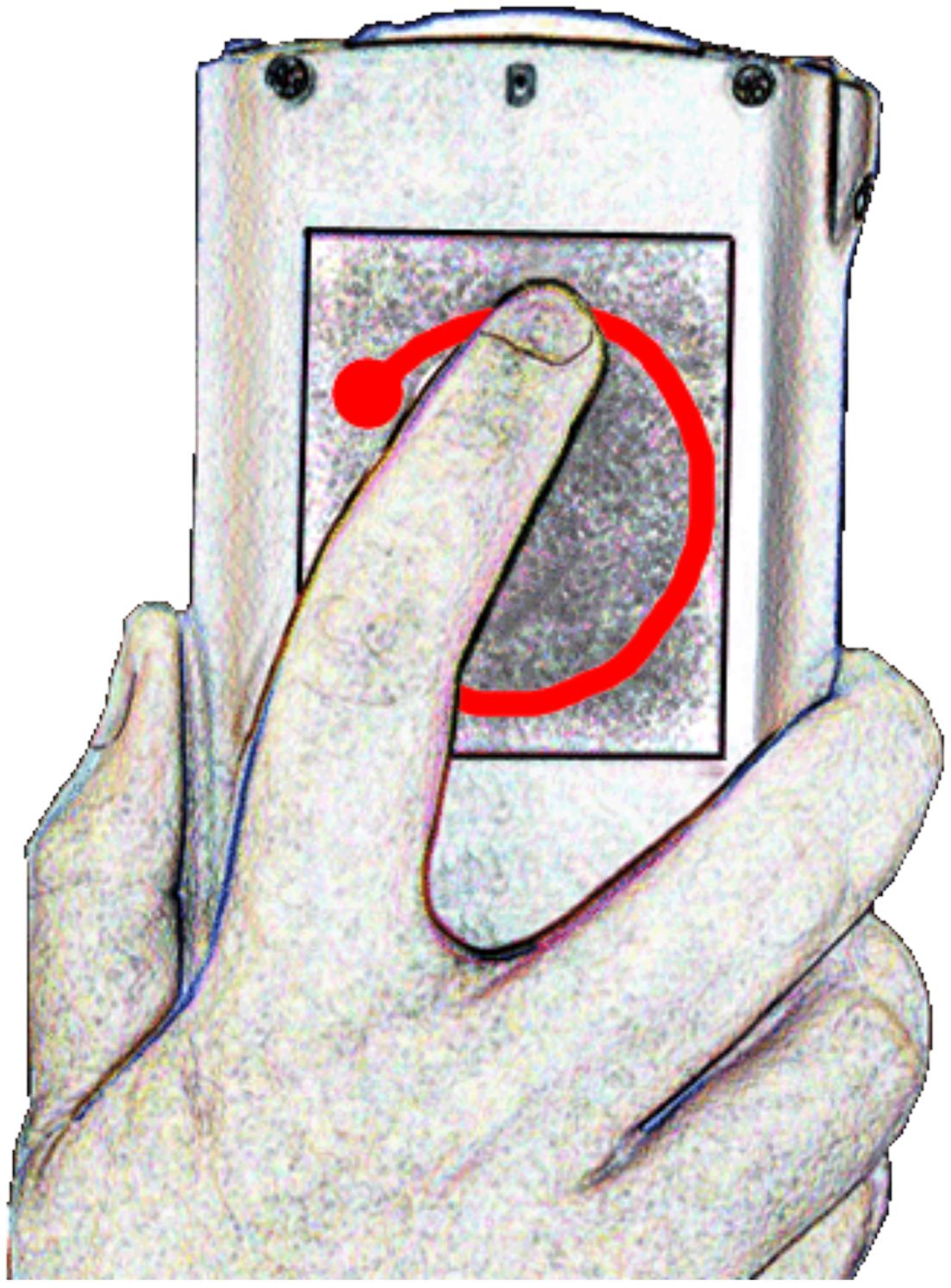
Behind touch

[Hiraoka et al. 2003]

Behind touch

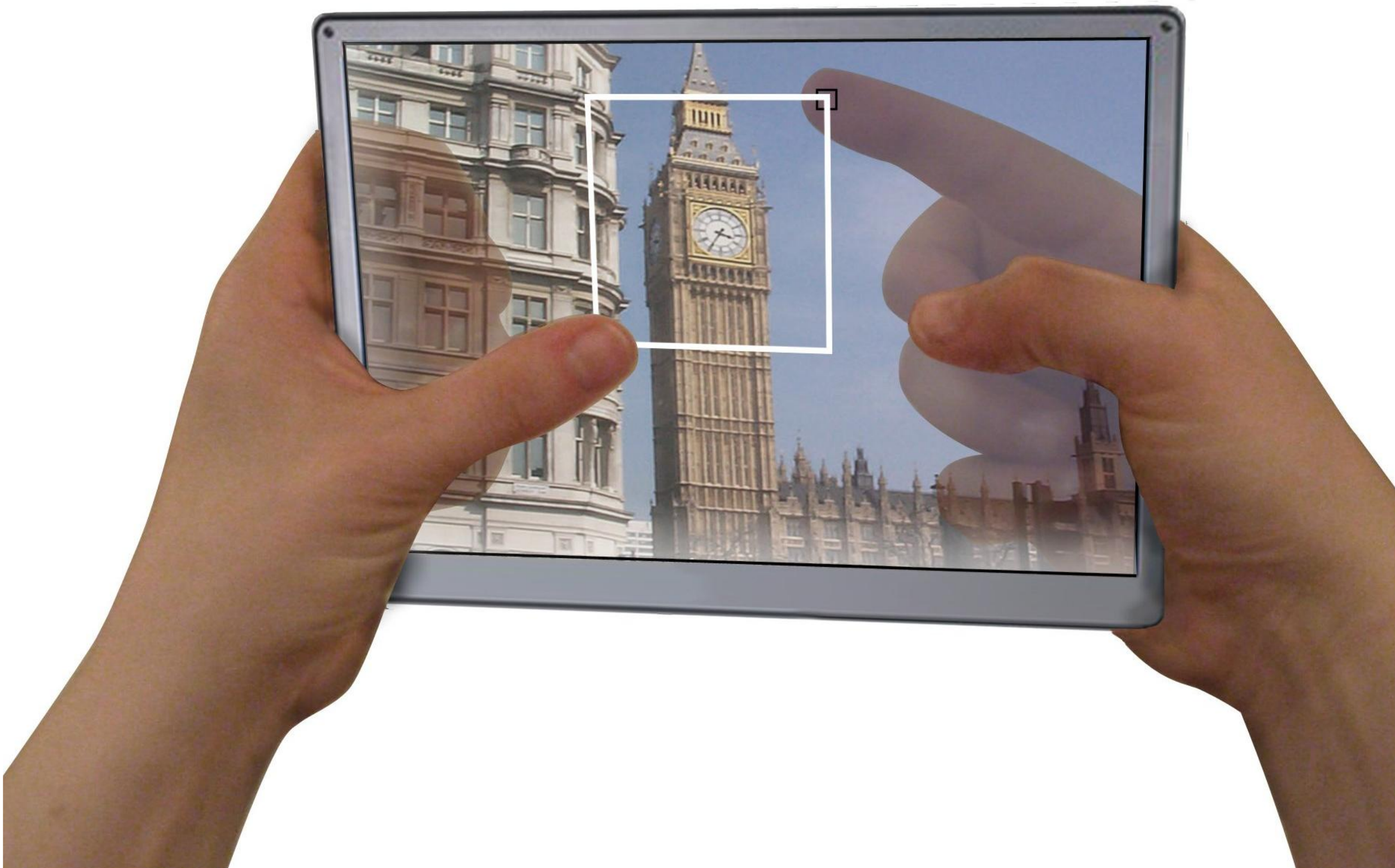
[Wigdor et al.]





Behind touch

[Wigdor et al.]



Lucid touch

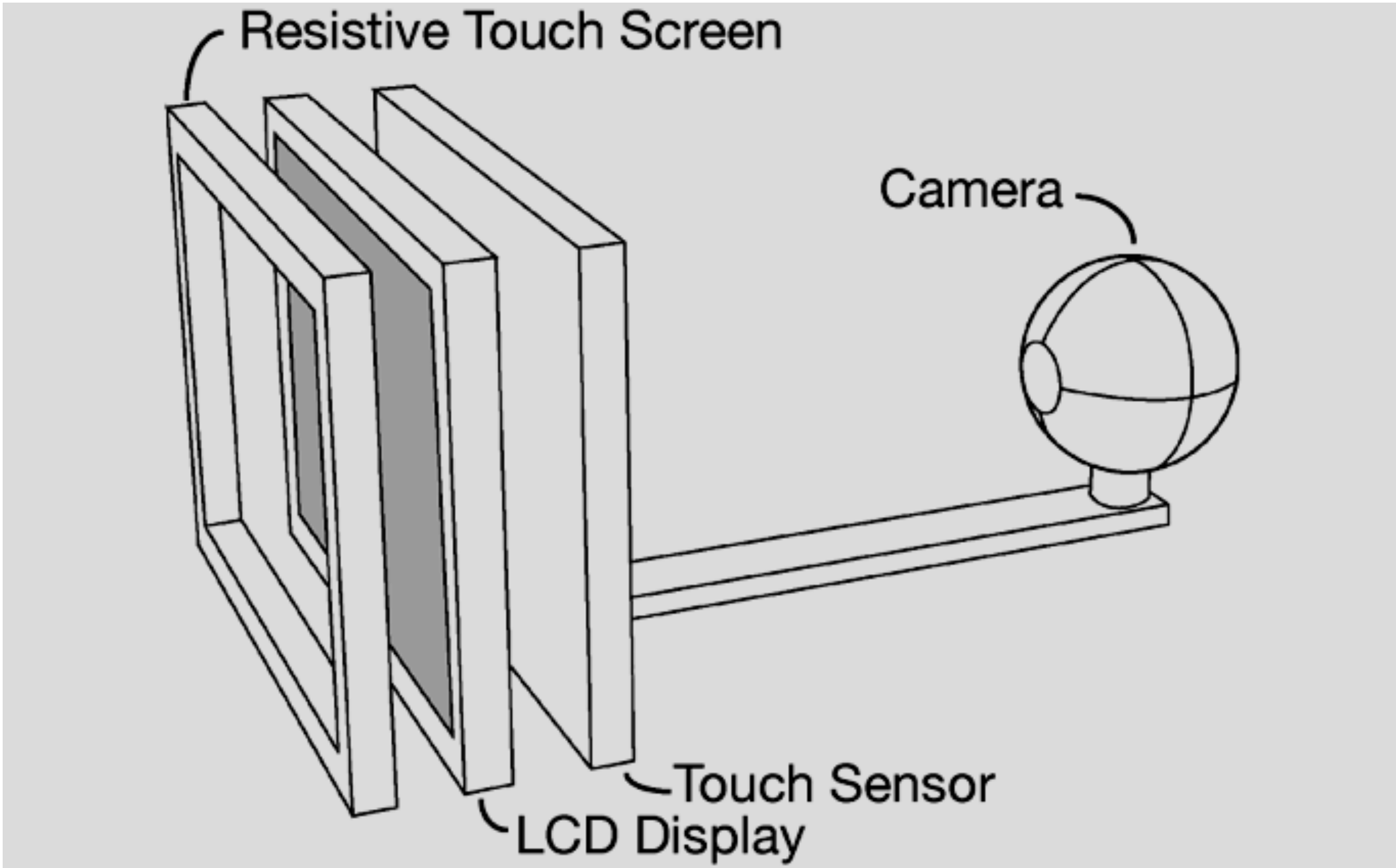
[Wobbrock et al.]

Lucid touch

[Wobbrock et al.]

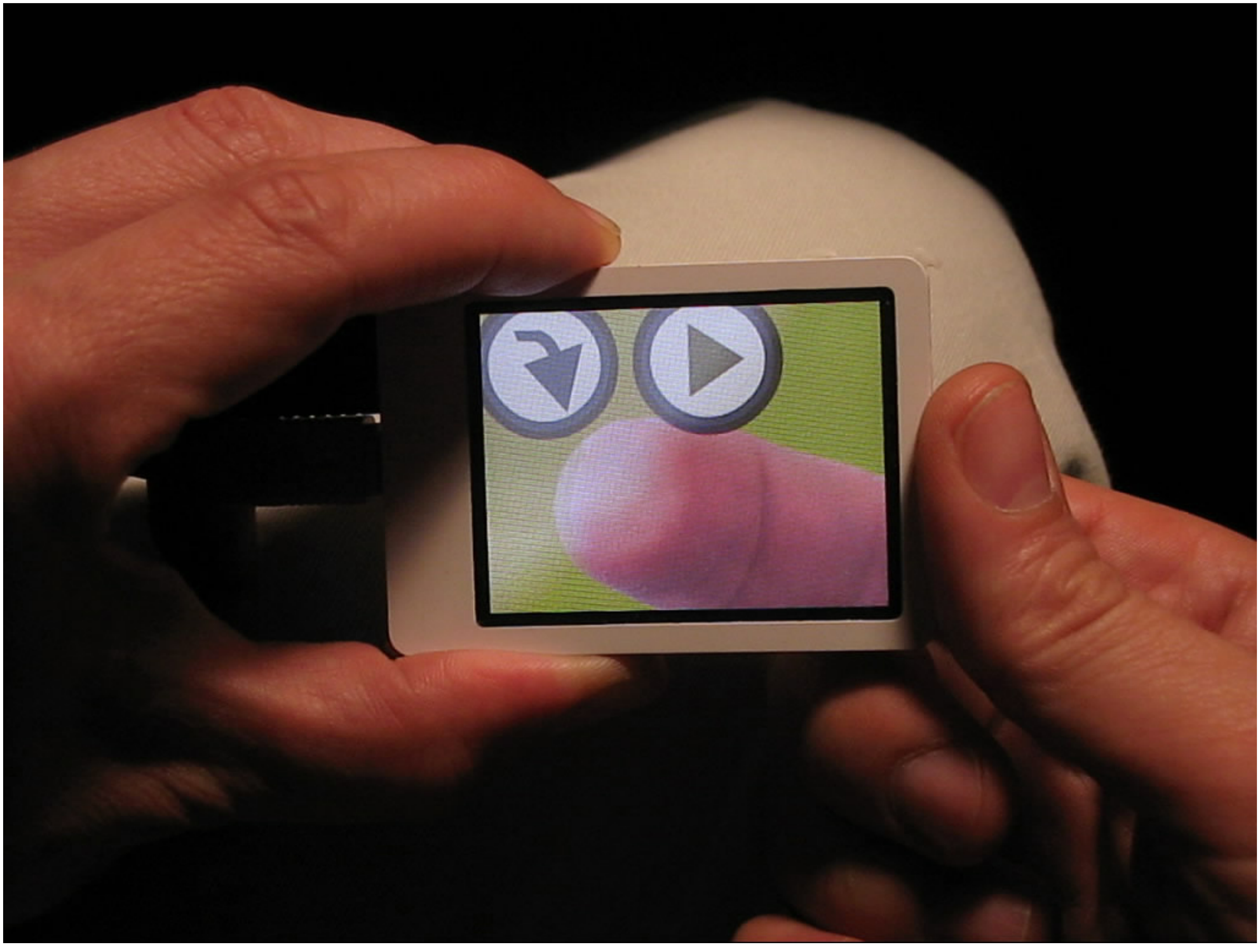
Lucid touch

[Wobbrock et al.]



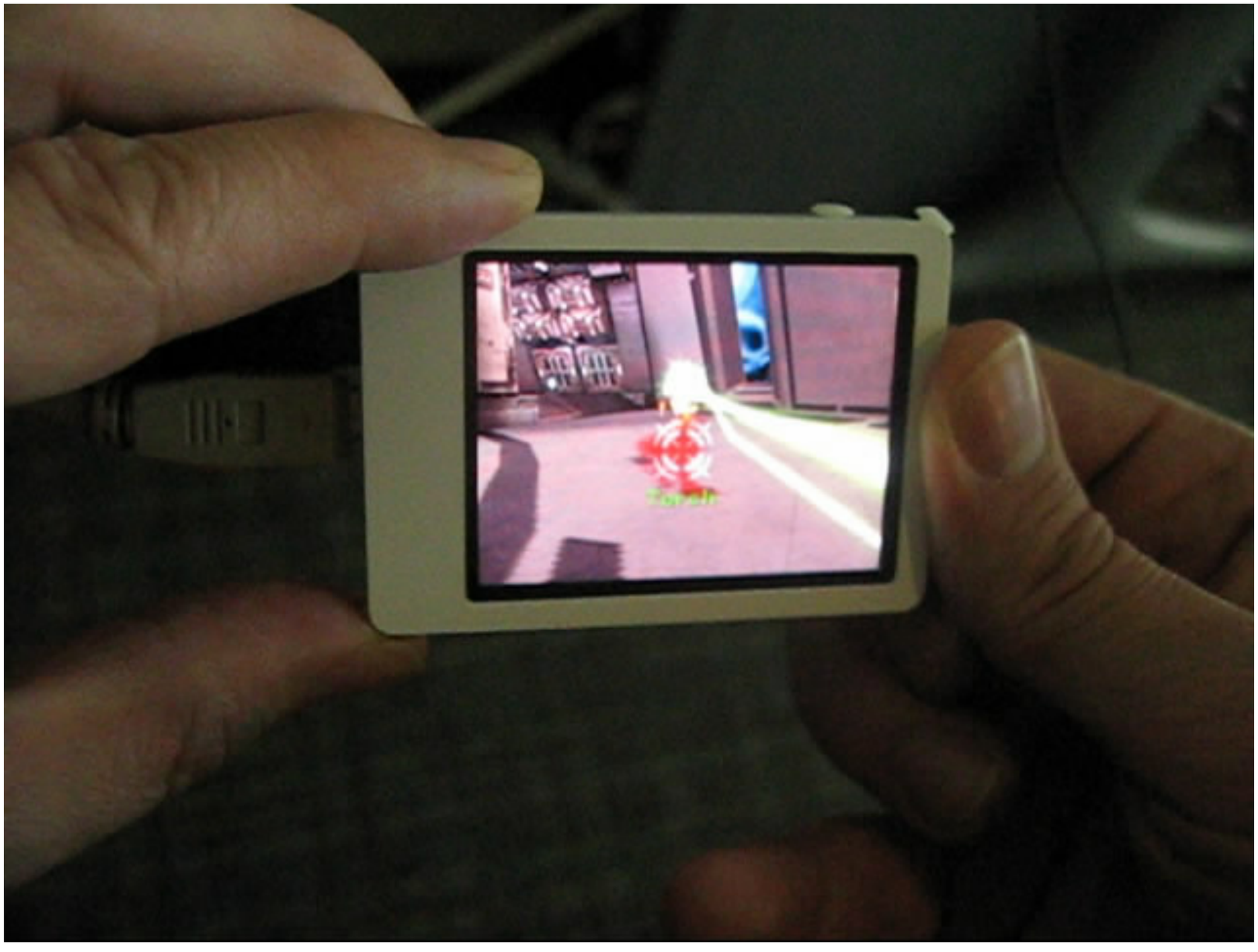
Lucid touch 2

[Baudisch and Chu]



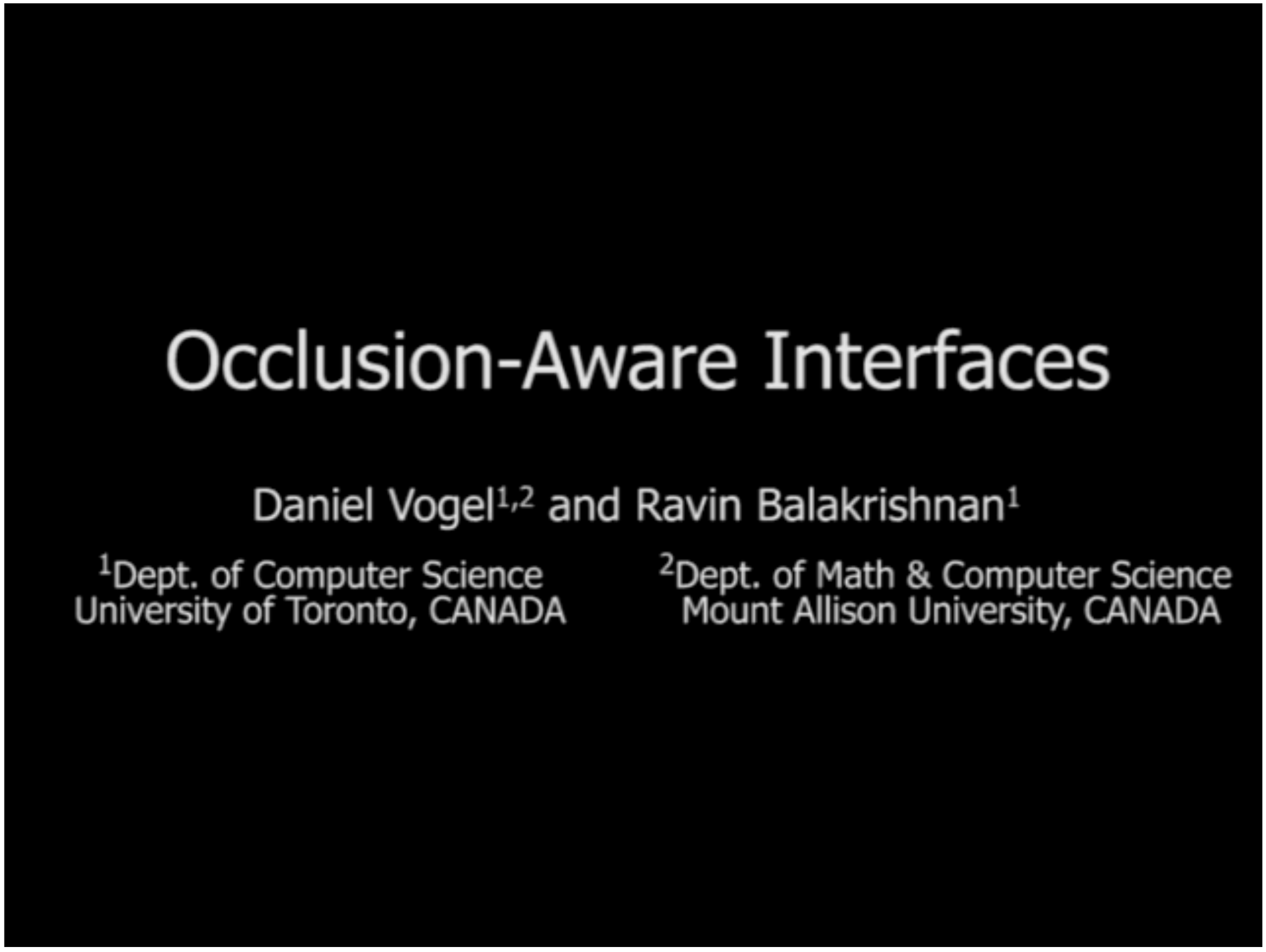
Lucid touch 2

[Baudisch and Chu]



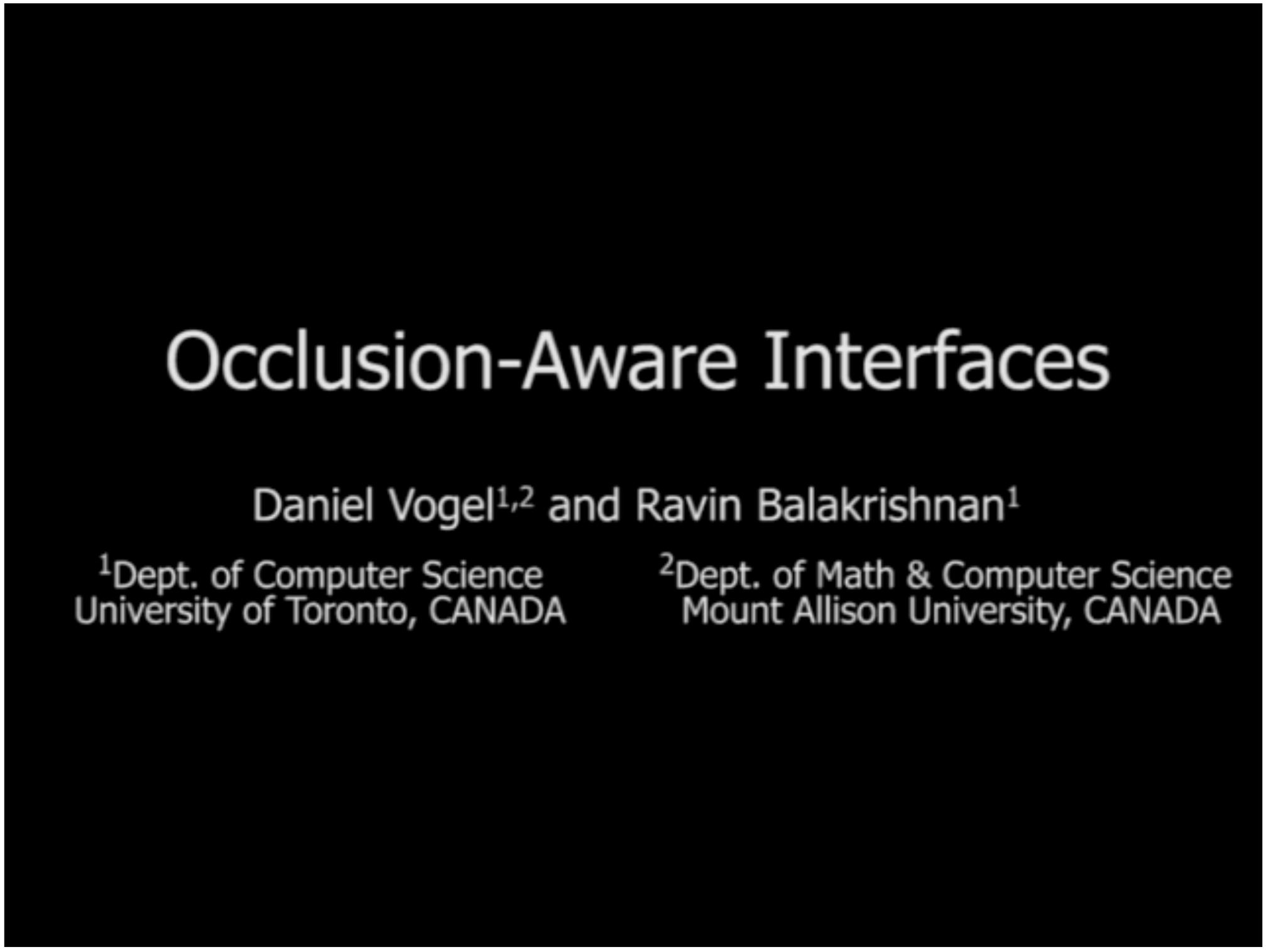
Problem

Occlusion



Problem

Occlusion

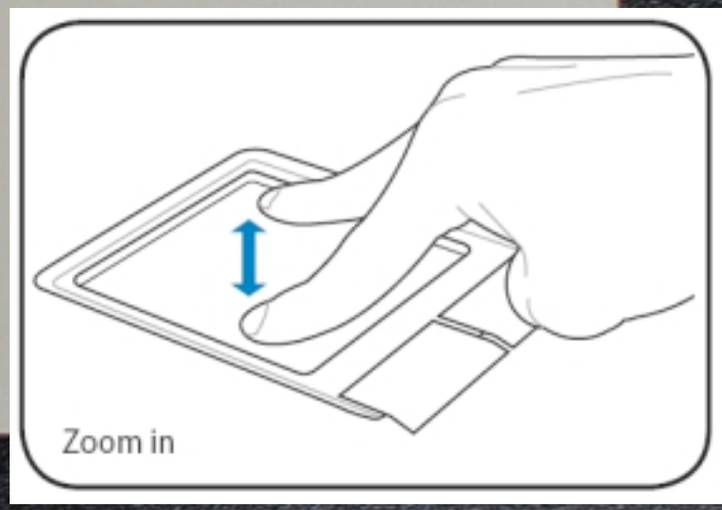


Contexts / usages

1 user

Smartphone, Tablets

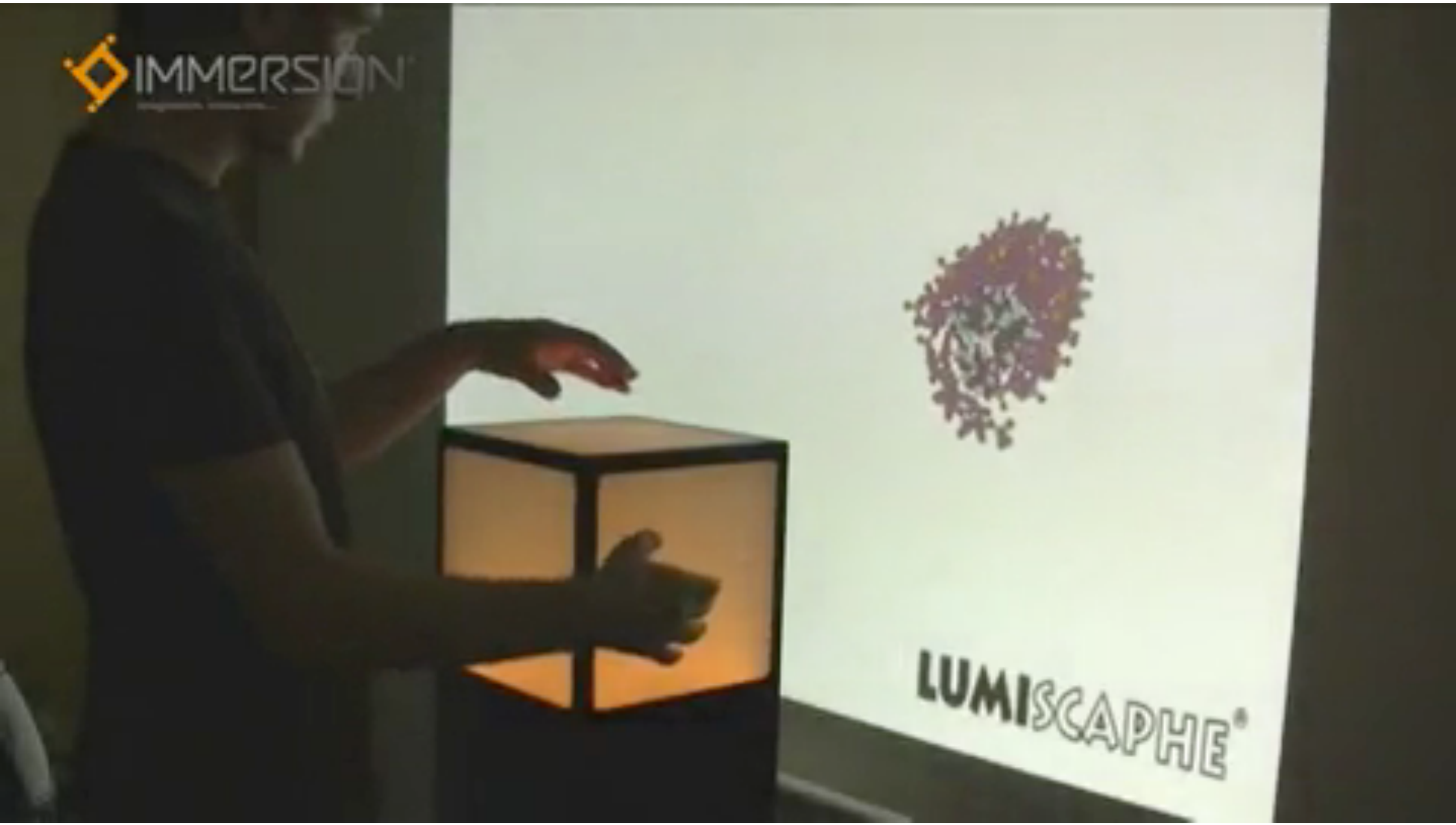
TouchPad:
multitouch + pressure + Tactile feedback



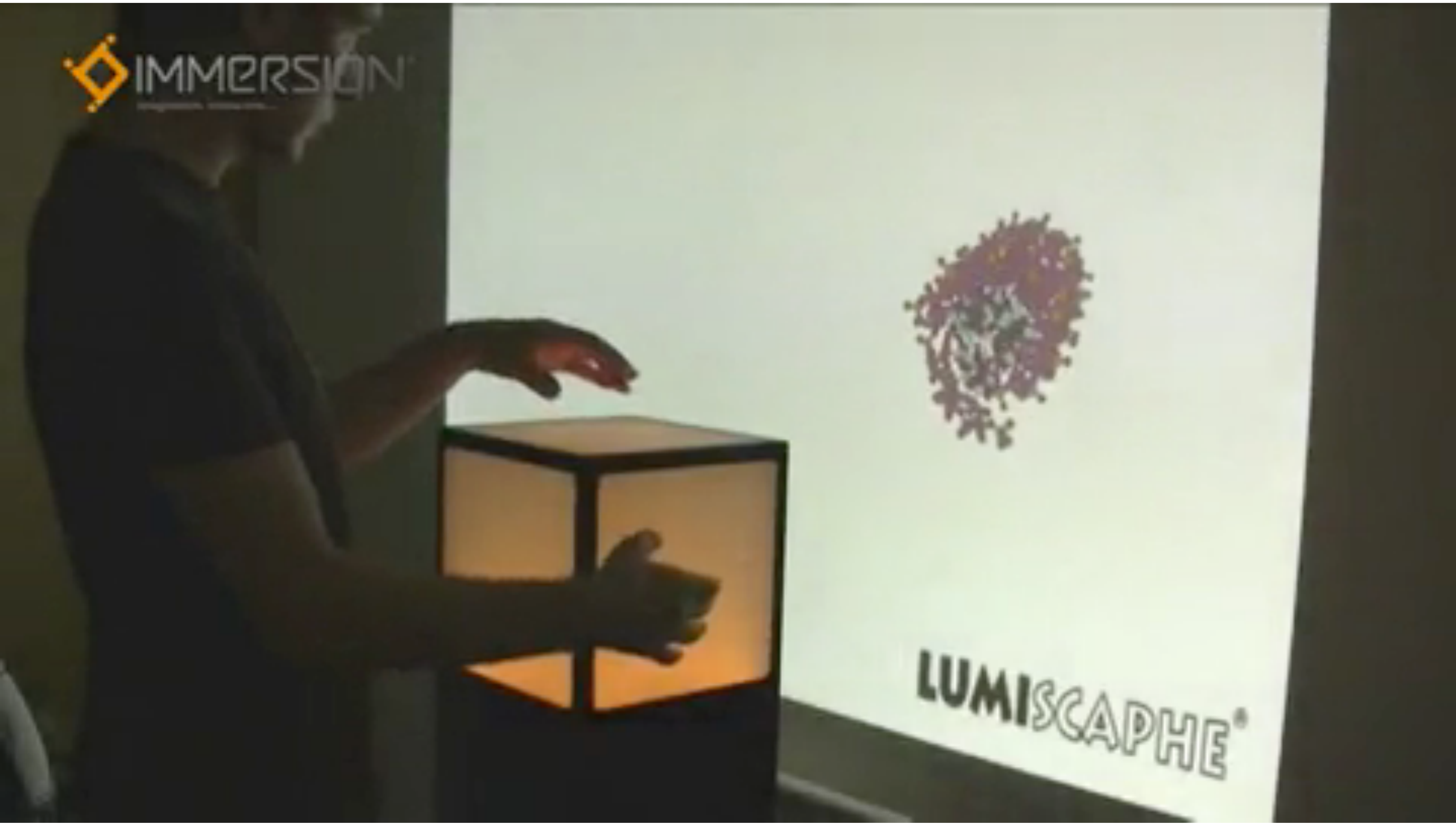
Touchscreen

Mouse

CubeTile [Immersion]



CubeTile [Immersion]



Sphere

Microsoft Sphere

Surfaceless

SixthSense [Mistry and Maes]

PREV

The Boston Globe
MONDAY, JANUARY 5, 2009

In the news

President-elect Barack Obama will call for about $300 billion in tax cuts in his stimulus plan, countering Republican worries that he would rely too heavily on huge spending. A2.

A suicide attack on Shi'ite Muslim pilgrims killed up to 38 people and wounded 72 in one of the worst assaults in Baghdad in months. A2.

Drama should be abundant this year in the Boston City Council, which must deal with a political campaign, a fiscal crunch, and a member under criminal indictment. B1.

A Beth Israel Deaconess opioid helps challenge a long-standing prohibition against giving testosterone to men who have had prostate cancer. A6.

FOR THE PROJECT PURPOSE ONLY

Smoke rose as Israeli infantry soldiers walked into Gaza yesterday. The battles so far have been outside urban areas.

Israelis split Gaza in two amid calls for a cease-fire

By Ethan Bronner
NEW YORK TIMES

ON THE ISRAELI-GAZA BORDER — Israeli ground combat appeared to have been comparatively restrained. Hamas, the Islamist rulers of Gaza, had warned that Israeli

GAZA, Page A6

Obama Cabinet nominee pulls out

Contract in... bogs down R...

First bump in proce... for president-elect

Richardson denied wrongdoing but said the investigation would probably remain unresolved until well after Obama's inauguration and he didn't want to disrupt the new

Obama had tapped Richardson for the secretaryship, Page A12

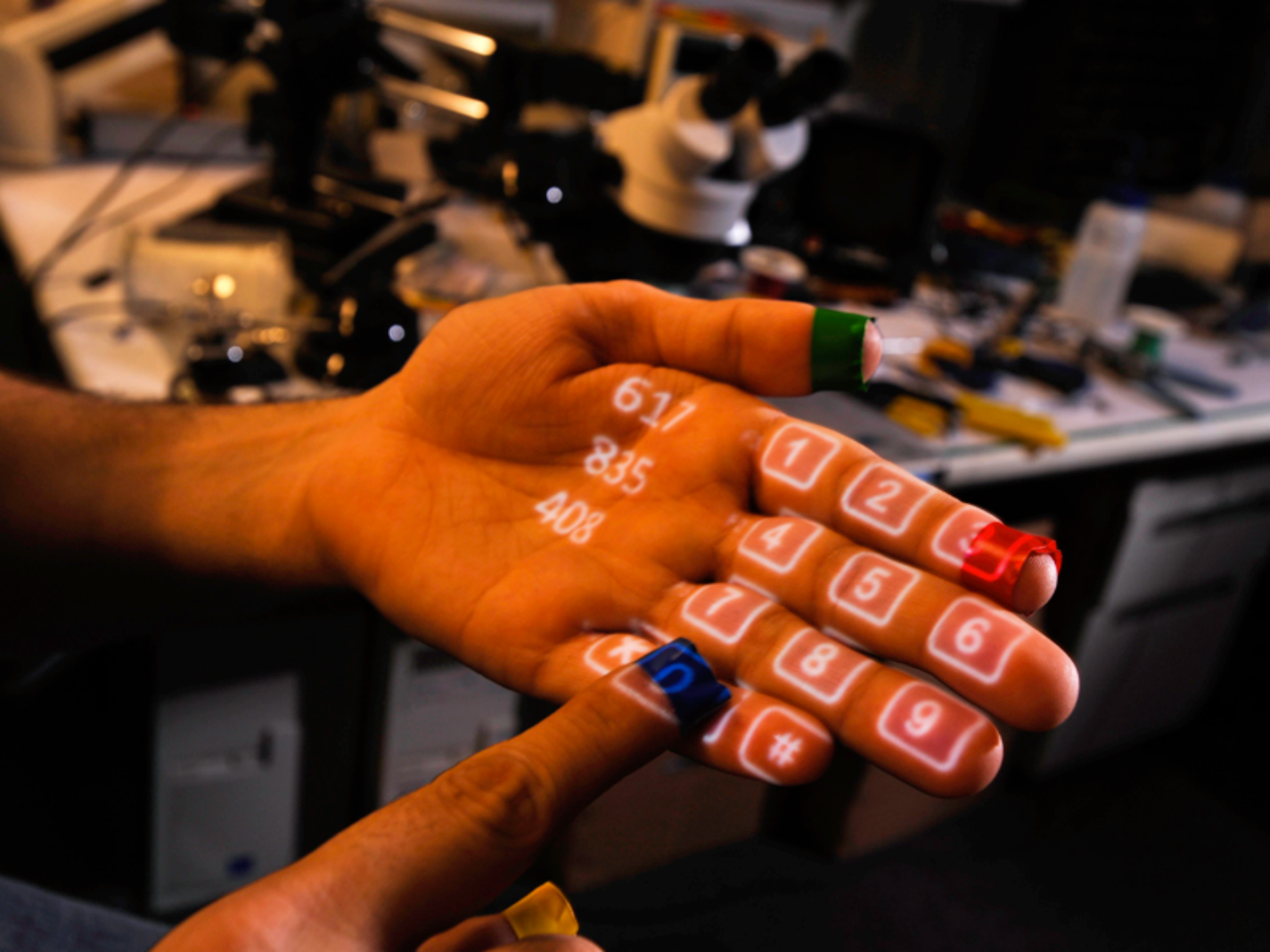
As rich rivals cut back, small colleges sell stability

Rely on tuitions, not endowment

Jumb...

Church struggles to keep its voic...


Cambridge
Harvard University
Boston
Boston University
Charles River
Back Bay
Fenway Park
Longwood
Northeastern University
Massachusetts Turnpike (Toll road)


617
835
408
1
2
3
4
5
6
7
8
9
*
0
#

2 users

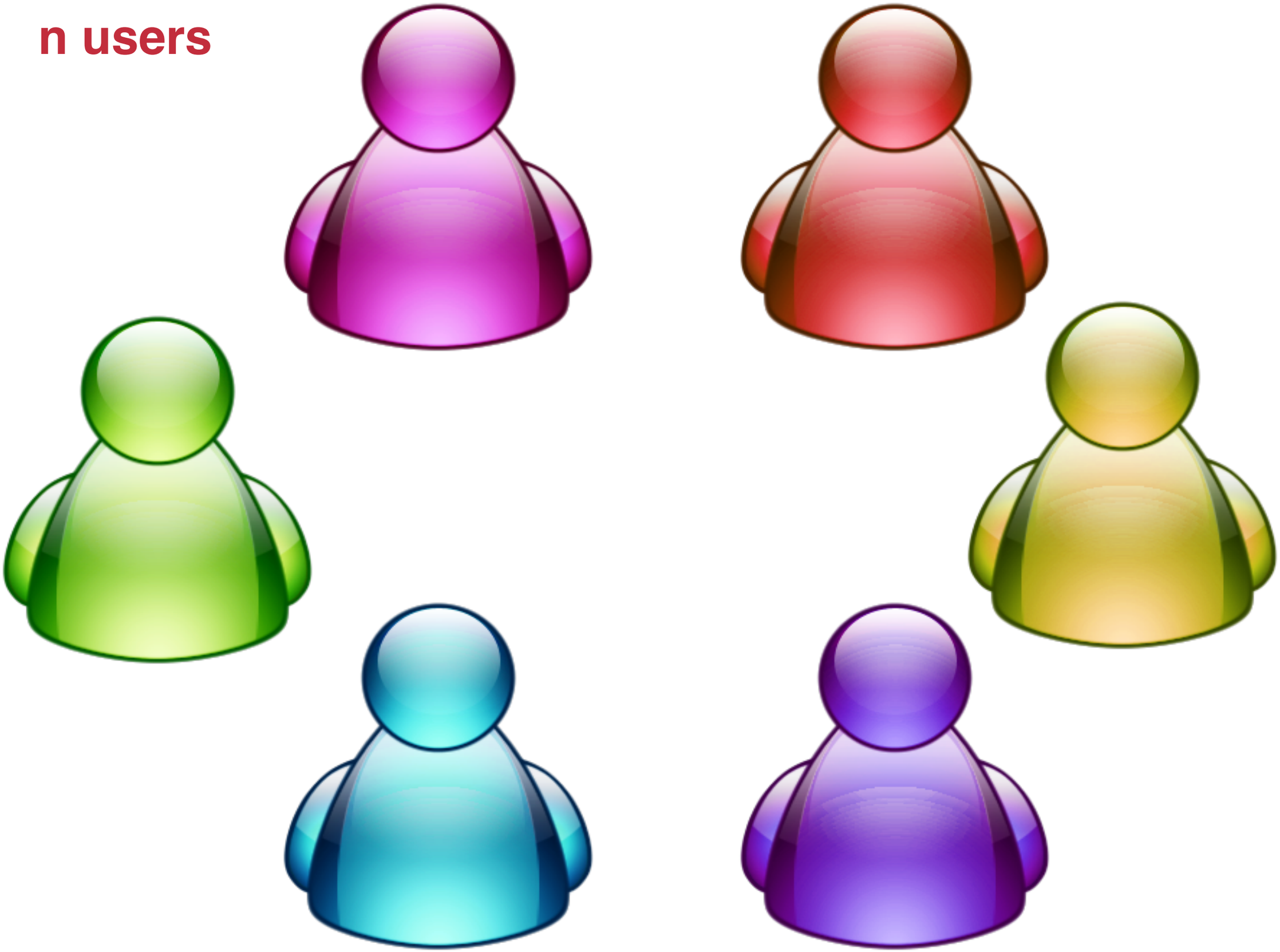
Microsoft Sphere

Microsoft Sphere

Coffee Table

Microsoft Surface

n users



Tabletop

ReacTable

TableTop

Reactable

http://reactable.com/

TableTop

Reactable

http://reactable.com/

Interactive wall displays

Interactive wall displays

Interactive floor

Interactive Floor

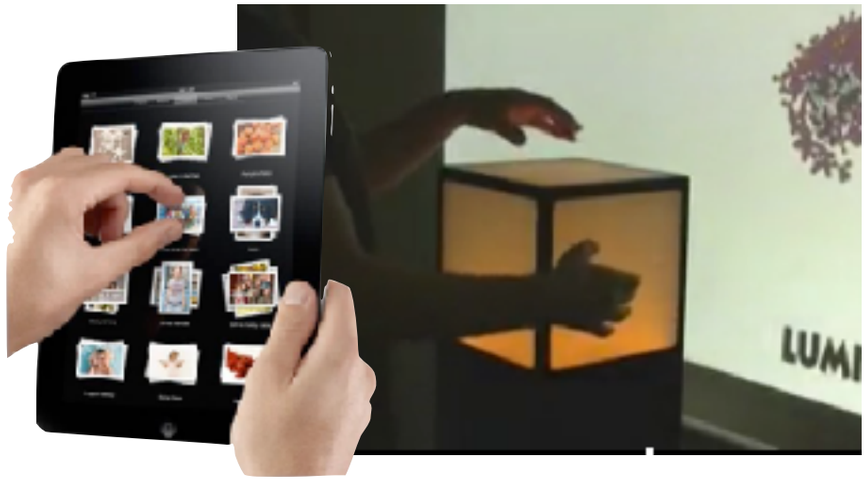
Multitoe [Fetzer et al.]

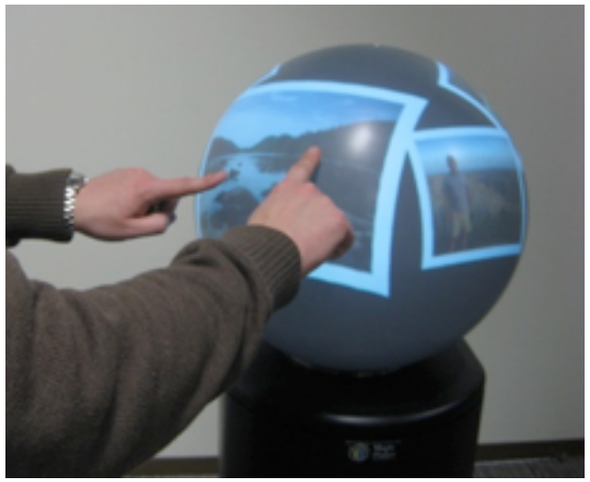
https://hpi.de/baudisch/projects/multitoe.html

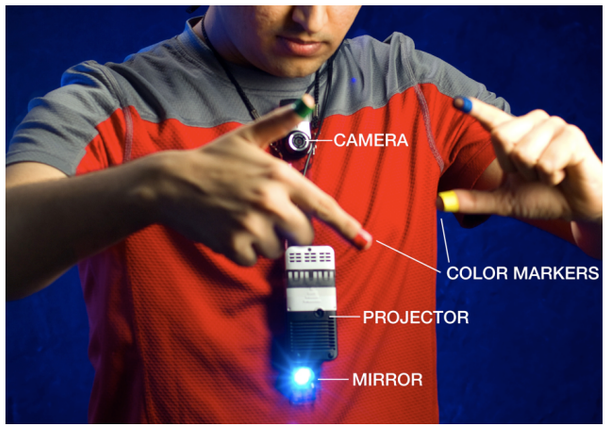
Interactive Floor

Multitoe [Fetzer et al.]

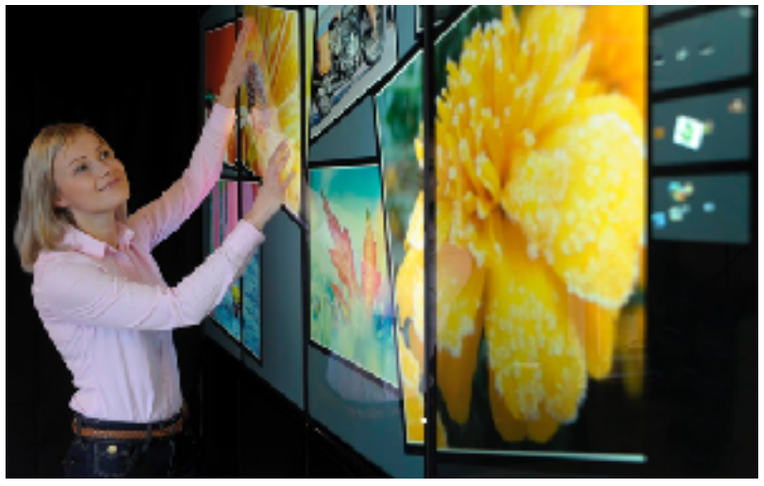
https://hpi.de/baudisch/projects/multitoe.html


LUMI




CAMERA
COLOR MARKERS
PROJECTOR
MIRROR

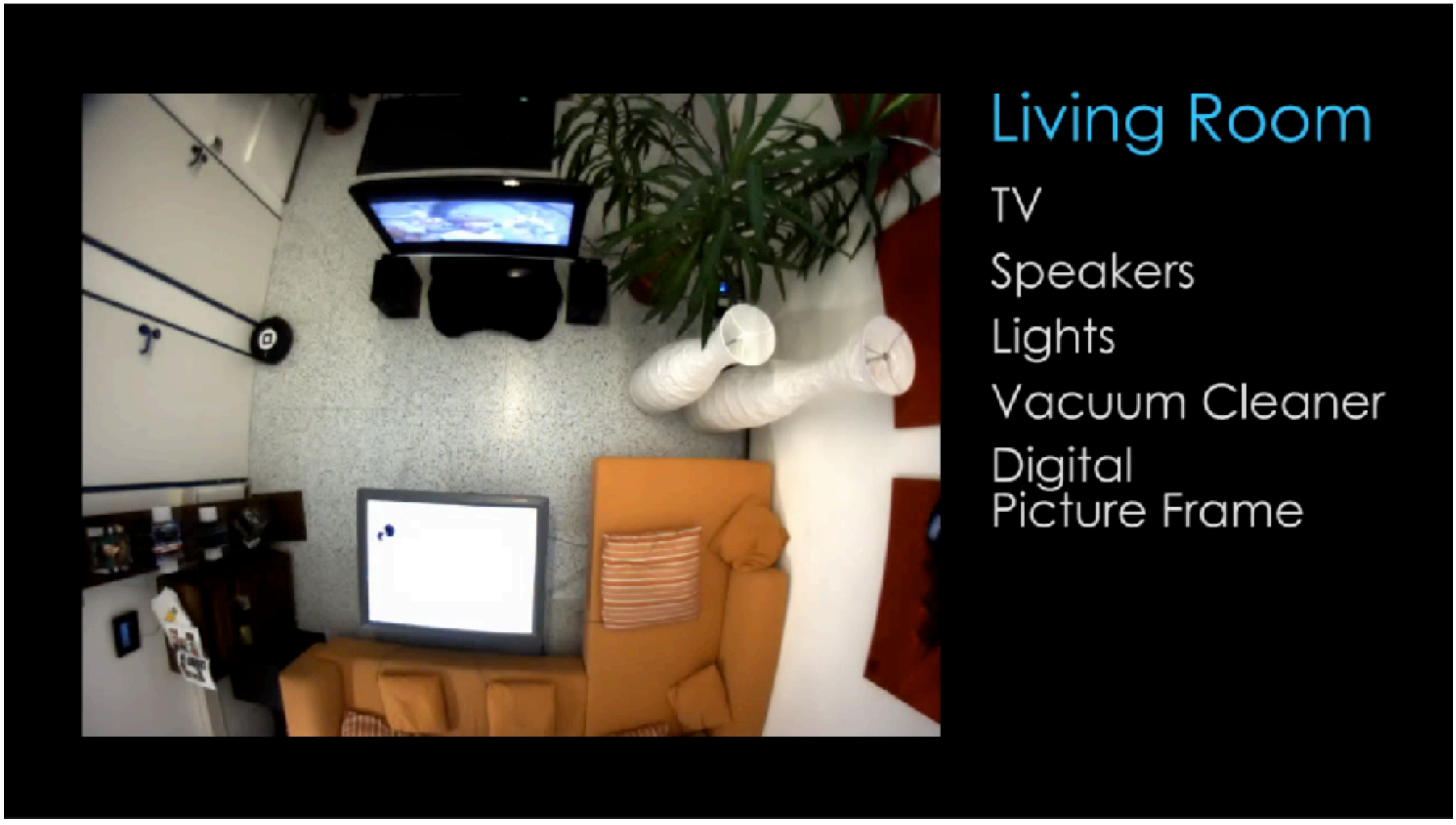

WHO ARE YOU?
Tom
Caro
René
Dan



Applications

Smart Home

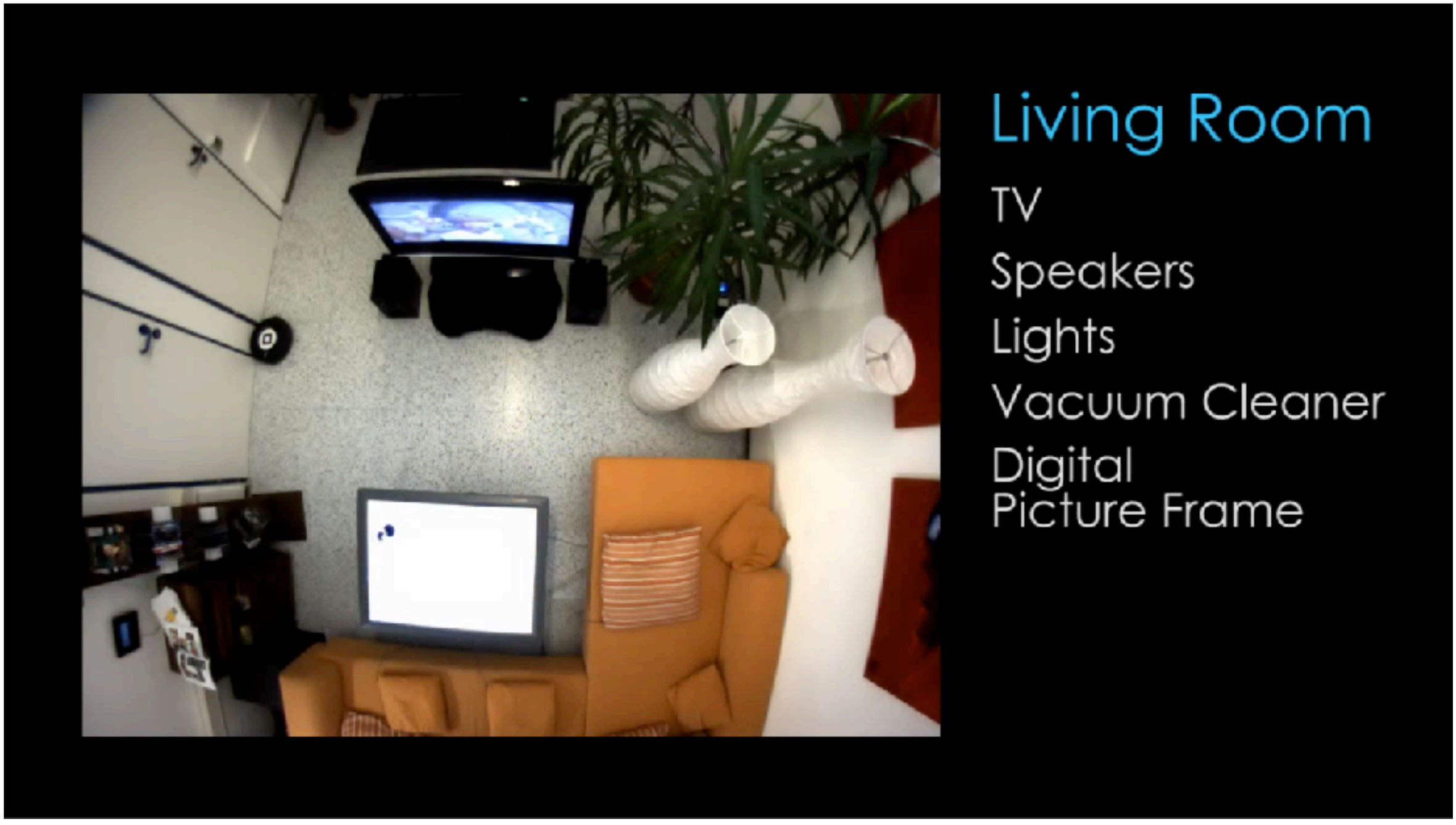
CRISTAL



http://mi-lab.org/projects/cristal/

Smart Home

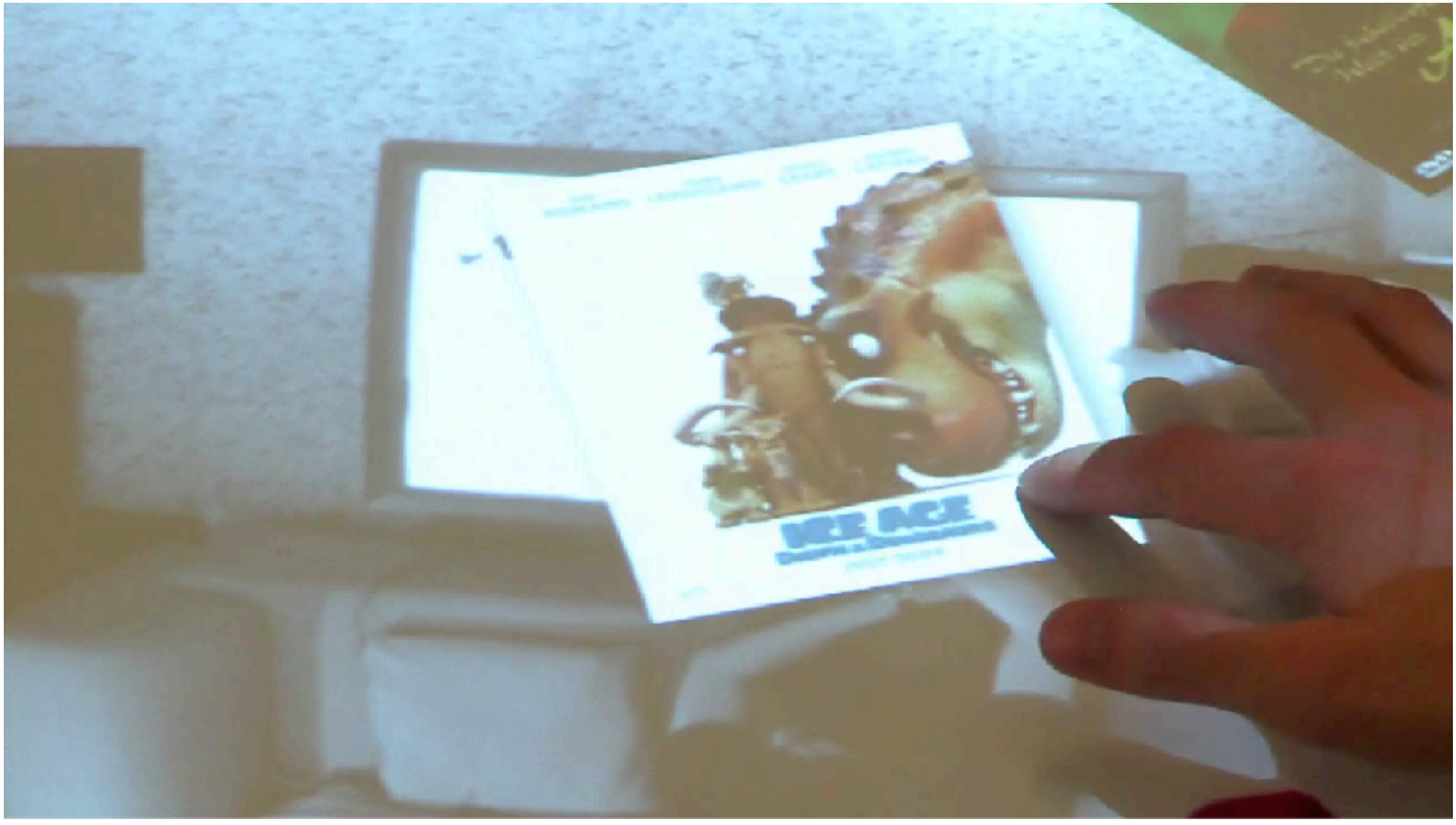
CRISTAL



http://mi-lab.org/projects/cristal/

Smart Home

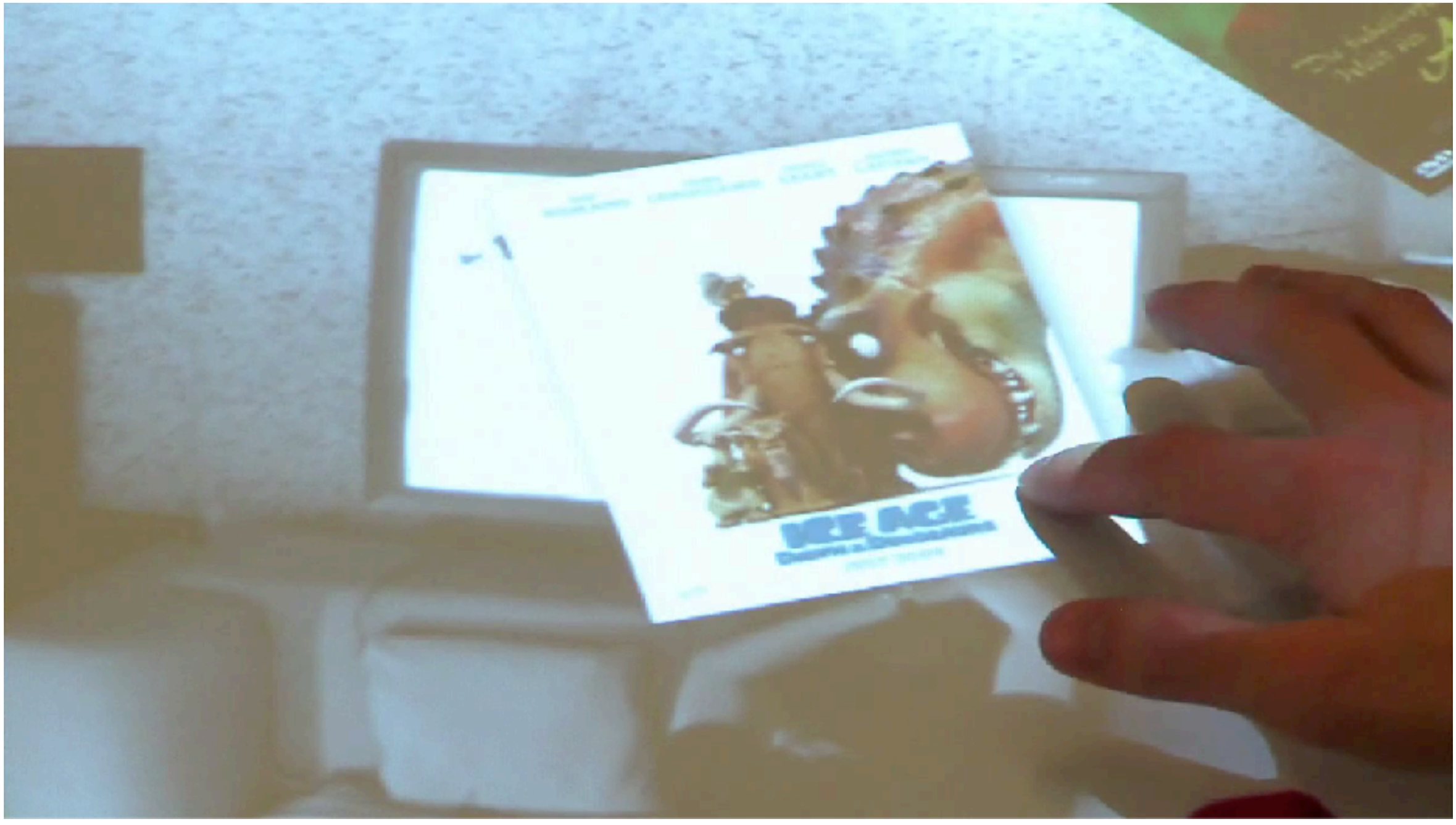
CRISTAL



http://mi-lab.org/projects/cristal/

Smart Home

CRISTAL



http://mi-lab.org/projects/cristal/

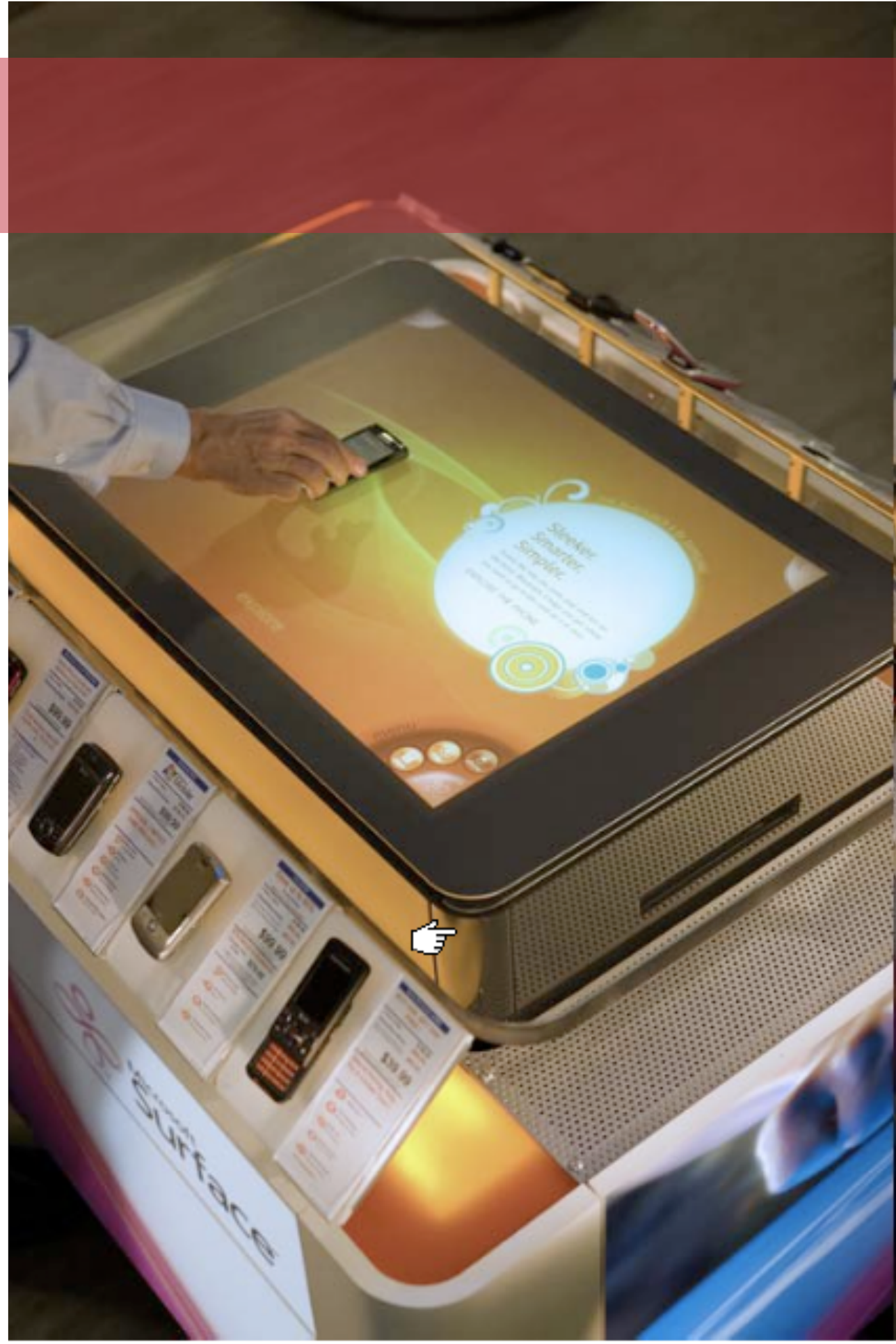
Museums / Expositions

Fiction

Gaming

Bars

Shops



Situation room

Music

Music

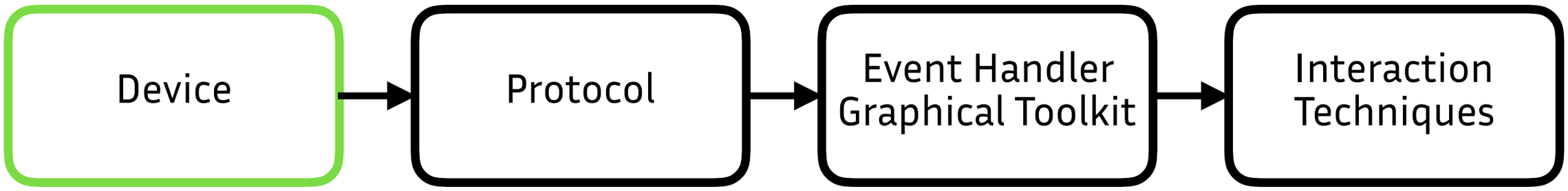
Digital art

SandCanvas - https://www.youtube.com/watch?v=NQ9FERXWWsQ

Digital art

SandCanvas - https://www.youtube.com/watch?v=NQ9FERXWWsQ

Multitouch pipeline



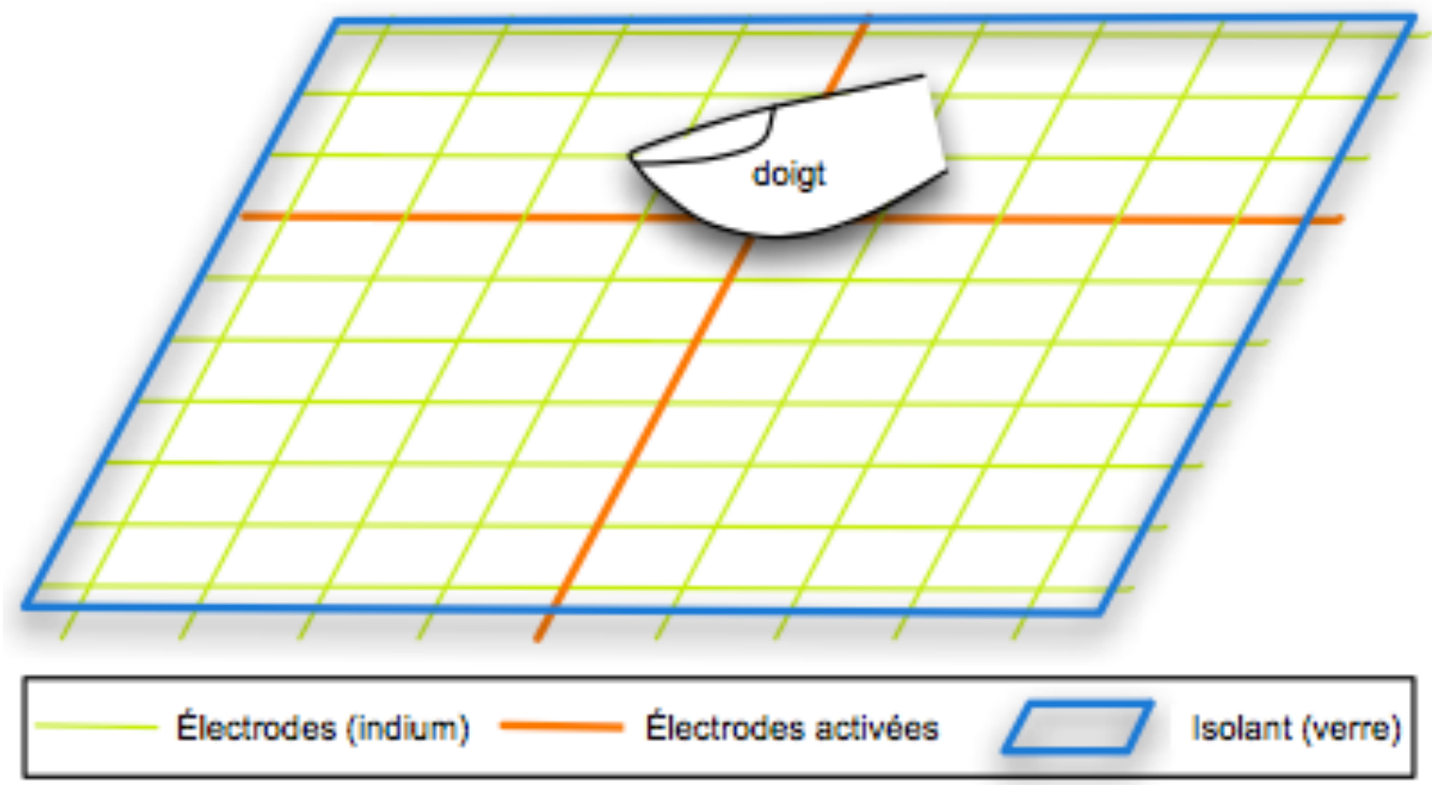
Technologies

Acoustique

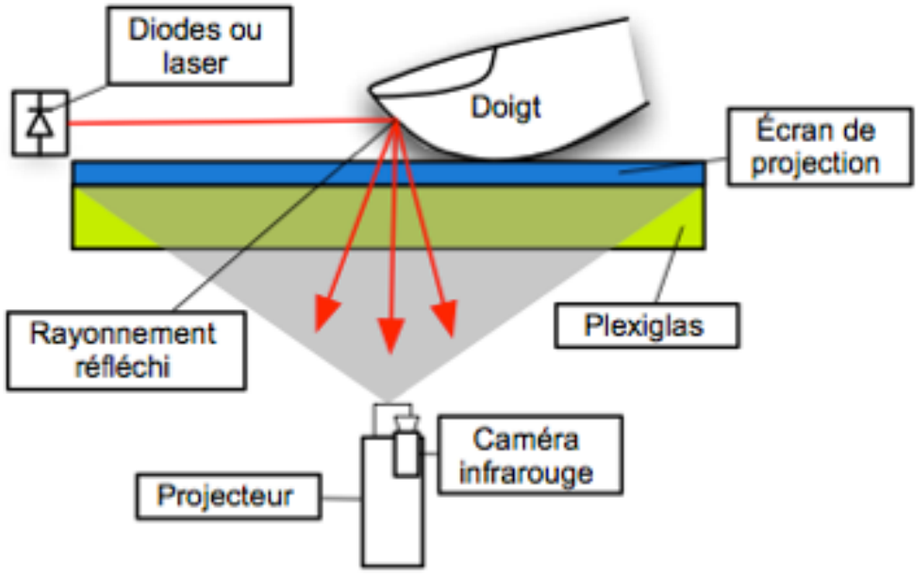
Résistive

Capacitive

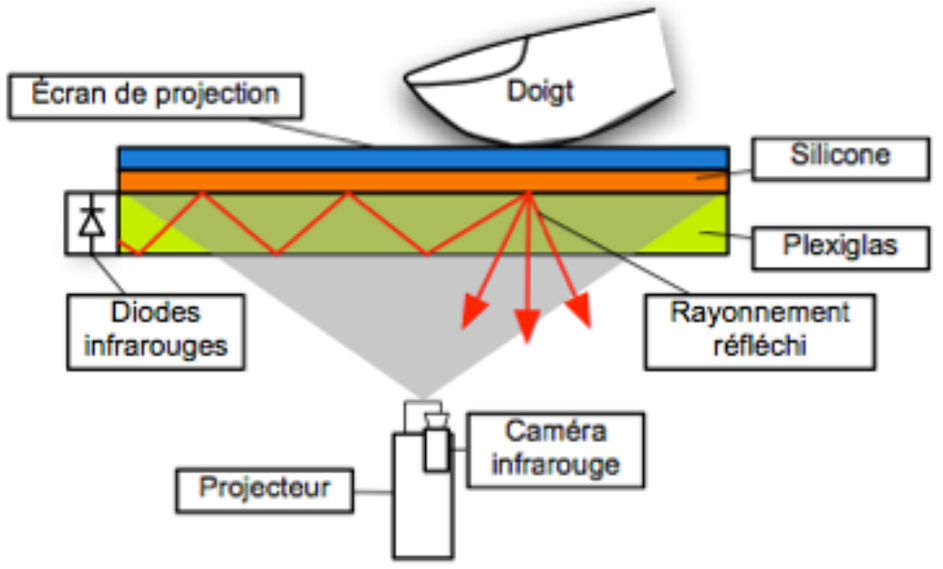
Optique



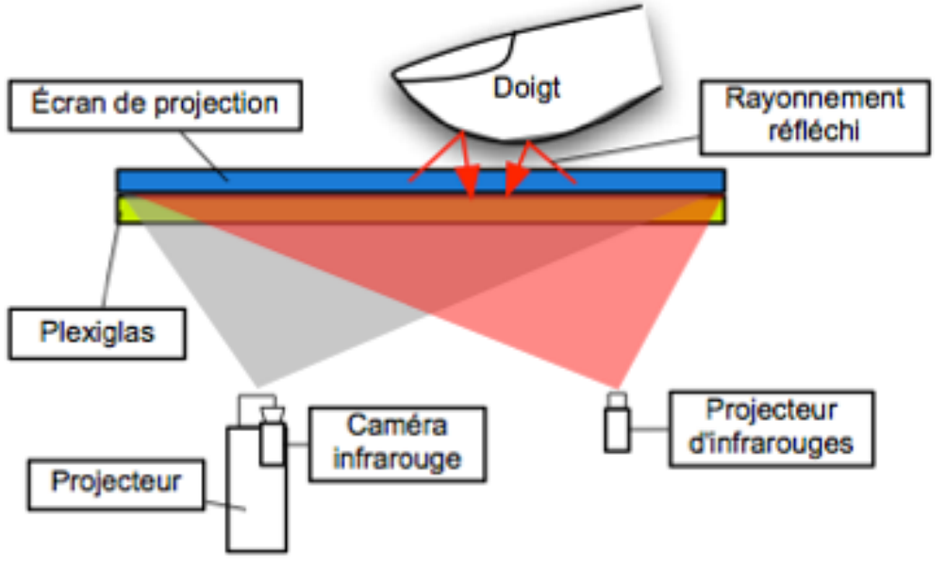
Technologie optique



(a) *Occlusion Sensing.*



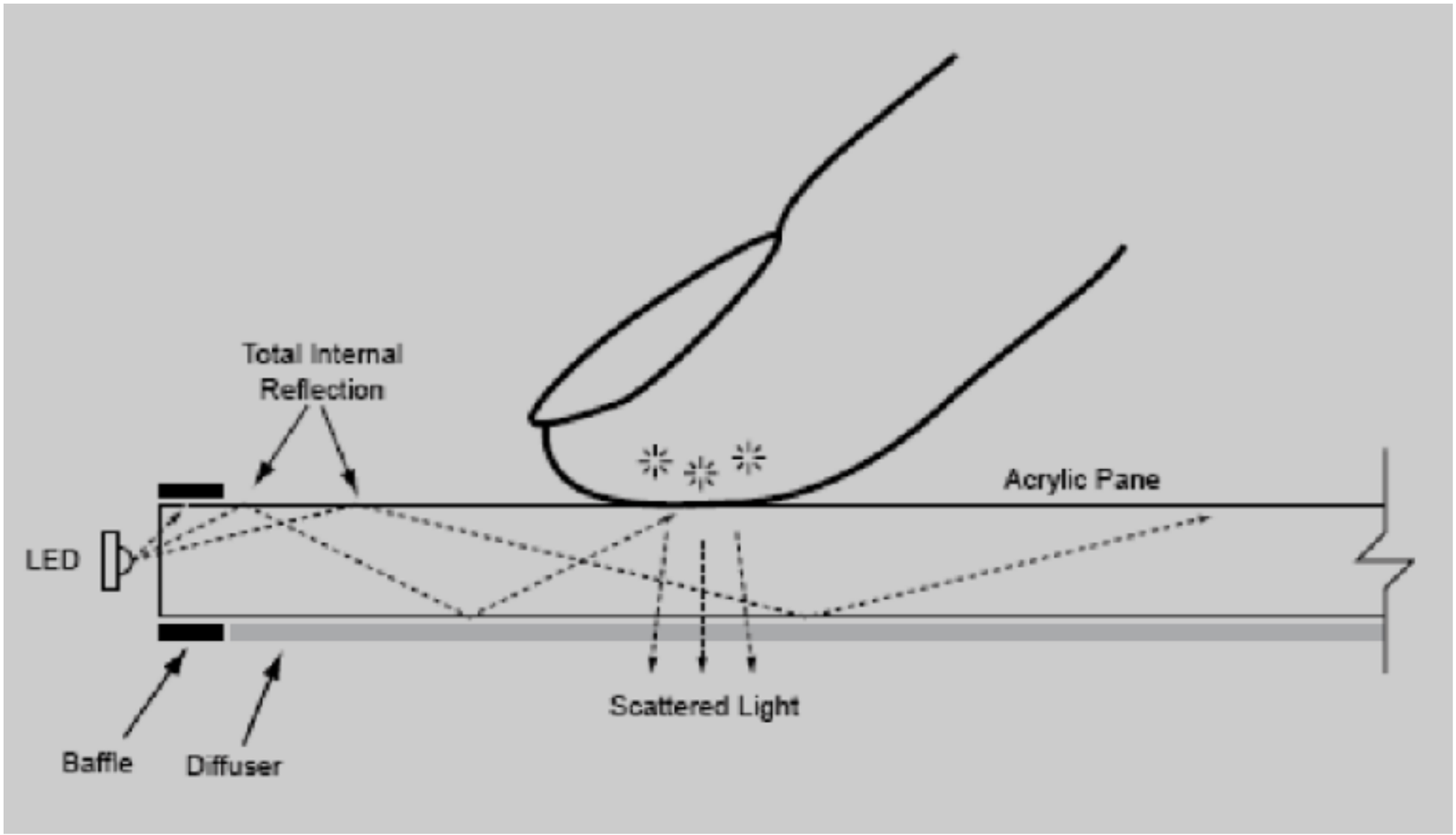
(b) *FTIR.*



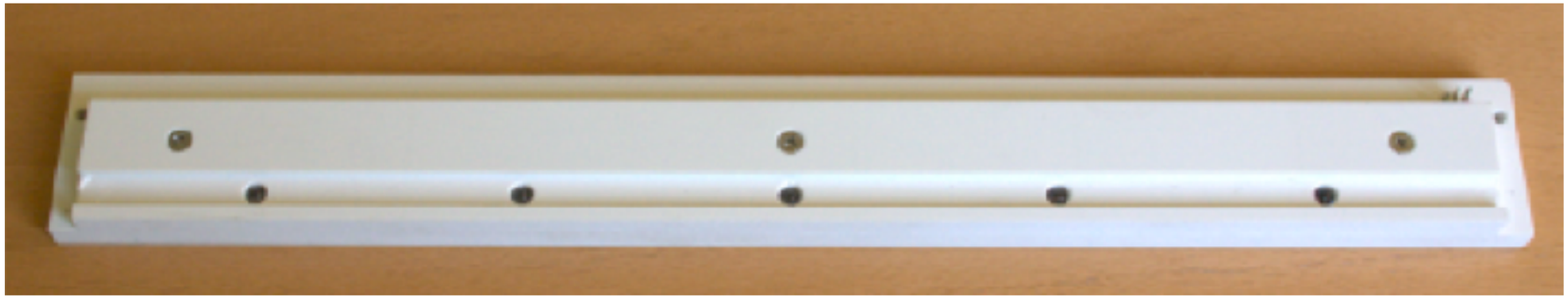
(c) *DI.*

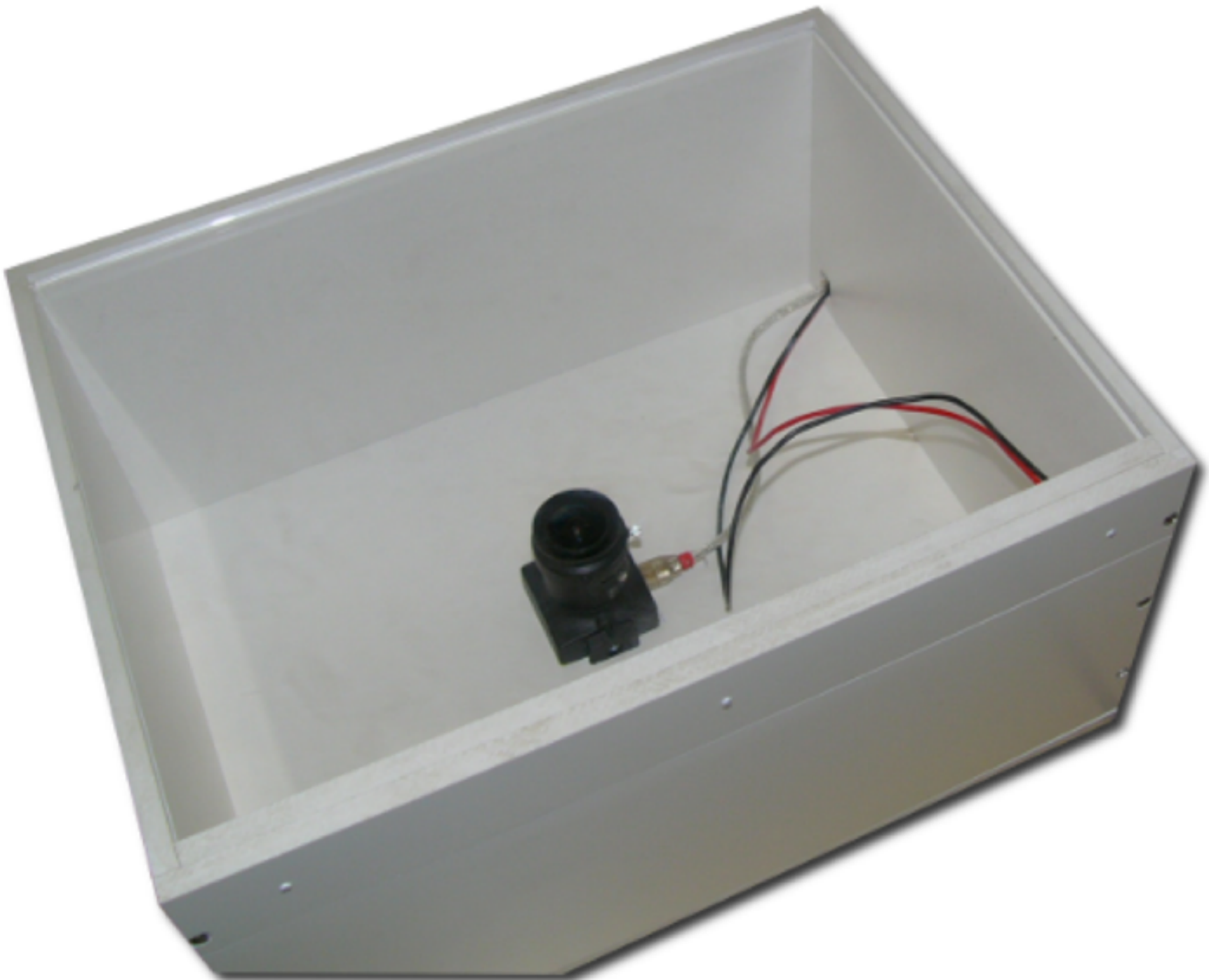
(d) *ThinShight.*

FTIR

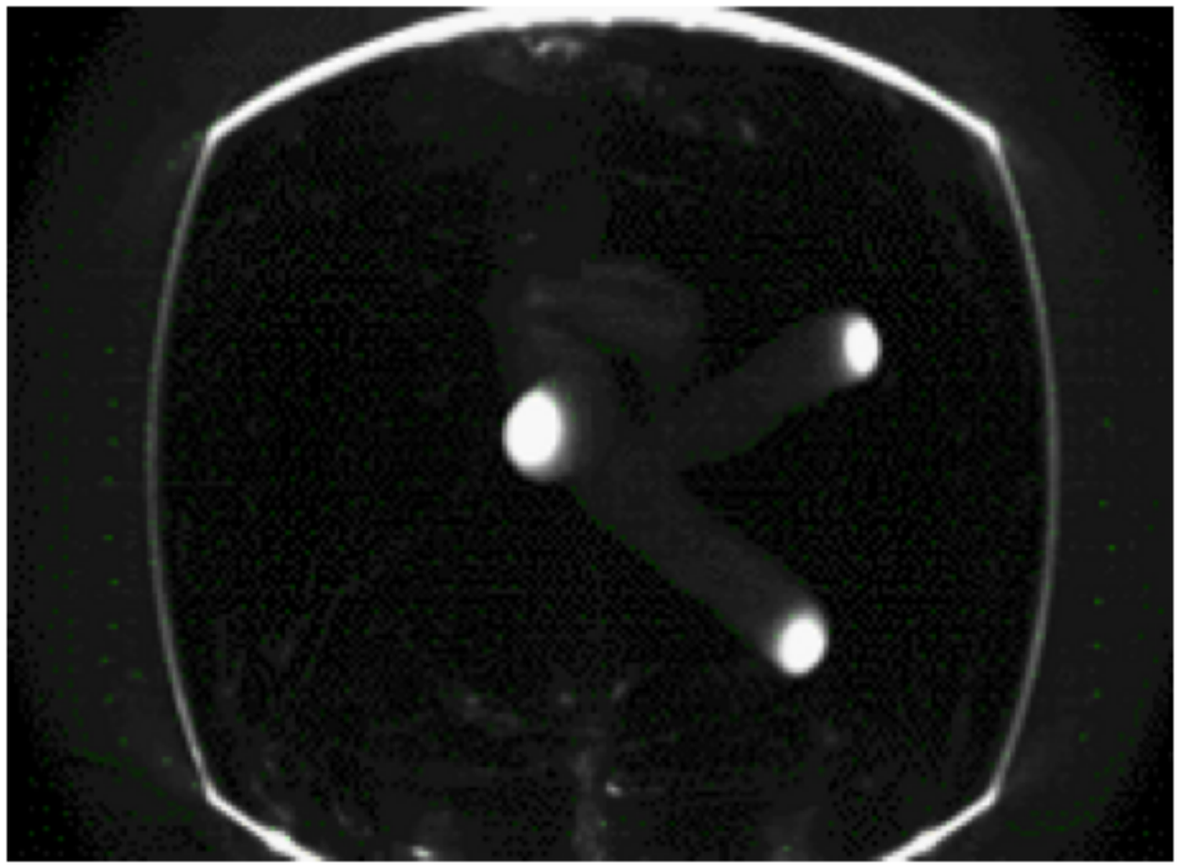

Total Internal
Reflection
Acrylic Pane
LED
Scattered Light
Baffle
Diffuser

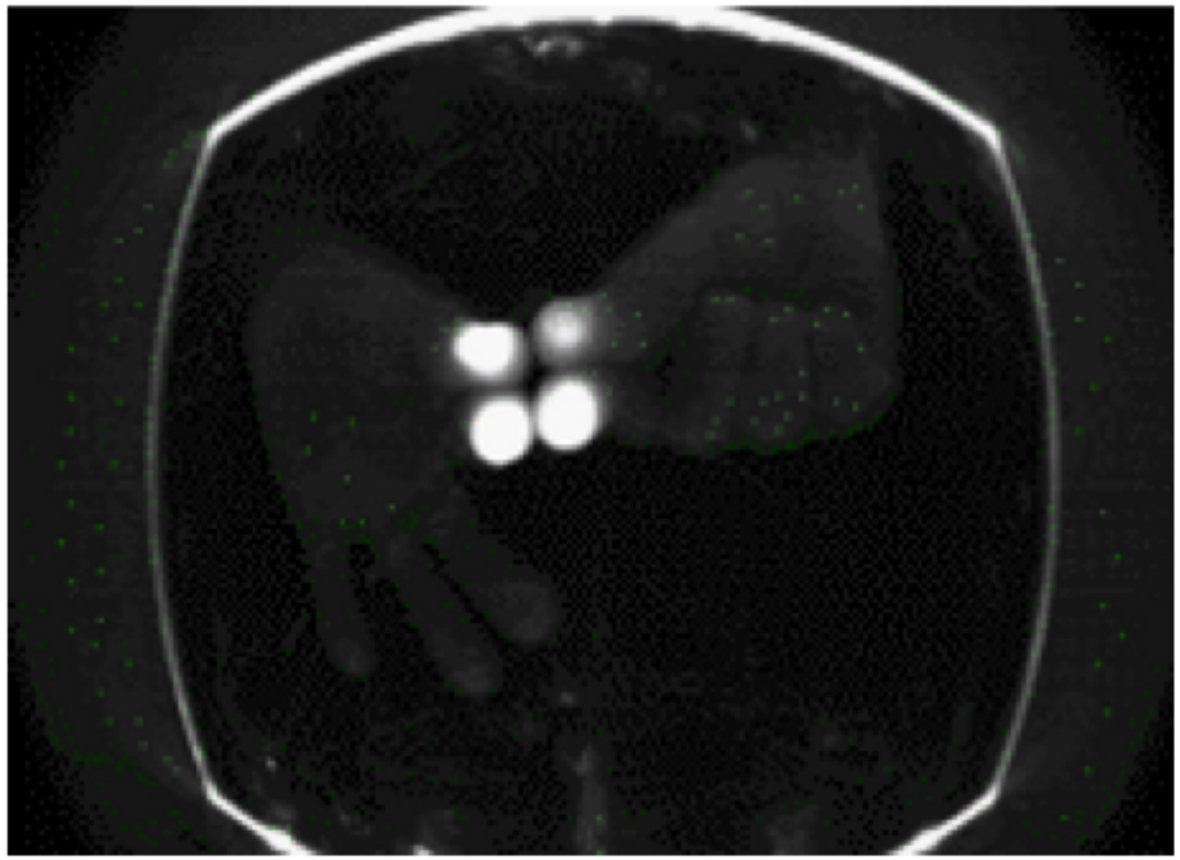
FTIR



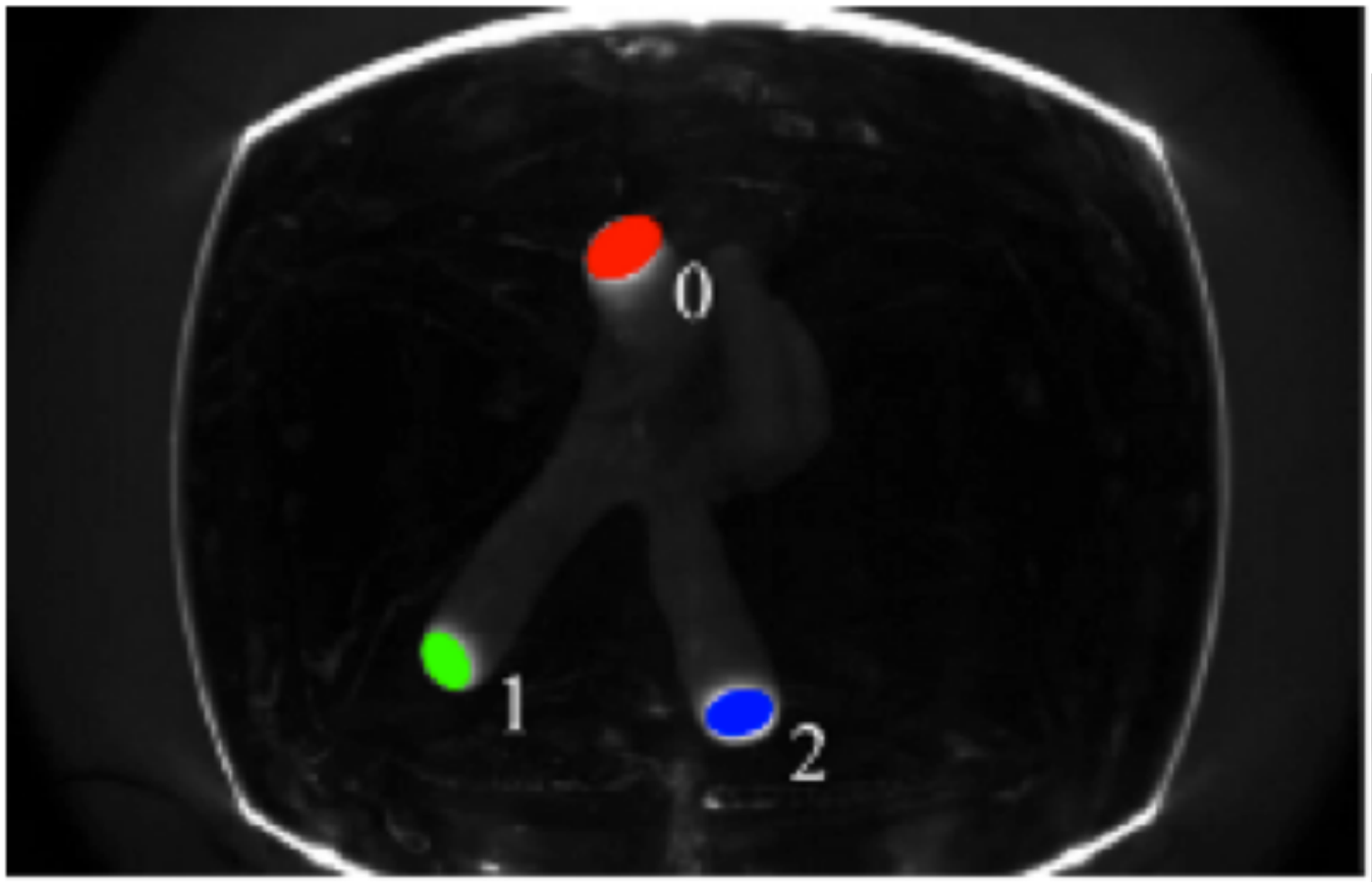


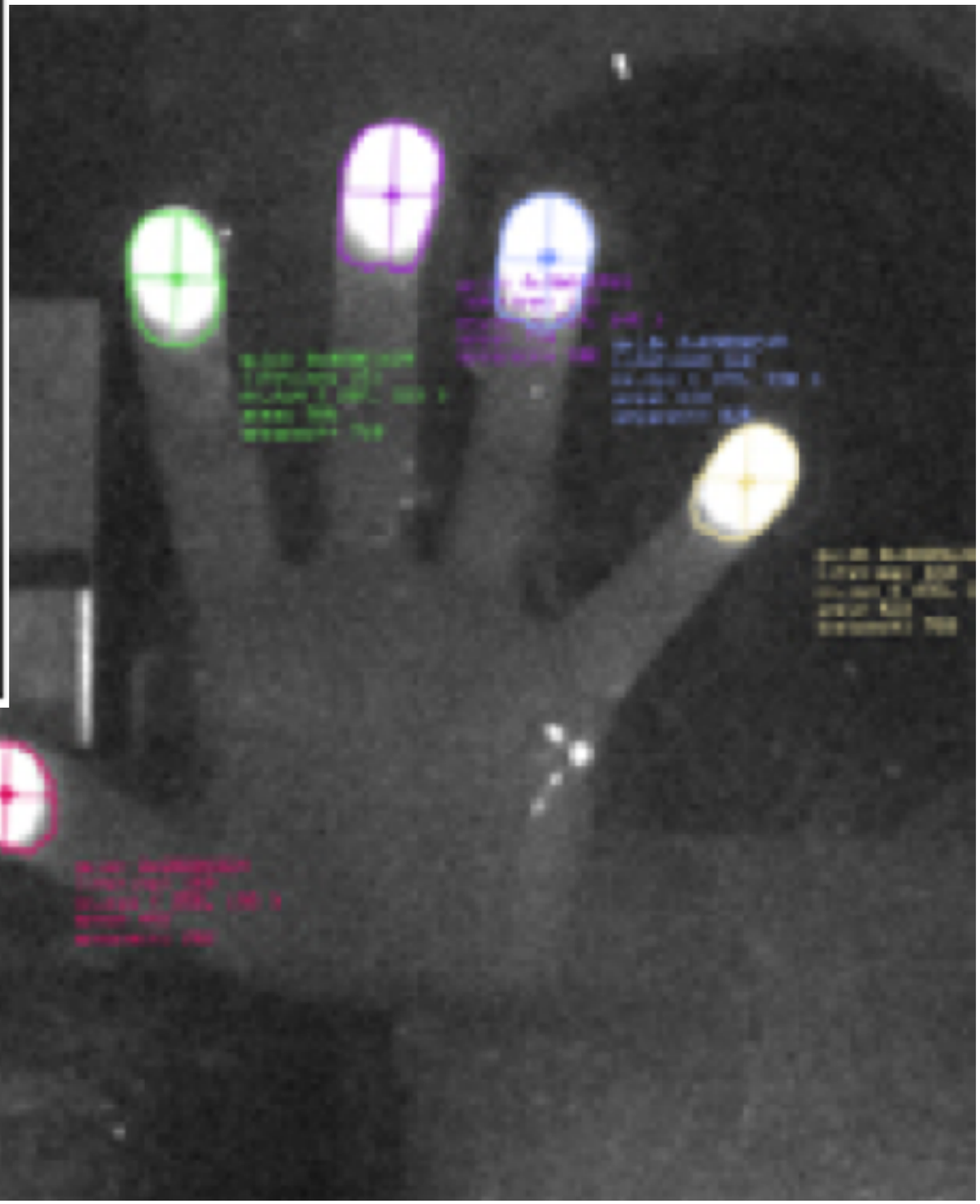
FTIR





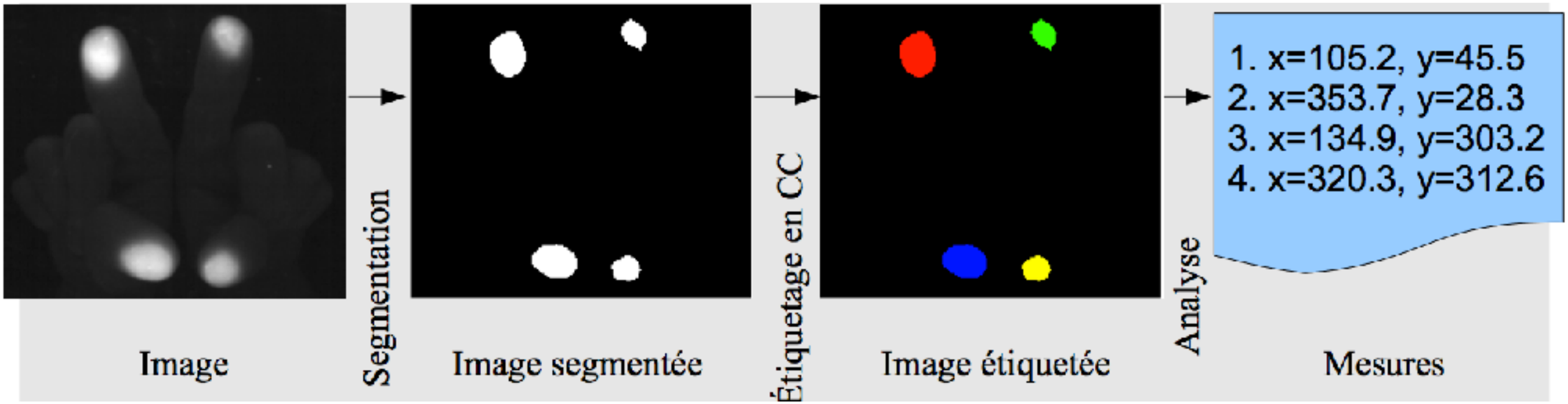
FTIR





Segmentation

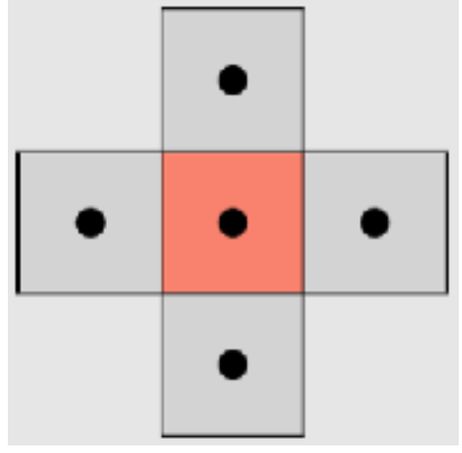
Binarisation



Détection des régions connexes

0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	1	1
0	1	1	0	0	1	0	1	1
0	1	1	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0

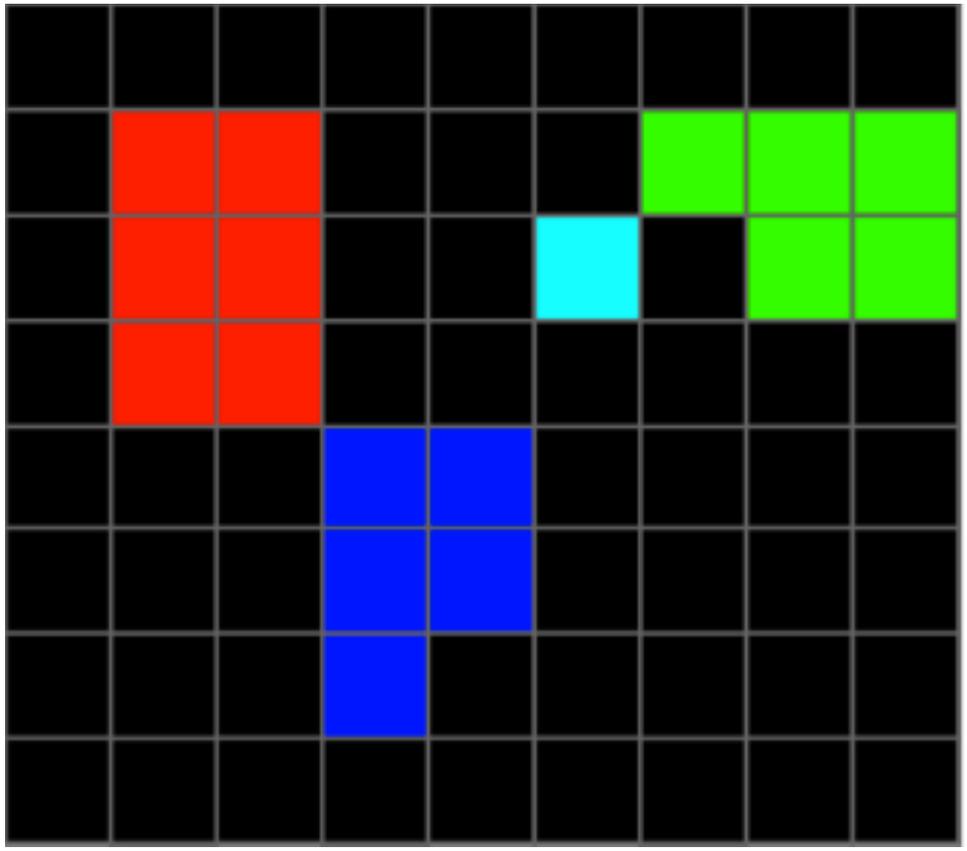
0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	1	1
0	1	1	0	0	1	0	1	1
0	1	1	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0



Etiquetage

0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	1	1
0	1	1	0	0	1	0	1	1
0	1	1	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	2	2	2
0	1	1	0	0	3	0	2	2
0	1	1	0	0	0	0	0	0
0	0	0	4	4	0	0	0	0
0	0	0	4	4	0	0	0	0
0	0	0	4	0	0	0	0	0
0	0	0	0	0	0	0	0	0



Double parcours

- **E/S**
  - Paramètre d'entrée : image binaire ***B***
  - Résultat de sortie : matrice (ou *carte*) d'étiquettes ***L***
- **Algorithme**
  - Premier parcours de l'image, dans le sens classique (*raster-scan order*) :
    À chaque pixel à 1 dans ***B***, on affecte
    - la plus petite étiquette parmi celles de ses voisins **haut** et **gauche**
      ou
    - une nouvelle étiquette si aucun de ces 2 voisins n'est encore étiqueté
  - Second parcours de l'image, dans le sens inverse :
    À chaque pixel précédemment étiqueté, on affecte la plus petite étiquette parmi la sienne et celles de ses voisins **bas** et **droite**.

Double parcours (1er parcours)

Exemple-1er parcours (1/3)

- Initialisation
  nbLabels=0

- Étape 1
  les voisins haut et gauche du premier pixel à 1 dans ***B*** ne sont pas encore étiquetés
  ⇨ nouvelle étiquette (*nbLabels*=1)

- Étape 2
  le voisin gauche du pixel suivant à 1 dans ***B*** est déjà étiqueté à 1 ⇨ affecter cette même étiquette au pixel

- Étape 3
  nouvelle étiquette (*nbLabels*=2)

B

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

L

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Double parcours (1er parcours)

Exemple-1er parcours (2/3)

- Étape 4
  affecter au pixel l'étiquette
  de son voisin gauche

- Étape 5
  nouvelle étiquette (*nbLabels*=3)

- Étape 6
  les voisins haut et gauche du pixel suivant à 1 dans ***B*** sont étiquetés différemment ⇨ affecter au pixel l'étiquette minimale

- Étape 7
  affecter au pixel l'étiquette
  de son voisin haut

B

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

L

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Double parcours (1er parcours)

Exemple-1er parcours (3/3)

- Étape 8
  affecter au pixel l'étiquette
  de son voisin haut

- Étape 9
  nouvelle étiquette (*nbLabels*=4)

- Étape 10
  affecter au pixel l'étiquette
  de son voisin gauche

- Étape 11
  les voisins haut et gauche du pixel suivant à 1 dans ***B*** sont étiquetés différemment ⇨ affecter au pixel l'étiquette minimale

B

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

L

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	0	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	4	0	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	4	4	0
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	4	4	2
0	0	0	0	0	0	0

Double parcours (2e parcours)

Exemple-2ème parcours (1/2)

- Image et carte initiales

- *1ère étiquette modifiée*

  Affecter au pixel l'étiquette de son voisin droit car elle est inférieure à la sienne

- *2ème étiquette modifiée*

  Affecter au pixel l'étiquette de son voisin droit car elle est inférieure à la sienne

- (*étiquette non modifiée*)

B

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

L

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	4	4	2
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	4	2	2
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	2	2	2
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	2	2	2
0	0	0	0	0	0	0

Double parcours (2e parcours)

Exemple-2ème parcours (2/2)

- (*étiquette non modifiée*)

- *3ème étiquette modifiée*

  Affecter au pixel l'étiquette de son voisin droit car elle est inférieure à la sienne et à celle de son voisin bas

- Carte à l'issue du 2ème parcours

  Aucune autre étiquette n'est plus modifiée

- ***Problème*** (*collisions*) : d'autres parcours (jusqu'à ce qu'il n'y ait plus de changement) sont nécessaires pour obtenir la carte finale. *Ex*. après 3ème parcours en sens classique :

B

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	1	1
0	1	1	0	0	0	1
0	1	0	0	1	1	1
0	0	0	0	0	0	0

L

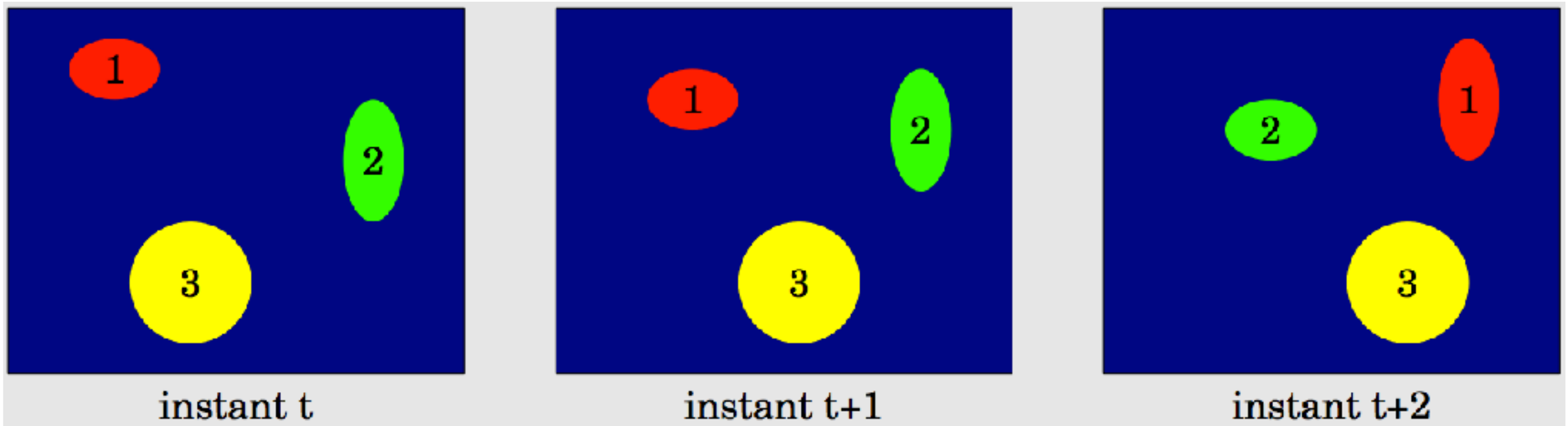
0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	3	1	0	0	0	2
0	3	0	0	2	2	2
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	1	1	0	0	0	2
0	3	0	0	2	2	2
0	0	0	0	0	0	0

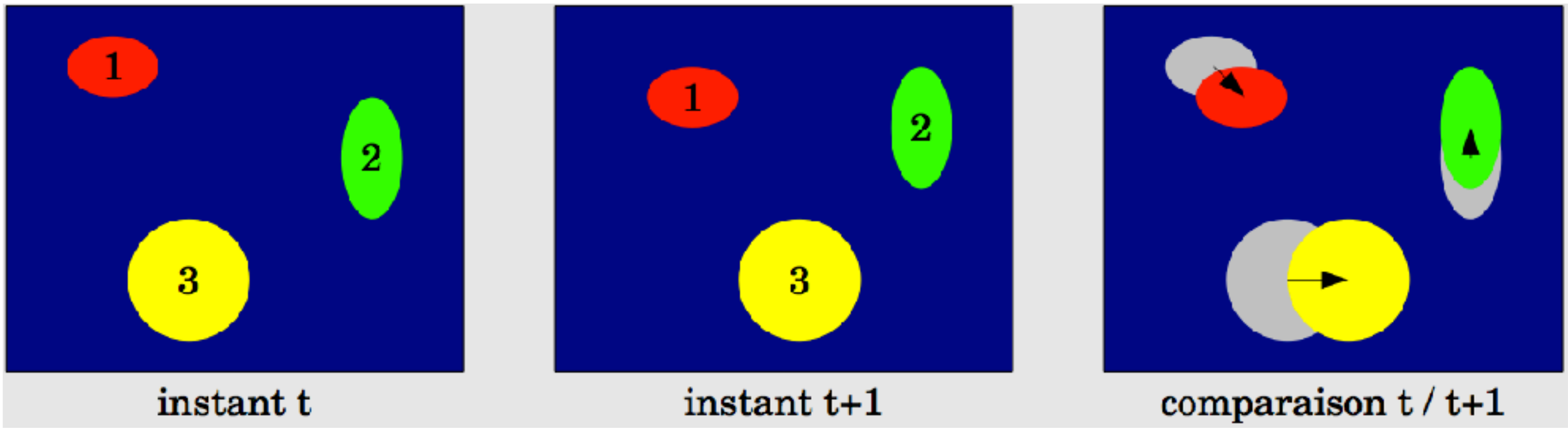
0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	1	1	0	0	0	2
0	3	0	0	2	2	2
0	0	0	0	0	0	0

0	0	0	0	0	0	0
0	0	1	1	0	2	2
0	1	1	0	0	0	2
0	1	0	0	2	2	2
0	0	0	0	0	0	0

Suivi des blobs

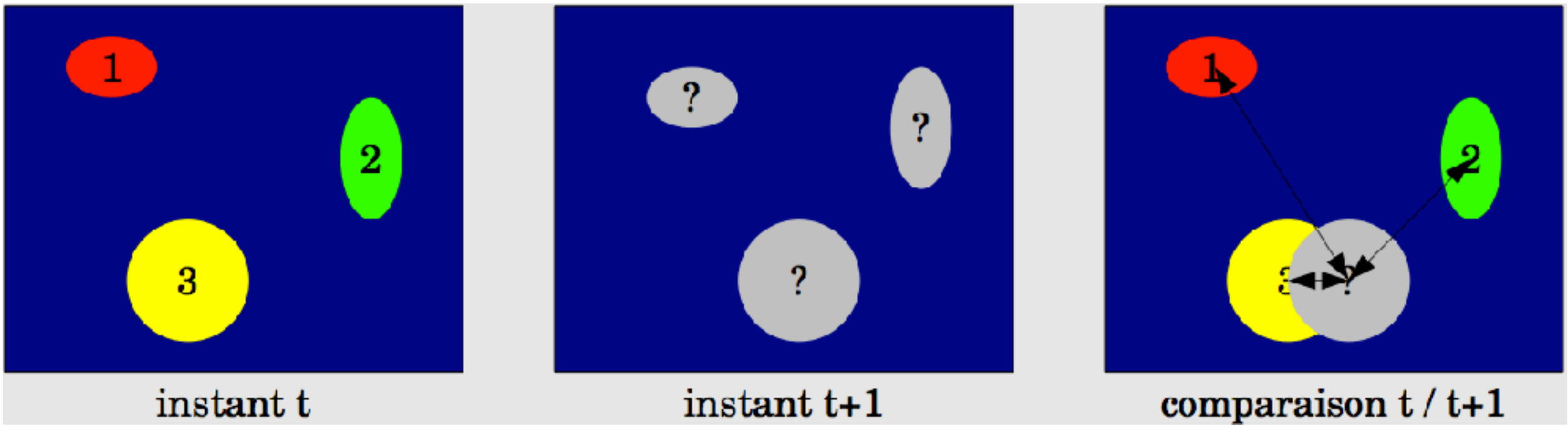


Distances inter-blobs

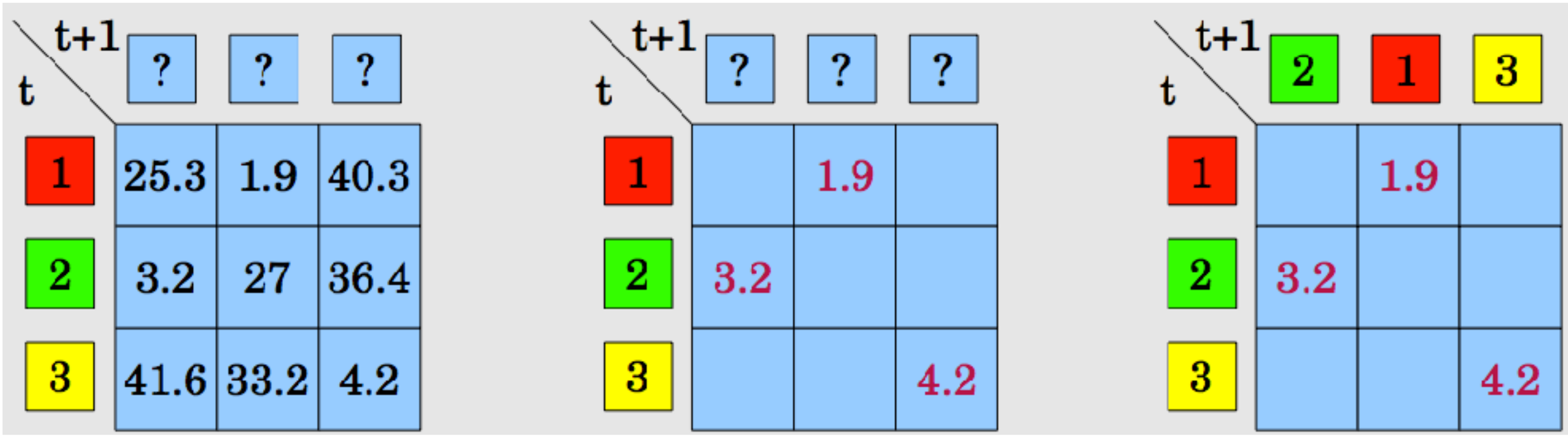


instant t | instant t+1 | comparaison t / t+1

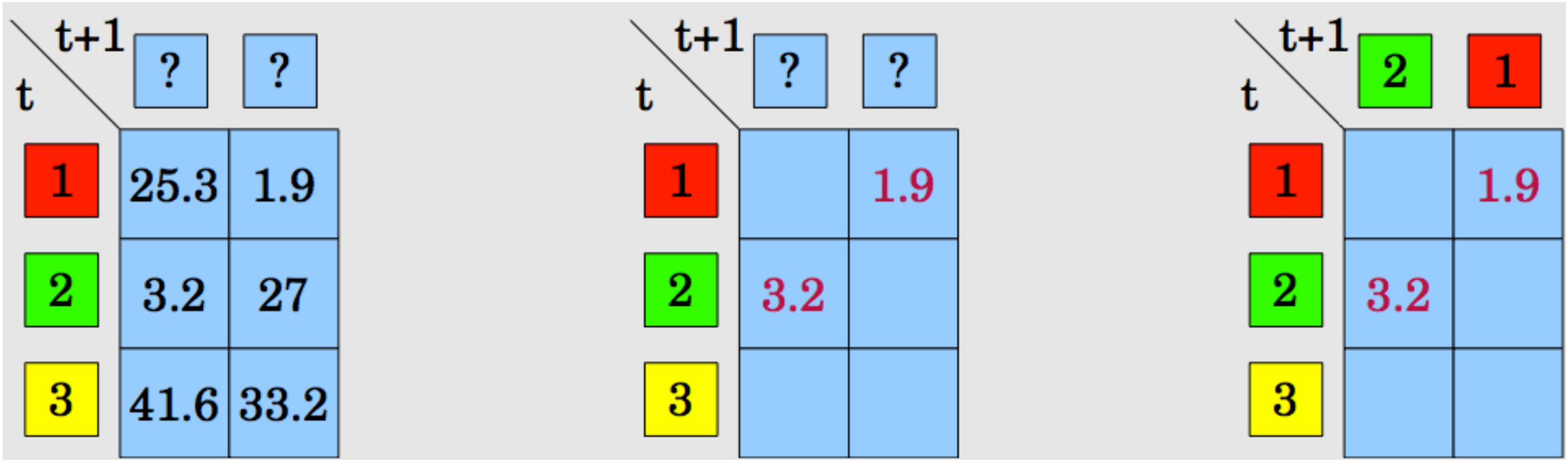
Distances inter-blobs



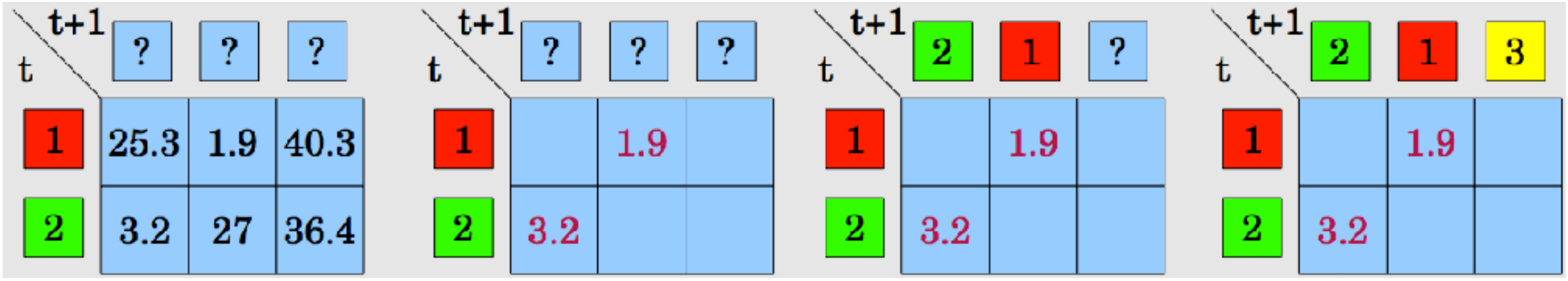
Distances inter-blobs



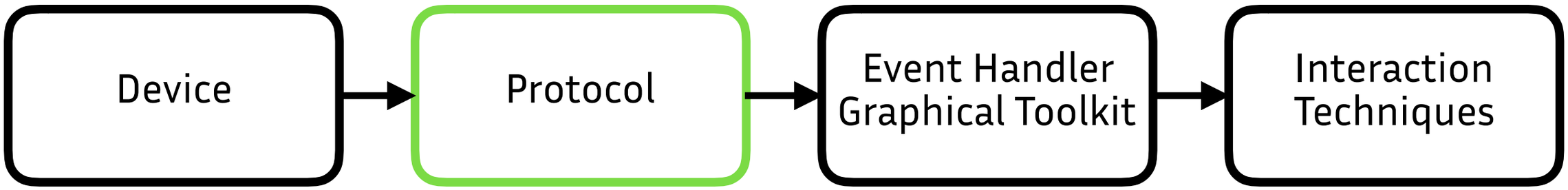
Disparition d’un objet



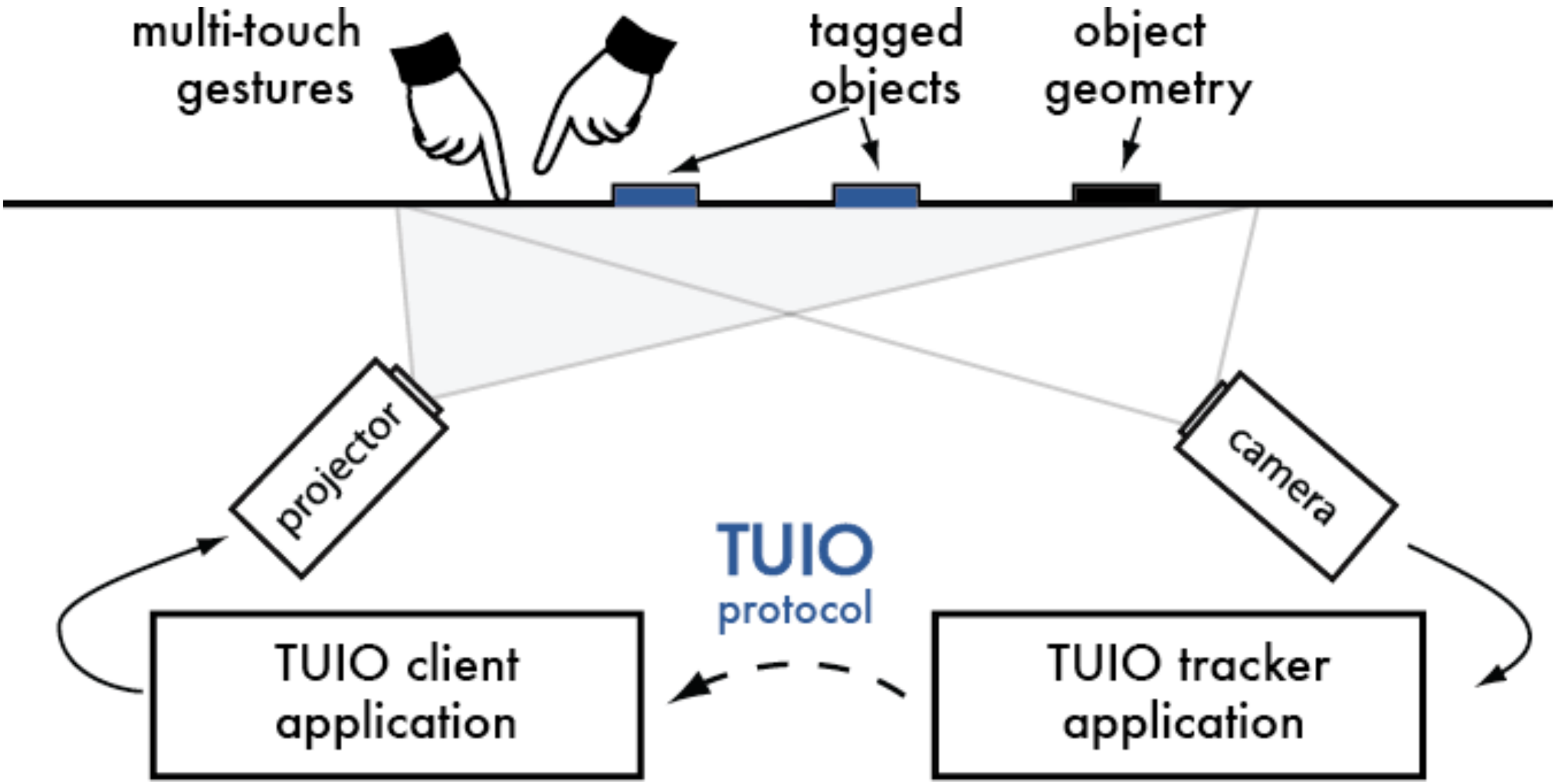
Apparition d’un objet



Multitouch pipeline

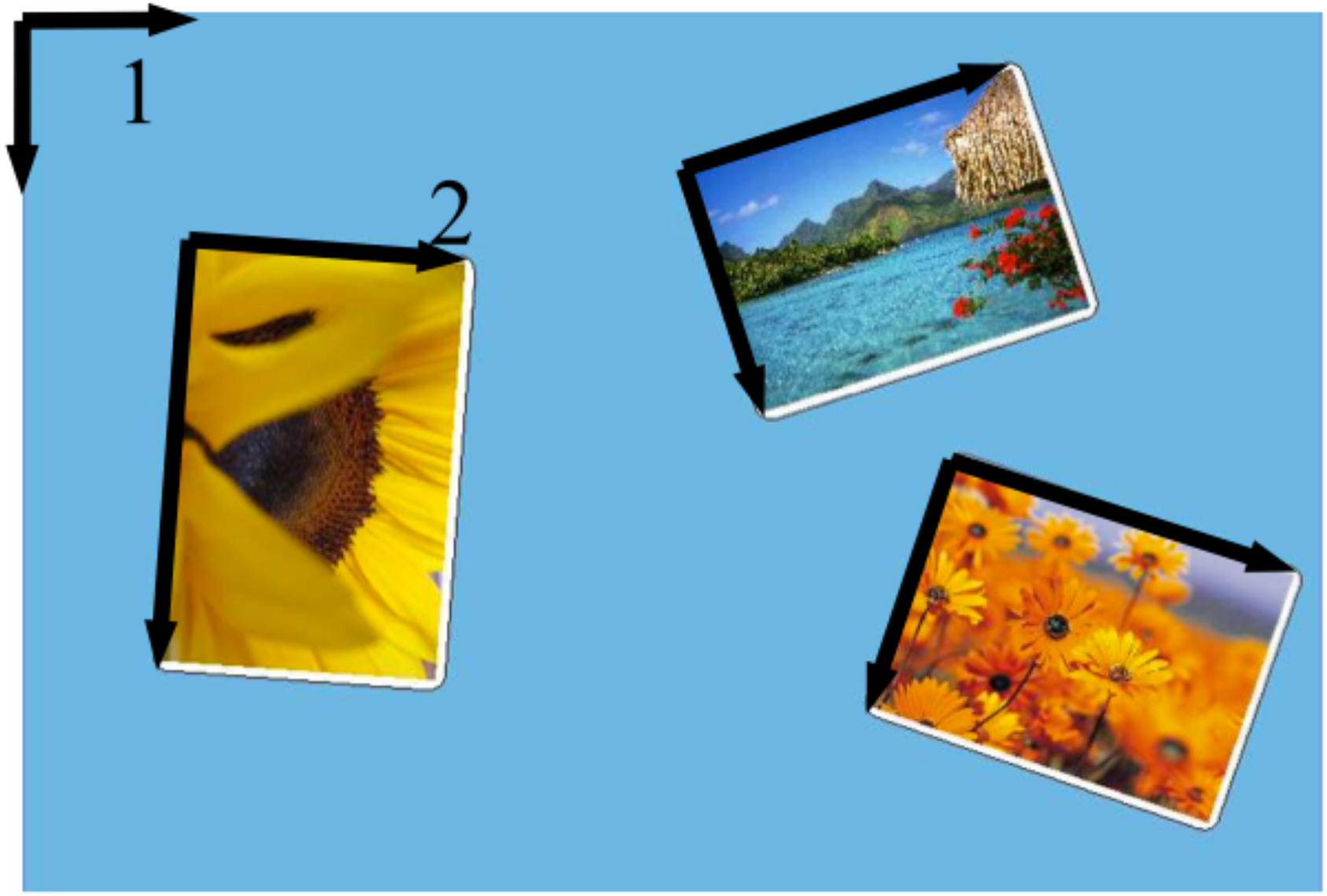


TUIO


multi-touch
gestures
tagged
objects
object
geometry
projector
camera
TUIO
protocol
TUIO client
application
TUIO tracker
application

Interaction

OBB



Le repère 2 est placé dans le repère 1 en déplaçant 1 vers 2 (on dit qu'on passe du repère 1 au repère 2, et sera noté $M_{1\to 2}$) :

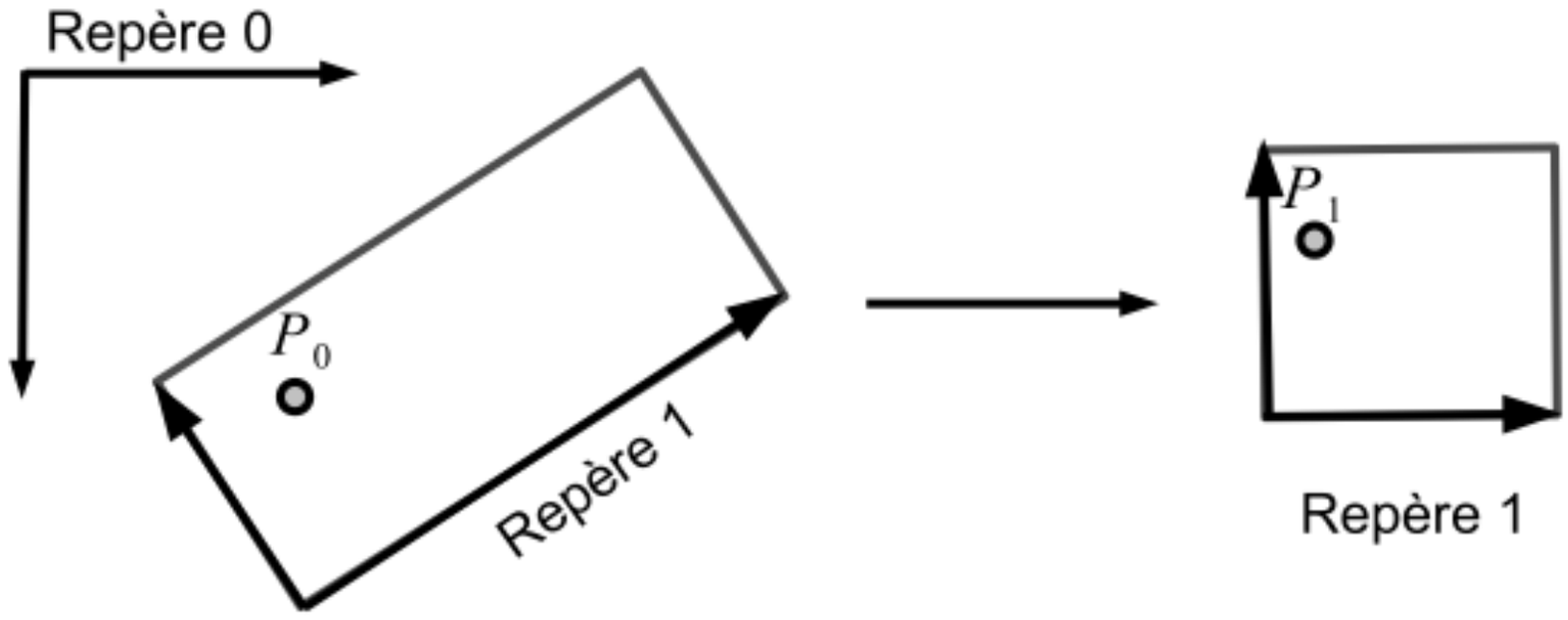
1. En faisant une translation (donnée par le champs `position`) notée T
2. **Puis** une rotation autour de l'origine **actuelle** (l'angle est donné par `angle`) notée R
3. **Puis** un changement d'échelle (l'axe x actuel est multiplié par `width`, l'axe actuel y par `height`) notée S.
4. $\Rightarrow$ on note ainsi le passage de 1 vers 2 : $M_{1\to 2} = TRS$.

Expression d'un point dans des repères différents

- Soit un point P connu dans un repère 2 (noté P_2). Soit un repère 1 dont on connait le passage $M_{1\to 2}$.
- Alors les coordonnées de P dans 1 sont donnés par la relation $P_1 = M_{1\to 2}P_2$.
- Exemple : $M_{1\to 2} = TRS$, et $P_2(x_2, y_2)$, alors $P_1(x_1, y_1) = TRSP_2(x_2, y_2)$:
  - $S(k_x, k_y) : x' = k_x \times x_2$ et $y' = k_y \times y_2$.
  - puis $R(\theta) : x'' = x' \cos\theta - y' \sin\theta$ et $y'' = x' \sin\theta + y' \cos\theta$
  - et finalement $T(t_x, t_y) : x_1 = x'' + t_x$ et $y_1 = y'' + t_y$.

Localiser un point dans une OBB

- Sélection d'un composant = lors d'un "addCursor(x,y)" on détermine à quel composant correspond (x, y).
- Donnée : un point $P(x, y)$ dans le repère initial 0 (curseur en coordonnée pixel).
- Problème : à quel composant appartient P ?



Localiser un point dans une OBB

- une OBB est un carré défini dans un repère local 1 dont on a fait subir $M_{0\to 1} = TRS$ pour le placer par rapport au repère 0 ($T = origin$, $R = angle$, $S = (width, height)$).
- il est plus aisé de tester l'appartenance du point P dans le carré $\Rightarrow$ exprimer P dans 1 par $P_1 = M_{1\to 0} P_0$.

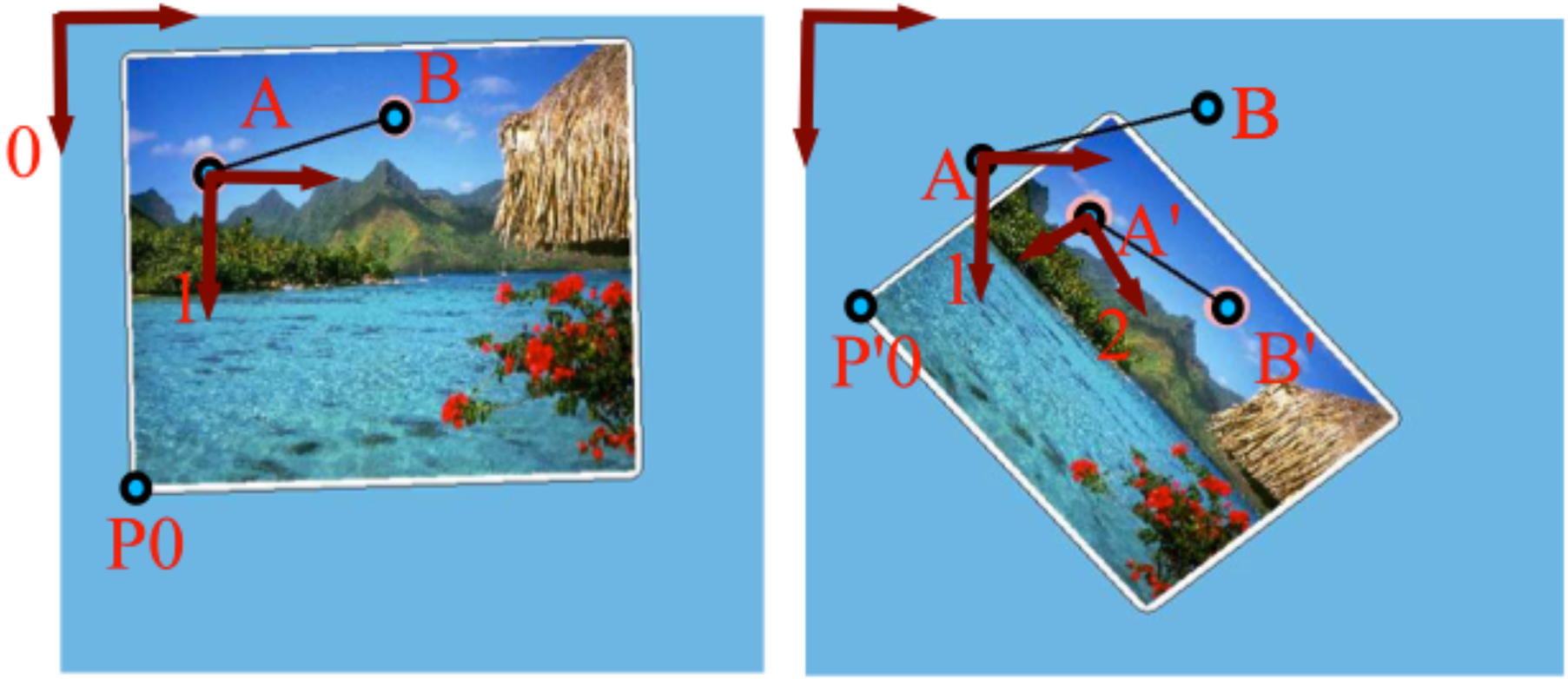
- Cas général : il faut inverser $M_{p\to q}$ pour obtenir $M_{q\to p}$.
- Cas d'une Composition : l'inverse de $M_{p\to q} M_{q\to r}$ est $M_{r\to q} M_{q\to p}$
- Par ailleurs $T^{-1} = -T$, $R^{-1}(\theta) = R(-\theta)$ et $S^{-1}(k_x, k_y) = S(\frac{1}{k_x}, \frac{1}{k_y})$.

Superposition de composants

- L'ordre dans la liste des composants définit l'ordre d'affichage (le premier à l'arrière-plan), ou profondeur d'affichage.
- Si il y a superposition de composants lors d'une sélection ⇒ le composant sélectionné est celui qui est visible (i.e. le moins profond).
- Une fois sélectionné, le composant passe à l'avant plan.

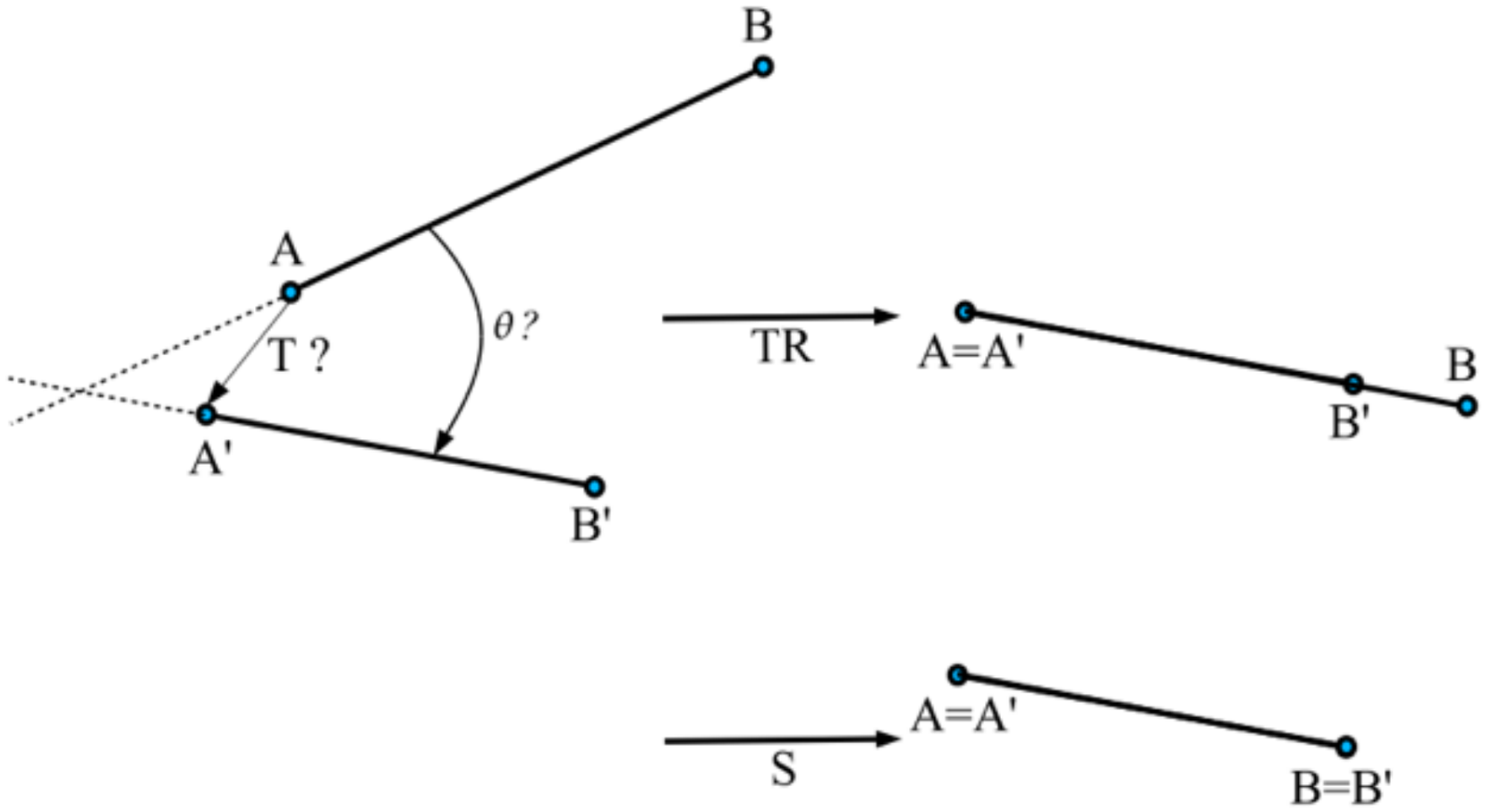
Mouvement d'un objet avec 2 doigts

- 2 curseurs sur l'image : A et B.
- Attacher l'image aux curseurs.
- Mouvement des curseurs : A déplacé en A' et B en B'.



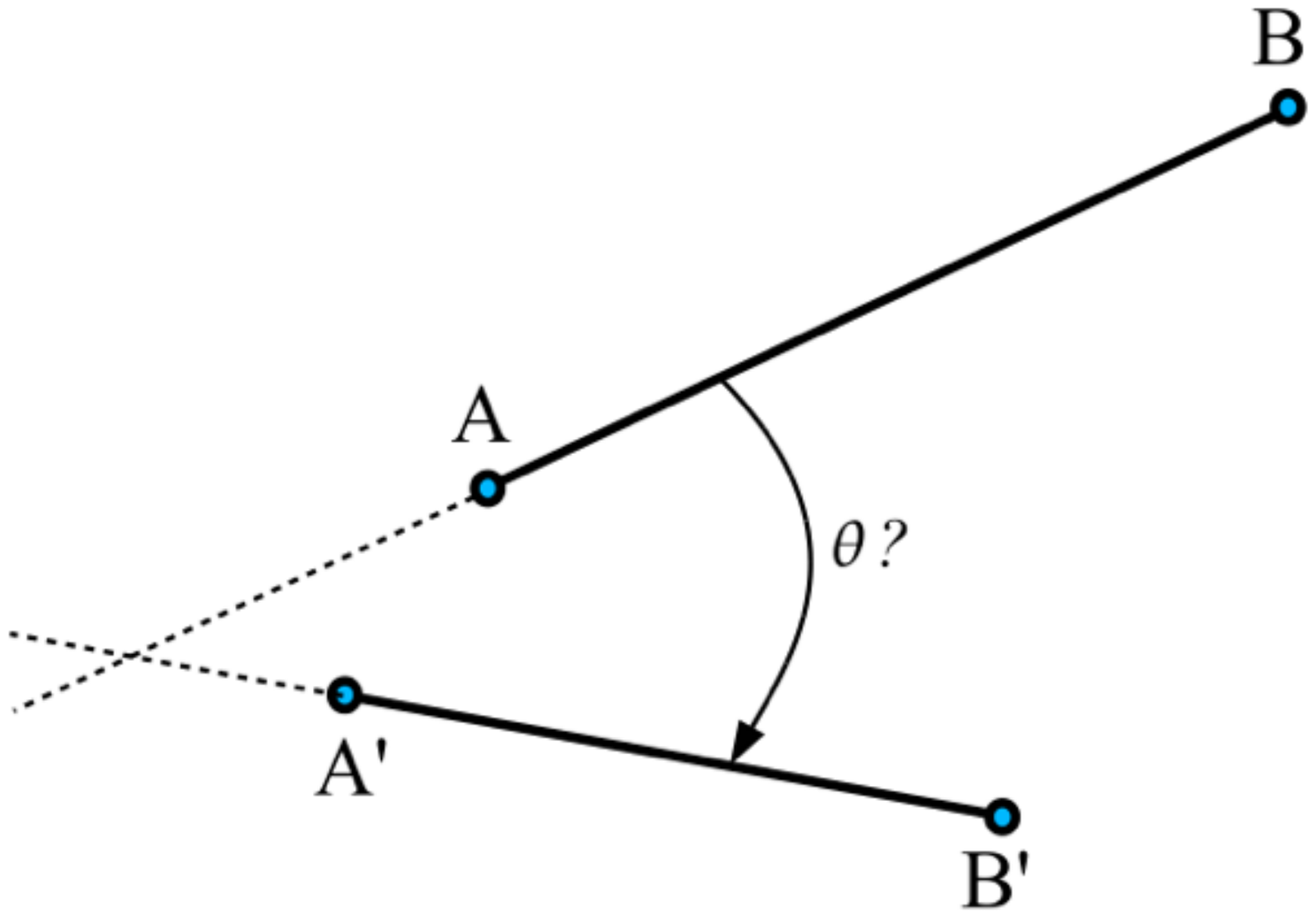
Transformation du segment AB

- On "attache" AB à un repère 1 (l'origine de 1 est A) et on exprime le changement de repère $M_{1\to 2}$ pour aller en $A'B'$ (l'origine de 2 est A') :



- $T =$ translation de vecteur AA'.
- puis $R =$ rotation d'angle ?
- puis $S =$ rapport des longueurs entre AB et $A'B'$.

Calcul de l'angle de rotation



- On utilise le produit scalaire entre AB et $A'B'$, car $AB \cdot A'B' = \|AB\| \|A'B'\| cos\theta$.

Produit scalaire

Soient $u = \begin{pmatrix} u_x \\ u_y \end{pmatrix}$, $v = \begin{pmatrix} v_x \\ v_y \end{pmatrix}$, le produit scalaire $u \cdot v$ (appelé dot en anglais) est le nombre donné par :

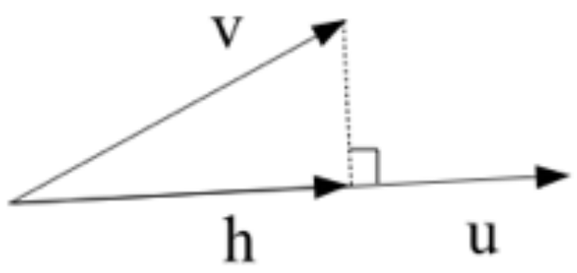
- $u \cdot v = u_x v_x + u_y v_y$ (Calcul par coordonnées)
- $u \cdot v = \|u\| \|v\| cos(u, v)$ (Calcul par cosinus)

Relation avec la norme (la « longueur ») du vecteur u :

- Norme (euclidienne) : $\|u\| = \sqrt{u \cdot u} = \sqrt{u_x u_x + u_y u_y}$
- Remarque : Normer u consiste à « rendre »le vecteur u de norme 1 : $u' = \frac{u}{\|u\|}$

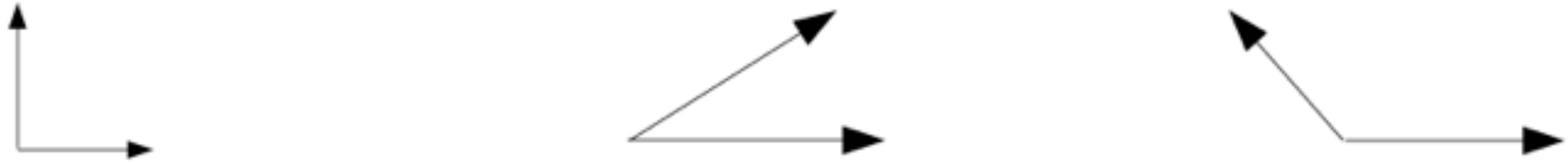
Produit scalaire

- Projection du vecteur v sur u :



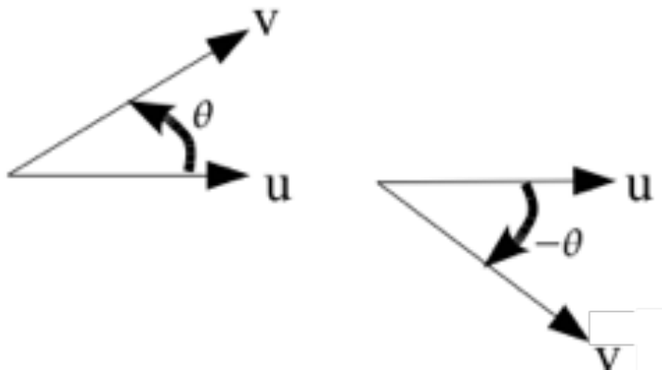
  - $u \cdot v = u \cdot h$
  - $\|h\| = \frac{|u \cdot v|}{\|u\|}$
  - Si u est unitaire : $h = (u.v)u$

- Localisation relative des vecteurs u et v :



$u \cdot v = 0$ (orthonormal) $u \cdot v > 0$ (aigu) $u \cdot v < 0$ (obtus)

- Si u et v sont de norme 1 :
  - $u \cdot v = cos(u, v)$
  - $acos(u \cdot v)$ donne un angle dans $[0, \pi]$.
  - $\Rightarrow$ le produit scalaire ne suffit pas à lui seul :



Déterminant

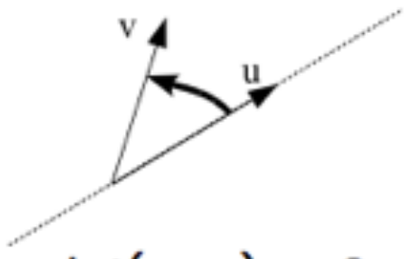
- Calcul :

  Soient $u = \begin{pmatrix} u_x \\ u_y \end{pmatrix}$, $v = \begin{pmatrix} v_x \\ v_y \end{pmatrix}$, le déterminant est donné par le nombre :

$$det(u, v) = u_x v_y - u_y v_x$$

  Remarque : il s'agit de la 3ième coordonnée du produit vectoriel entre $\begin{pmatrix} u_x \\ u_y \\ u_z = 0 \end{pmatrix}$ et $\begin{pmatrix} v_x \\ v_y \\ v_z = 0 \end{pmatrix}$

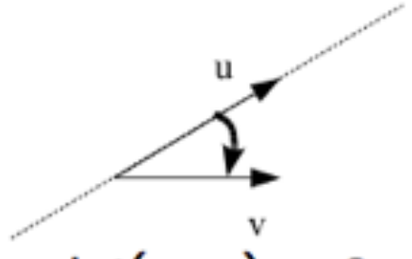
- Interprétation :



$det(u, v) > 0$

u vers v : dans le sens direct

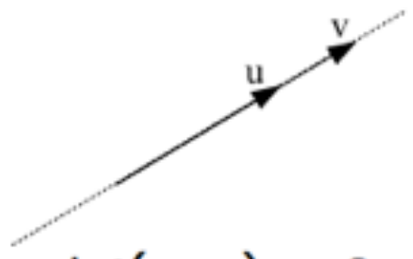
appliquer θ



$det(u, v) < 0$

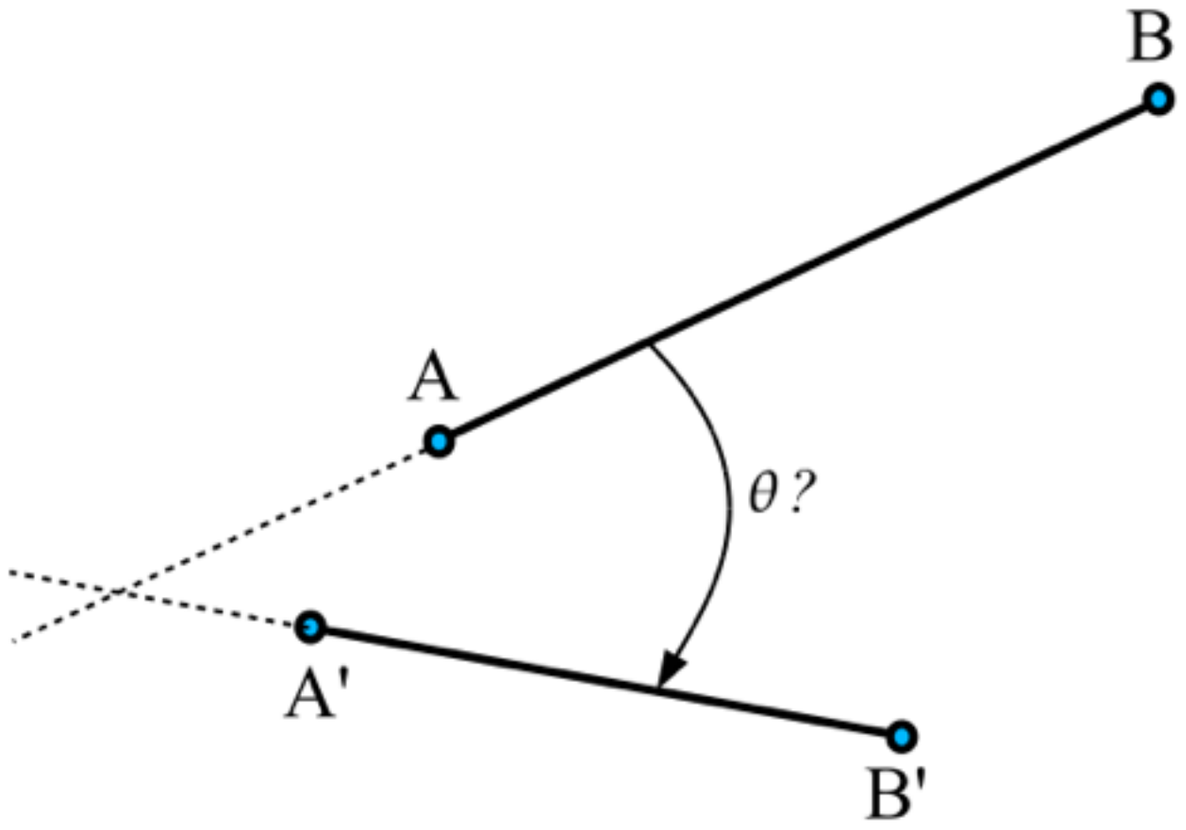
u vers v : dans le sens indirect

appliquer -θ



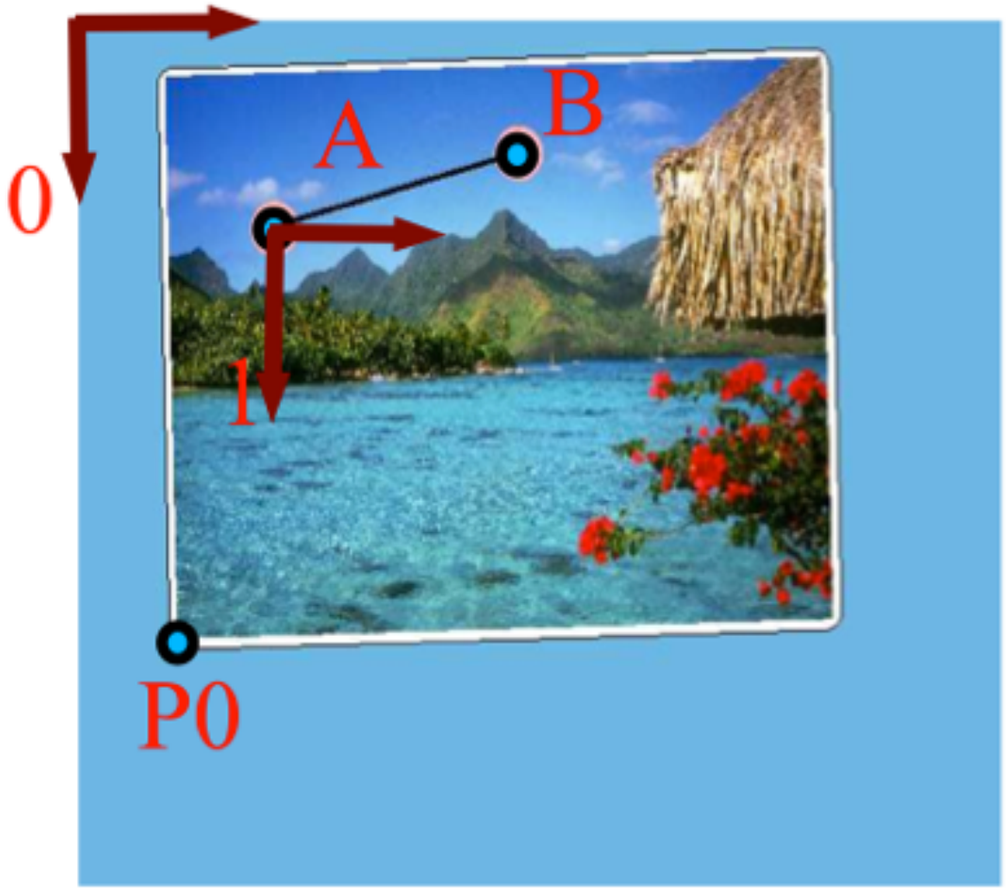
$det(u, v) = 0$

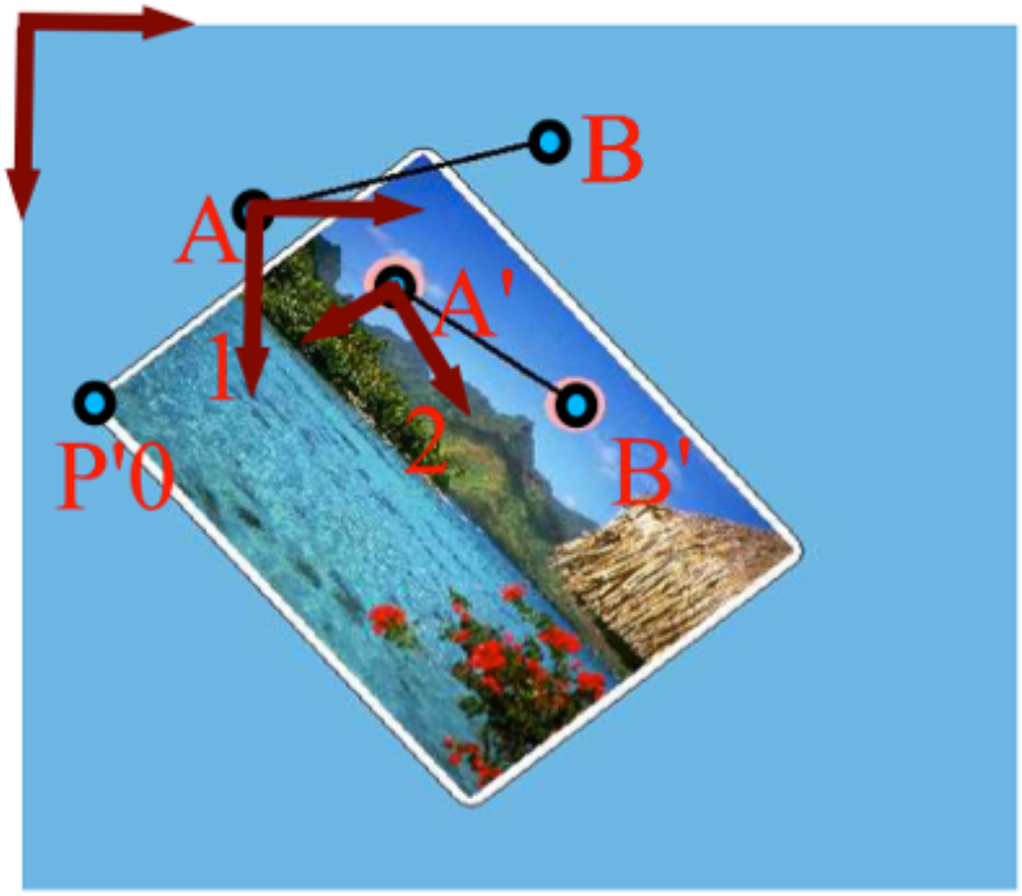
Résumé du calcul de l'angle de rotation



- $u = AB$, $v = A'B'$
- On norme u et $v \Rightarrow u \cdot v = cos(\theta) \Rightarrow \theta = acos(u \cdot v)$
- Calculer $det(u, v)$ pour savoir si θ est négatif ou positif (i.e. si négatif, prendre $-\theta$ comme angle de rotation).

Résumé du TRS à deux doigts



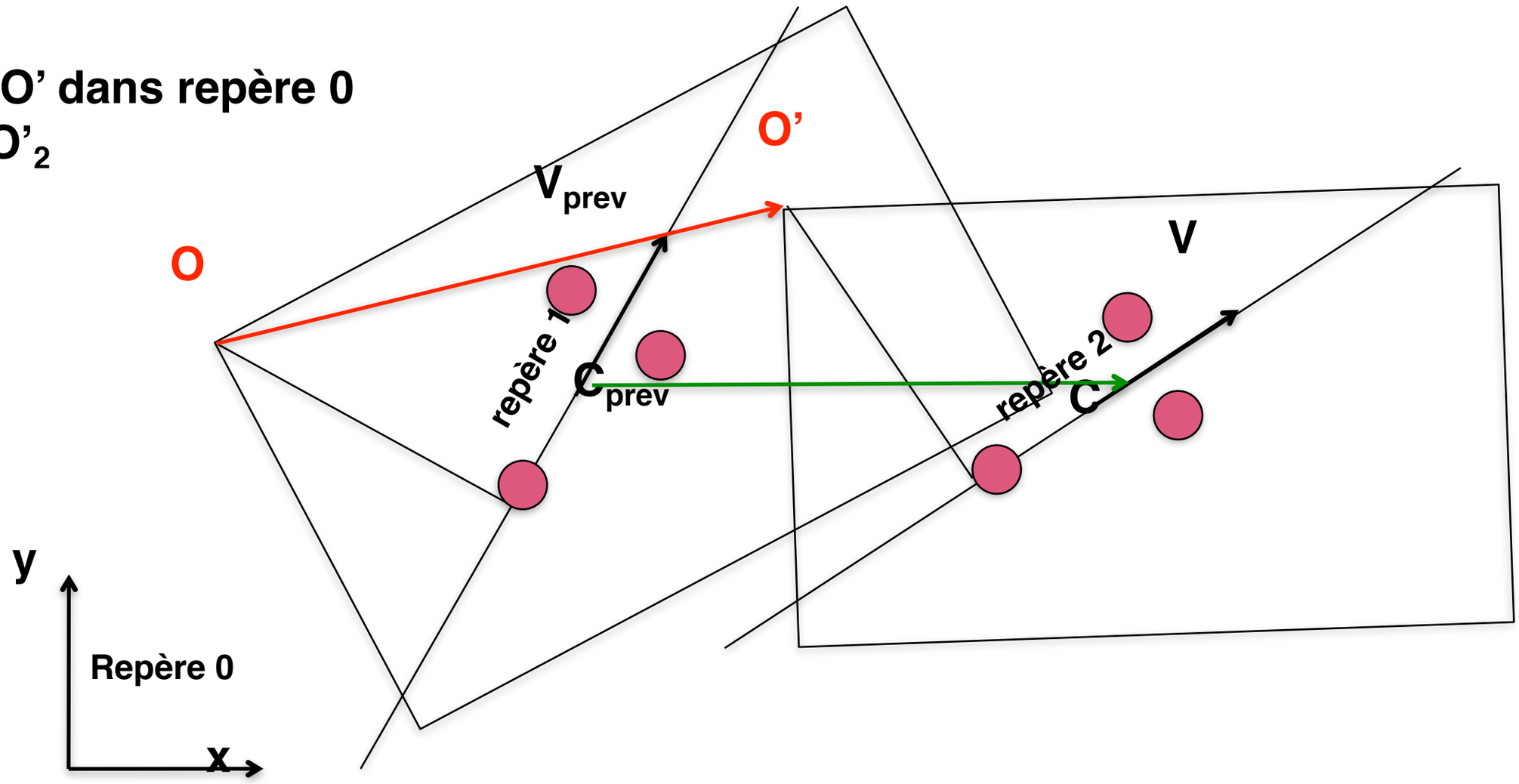


- `width` et `height` subissent le rapport $\frac{\|A'B'\|}{\|AB\|}$
- `angle` subit l'angle entre AB et $A'B'$
- `position` subit le mouvement de P_0 à P'_0

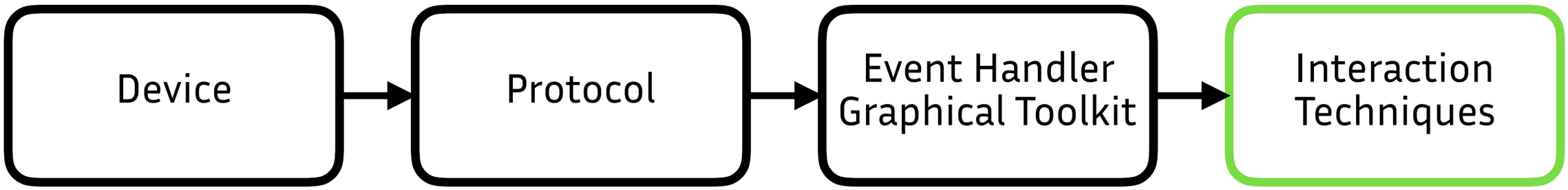
Résumé du TRS à deux doigts

m_{01}: matrice de passage du repère 0 au repère 1
m_{02}: matrice de passage du repère 0 au repère 2

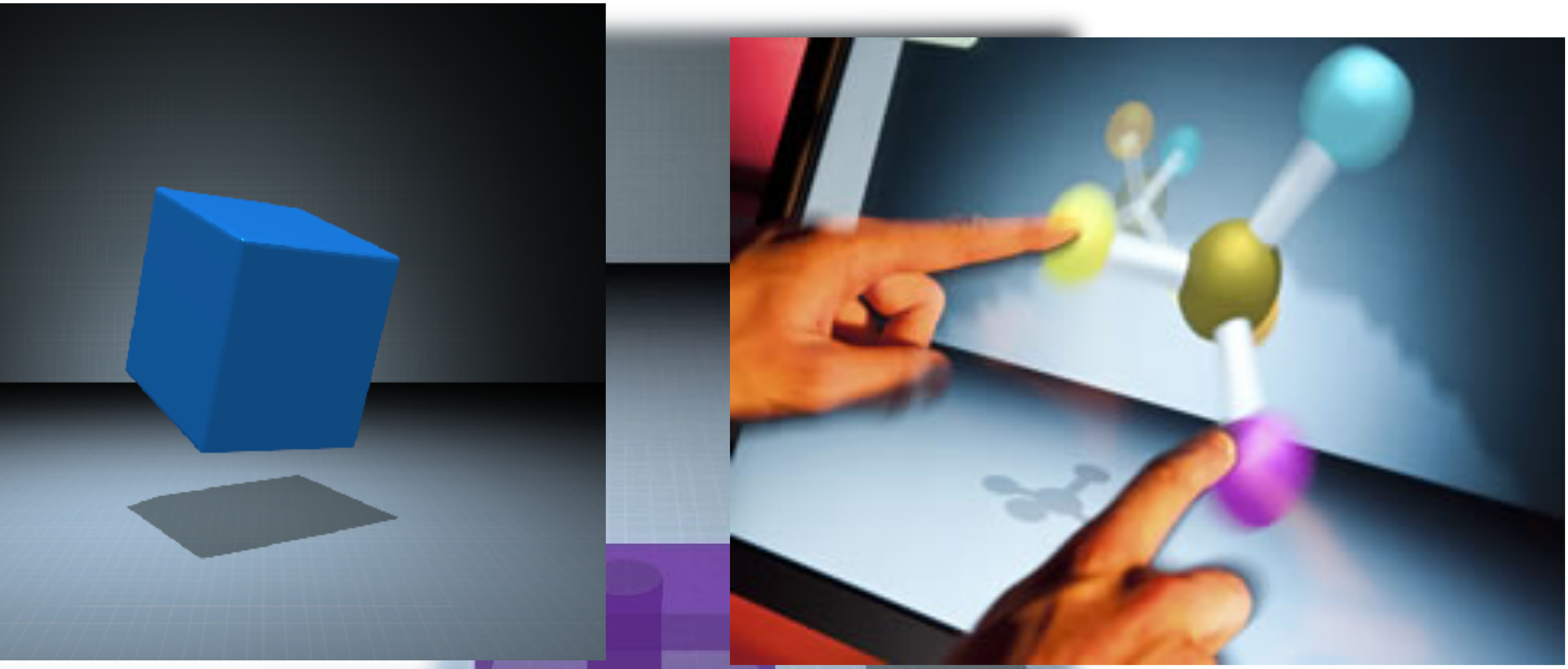
1) Calcul des coordonnées de 0 dans le repère 1:
$O_1 = m_{01}^{-1} O_0$
2) $O'_2 = O_1$ (sans tenir compte du changement d'échelle)
3) Calcul de O' dans repère 0
$O'_0 = m_{02} O'_2$



Multitouch pipeline



Manipulation 3D

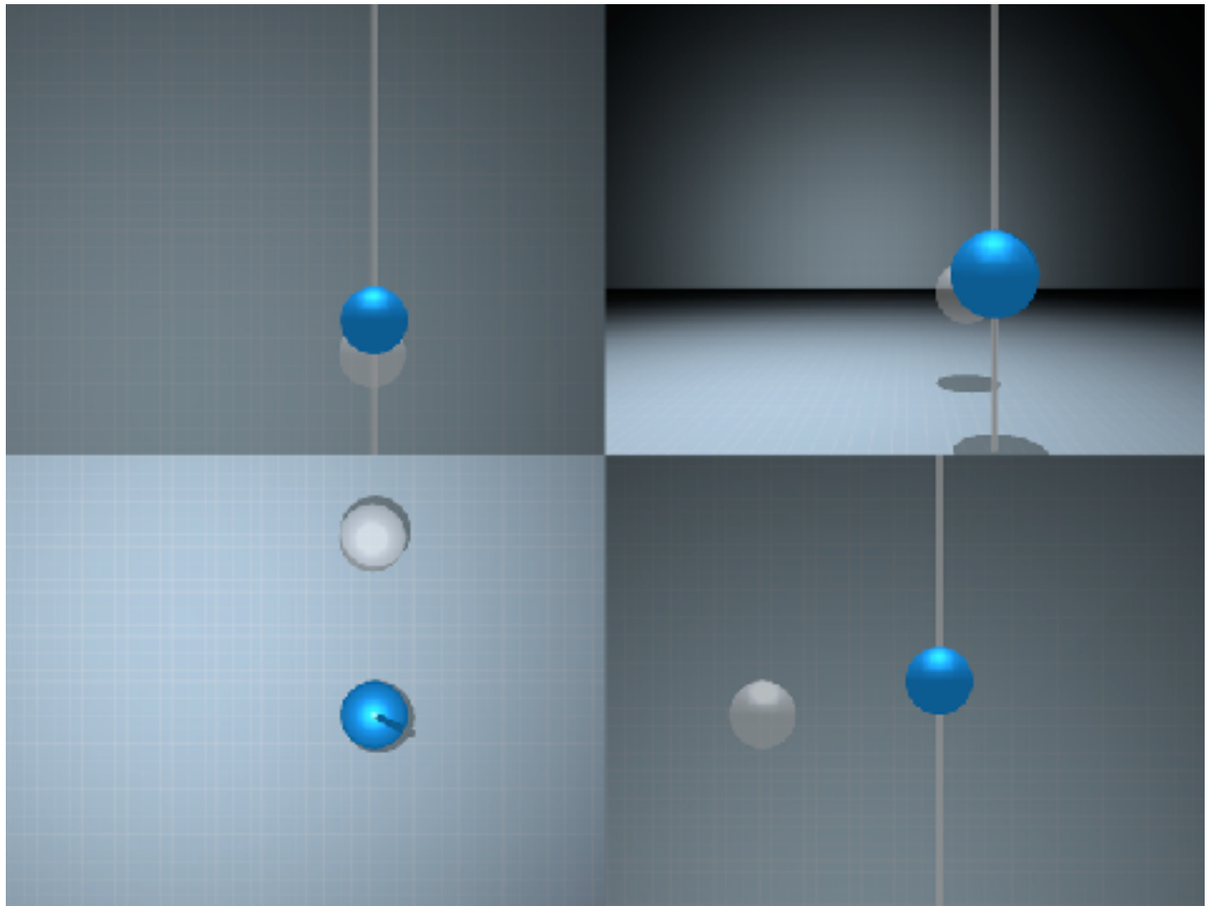


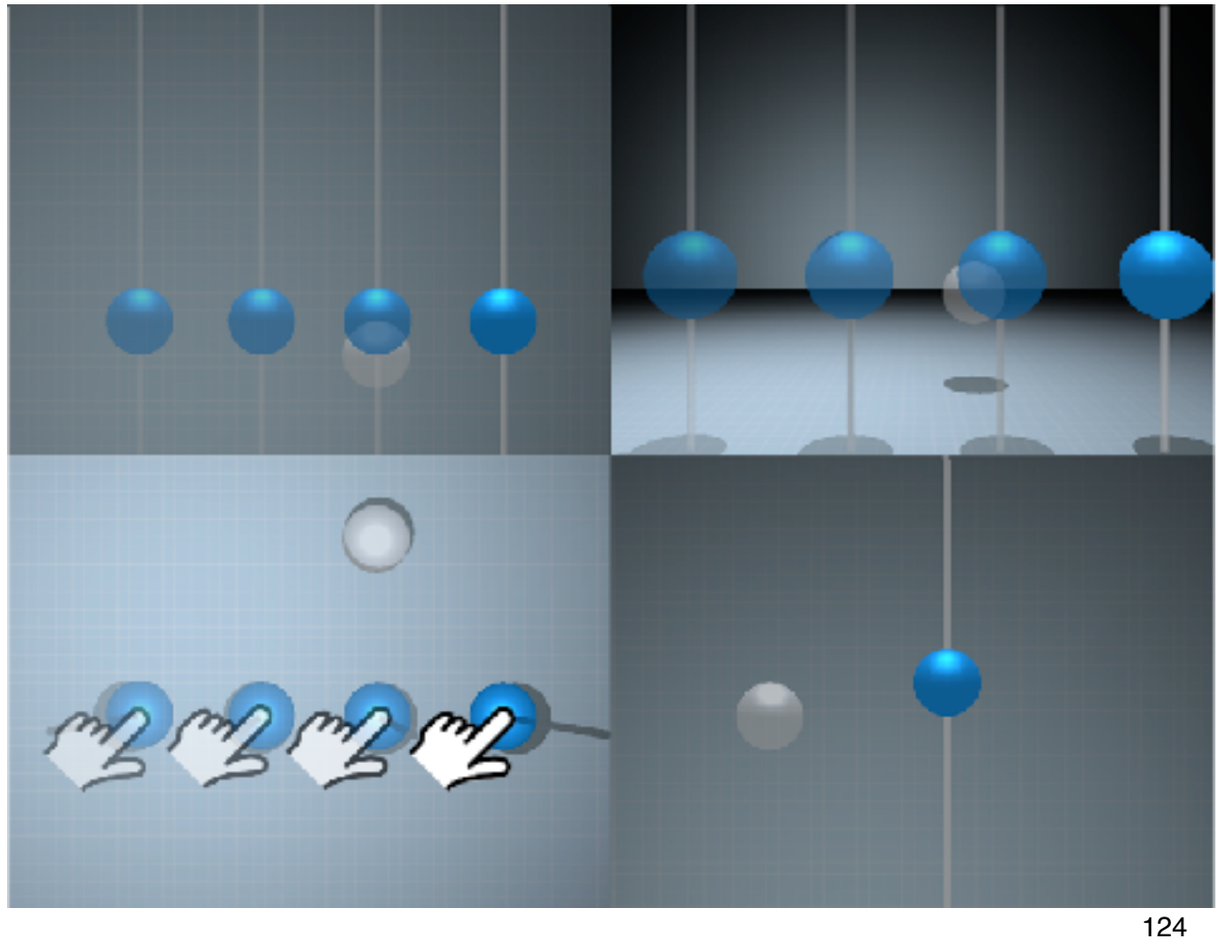
Toucheo

Toucheo

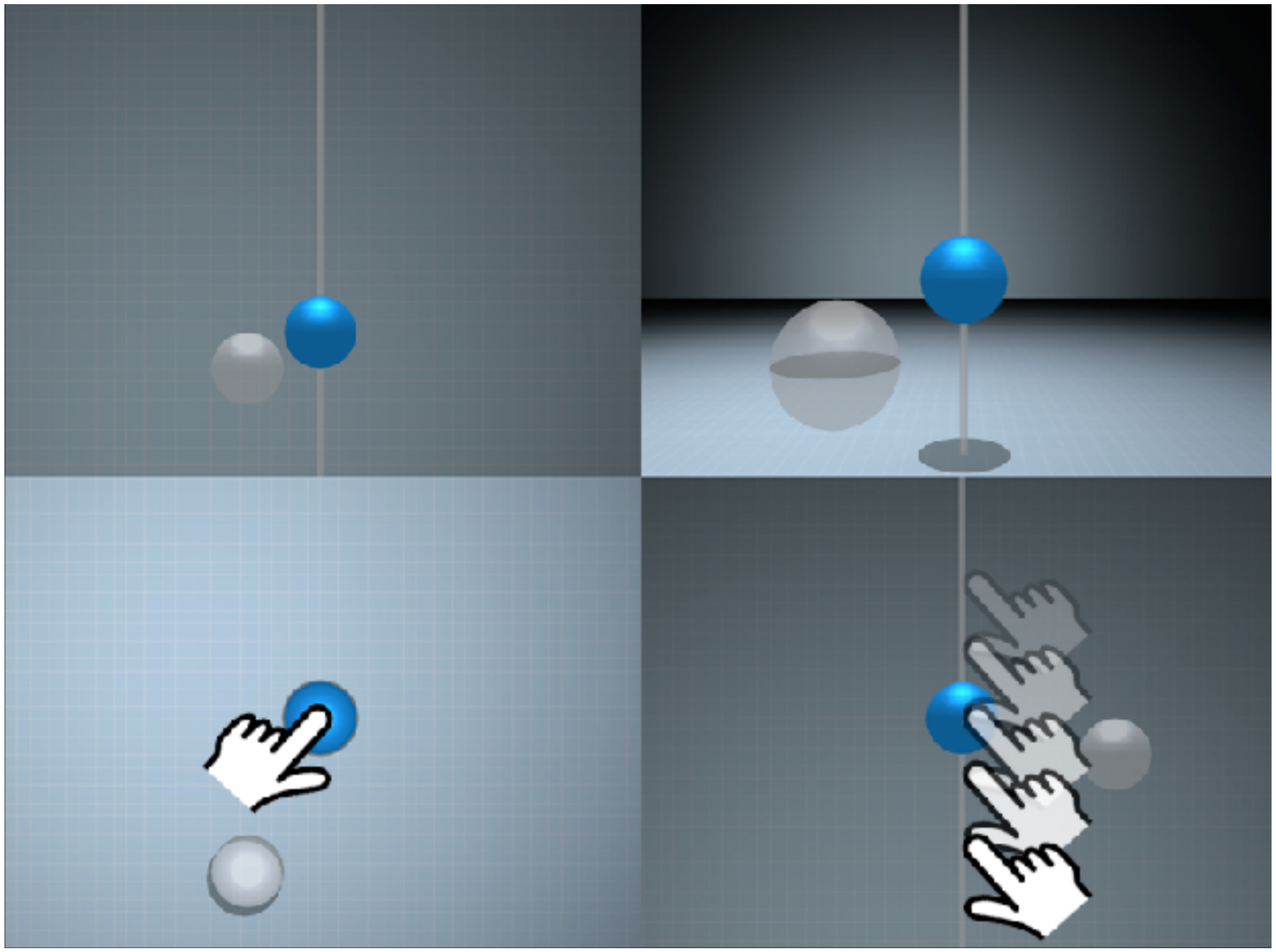
Amélioration d'une technique traditionnelle

1 vue = 2 DDL

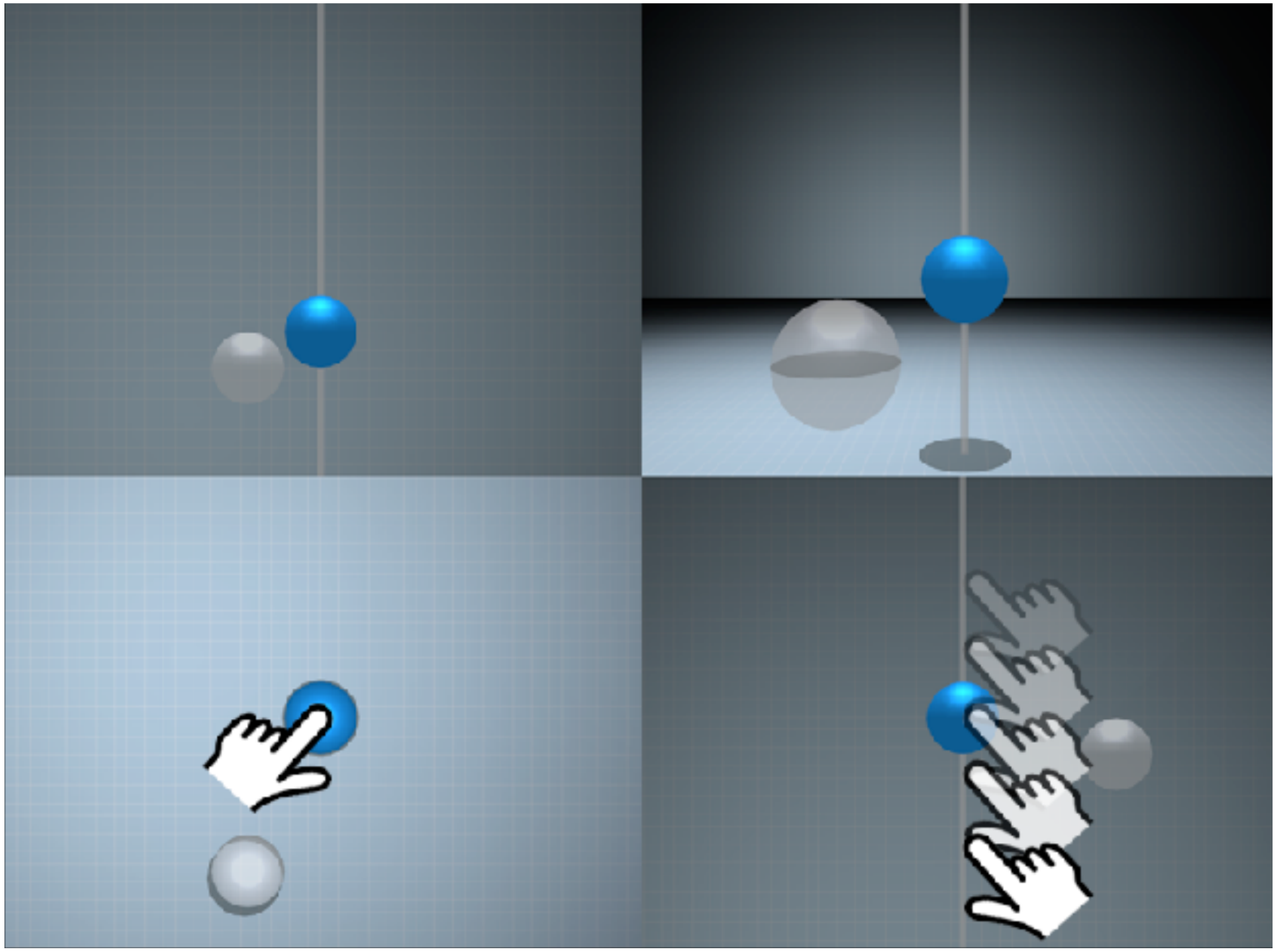




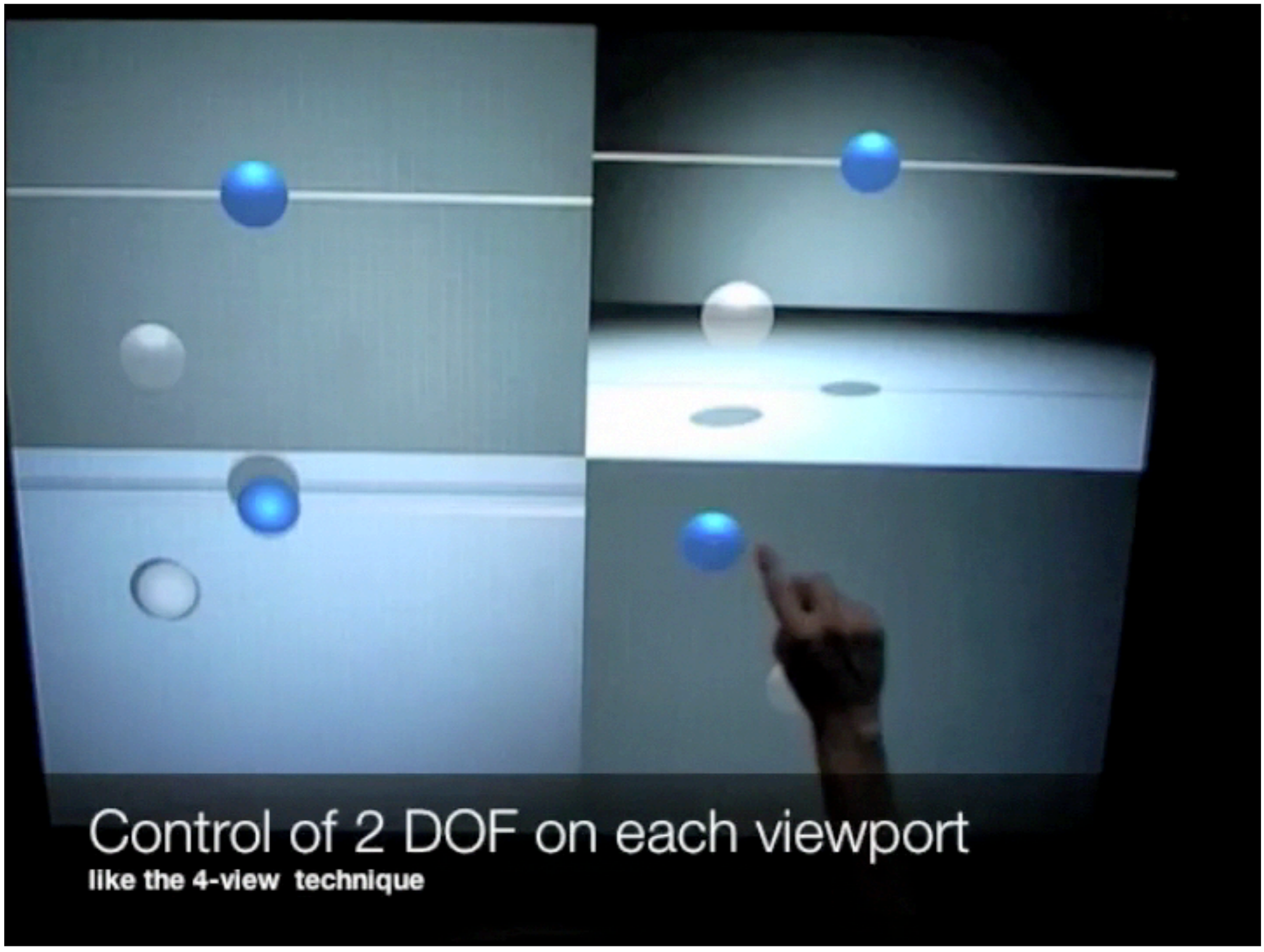
MT-Viewport



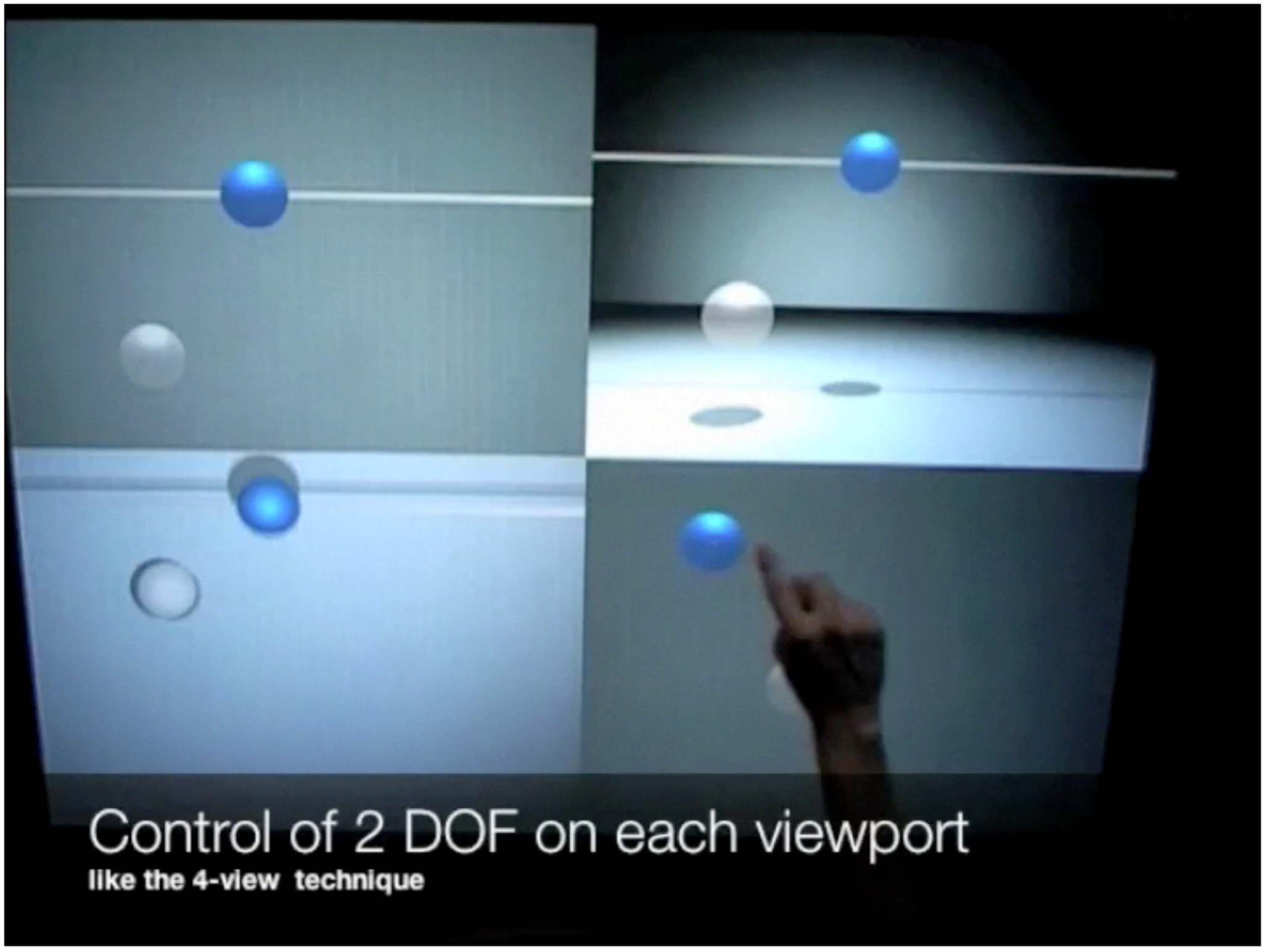
3ème DDL dans les autres vues



MT-Viewport



MT-Viewport

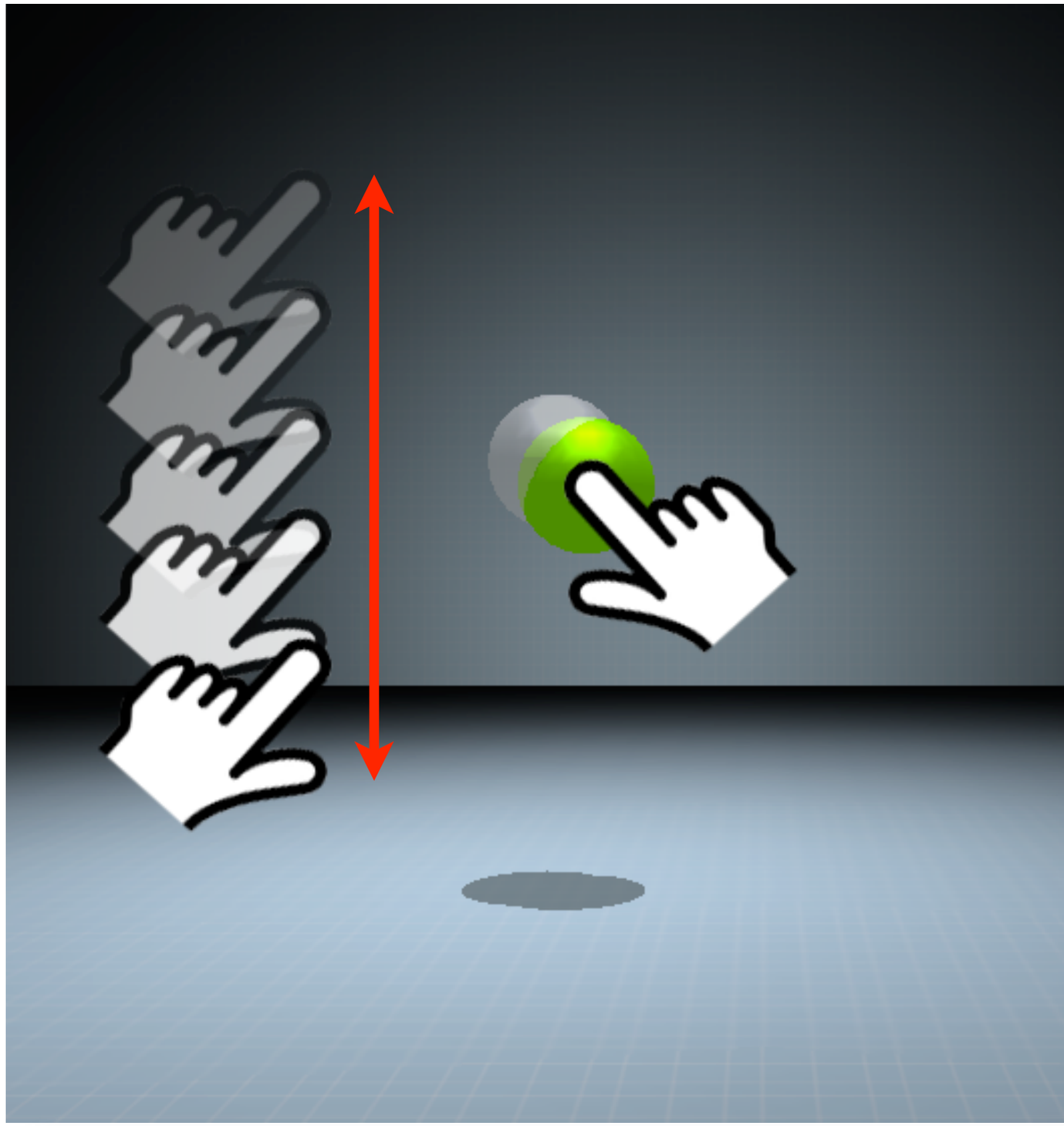


Z-technique

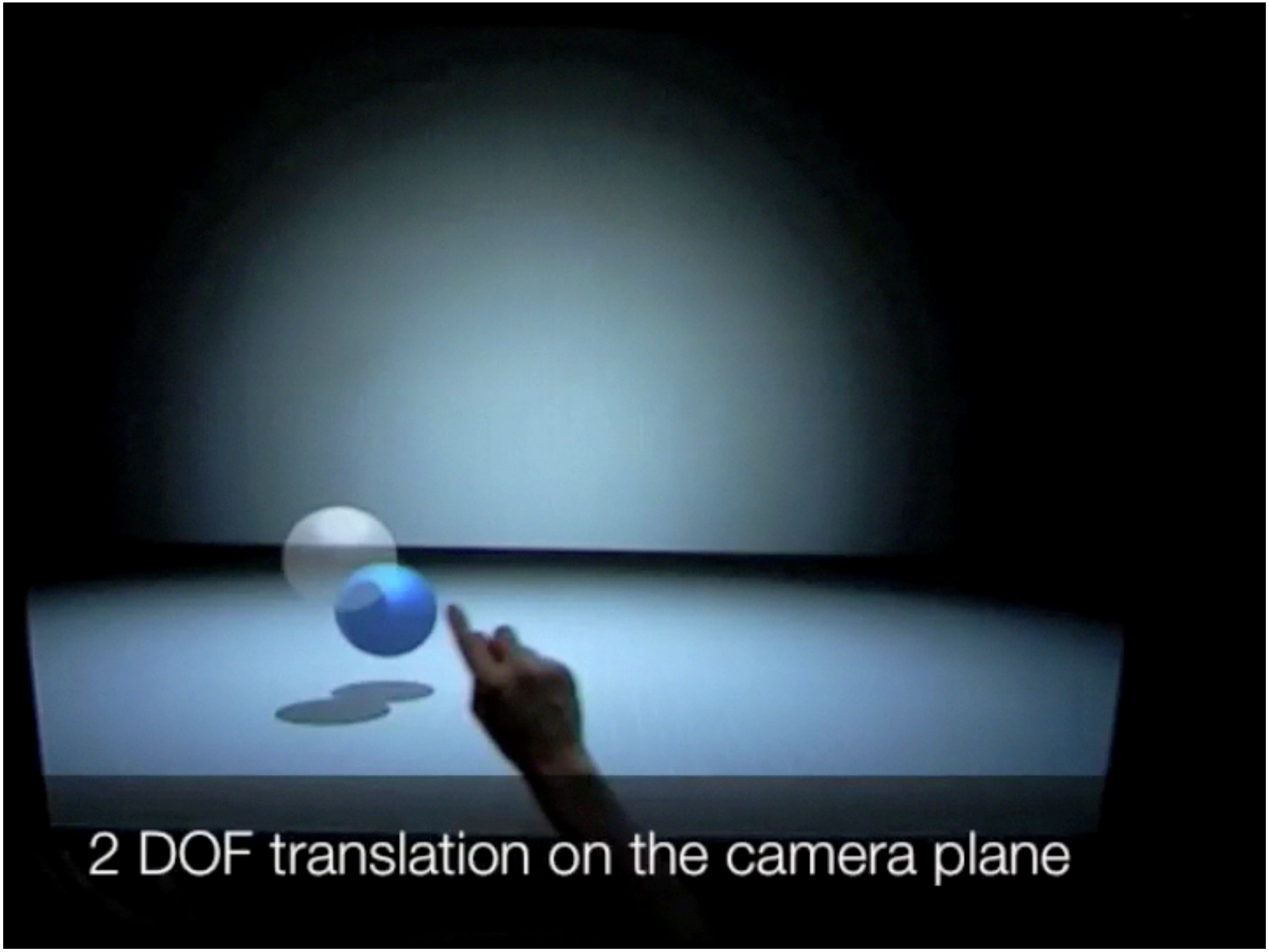
1 doigt : 2 DDL

Doigt indirect :

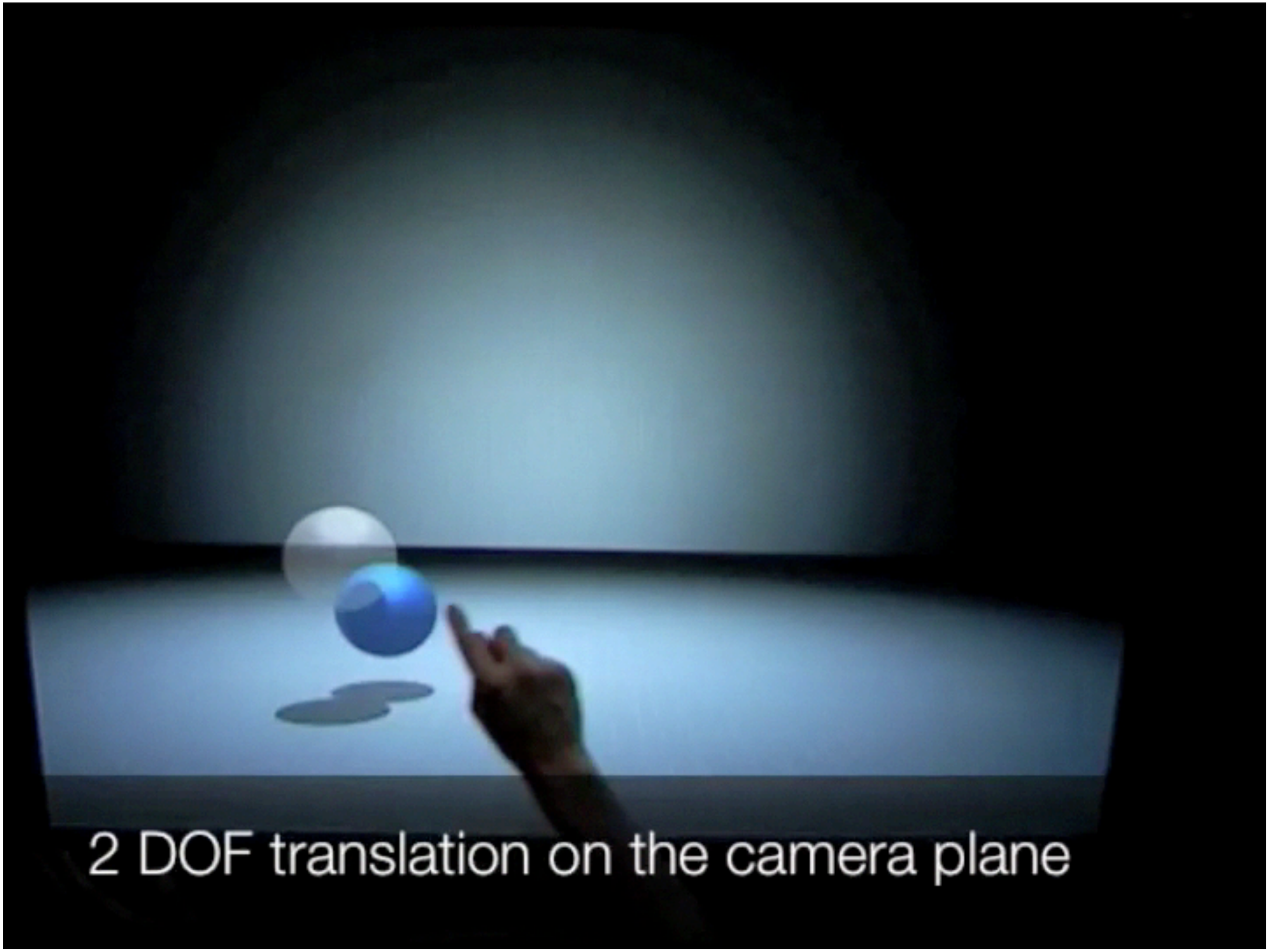
dernier DDL



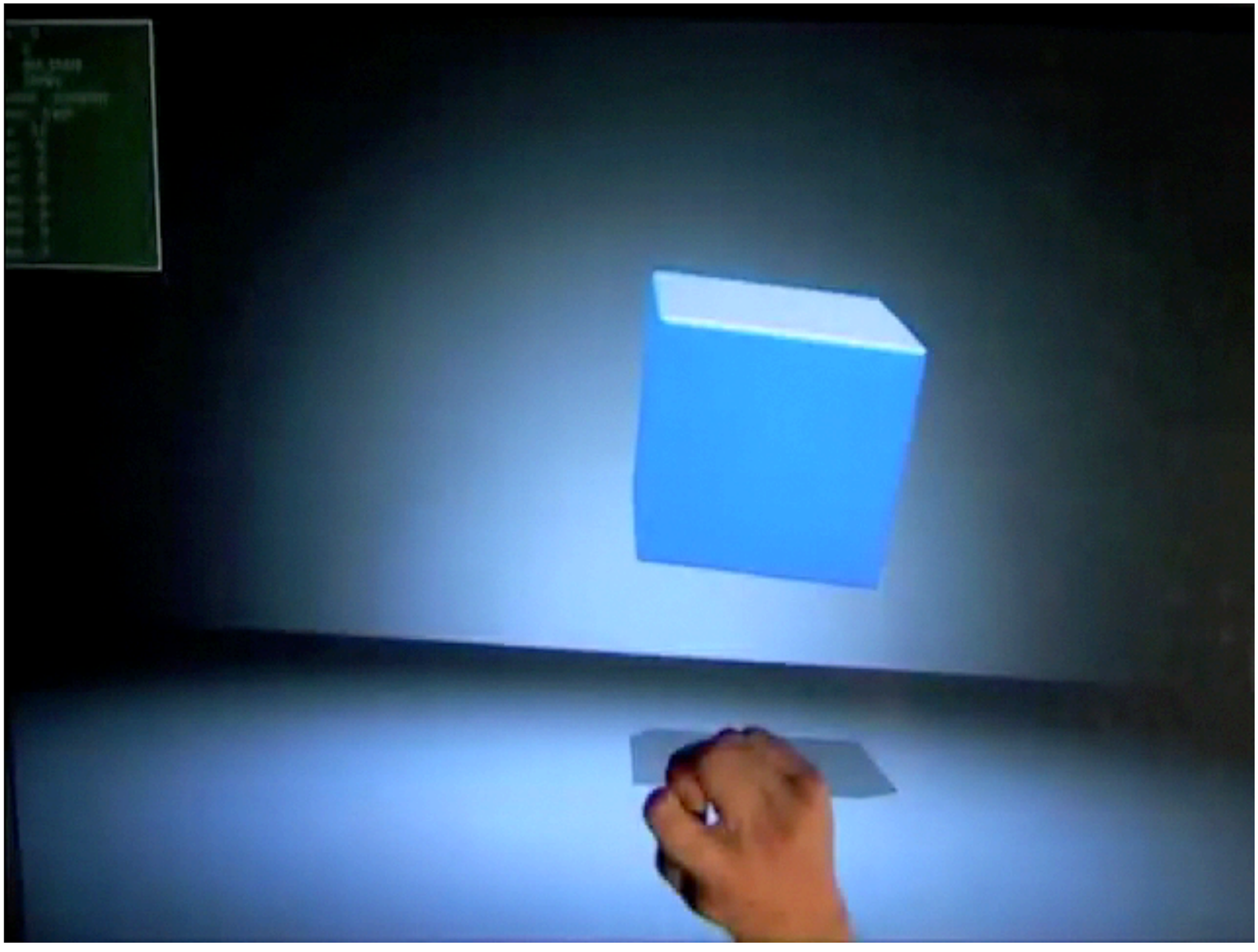
Z-technique



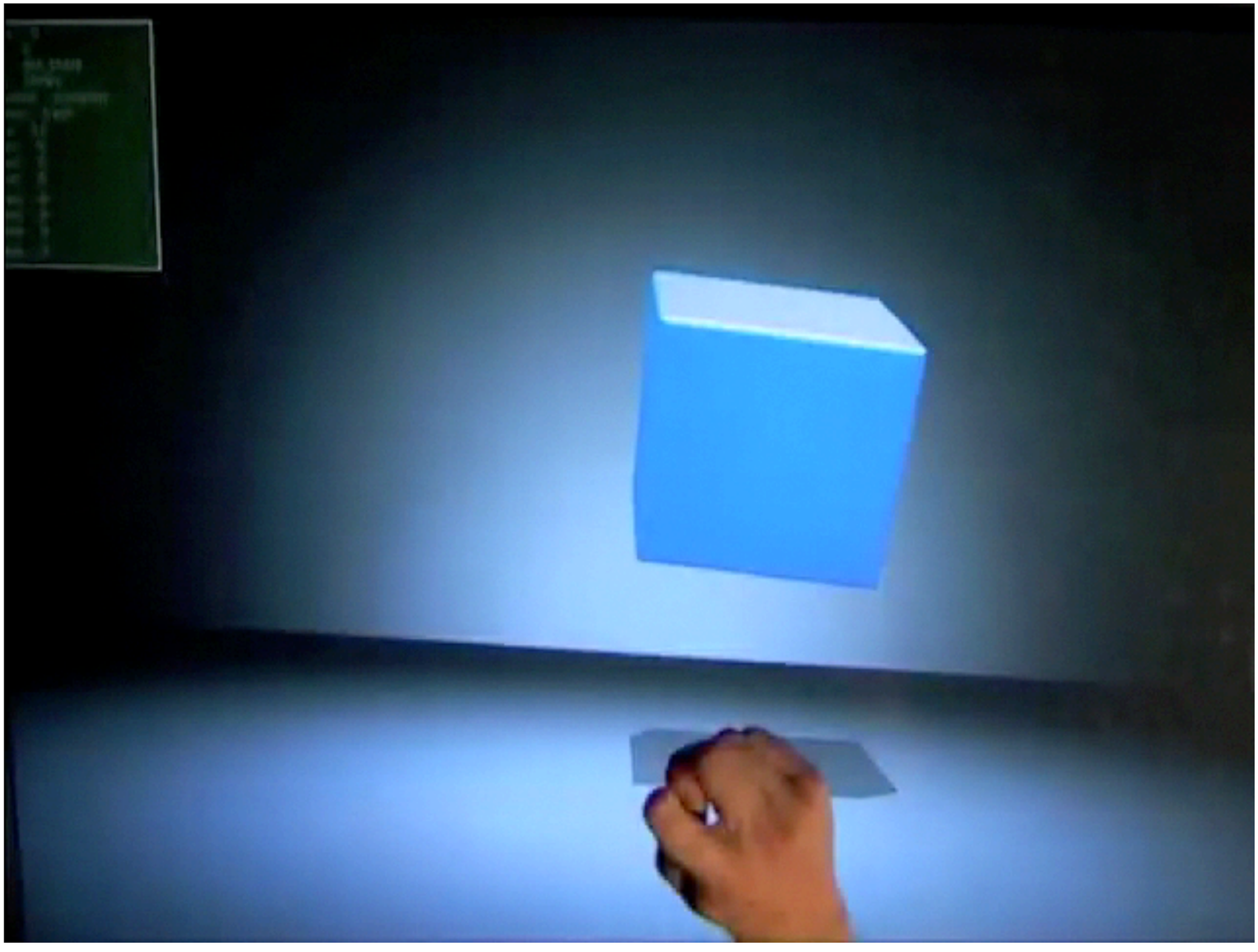
Z-technique



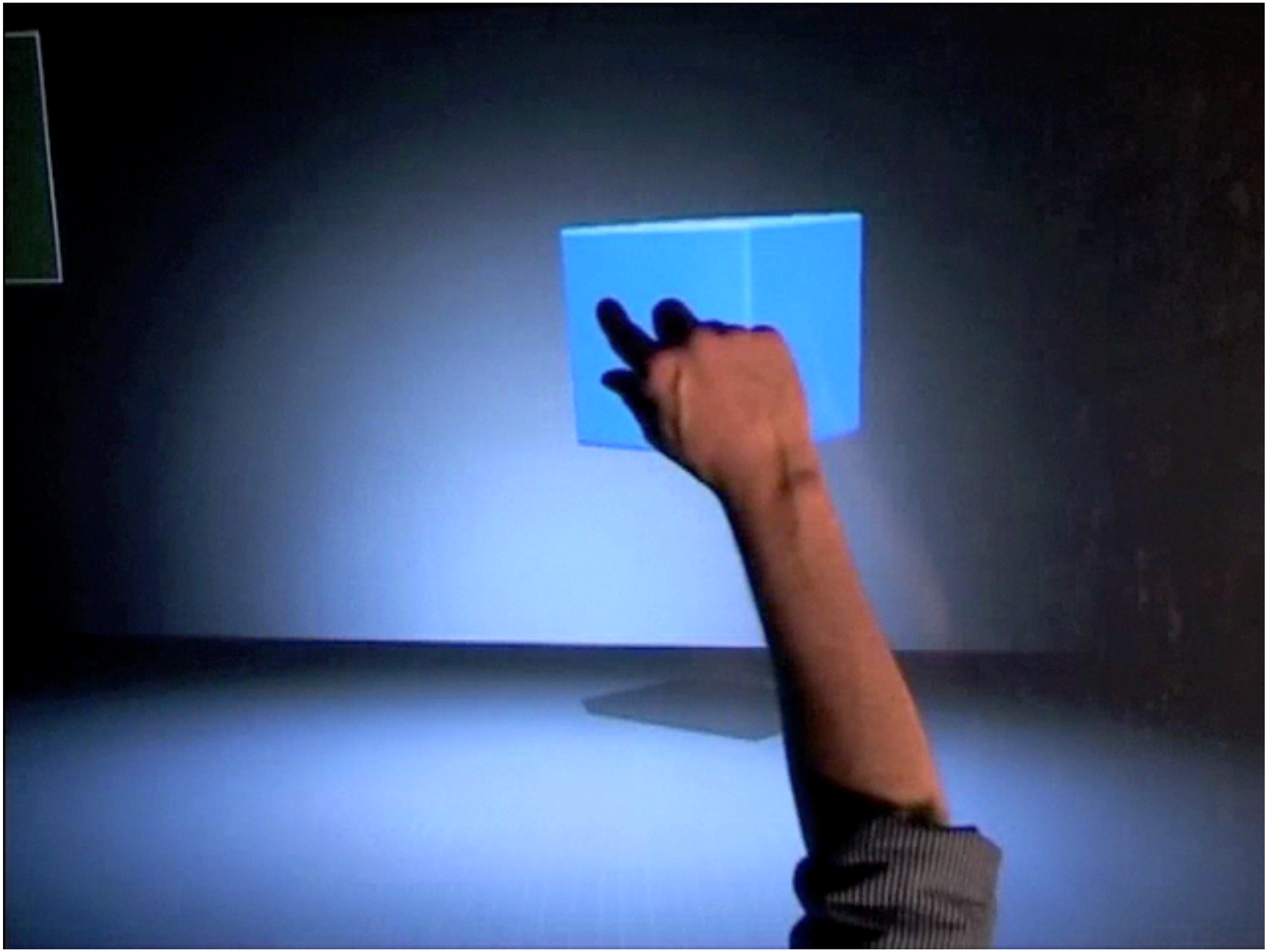
Sticky Tools [Hancock et al. 2009]



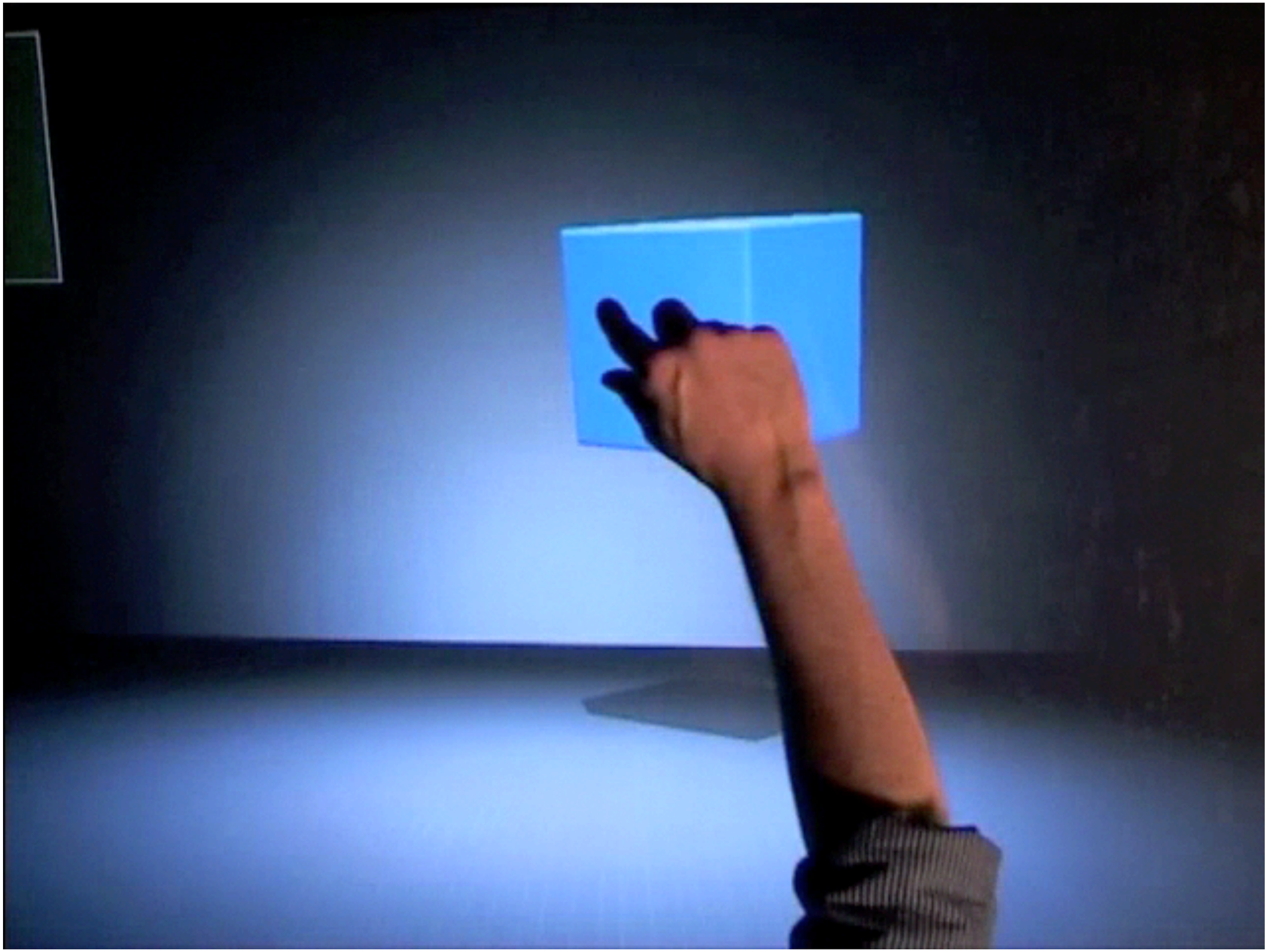
Sticky Tools [Hancock et al. 2009]



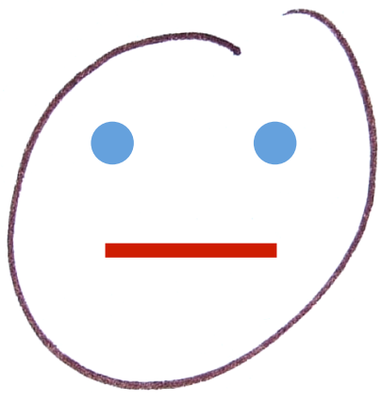
Screenspace [Reisman et al. 2009]



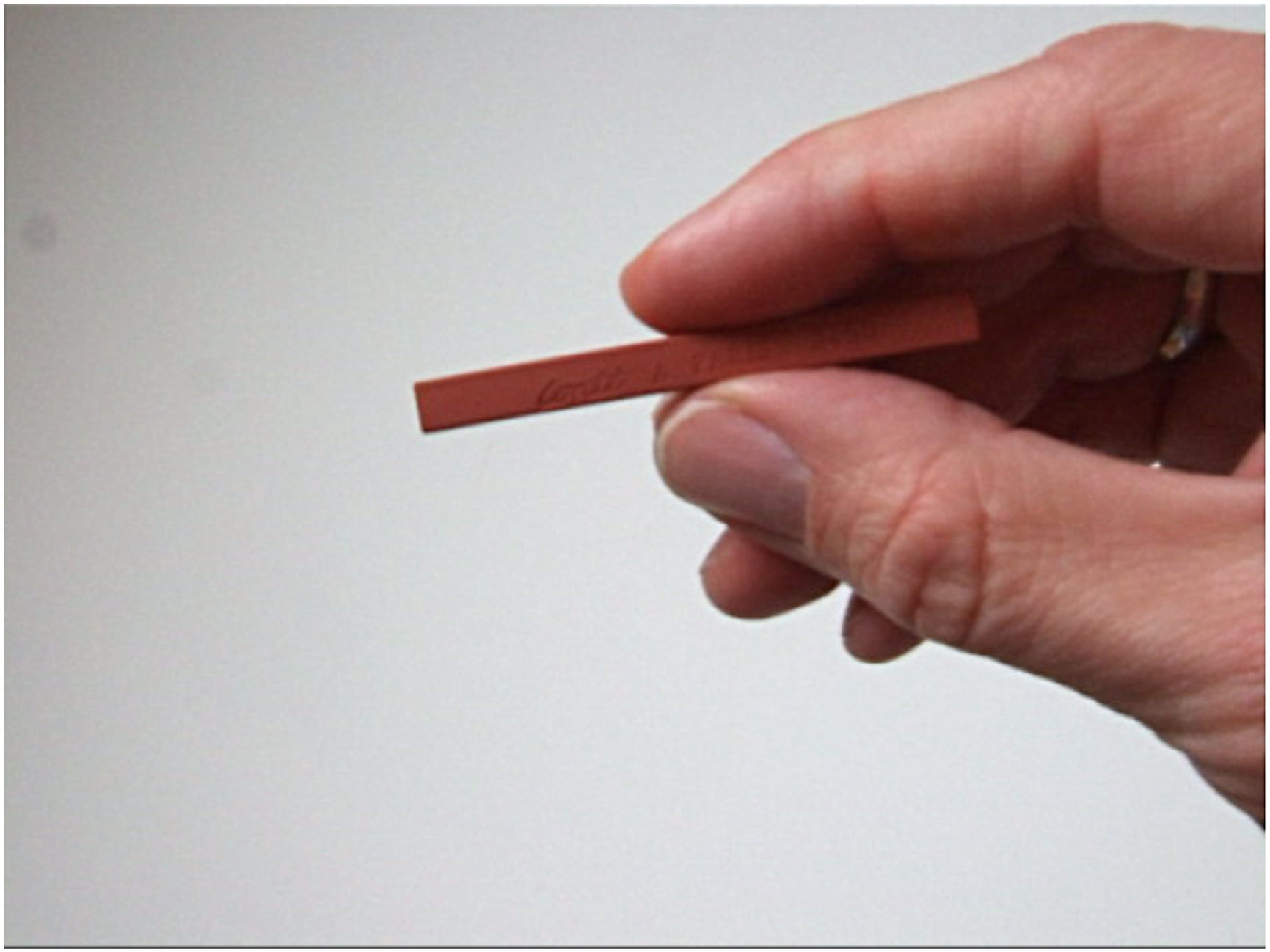
Screenspace [Reisman et al. 2009]



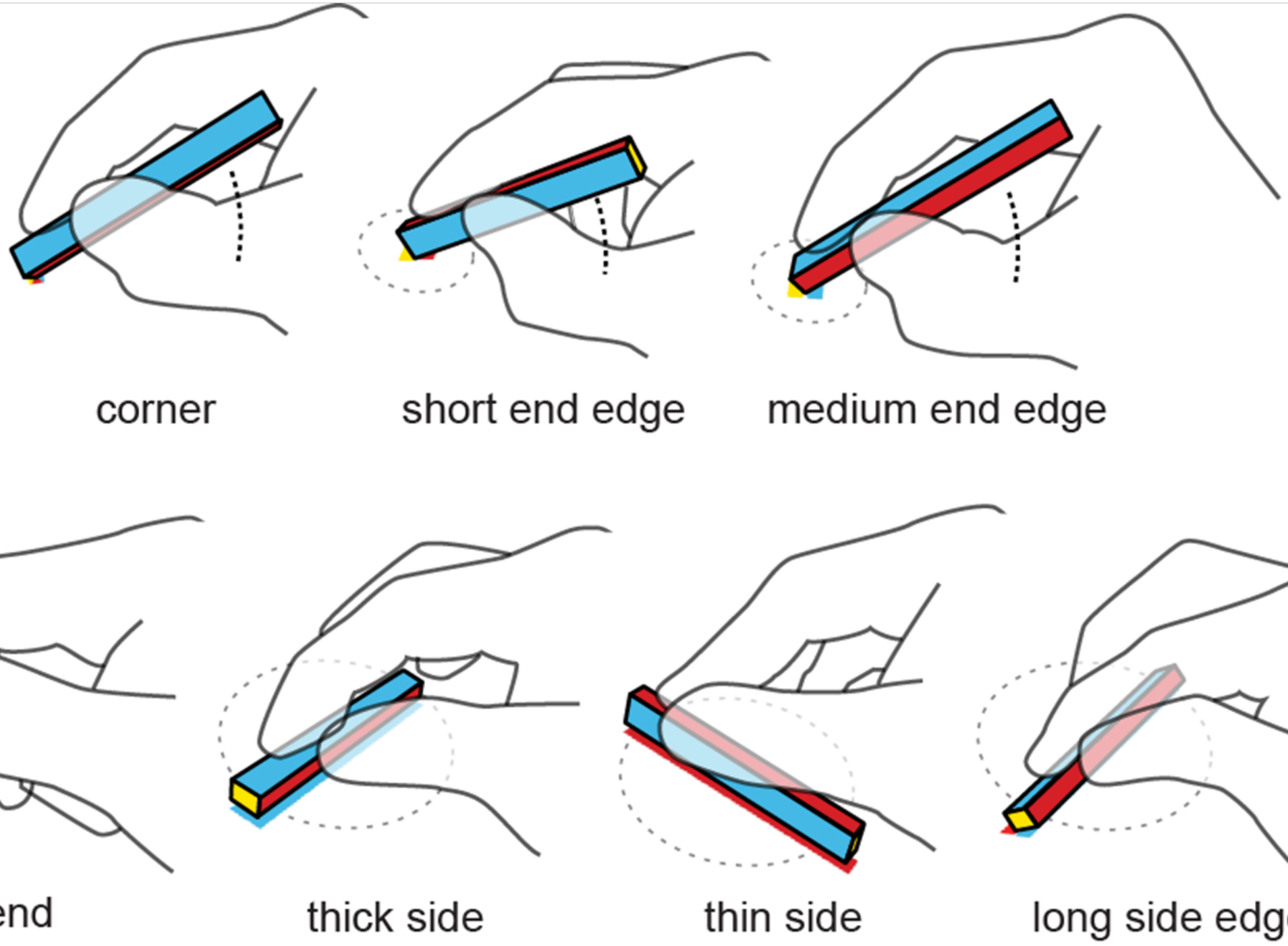
Conté [Vogel & Casiez 2011]



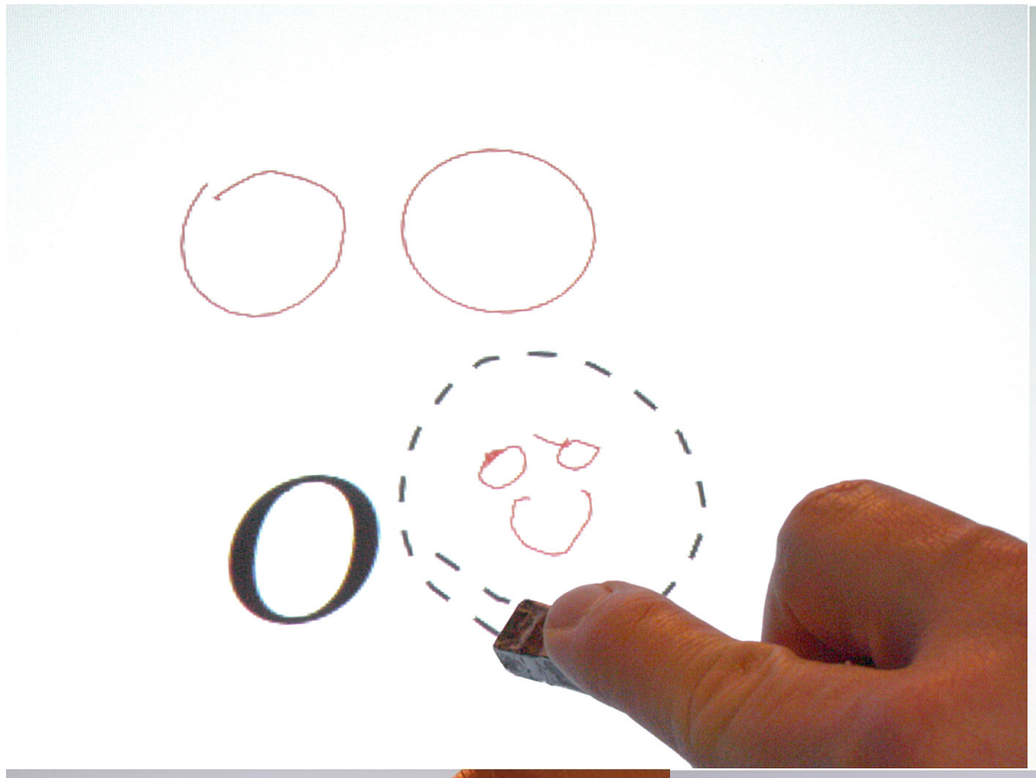
Conté

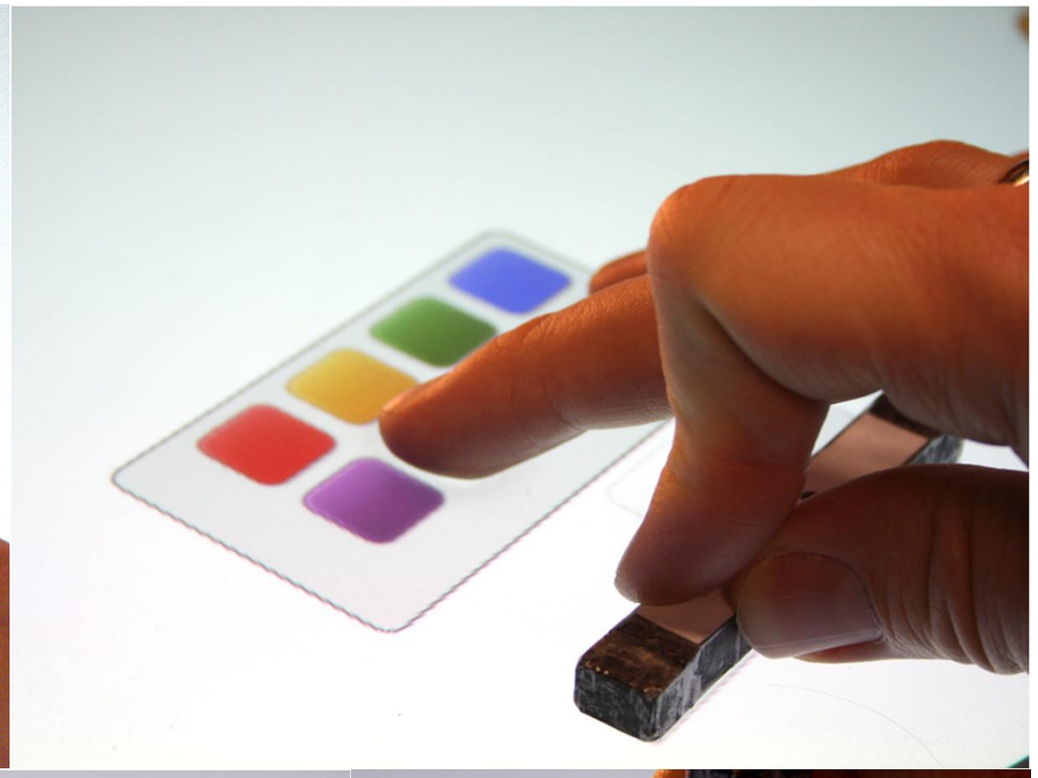


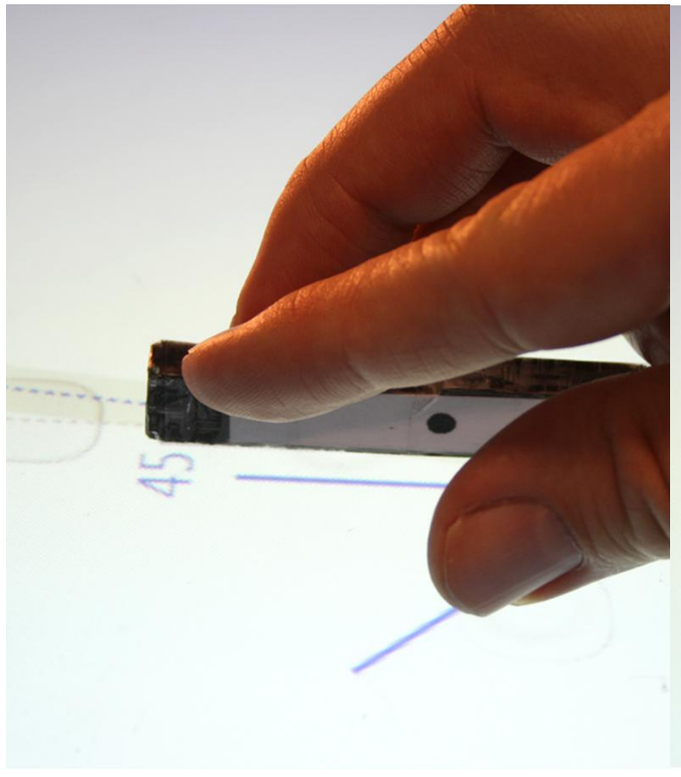
Conté

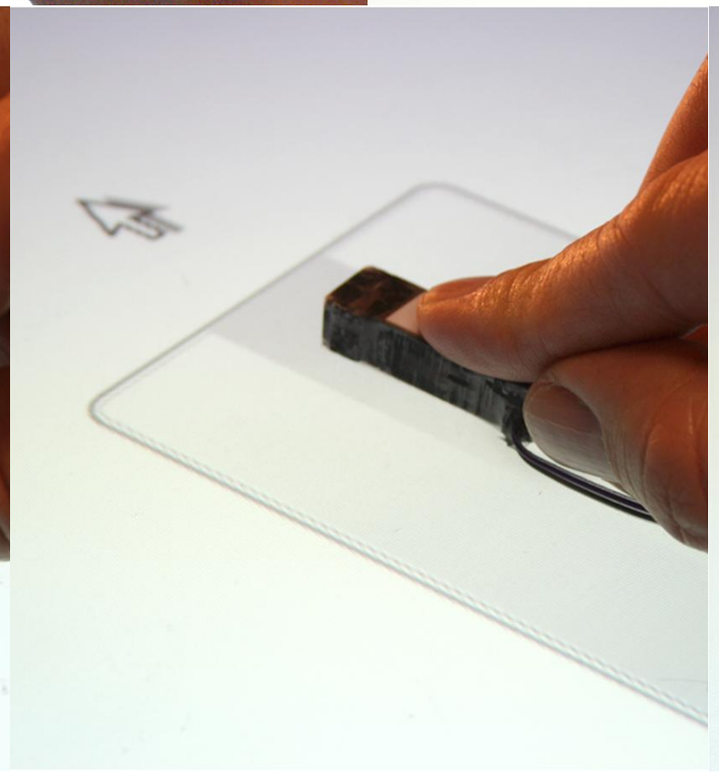

corner
short end edge
medium end edge
end
thick side
thin side
long side edge

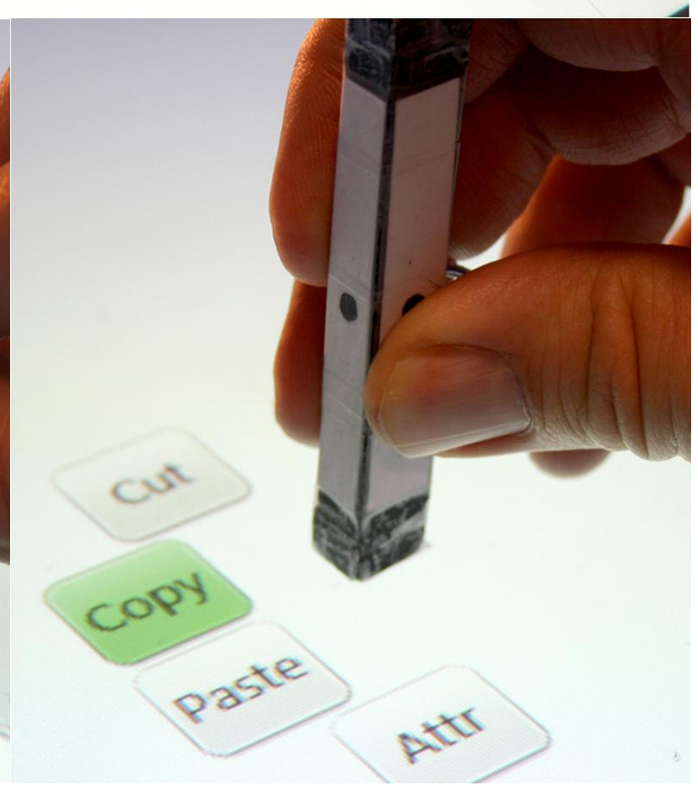
Conté



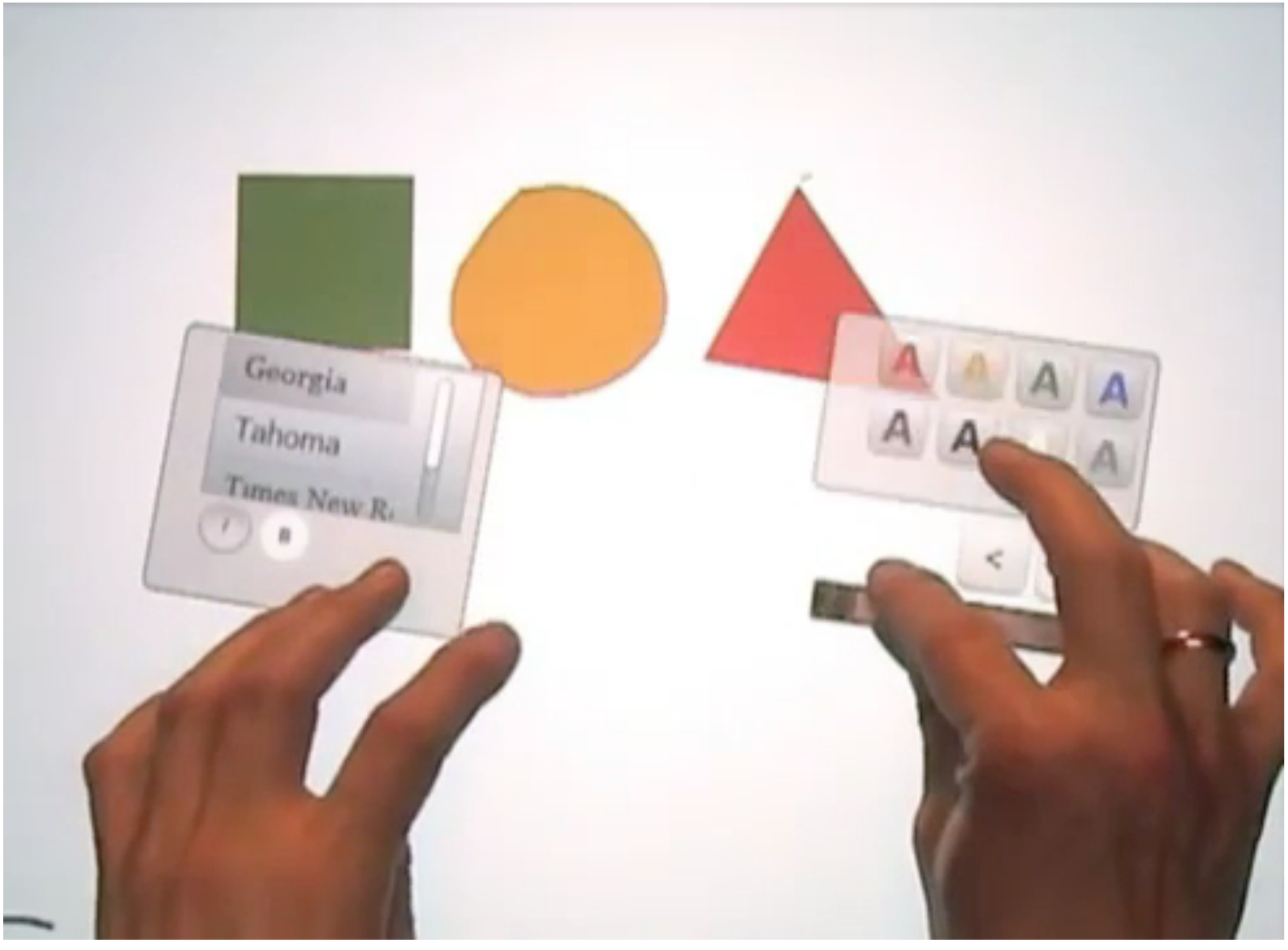




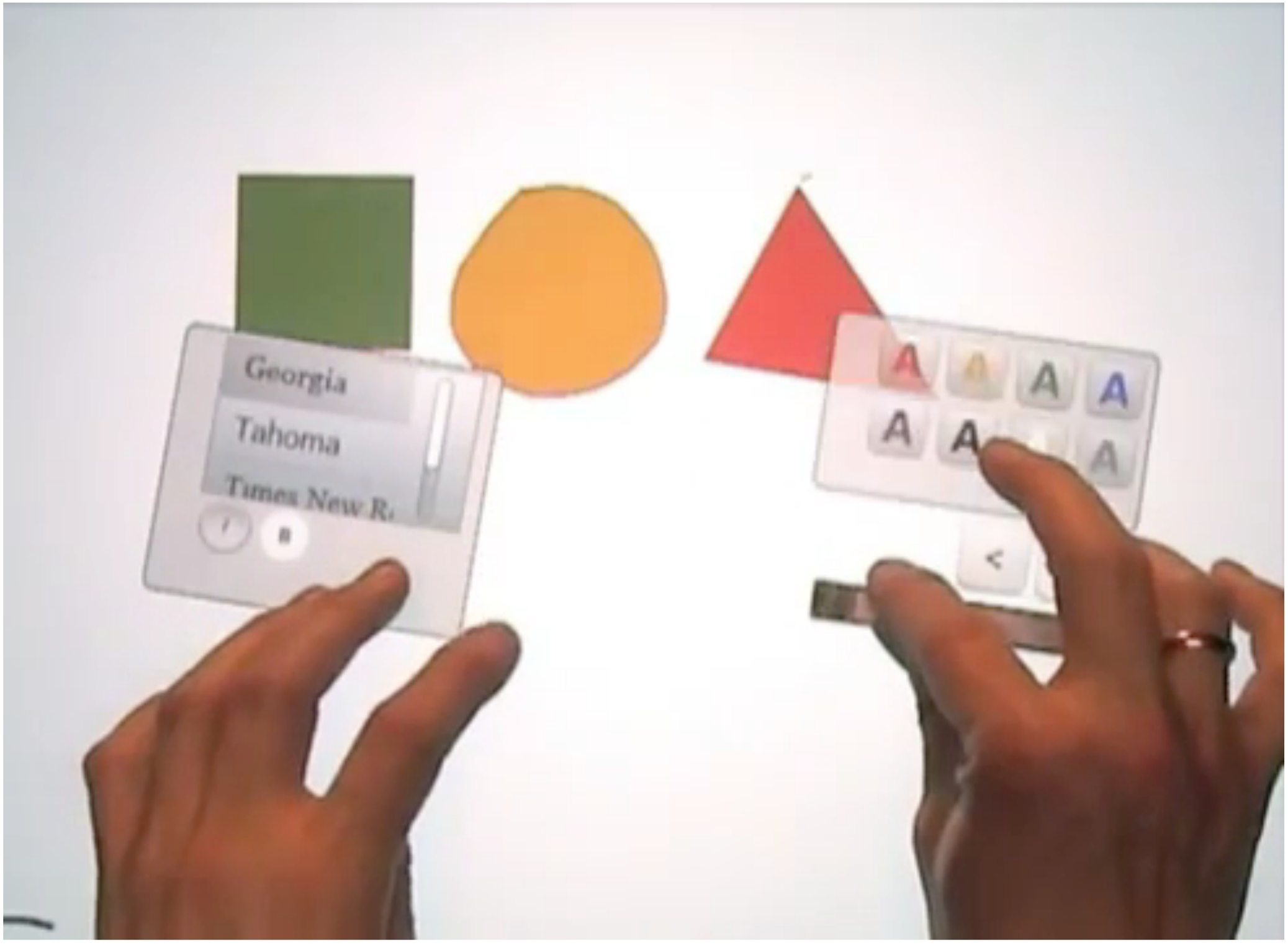


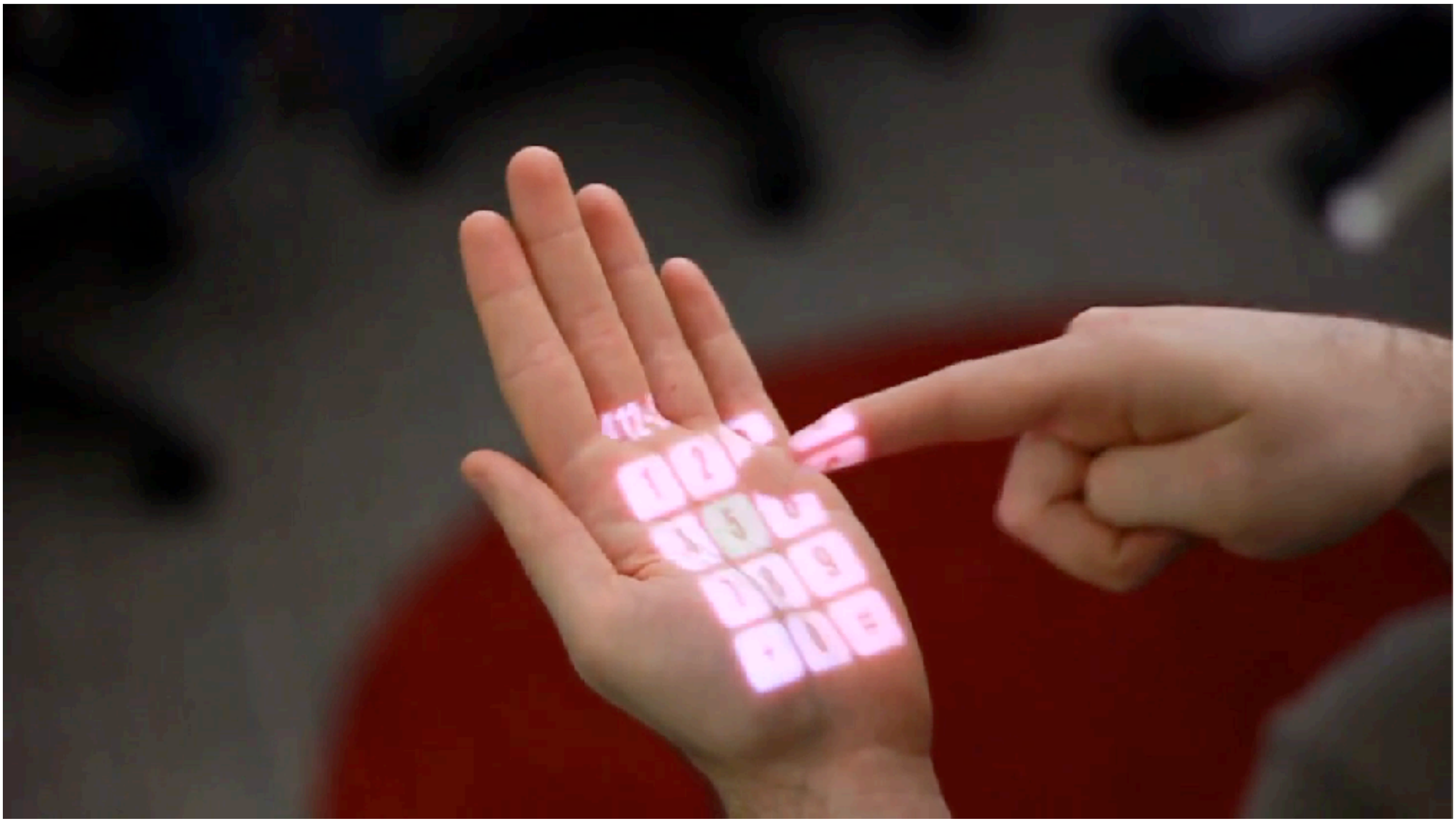


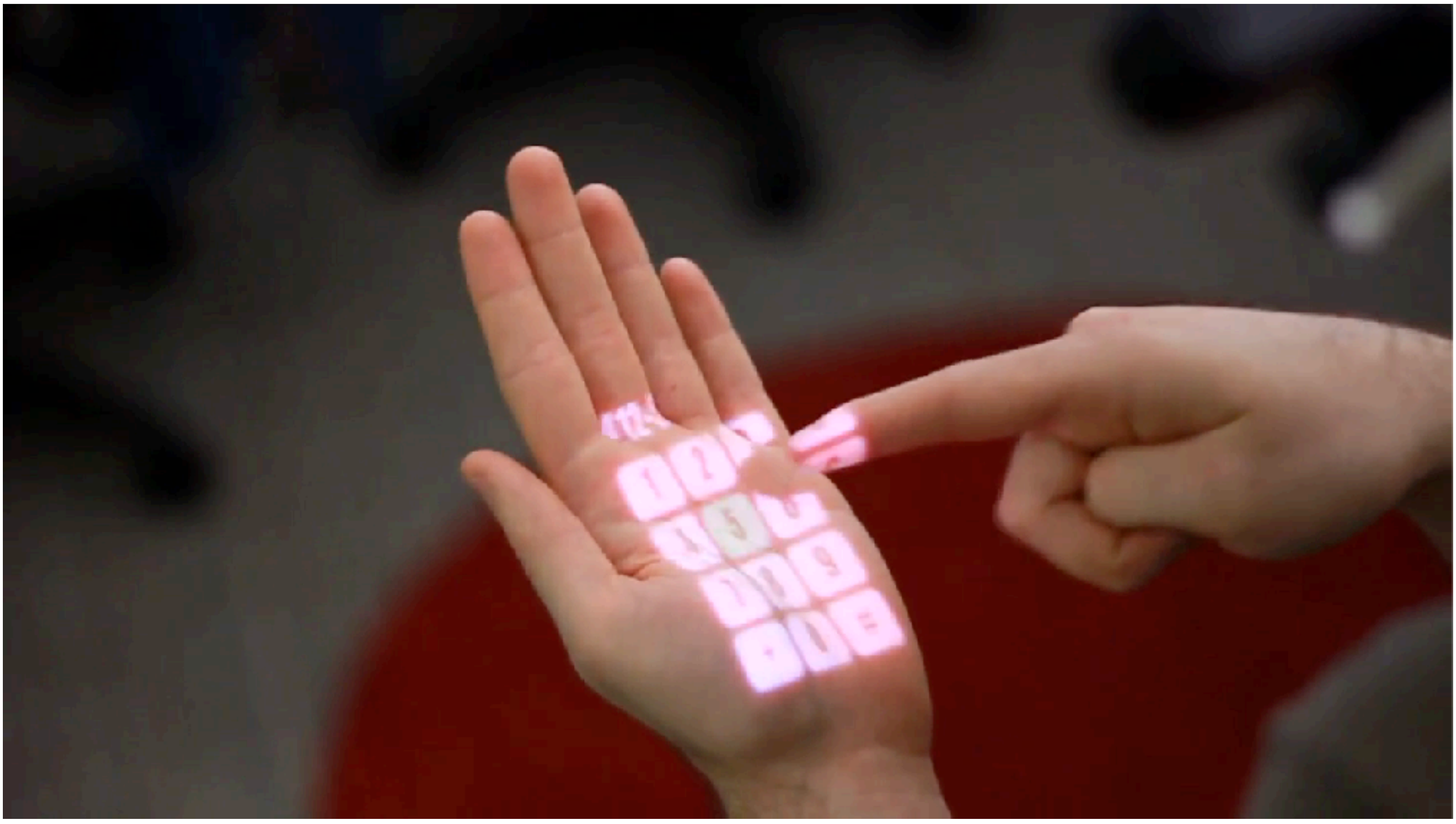
Conté

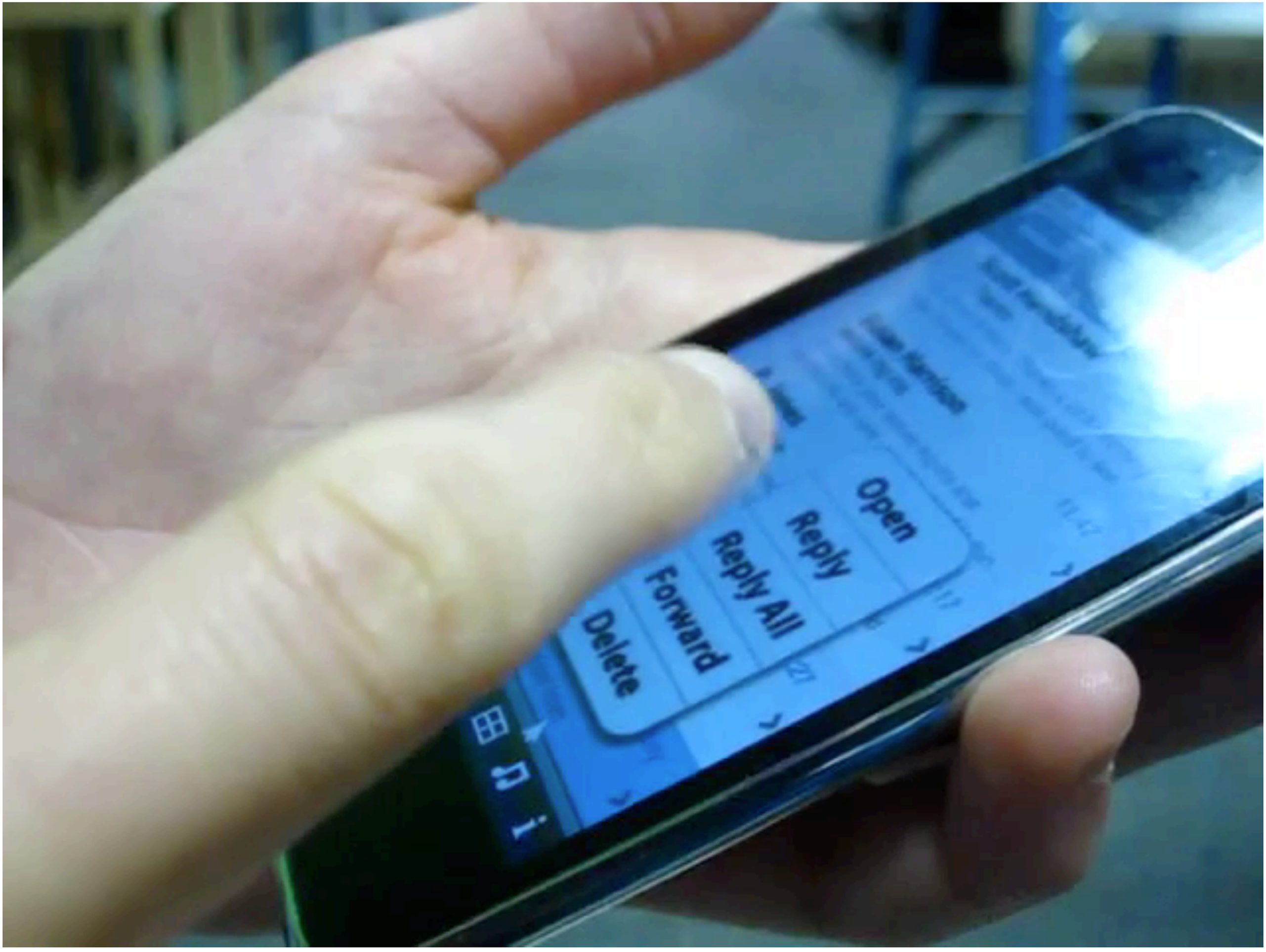


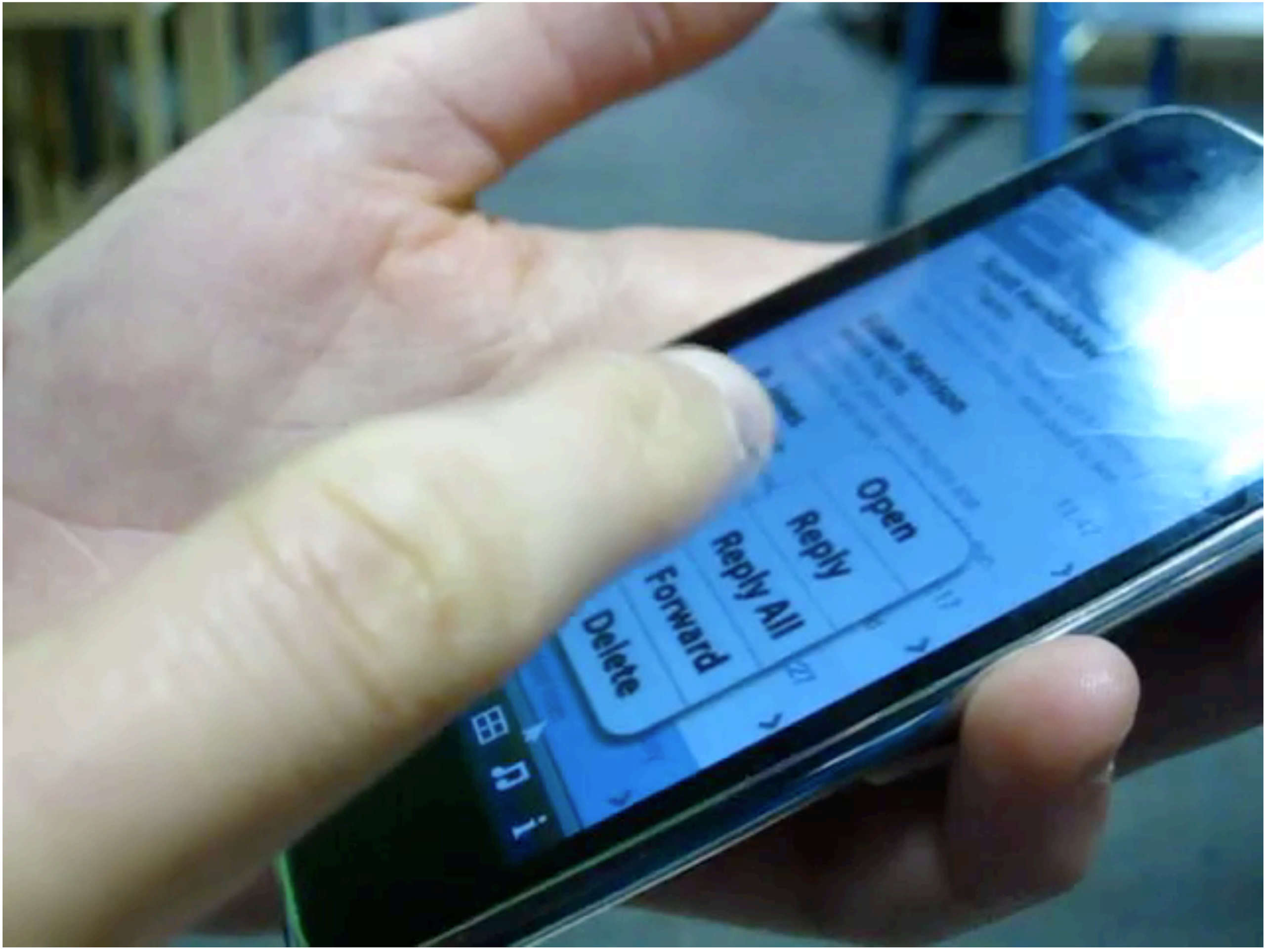
Conté







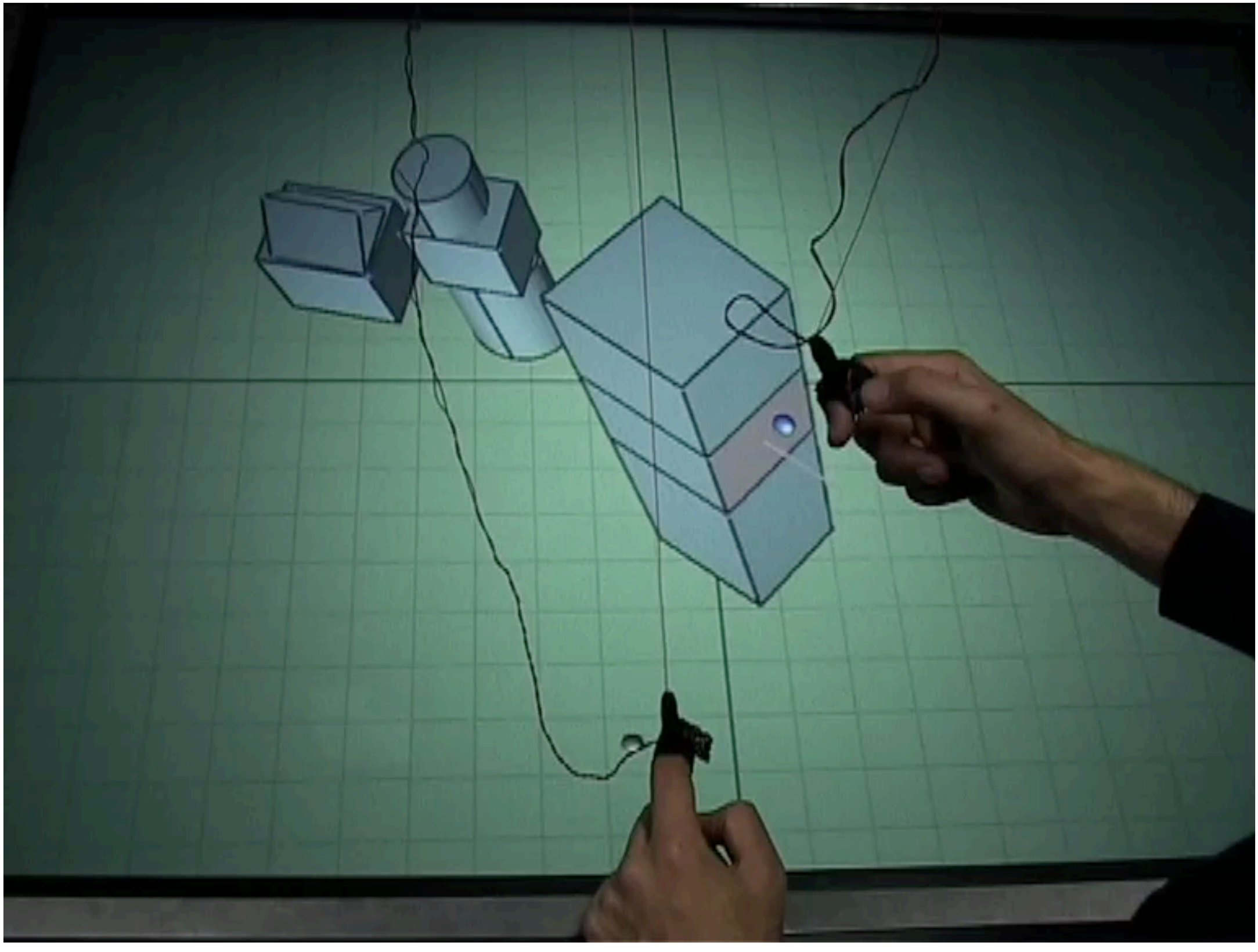

Open
Reply
Reply All
Forward
Delete


Open
Reply
Reply All
Forward
Delete

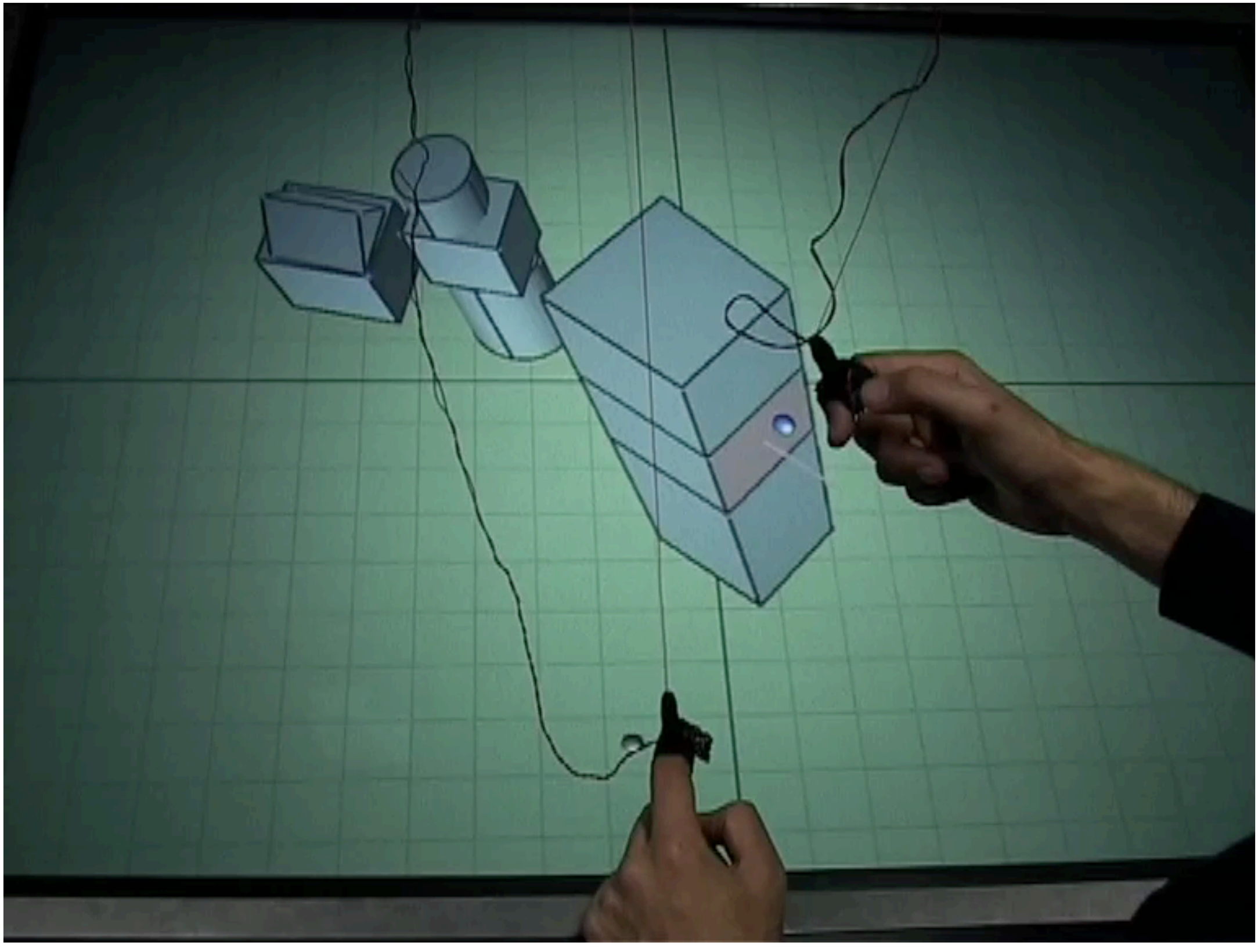
Forces tengentielles

Forces tengentielles

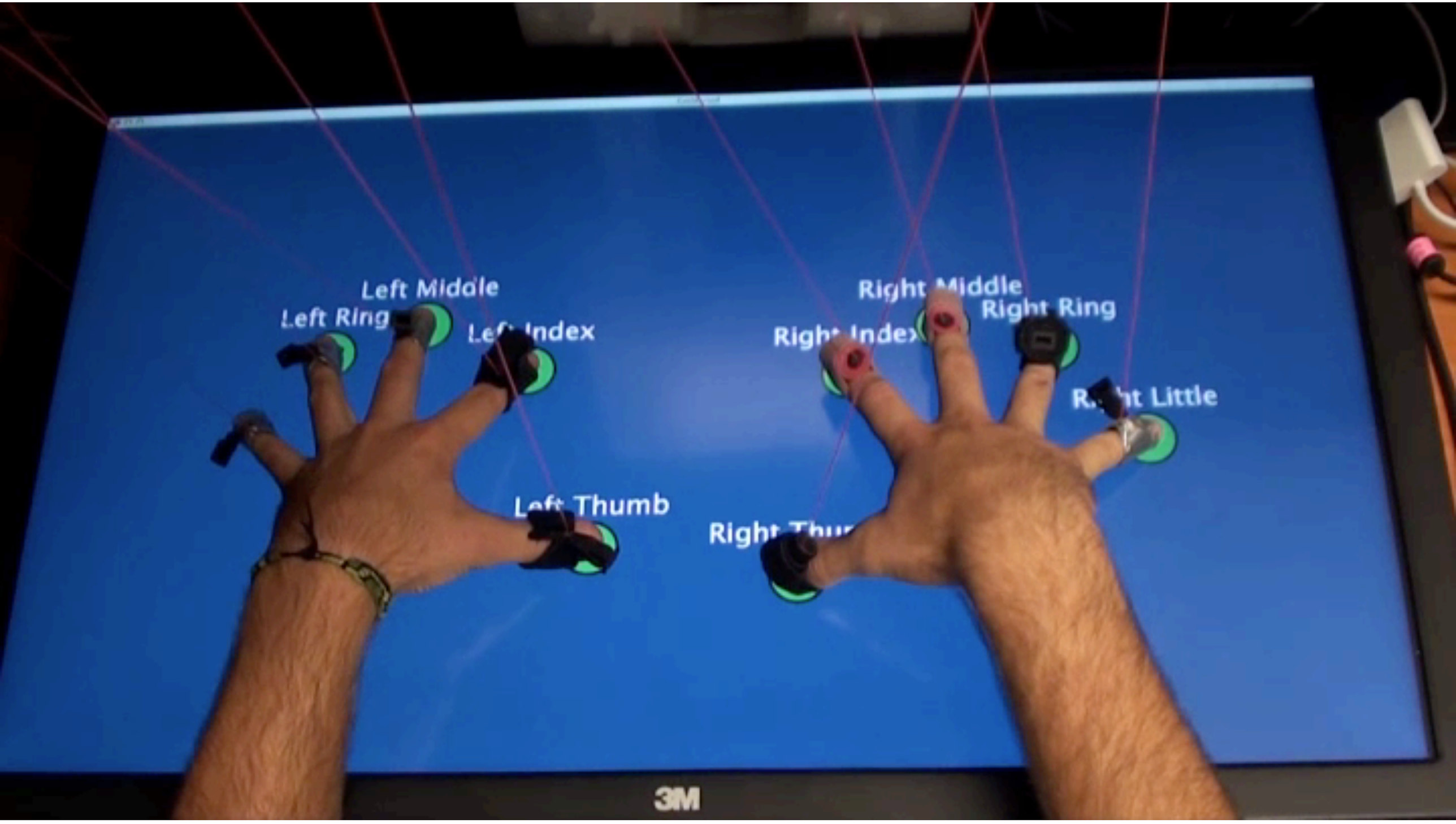
Mockup Builder [Araujo, Casiez et al. 2012]



Mockup Builder [Araujo, Casiez et al. 2012]



HotFingers [Goguey, Casiez et al. 2014]



HotFingers [Goguey, Casiez et al. 2014]