Petra Isenberg

INRIA

Visualization for Large Multi-touch Interactive Surfaces

Tutorial PacificVis 2011

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Tutorial PacificVis 2011

Background

Diplom, University of Magdeburg

Computational Visualistics

PhD , University of Calgary

Computer Science

PostDoc

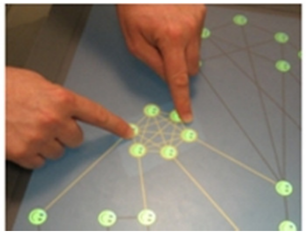
↓

Research Scientist, INRIA

French National Research Institute for CS

Past Research Overview

- Interaction


graph layout


data selection


data manipulation

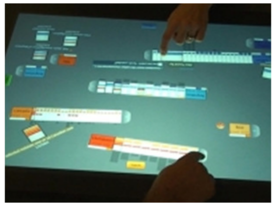

3D data interaction

multi-touch/
direct-touch

- Socio-technical aspects


context


coordination


awareness


reasoning


information sharing

collaboration

- Current Work


infrastructure


perception


tangible infovis

opportunities

why large multi-touch displays?

people work not only on desks

people interact with their environment directly

people work not always by themselves

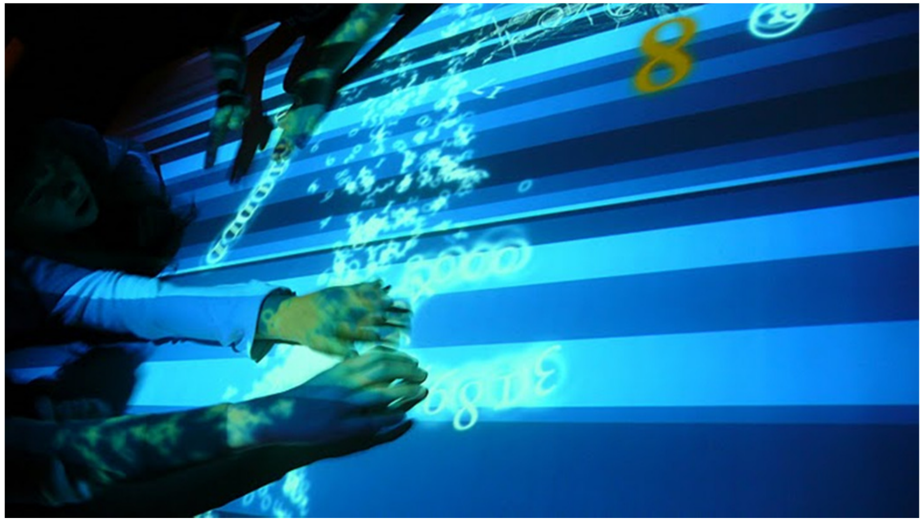
desktop screens are often too small

support new data analysis scenarios & environments

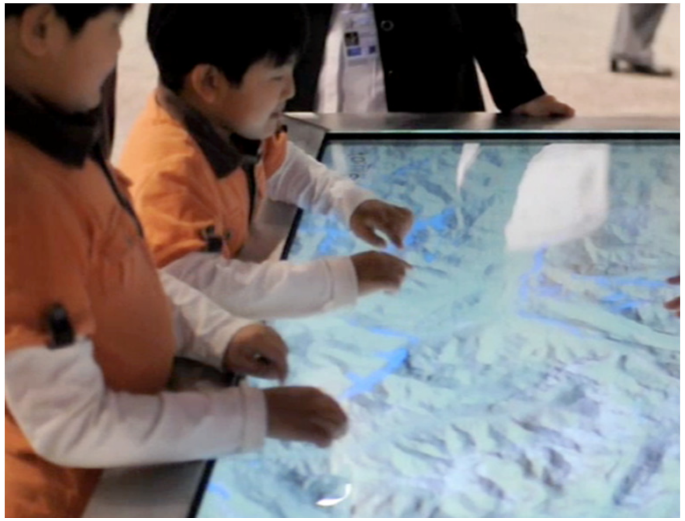
Picture from (McGee, 2001)

exciting possibilities for visualization

new audiences



@ Ars Electronica Center, Linz



http://www.multigesture.net/

new audiences: example

SyncLost is a multi-user installation for immersion in the history of electronic music

http://3bits.net/synclost/

floating.numbers (2004)

visualizes the relevance of numbers
exhibition at the Jewish Museum/Berlin

exciting possibilities for visualization

new environments

meeting rooms

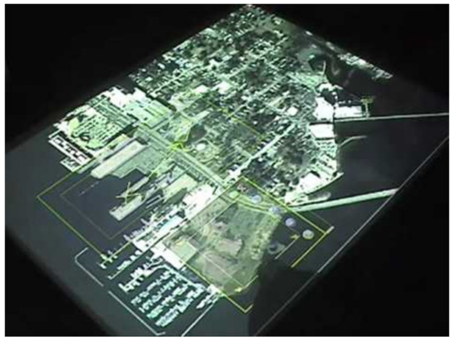
museums

emergency response / war rooms

shared work spaces (research labs, offices, ...)

ambient displays (hallways, ...)

MS Surface Blog



WorldNews.com

Perceptive Pixels

Images collected by Michael Haller, Petra Isenberg

exciting possibilities for visualization

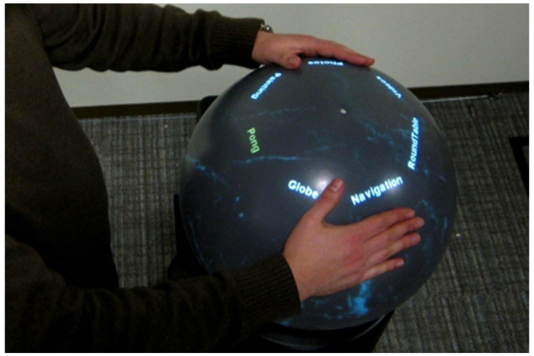
new presentation & interaction possibilities

more degrees-of-freedom input

higher pixel count

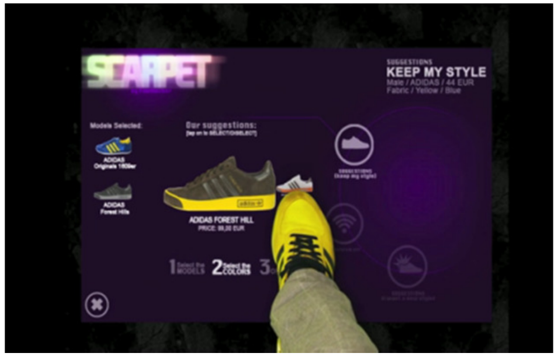
different data projections

touch & cognition?



Sphere (Benko et al., UIST 08)

WILD Wall + Tabletop (INRIA)



Scarpet - http://vimeo.com/19933042

Sphere multi-touch

today

13:30 – 15:00

Large Display Technology

Software Frameworks

Coffee Break

15:30 – 17:00

Visualization Challenges & current solutions

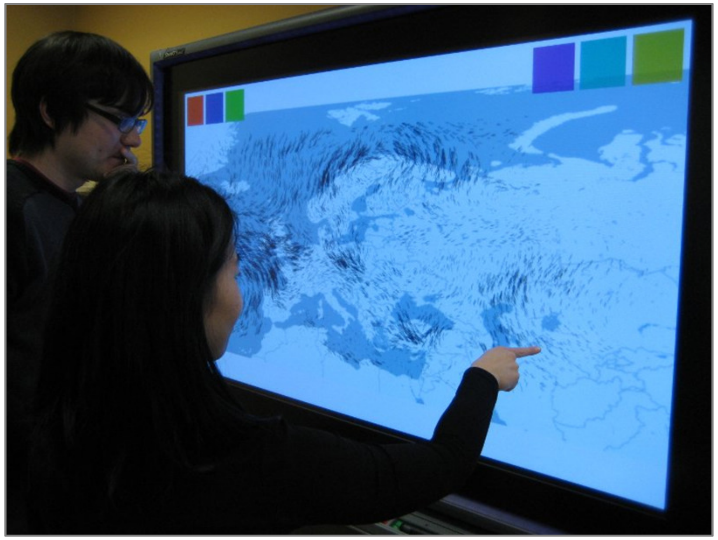
Collaboration Challenges & current solutions

multi-touch large interactive display

>= 30''

surface as main interface

several simultaneous inputs



part I.I:

Large Display Technology

part I.I:

a bit of a history

PLATO (mid 1960s)

Touch screens (single touch)
Flat panel plasma displays

http://www.billbuxton.com

http://advancedtrading.com/

One-Point Touch Input of Vector Information (1978)

8 signals from one touch point

http://www.youtube.com/watch?v=vMkYfd0sOLM (via billbuxton.com)

Touch-Sensitive Tablet (1985)

A MULTI-TOUCH THREE DIMENSIONAL TOUCH-SENSITIVE TABLET
SK. Lee, W. Buxton, K.C. Smith

Digital Desk (1991)

A real classic!

Wellner, P. (1991). The Digital Desk Calculator: Tactile manipulation on a desktop display. *Proceedings of the Fourth Annual Symposium on User Interface Software and Technology (UIST '91)*

Responsive Workbench (1994)

required glasses & gloves
multi-user
visualization applications

Krüger, W., Fröhlich, B.
The Responsive Workbench
IEEE Computer Graphics and Applications, 14(3), pp. 12-15, 1994

More vis examples later…

the perfect display for visualization

- Large display space
- Seamless
- High display resolution
- High input resolution
- (Reliable) multi-touch
- Identity Tracking
- Marker detection

Does not quite exist

basic choice: vertical vs. horizontal

Microsoft Surface

Perceptive Pixels

Tasks with equal participation

Presentation

Rogers, Y. and Lindley, S. (2004) Collaborating around *vertical* and *horizontal* displays: which *way is best*? Interacting With Computers, 16, 1133-1152

part I:

a selection of current examples

Disclaimer:
I do not guarantee any pricing information to be correct
Prices may or may not include additional hardware/software/support

horizontal MT displays

Microsoft Surface 1.0

Tradeoff

Screen Size	30”
Resolution	1024 x 768
Marker Detection	Yes
Identity Detection	No
Multi-touch	52
Display	Bottom-projected
Cost	~~$12,500 US~~ (no longer sold)

horizontal MT displays

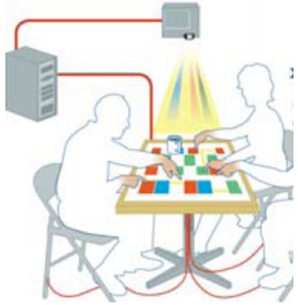
SMART Table

Screen Size	30"
Resolution	1024 x 768
Marker Detection	No
Identity Detection	No
Multi-touch	120
Display	Bottom-projected
Cost	$5999 USD

http://smarttech.com

horizontal MT displays

DiamondTouch



Screen Size	42"
Resolution	Projector dependent
Marker Detection	No
Identity Detection	Yes
Multi-touch	1 per person
Display	Top-projected
Cost	$12,500 USD

http://www.circletwelve.com/

horizontal MT displays

ICT-Multitouch

http://www.ict-multitouch.de

Screen Size	50"
Resolution	1920 x 1200 (44ppi)
Marker Detection	Yes
Identity Detection	No
Multi-touch	32
Display	Bottom-projected
Cost	~$60 000 USD

horizontal MT displays

Other companies:

IntuiFace (France)

Reactable (Spain → dedicated music platform)

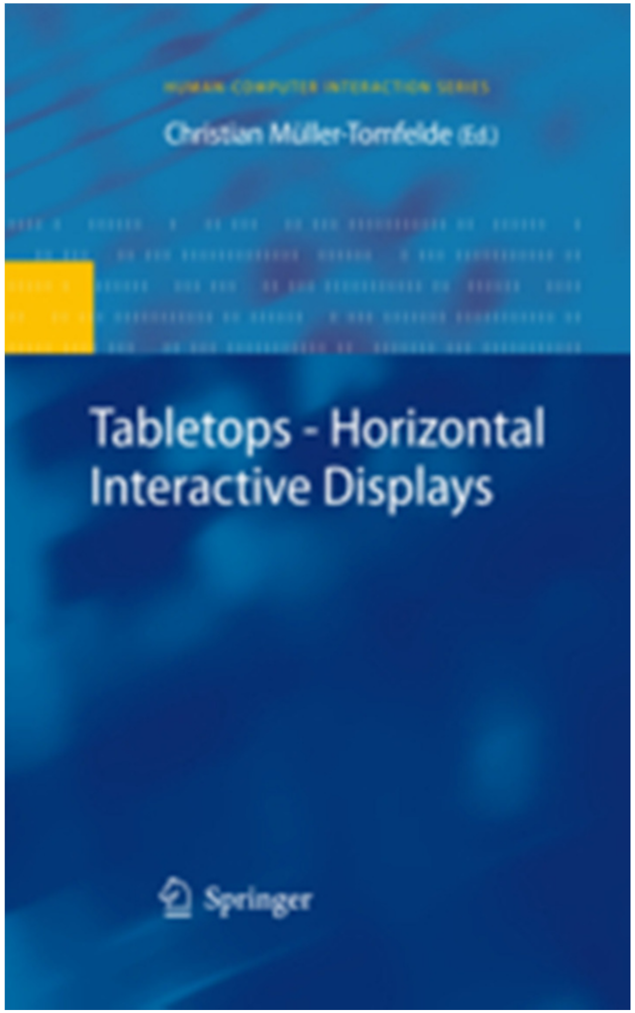
...

Other solutions:

DIY (later)

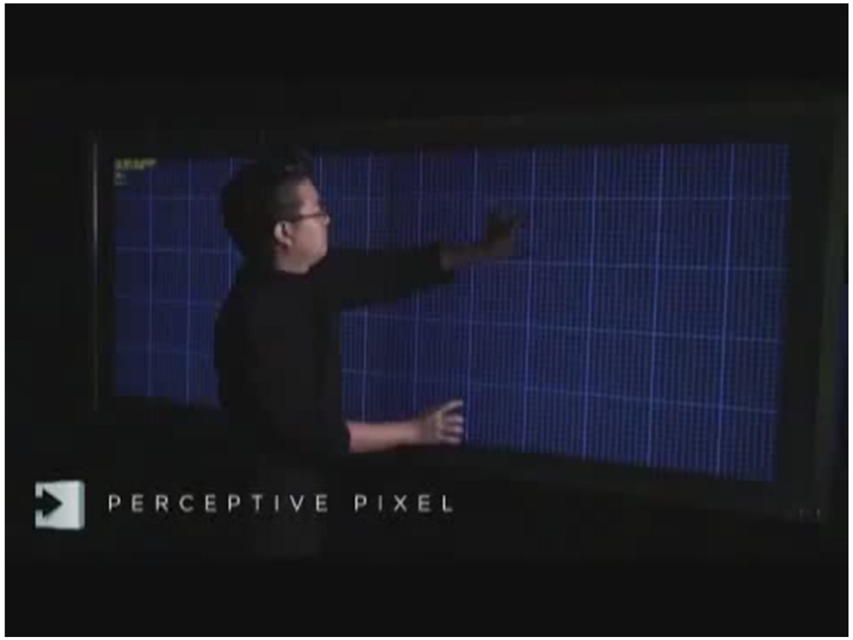
Further Reading:

http://sethsandler.com/interactive-table-list/


HUMAN COMPUTER INTERACTION SERIES
Christian Müller-Tomfelde (Ed.)
Tabletops - Horizontal Interactive Displays
Springer

vertical MT displays

Perceptive Pixels Multi-touch Wall



Screen Size	88″
Resolution	1920 x 1080 (25ppi)
Marker Detection	No
Identity Detection	No
Multi-touch	unlimited
Display	Back-projected
Cost	$75K-$140K (depending on projector)

http://www.perceptivepixel.com/

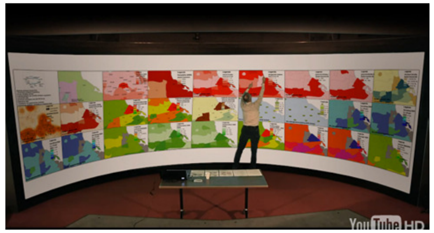
vertical MT displays

Multi-touch Cells

Screen Size	Modular (46″ each) up to 14 connected
Resolution	1920 x 1080
Marker Detection	yes
Identity Detection	No
Multi-touch	unlimited
Display	LCD
Cost	€8500 - €11500 each

http://multitouch.fi/

vertical MT displays



University of Groningen – curved multi-touch wall

http://www.youtube.com/watch?v=AlWFtF06RFo

Screen Size	10m x 2.8m
Resolution	4900 x 1700 (~13ppi)
Marker Detection	~
Identity Detection	no
Multi-touch	yes
Display	backprojected
Cost	DIY project

vertical MT displays

ring°wall

Screen Size	1771″
Resolution	28,800 x 1,200 (~16ppi)
Marker Detection	~
Identity Detection	no
Multi-touch	yes
Display	back-projected
Cost	custom made

sensory-minds.com

LCD/Plasma MT displays

Surface 2.0

Screen Size	40″
Resolution	1920 x 1080
Marker Detection	yes
Identity Detection	no
Multi-touch	yes
Display	LCD
Cost	$7,600 Summer 2011

http://www.microsoft.com/surface/

LCD/Plasma MT displays

NUITEQ Flat 46" Multi-touch Frame

Screen Size	46”
Resolution	1920 x 1080
Marker Detection	no
Identity Detection	no
Multi-touch	32
Display	LCD
Cost	9000 € ~$12.000 USD

http://www.microsoft.com/surface/

LCD/Plasma MT displays

PQLabs 46" Multi-touch Frame

Screen Size	46” (up to 250” possible)
Resolution	up to you
Marker Detection	no
Identity Detection	no
Multi-touch	32
Display	LCD
Cost	~$3000 USD (46”)

LCD/Plasma MT displays

Many different overlays from other manufacturers:

SMART

…

EVOLUCE

ict Meeting the challenge. Matching the emotion.

nextwindow

PERCEPTIVE PIXEL

further reading

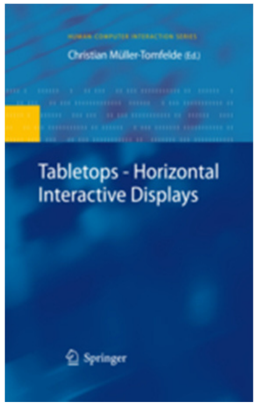
http://perspectivevoxel.posterous.com/ (Johannes Schöning)
http://interactivemultimediatechnology.blogspot.com/ (Lynn Marentette)
http://www.touchuserinterface.com/

what resolution is good enough?

Resolution:
\# of pixels per unit distance, here: per inch = ppi

Assume:
regular grid, square pixels

Further Reading:
Chapter: High-resolution Interactive Displays (Ashdown et al.)



what resolution is good enough?

Minimum Resolution:

Based on text readability:

min. 48ppi to read 12pt text

min. **60ppi** to read 10pt text — Tuddenham P (2008) PhD Thesis

min. 6pt font on Windows w/ 96ppi — Tullis TS, Boynton JL, Hersh H (1995) Readability of Fonts in the Windows Environment

Maximum Resolution:

Assume: use at arm's length (61cm) 0.59 arc minutes visual acuity

max. 300 – 500 ppi

Practically most monitors ~ 110ppi

OS assume between 72ppi (MacOS) – 100ppi (X)

what resolution is good enough?

Tabletop system	Front/ Rear	Native (pixels) Horiz	Vert	Diag	Physical (inches) Horiz	Vert	Diag	Mpxl	Res. (ppi)
DigitalDesk [7]	F	1120	780	1365	18	12	22	0.87	63
DigiTable [15]	F	1024	768	1280	34	26	42	0.79	30
DViT Table (med. res.) [16]	F	2048	1024	2290	60	48	77	2.10	30
DViT Table (high res.) [17]	R	2800	2100	3500	60	48	77	5.88	45
Escritoire (fovea) [18]	F	1024	768	1280	17	12	20	0.79	63
Escritoire (periphery) [18]	F	1024	768	1280	48	36	60	0.79	21
i-m-Top (fovea) [19]	R	1280	720	1469	12	8	14	0.92	106
i-m-Top (periphery) [19]	R	1280	768	1493	47	32	57	0.98	26
InteracTable [20]	R	1024	768	1280	33	26	42	0.79	30
Lumisight [21]	R	1024	768	1280	16	16	22	0.79	57
Origami [4]	F	1024	768	1280	16	12	20	0.79	64
Surface [22]	R	1024	768	1280	26	15	30	0.79	43
T3 [23]	F	3072	1536	3435	48	36	60	4.72	57

Data from 2009

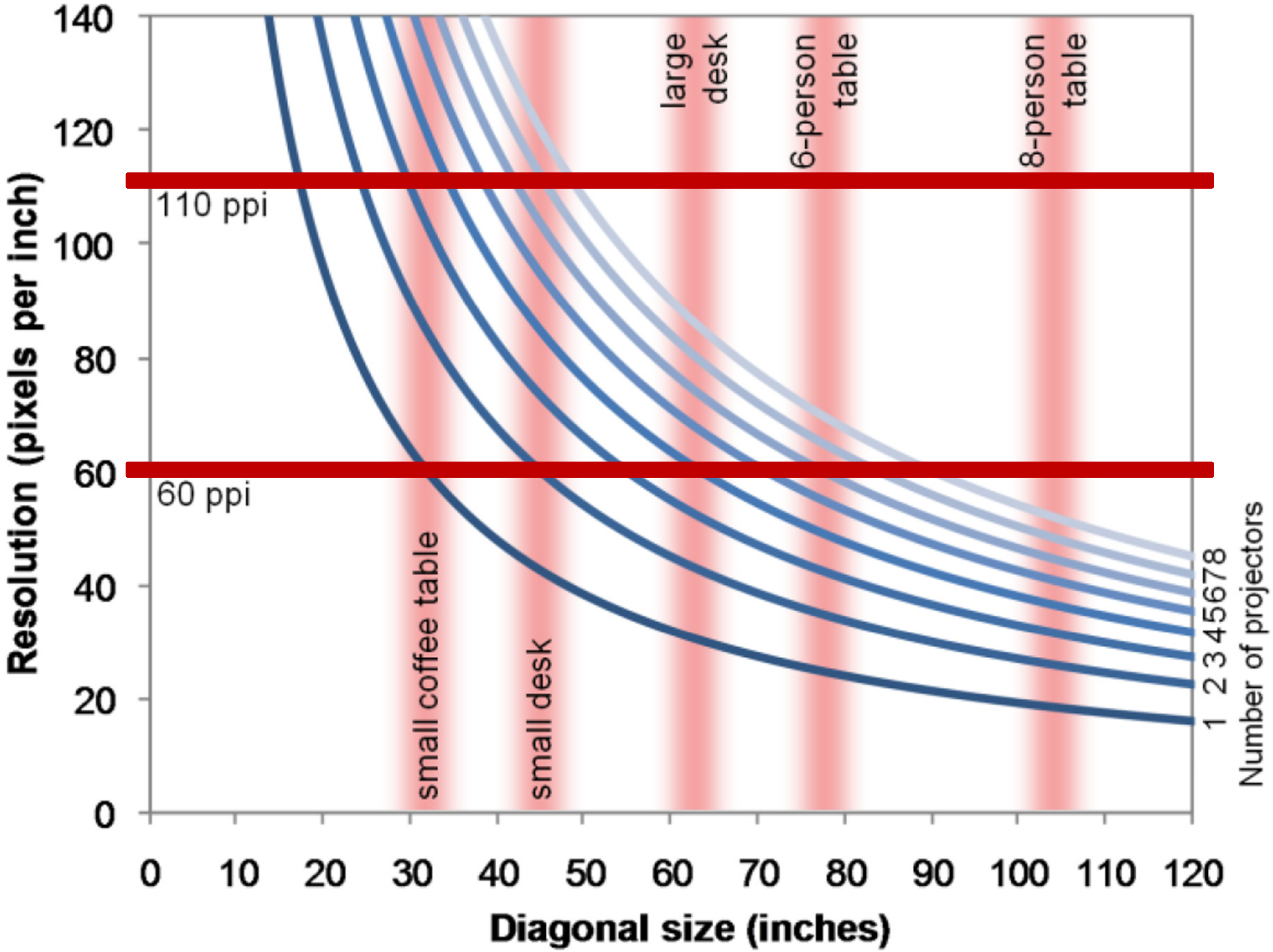
for good resolution:

multi-projector solution
+ DIY DI

high resolution displays
+ overlay

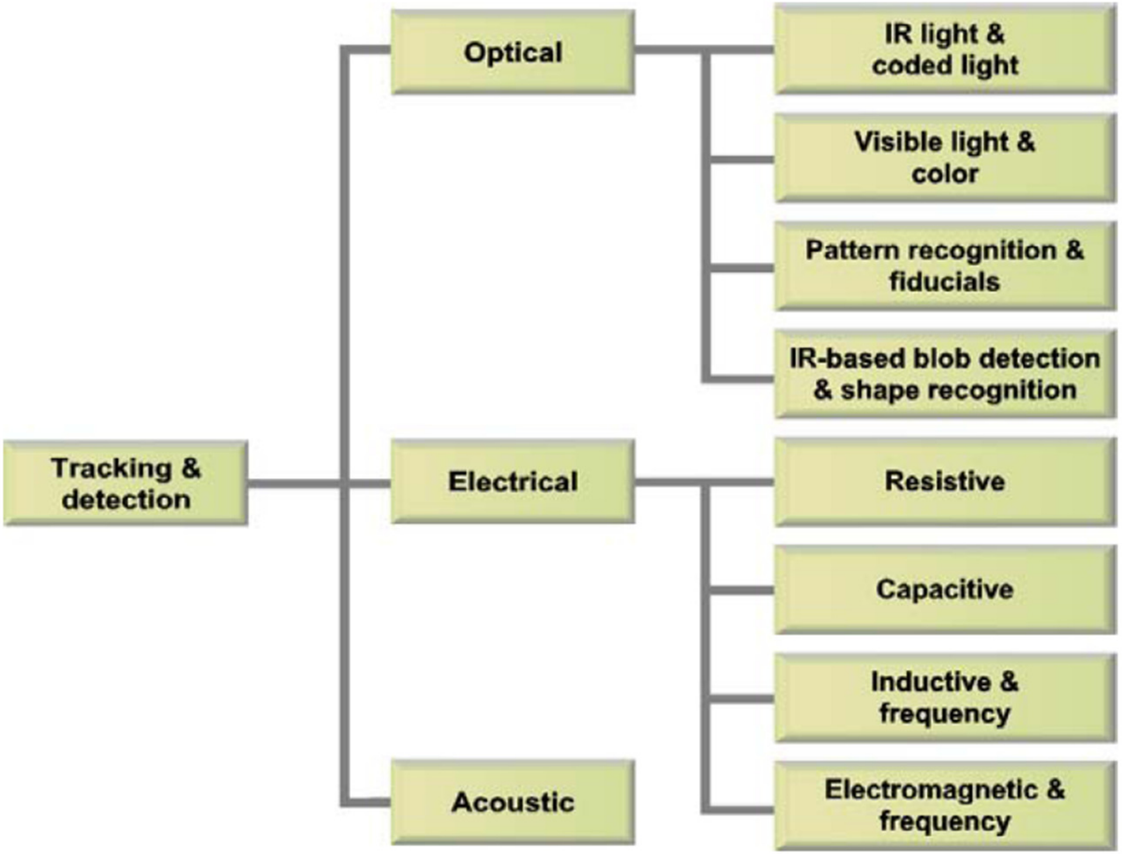
e.g. 4k display at 64″ (~72ppi)

http://www.eyevis.de

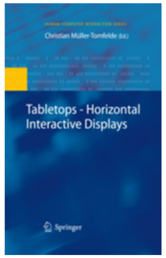


assuming 1080p projectors

touch input



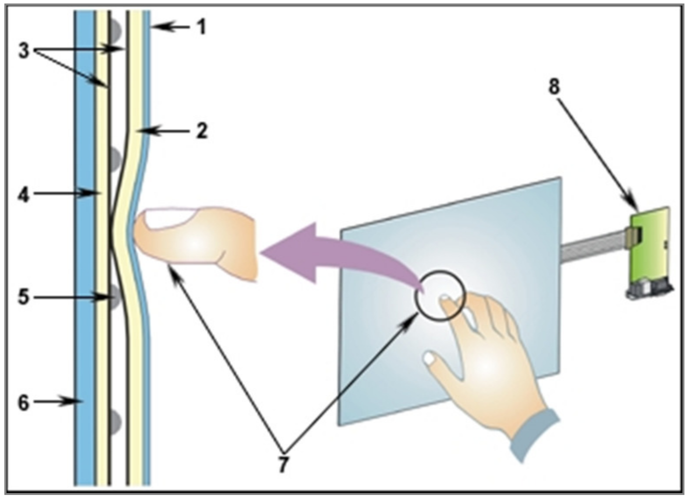
Further Reading:
Chapter: From Table–System to Tabletop: Integrating Technology into Interactive Surfaces (Kunz & Fjeld)

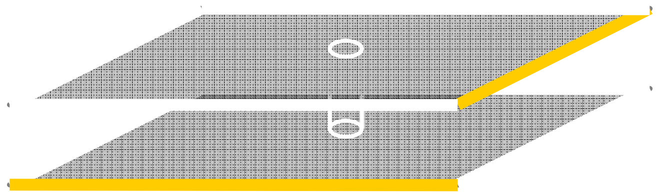


Early Touch Input: Resistive

resistive sensing

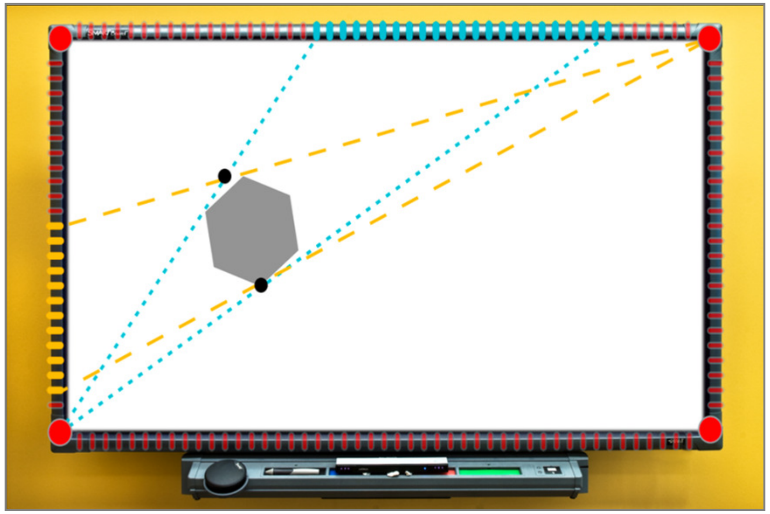
- overlay of two transparent layers of conducting material
- gap between them closed by touch: connection
- location from linear system

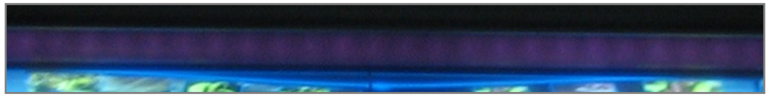




- only one simultaneous touch

DViT Input

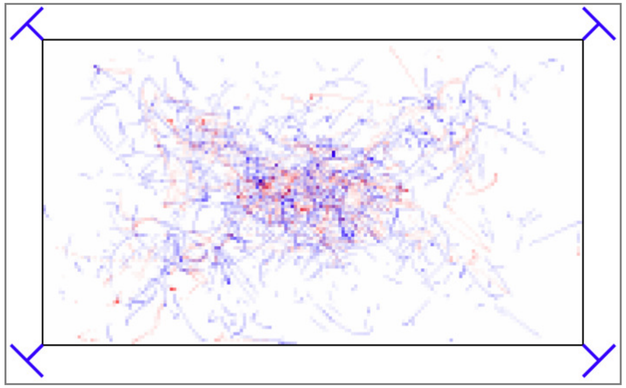


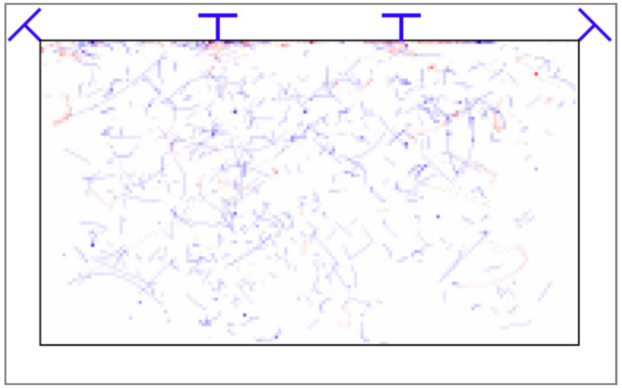


- Digital Vision Touch
  - IR light strips along sides
  - cameras in four corners
  - cameras see “shadow” of touch before the IR strips
  - triangulation to find positions
- domains: tables & walls
- pros: back & front-projection, touch size detection
- cons: ≤2 independent touches, each touch counts

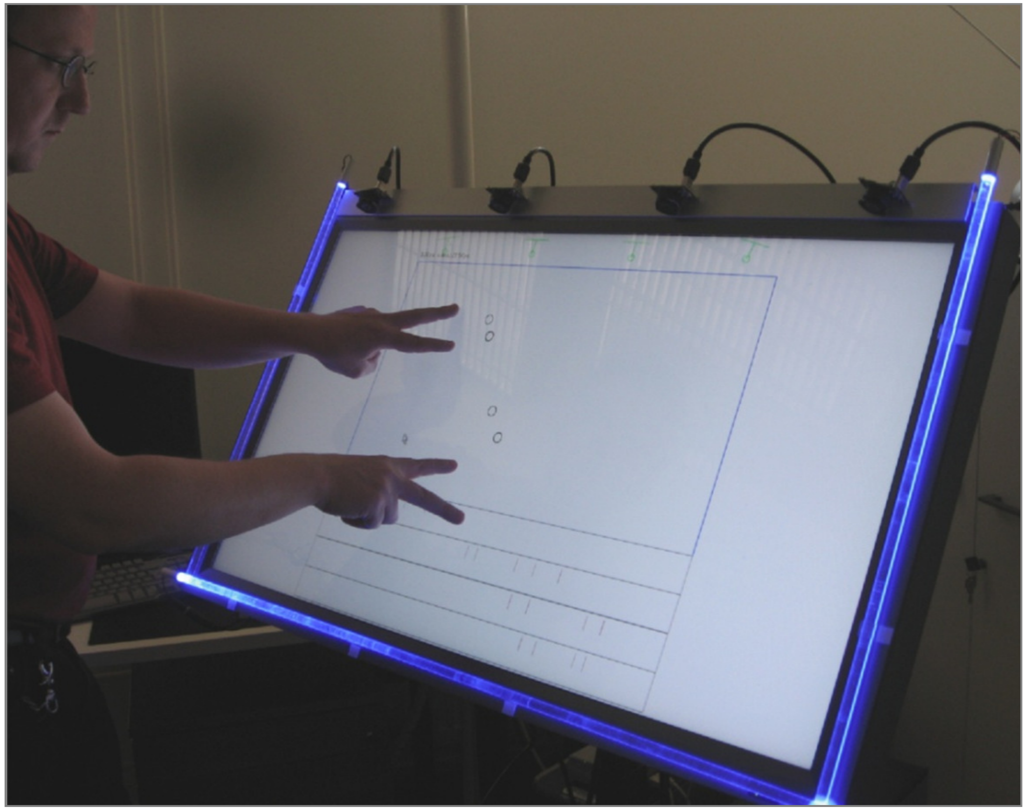
Ack. Tobias Isenberg

DIY DViT *[Korkalo and Honkamaa, 2010]*





- camera arrangement important
- fast cameras
- stable detection of 4–5 touchpoints



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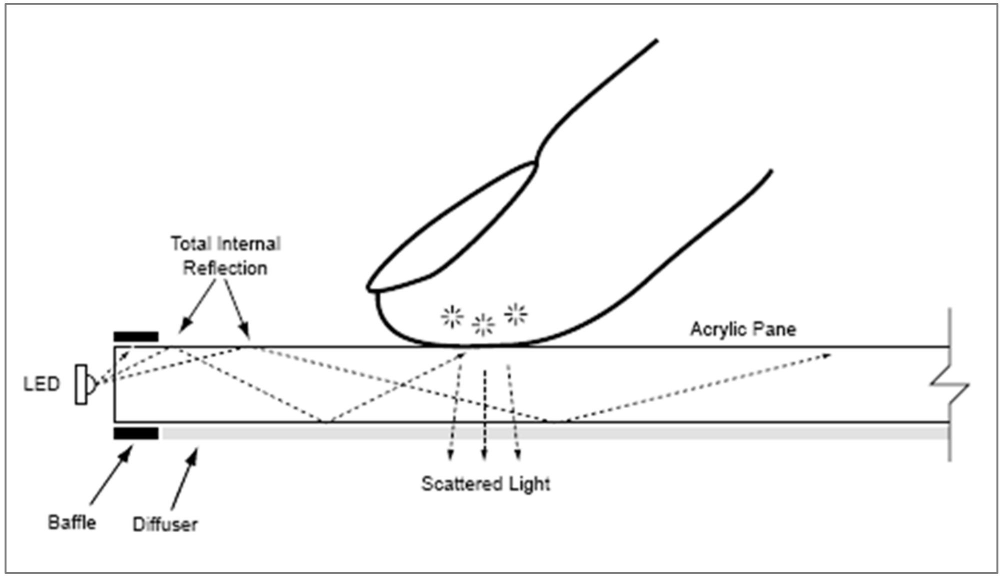
[redacted]

FTIR Input

- Frustrated Total Internal Reflection (Han, 2005)



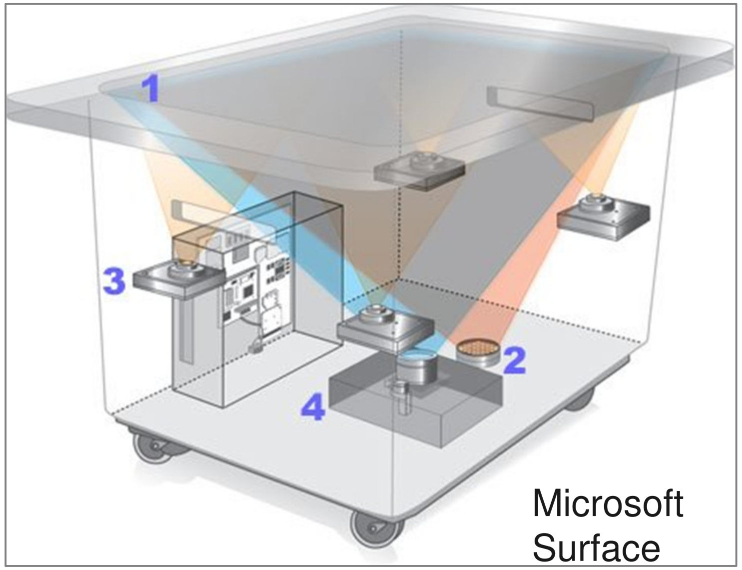
- domains: tables & (large) walls (e.g., CNN etc.)
- pros: general shapes, many touches
- cons: general shapes, special surface, no ID, bulky bottom

Ack. Tobias Isenberg

more details : http://www.anneroudaut.fr/ (the original)
http://www.aviz.fr/~isenberg (some additional detail)

Diffuse Illumination

- back-projected (4) screen (1)
- IR flooding from below (2)
- cameras (3) to capture the IR light reflected from touch
- multi-touch, shapes, and reflection patterns (e.g., 2D barcodes)

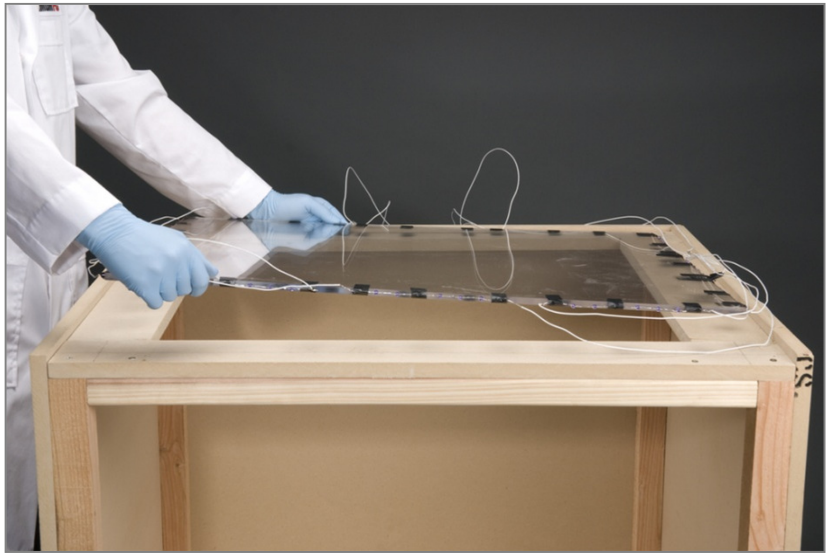


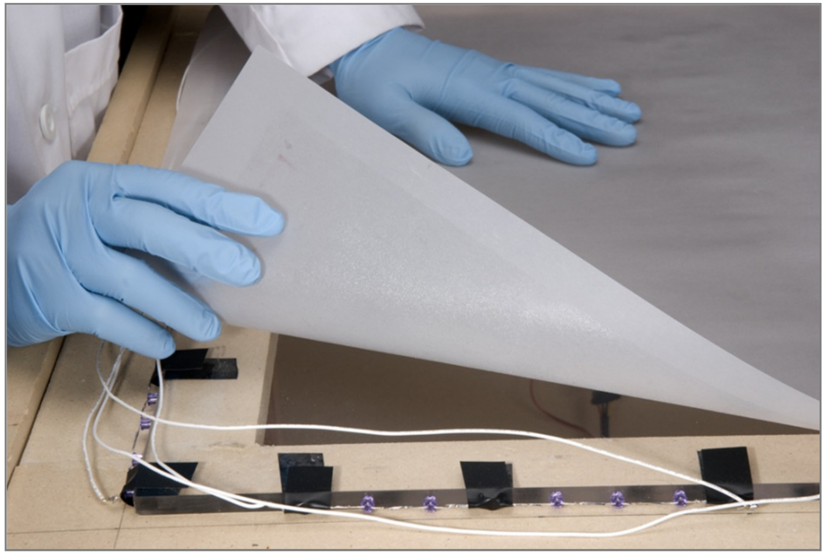
Microsoft Surface

- domains: (smaller) tables & walls (e.g., MS Surface)
- pros: hover, shapes & patterns, many touches
- cons: hover, no ID, bulky bottom

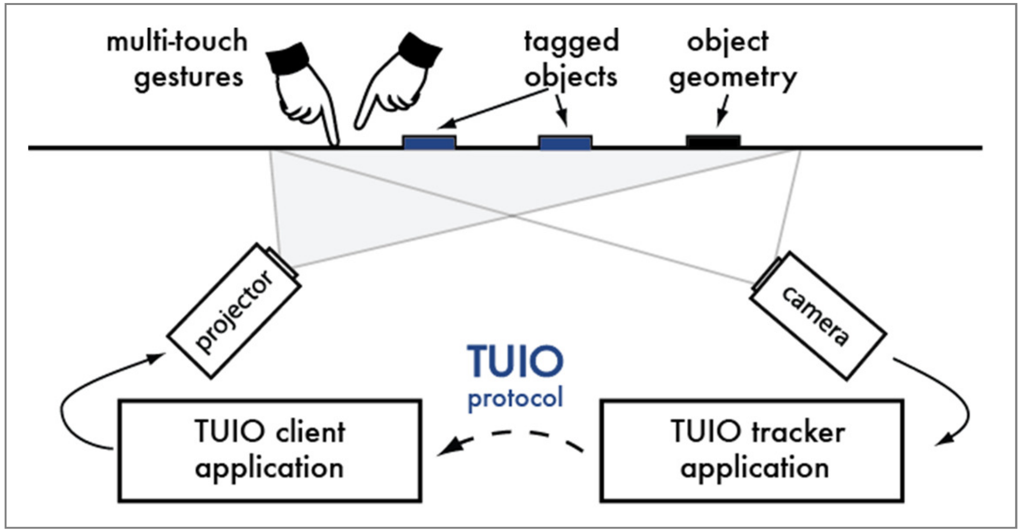
Ack. Tobias Isenberg

DIY FTIR & DI





by Alex Castle



http://www.tuio.org/

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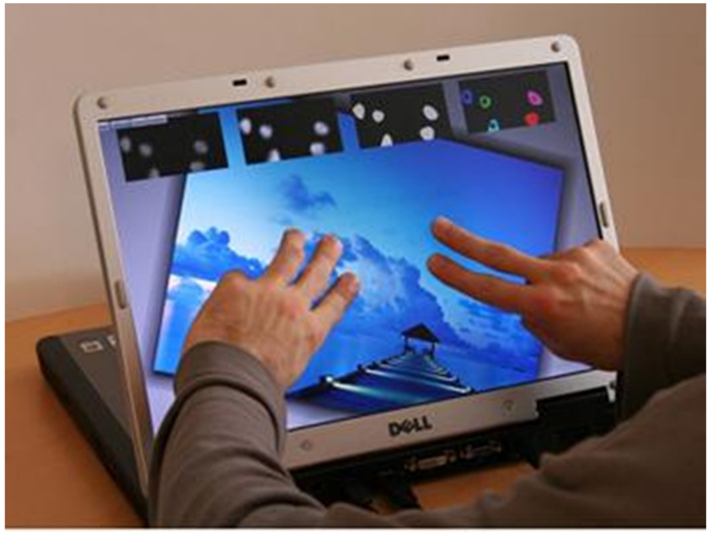
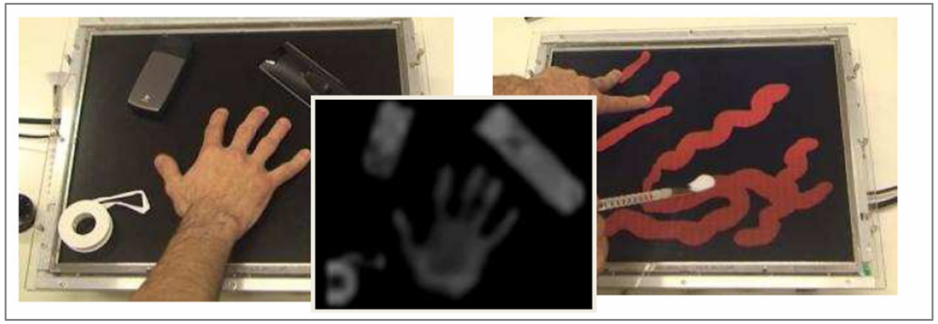
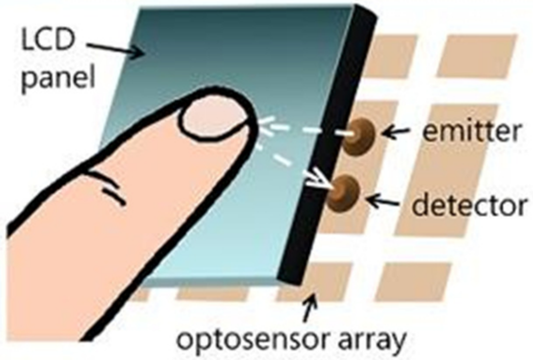
Embedded Optical Sensing

- extension of the diffuse IR flooding technique
- several smaller IR emitters & sensors (cameras)







- pros: thin, scalable, multi-touch, general shapes one of most promising solutions

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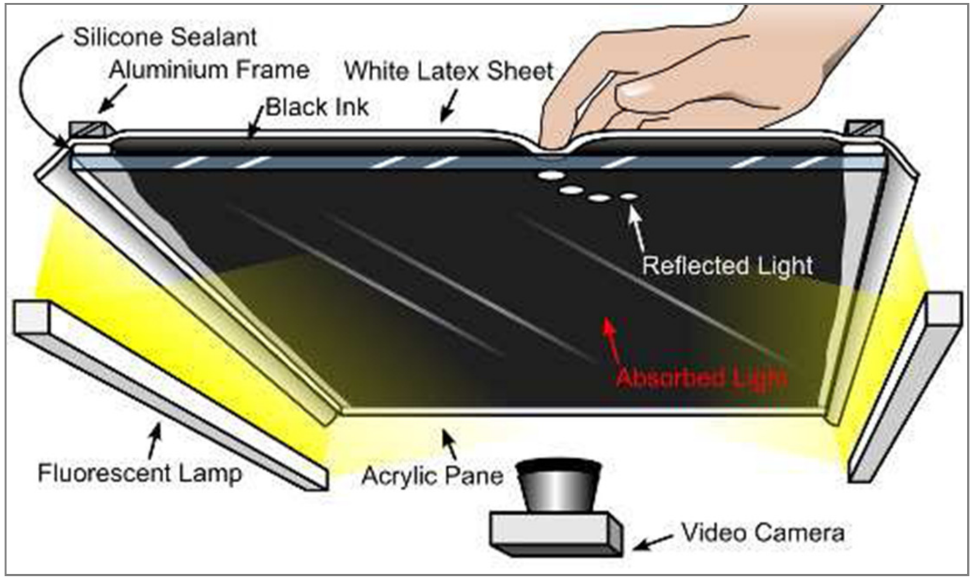
Liquid Displacement Sensing

- malleable surface for top-projected display
- setup:
  - plexiglas carrier
  - black ink layer
  - latex sheet seal
  - camera below surface
  - touch displaces ink
  - bright spot visible
  - captured by camera
- pros: pressure-sensitive, any shapes, simple setup
- cons: only horizontal surfaces, only front projection



Hilliges et al., 2008

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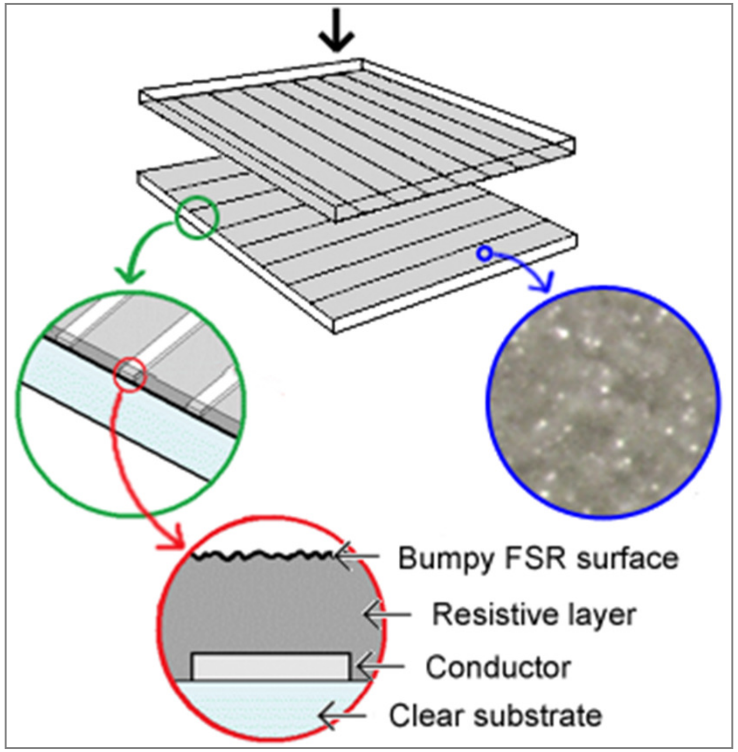
Creating Malleable Interactive Surfaces using Liquid Displacement Sensing

Advanced Resistive Touch Sensing: IFSR

- IFSR: Interpolating Force-Sensitive Resistance
- main ideas:
  1. not only wires at borders, but grid of wires
  2. force-sensitive resistive materials (bumpy layers)
- results:
  - produces pressure image
  - thin overlays possible
  - transparent overlays possible
  - multi-resolution sensing possible, inexpensive, flat
  - fingers and pens are easily distinguishable



Rosenberg and Perlin, 2009

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What if I want to build my own?

- Many videos out there
- Tutorials available:
  - e.g. http://wiki.nuigroup.com/

- Can be fun but be warned: A lot of fiddling required (be patient and ready to test and try)
- My opinion: if you have the money – buy something that works out of the box
  (if your main interest is on the vis side)

More information on current technologies

- Tutorial material at www.its2010.org
- Blogs, Wikipedia, ...

part I.II:

Software Frameworks

Criteria

- Several touch input frameworks available:
  - OS independence
  - Open source

  - Basic multi-touch detection (find touch-points)
  - Addition. per-touch data (extension, orientation,…)
  - Support for tangibles
  - Access to raw image
  - Gesture detection
  - …

Information based on Framework tutorial by Ulrich von Zadow, ITS 2010

TUIO http://www.tuio.org/

- It's a protocol - not a library
- De facto industry standard

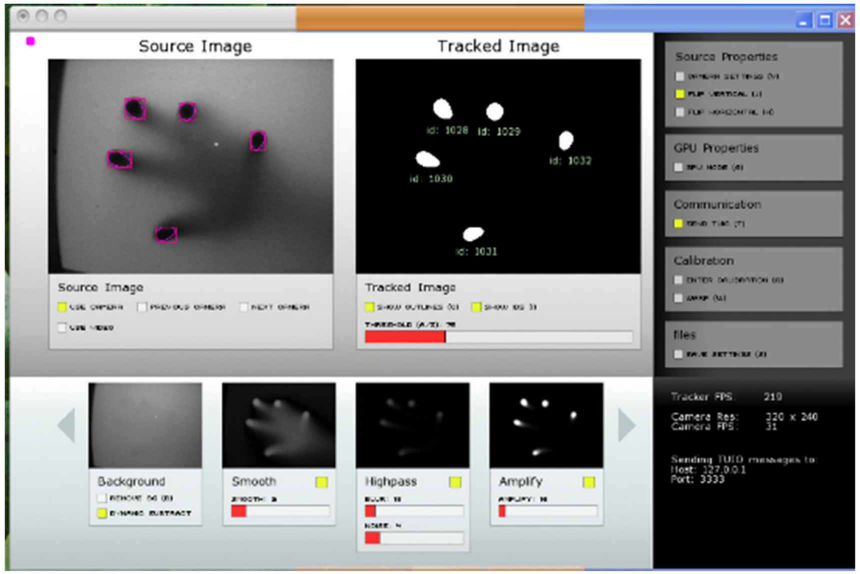
	TUIO		
	1	1.1	2
Basic Multitouch Detection	Y	Y	Y
Additional per-touch Data	N	ellipse data	ellipse data, geometry, pressure
Tangible Support	Y	Y	Y
Raw Image	N	N	Y
Hover	N	N	negative pressure
OS Independent	Y	Y	Y
Open Source	Y	Y	Y

Information based on Framework tutorial by Ulrich von Zadow, ITS 2010

CCV http://ccv.nuigroup.com/

- TUIO tracker implementation – delivers TUIO events
- Works with all optical setups (FTIR, DI, DSI, …)

Basic Multitouch Detection	Y
Additional per-touch Data	Y
Tangible Support	Y
Raw Image	N
Hover	N
OS Independent	Y
Open Source	Y



Bridges

TUIO → **Multi-Touch Vista** → Windows 7 Touch

MS Surface Touch → Squidy Interaction Library → TUIO

Many more…

http://www.tuio.org/?software

Microsoft APIs

- Integrated into WPF event model

	Microsoft WPF Touch (4.0)	Surface SP1
Basic Multitouch Detection	Y	Y
Additional per-touch Data	N	N
Tangible Support	N	Y
Raw Image	N	Y
Hover	N	N
OS Independent	N	N
Open Source	N	N
Hand-Finger Correlation	N	N
Gestures		
Integrated Zoom/Pan/Rotate	Y	Y
Other Gesture Support	N	only tap & hold
Inertia	Y	Y
Widget Support	basic widgets, not multiuser	Y

Information based on Framework tutorial by Ulrich von Zadow, ITS 2010

Python API: PyMT http://pymt.eu/

- Followed by new project: Kivy http://kivy.org/

	PyMT
Basic Multitouch Detection	Y
Additional per-touch Data	Y
Tangible Support	Y
Raw Image	N
Hover	N
OS Independent	Y
Open Source	Y
Hand-Finger Correlation	N
Gestures	
Integrated Zoom/Pan/Rotate	Y
Other Gesture Support	?
Inertia	N
Widget Support	Y

Information based on Framework tutorial by Ulrich von Zadow, ITS 2010

libavg http://www.libavg.de/

- Framework with Python API
- Screen layout (xml) + interaction (python)

Basic Multitouch Detection	Y
Additional per-touch Data	Y
Tangible Support	N
Raw Image	Y
Hover	Y
OS Independent	Y
Open Source	Y
Hand-Finger Correlation	Y
Gestures	
Basic Zoom/Pan/Rotate	
Integrated Zoom/Pan/Rotate	Y
Other Gesture Support	N
Inertia	Y
Widget Support	basic

Information based on Framework tutorial by Ulrich von Zadow, ITS 2010

Visualization/Graphics frameworks/TK with MT input support

- Processing (check out MT4j)
- VTK (possible example here: https://sites.google.com/site/pierrefillard/coding-blog/multi-touchgesturesinvtk)
- InfoVis toolkit (not in online version)
- Flare (through flash libraries)

part II:

visualization applications for large touch technology

New Contexts

for

information visualization

Interaction Design

Representation Design

Socio-Technical Aspects of Data Analysis

Infrastructure

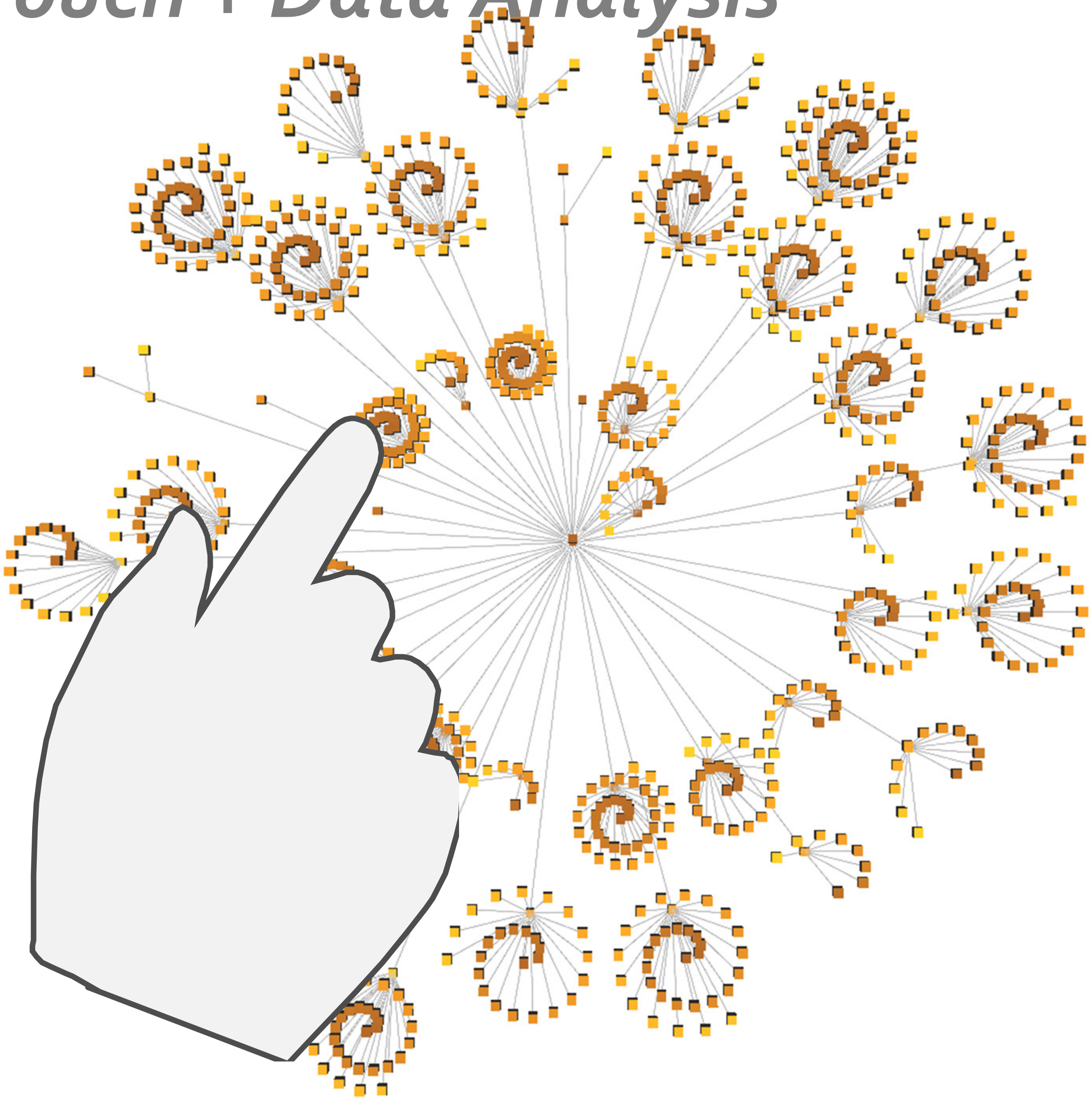
part II.I:

interaction challenges

Multi-Touch Devices

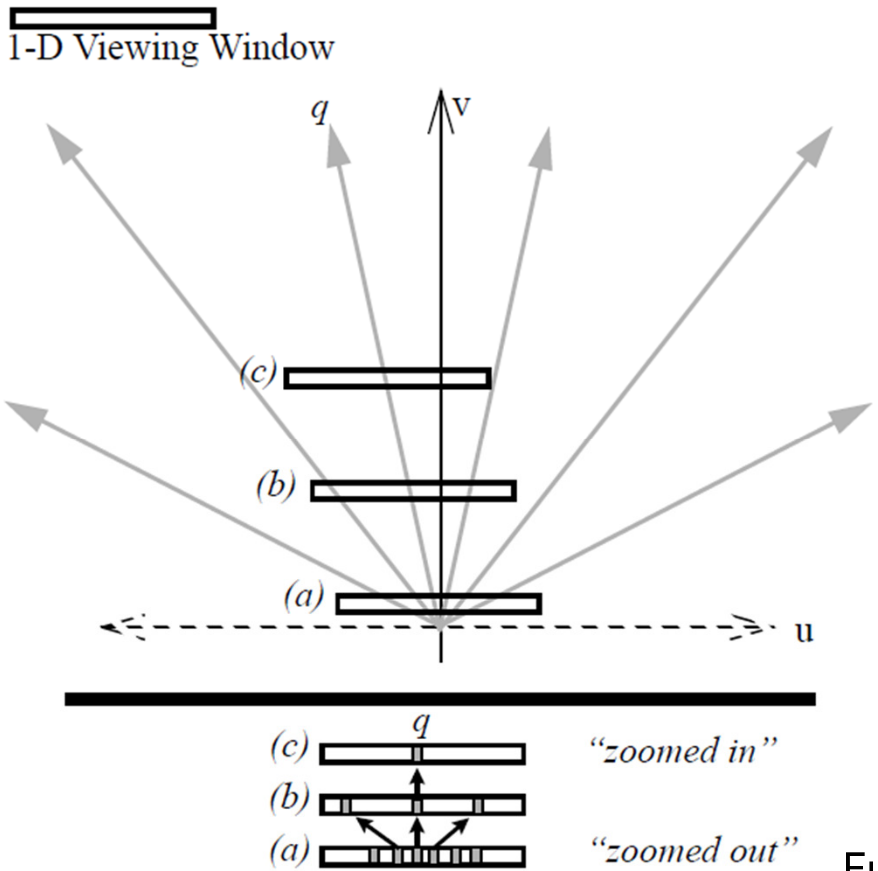
Opportunities:	Multiple DOF, Engaging, Collaboration, Kinesthetics(?) …
Challenges:	Fat fingers, Fatigue, Infrastructure …

Multi-Touch + Data Analysis



Visualization Interaction Challenges

- Multiple levels of detail



Furnas & Bederson, CHI 1995

Visualization Interaction Challenges

- Multiple levels of detail
- Multitude of interaction types

Publications	Taxonomic units
Taxonomies of low-level interaction techniques	
Shneiderman (1996) [37]	Overview, zoom, filter, details-on-demand, relate, history, and extract
Buja, Cook, and Swayne (1996) [9]	Focusing (choice of [projection, aspect ratio, zoom, pan], choice of [variable, order, scale, scale-aspect ratio, animation, and 3-D rotation]), linking (brushing as conditioning / sectioning / database query), and arranging views (scatter plot matrix and conditional plot)
Chuah and Roth (1996) [13]	Basic visualization interaction (BVI) operations: graphical operations (encode data, set graphical value, manipulate objects), set operations (create set, delete set, summarize set, other), and data operations (add, delete, derived attributes, other)
Dix and Ellis (1998) [15]	Highlighting and focus, accessing extra information – drill down and hyperlinks, overview and context, same representation / changing parameters, same data / changing representation, linking representation – temporal fusion
Keim (2002) [24]	Dynamic projections, interactive filtering, interactive zooming, interactive distortion, interactive linking and brushing
Wilkinson (2005) [54]	Filtering (categorical/continuous/multiple/fast filtering), navigating (zooming/panning/lens), manipulating (node dragging/categorical reordering), brushing and linking (brush

Yi et al., InfoVis 2007

Visualization Interaction Challenges

- Multiple levels of detail
- Multitude of interaction types
- Multitude of complex representations

One example:

Information Visualization Interaction with

DIRECT-MANIPULATION

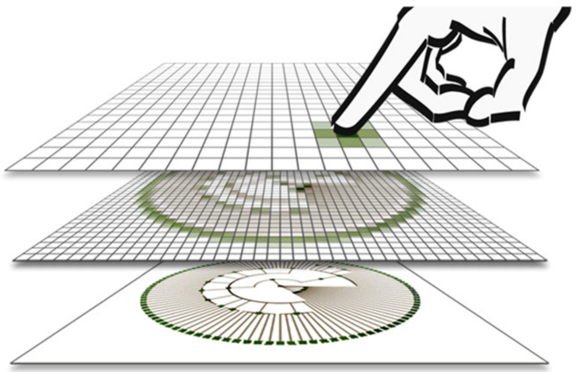
Tabletop Workspace

Voida et al. - ITS/Tabletop 2009

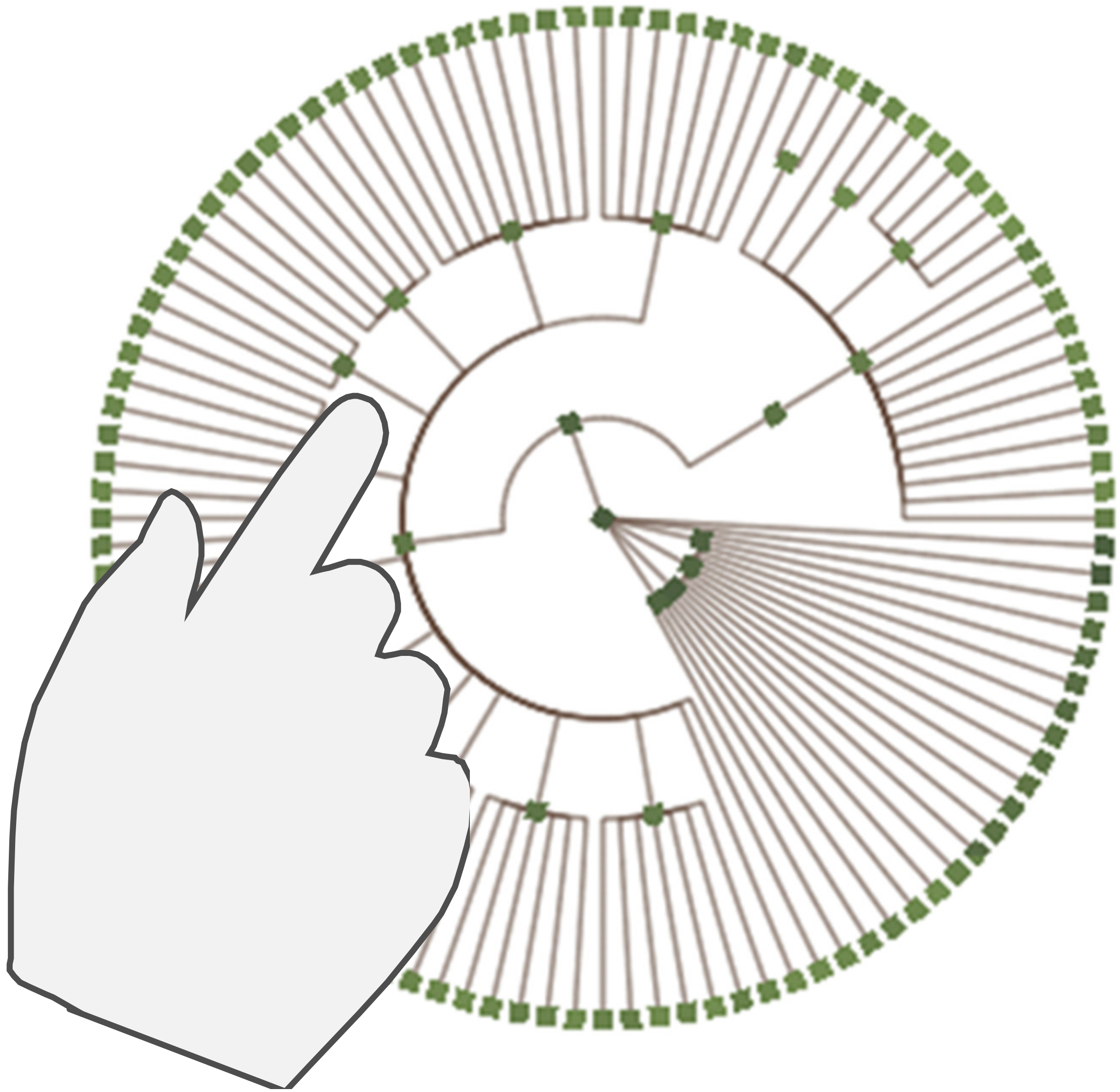
iLoupe/iPodLoupe

Explorations into:

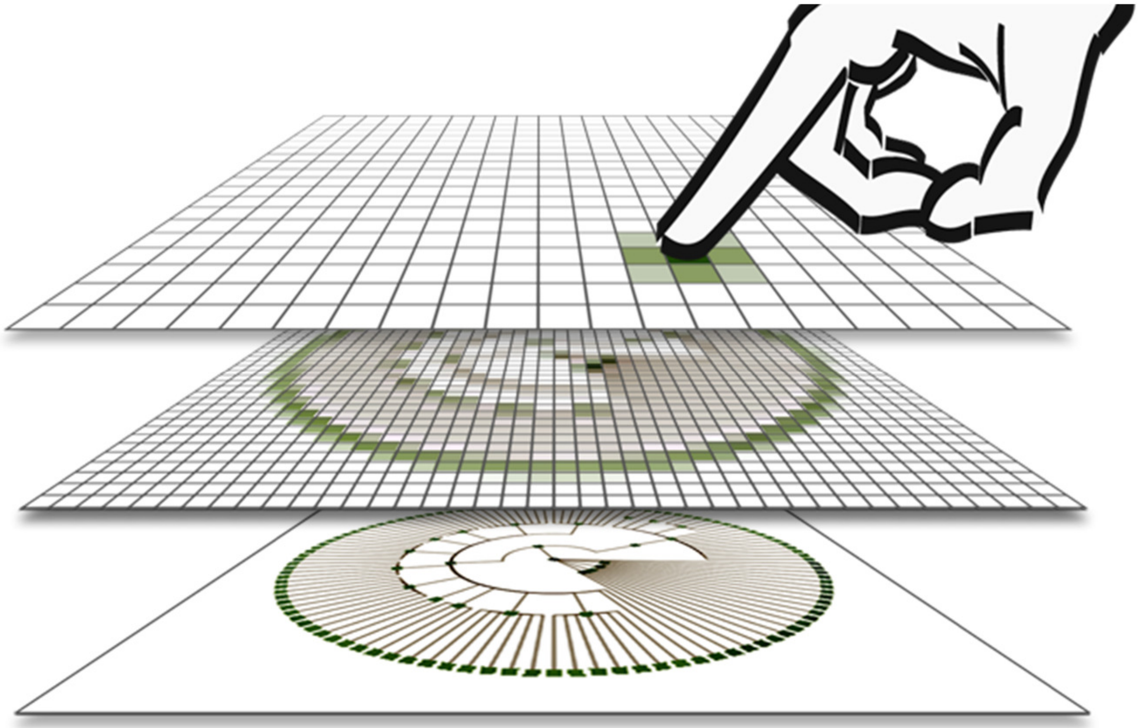
- Resolution discrepancies among data, display, and input
- Facilitating face-to-face interaction



Resolution Discrepancies



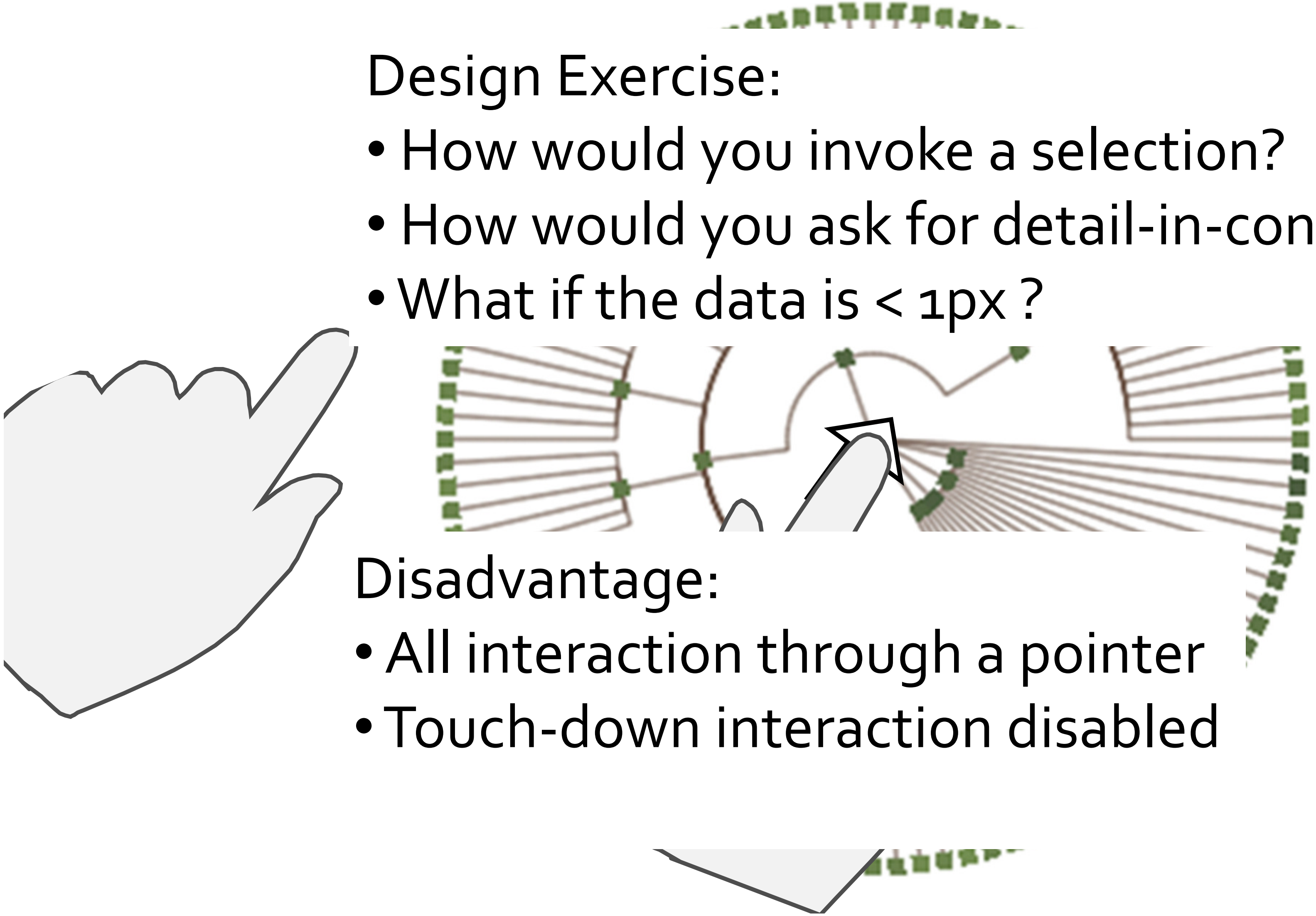
Resolution Discrepancies



Related Work

- Heavily explored in HCI
- How does this transfer to Visualization application?

Dual-Finger Offset



Design Exercise:

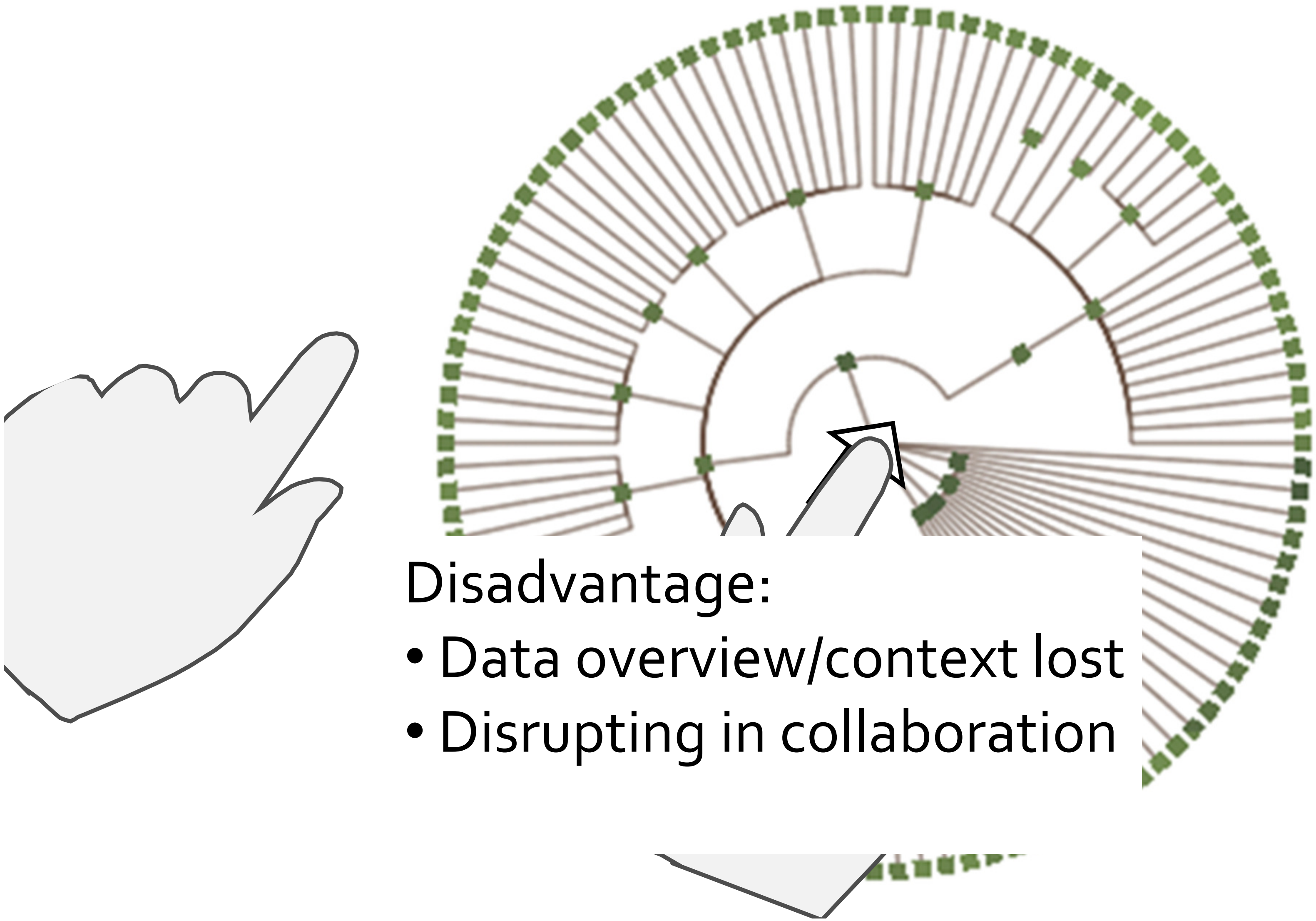
- How would you invoke a selection?
- How would you ask for detail-in-context?
- What if the data is < 1px ?

Disadvantage:

- All interaction through a pointer
- Touch-down interaction disabled

Benko et al., CHI 2006

Dual-Finger Stretch



Disadvantage:
- Data overview/context lost
- Disrupting in collaboration

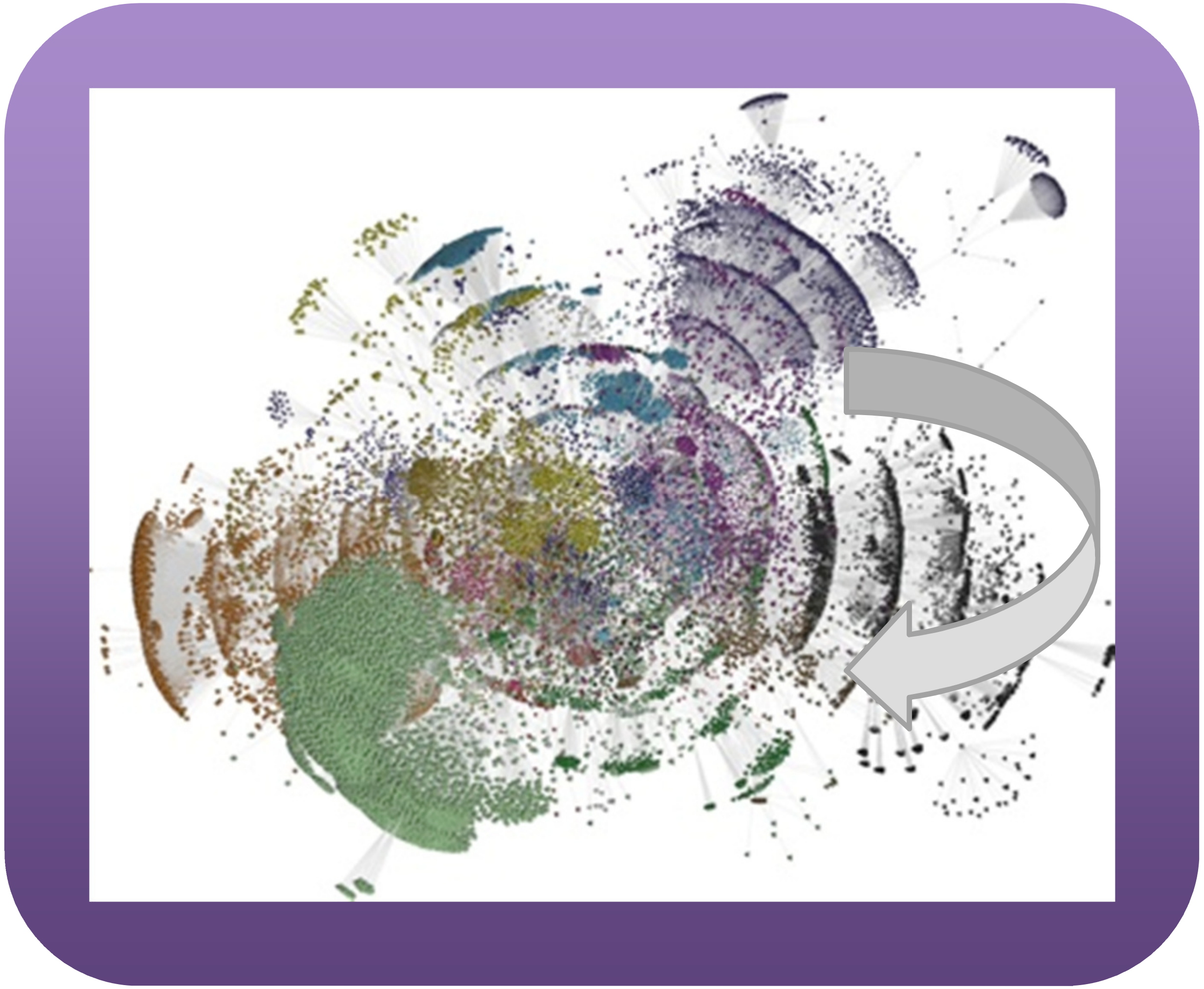
Benko et al., CHI 2006

LucidTouch

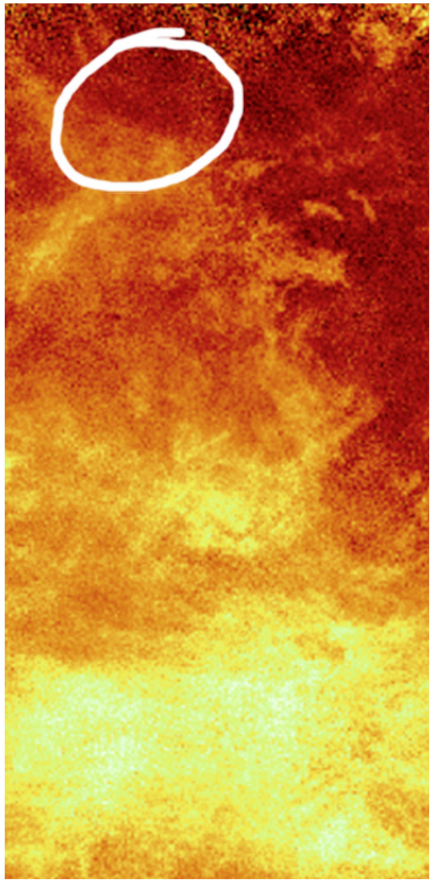
RidgePad

Holz & Baudisch, CHI 2010

View Changes

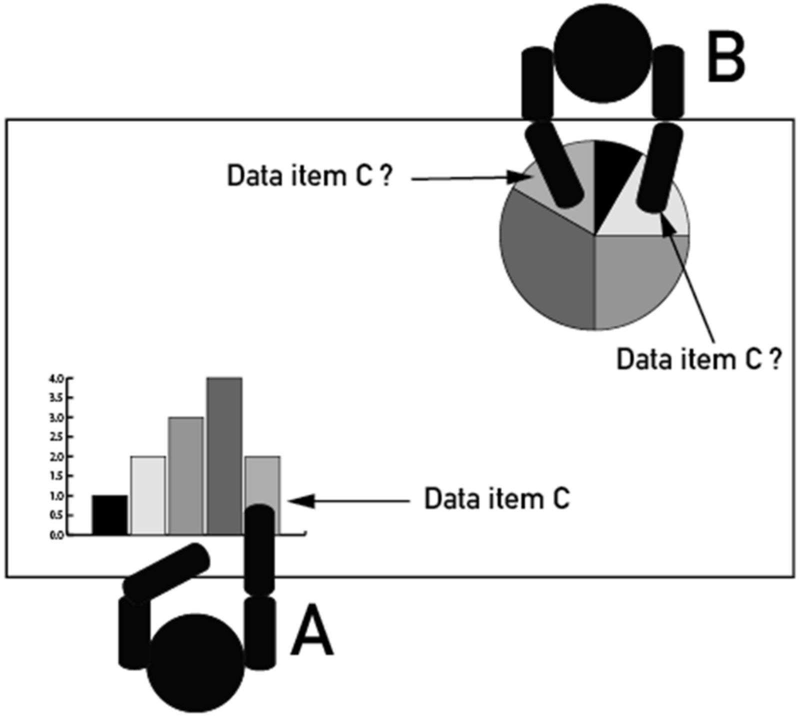


Value Operations



View vs. Value Operations

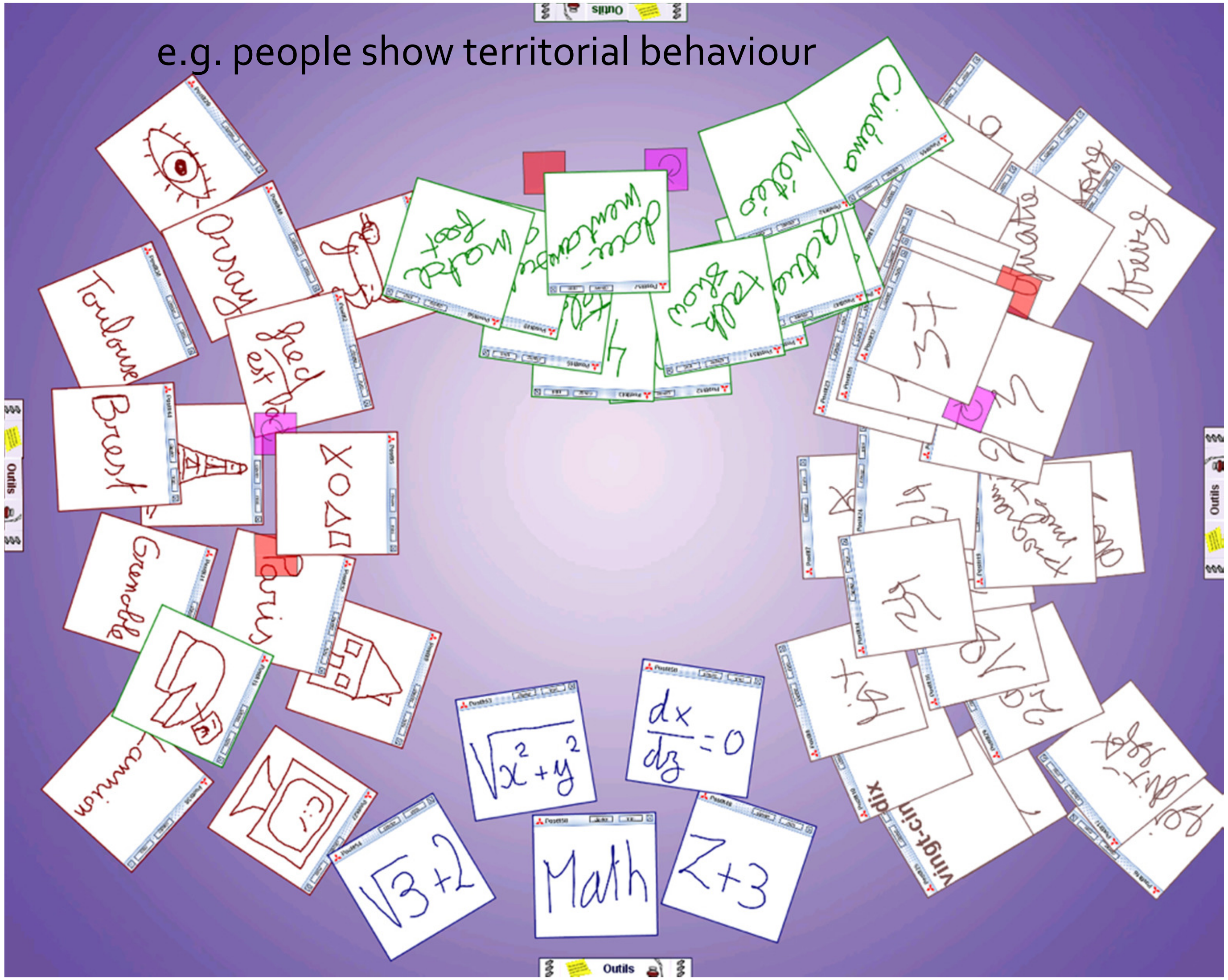
- Important to consider in visualization
  - Changes to data by one person
    = changes to data viewed by another person?
  - How does one relate views?



Collaboration

Collaboration

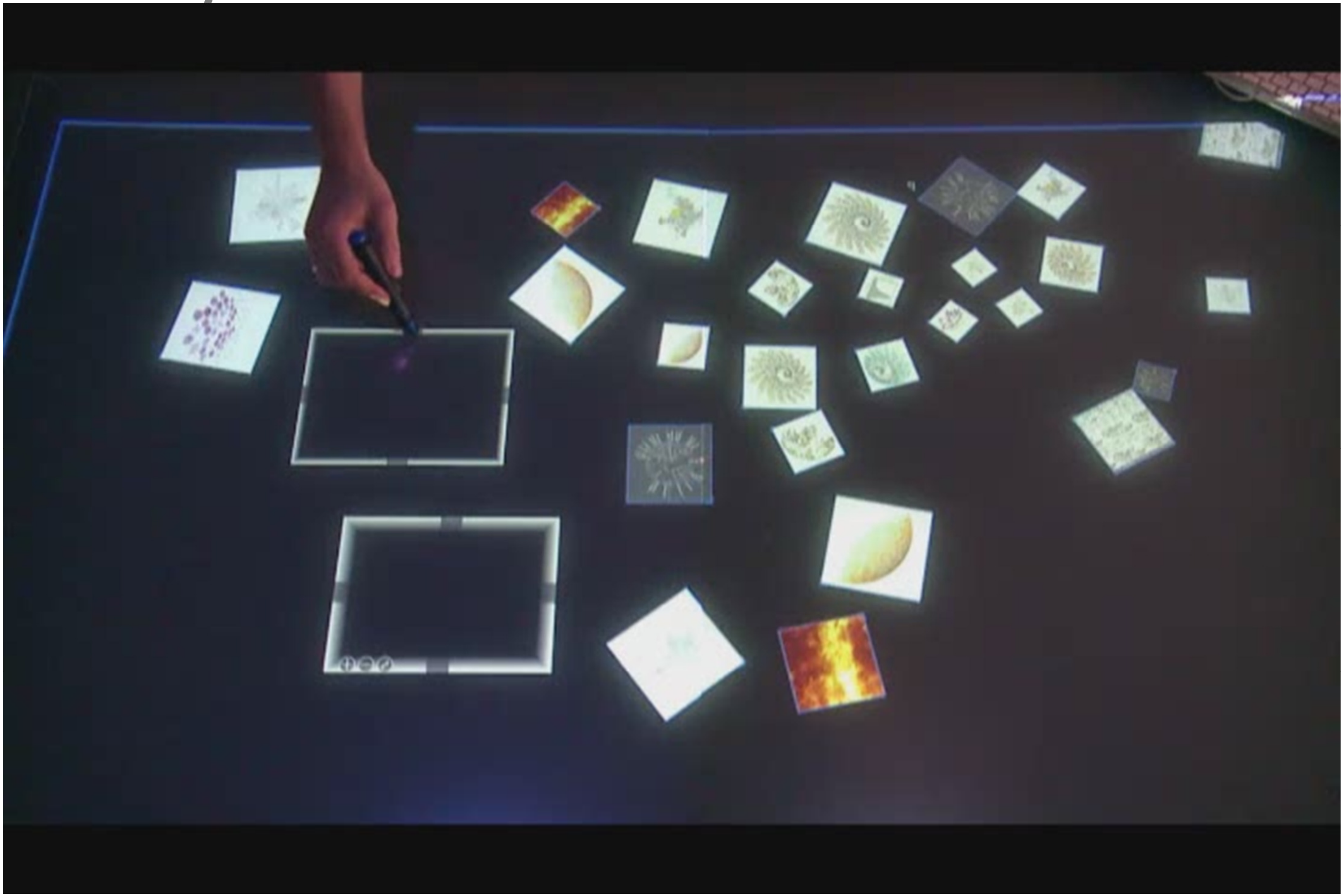
e.g. people show territorial behaviour



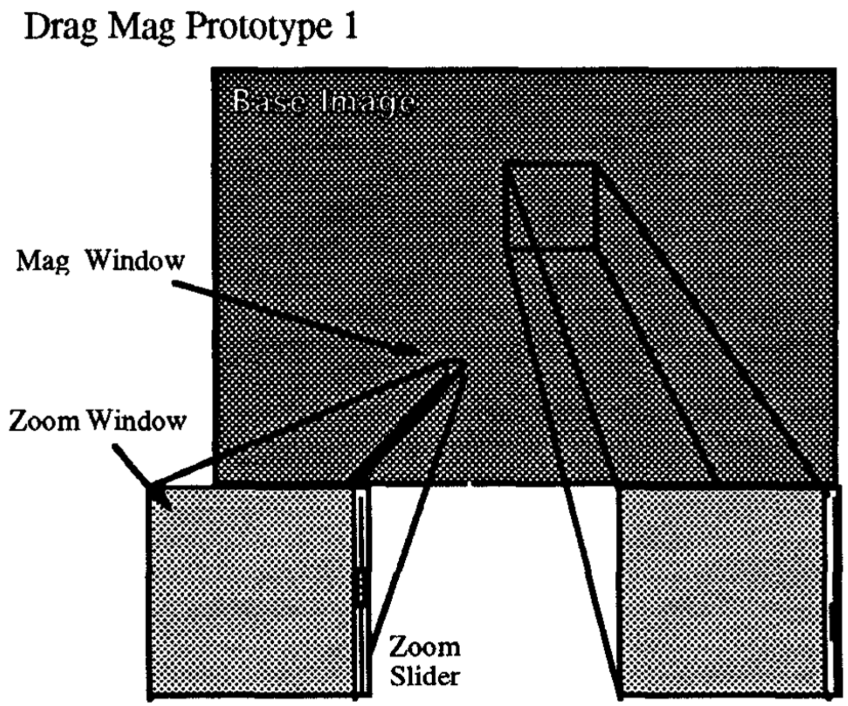
additional social challenges to take into account

http://diamonspin.free.fr

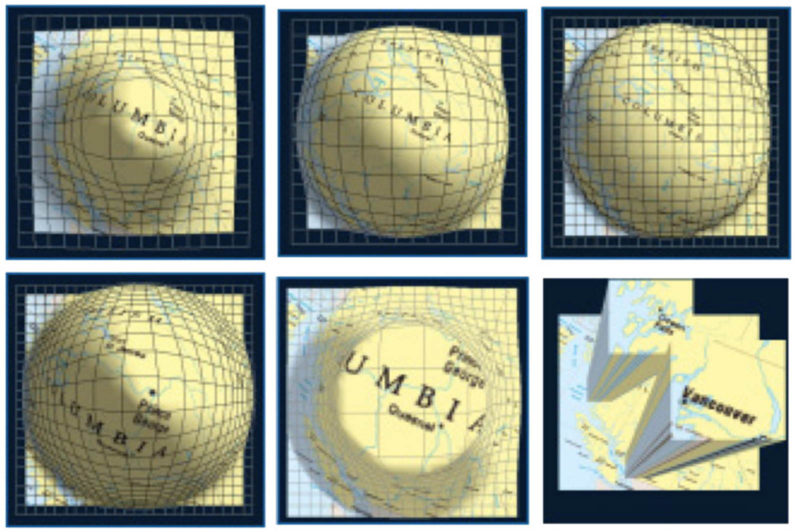
iLoupe



Past Solutions

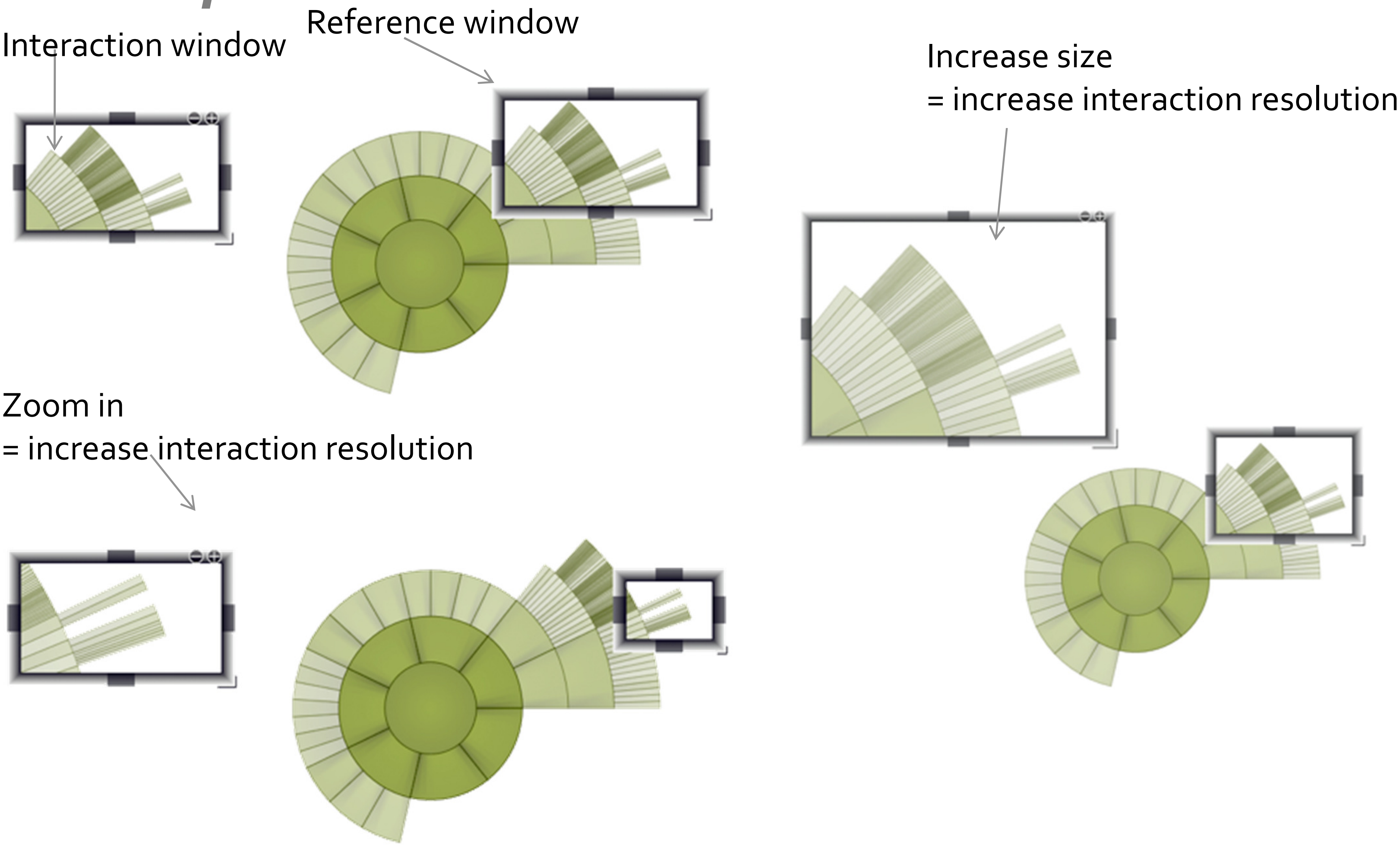


Ware and Lewis, 1995

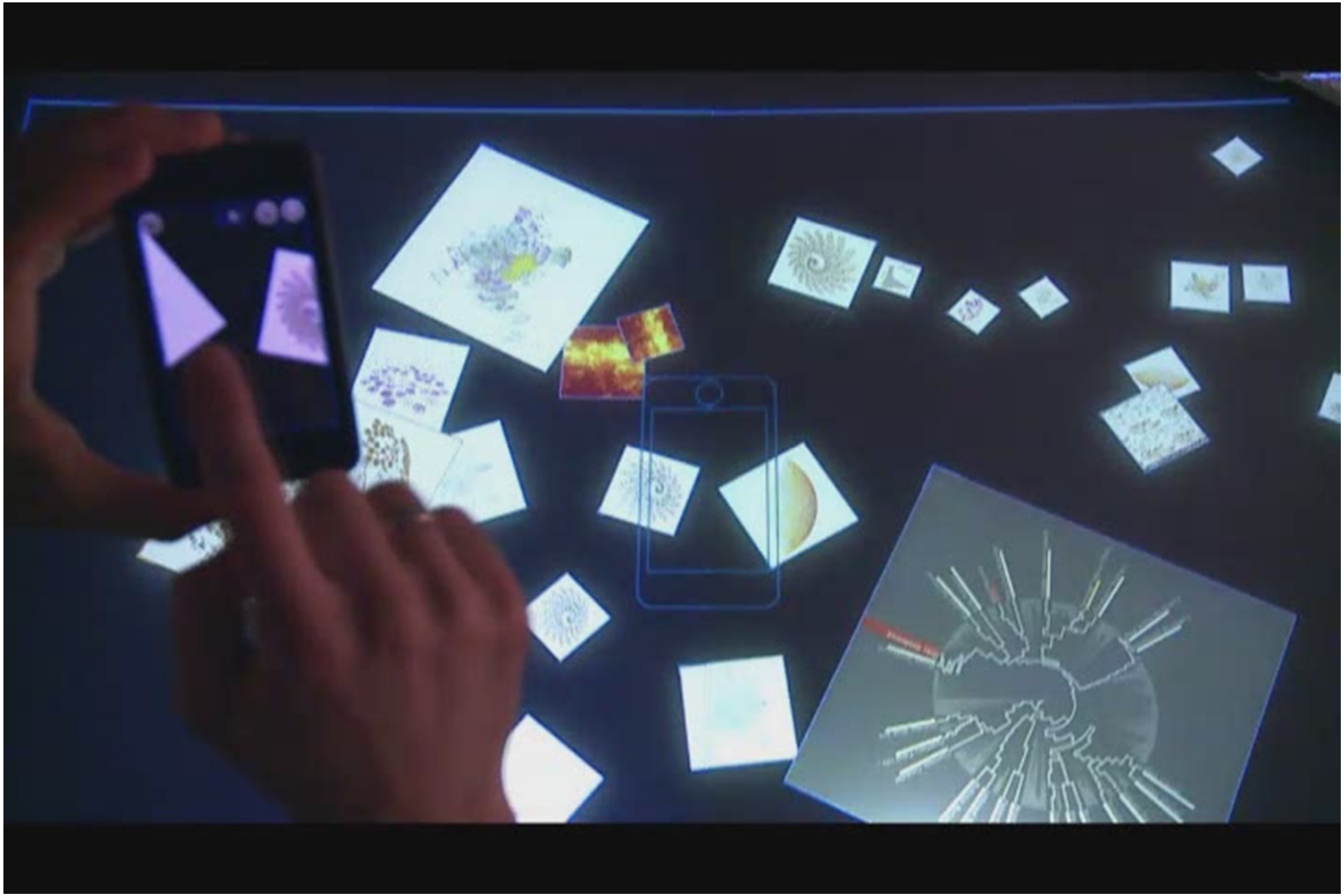


Carpendale & Montagnese, 2001

iLoupe


Interaction window
Reference window
Increase size
= increase interaction resolution
Zoom in
= increase interaction resolution

iPodLoupe



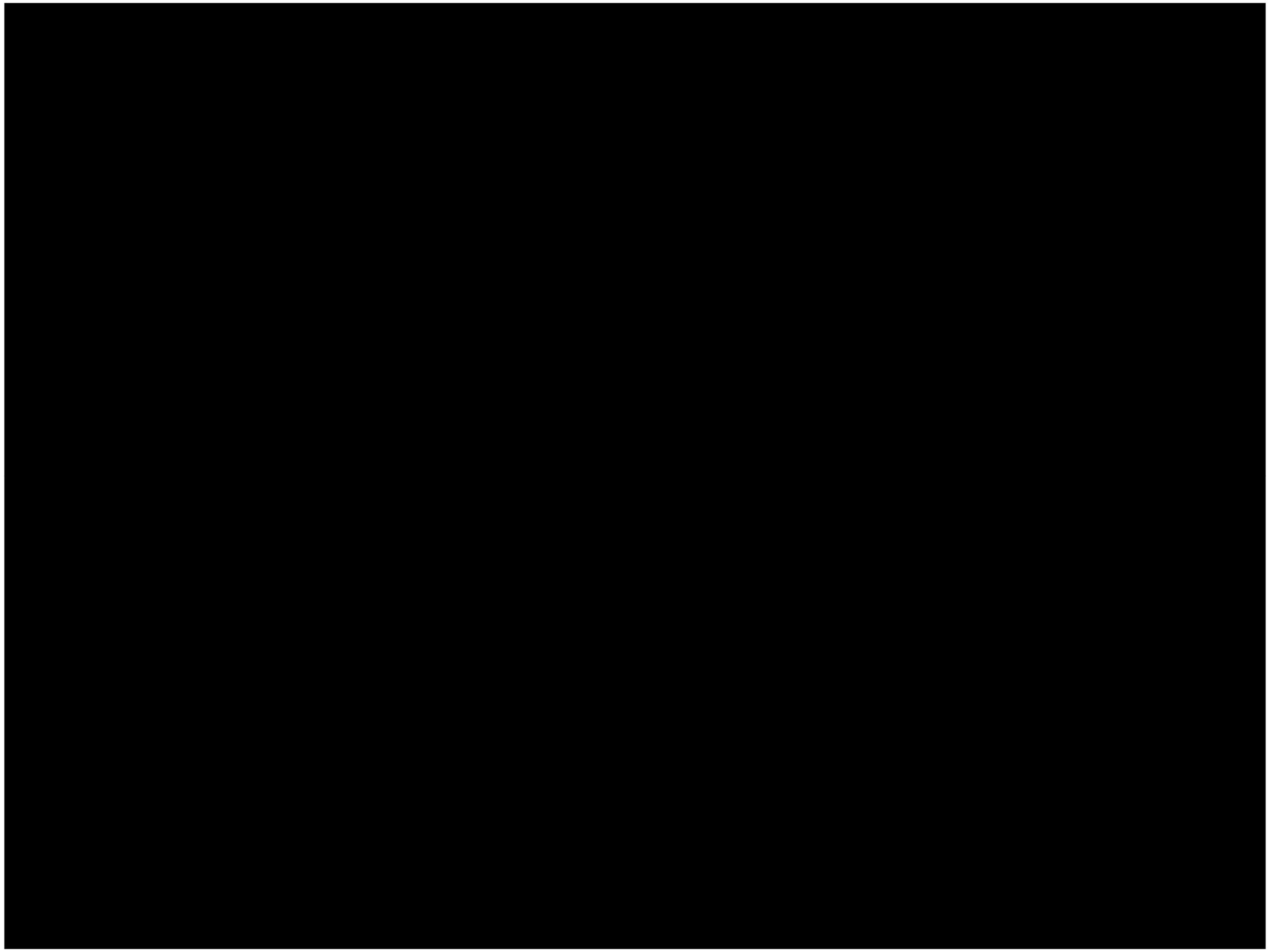
Comparison

		
Resolution Discrepancy	Overlay (Non-Distorted) Direct resize, widgets	Secondary device Direct resize, widgets
View and Value Interaction	Control via lens' frame Interaction through interior of the lens	Multi-touch/gesture Interaction through entire device surface
Face-Face Interaction	Free, portal-based magnification and rotation	Free, device-based magnification and rotation

Summary

- loupe approach to address
  - resolution discrepancy
  - view & value interactions
  - collaboration
- BUT
  - interaction not very fluid
  - all interaction immediate (can still be disruptive)
  - context integration not great

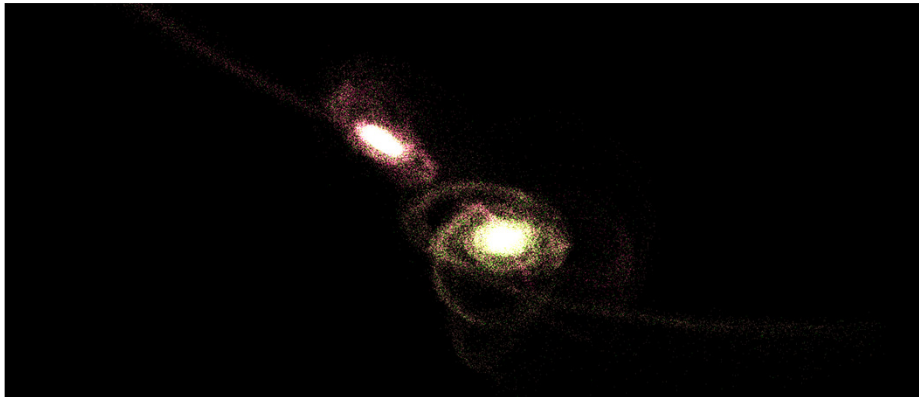
Tangible Views



…but what if we want to invoke

VIEW CHANGES WITH DIRECT-TOUCH?

Challenge



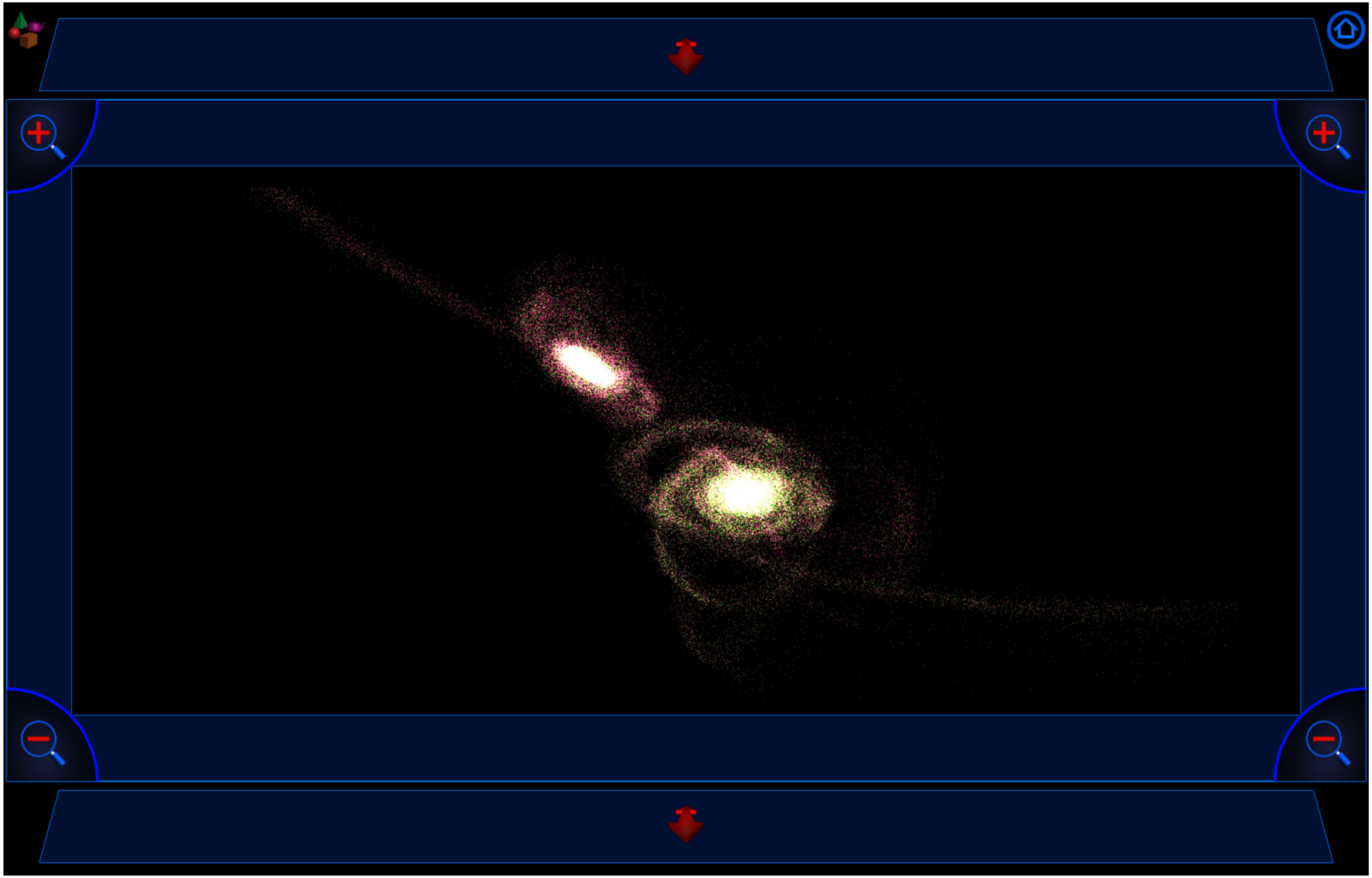
3D visualization requires:

- view manipulation with 7DOF
  (x/y/z translation, x/y/z rotation, zoom)

But:

- 2-touch input
  - > 4DOF

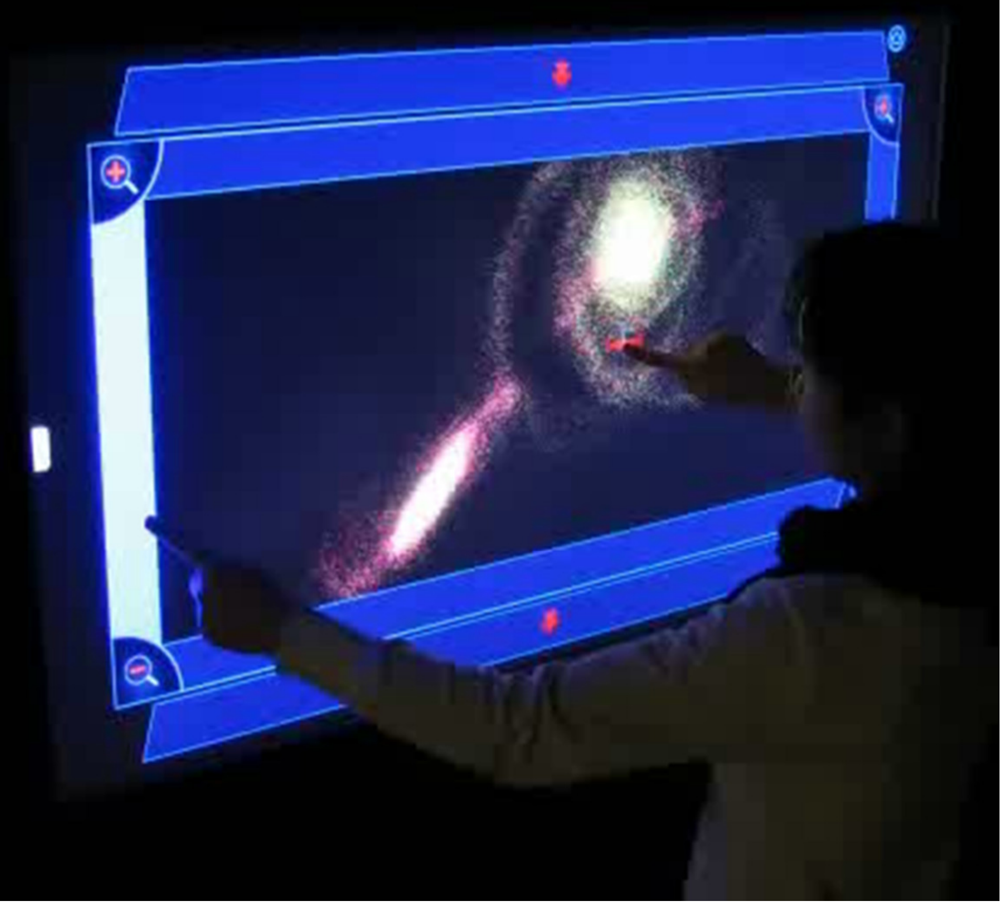
Design: Frame Interaction



Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces

Lingyun Yu
Pjotr Svetachov
Petra Isenberg
Maarten H. Everts
Tobias Isenberg

university of groningen



…but what next?

VIEW CHANGES AREN'T EVERYTHING!

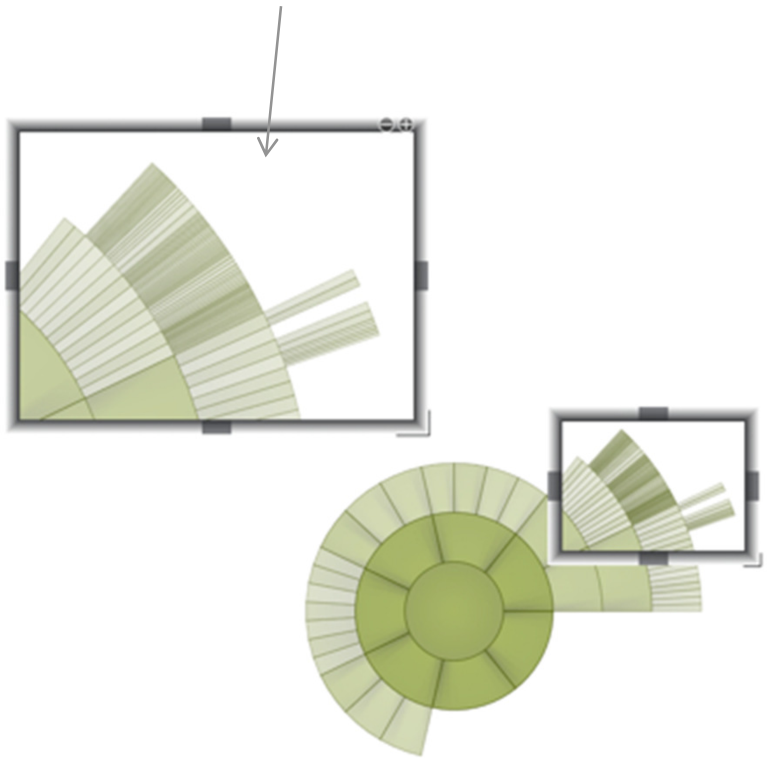
Let’s look closer at…

THE CASE OF SELECTION

One approach

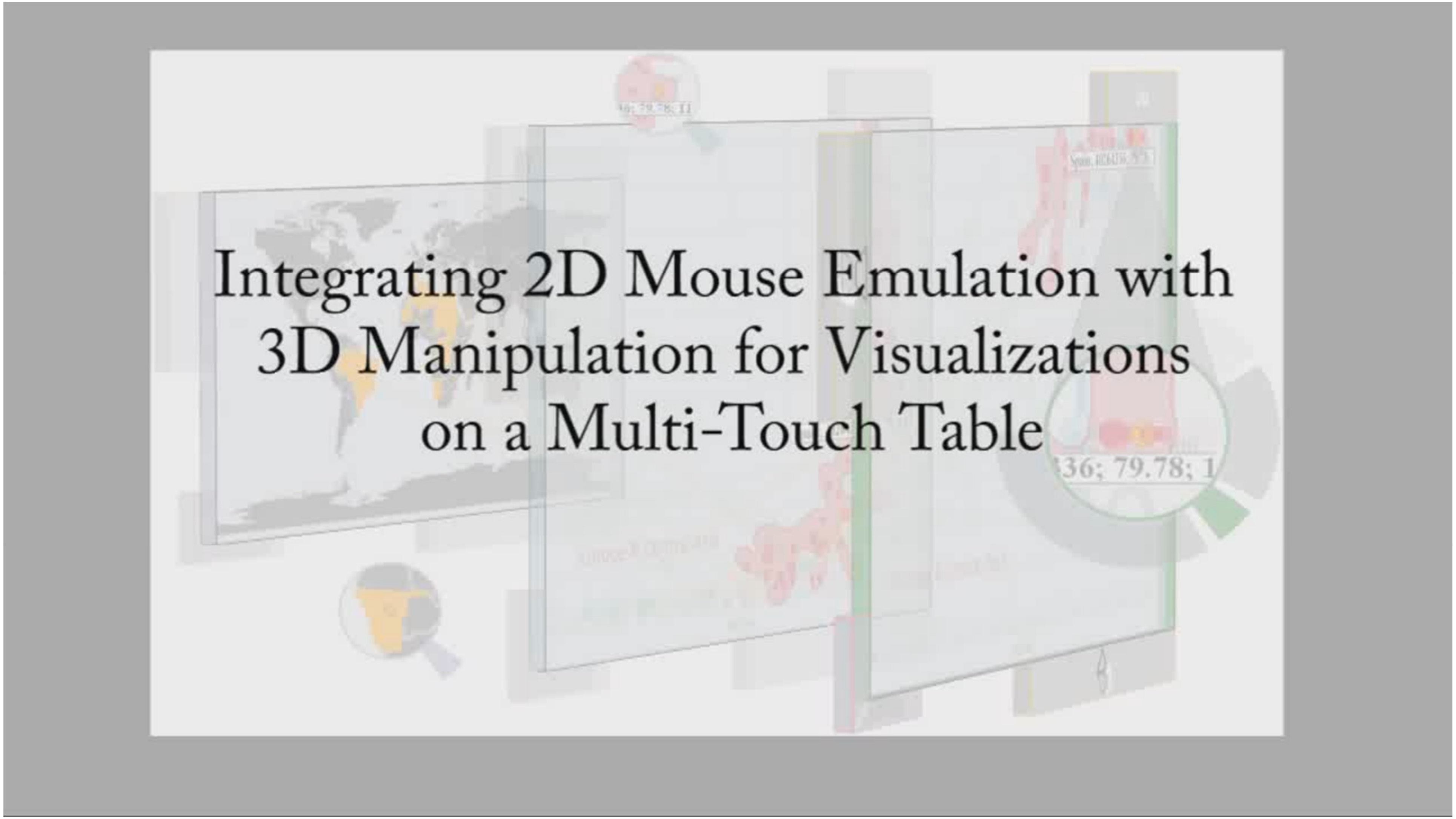
- Lenses

Increase size
= increase interaction resolution



Another…

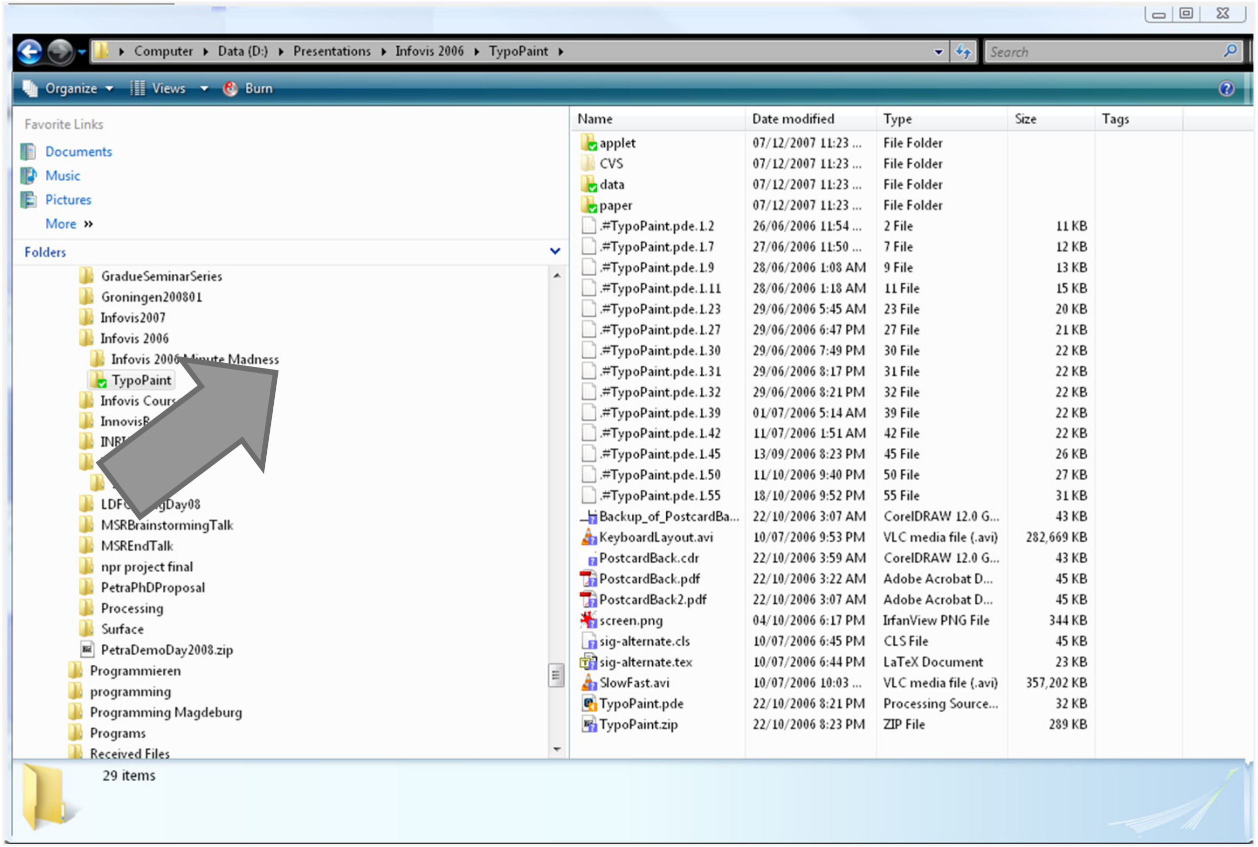
- Use of interaction tools



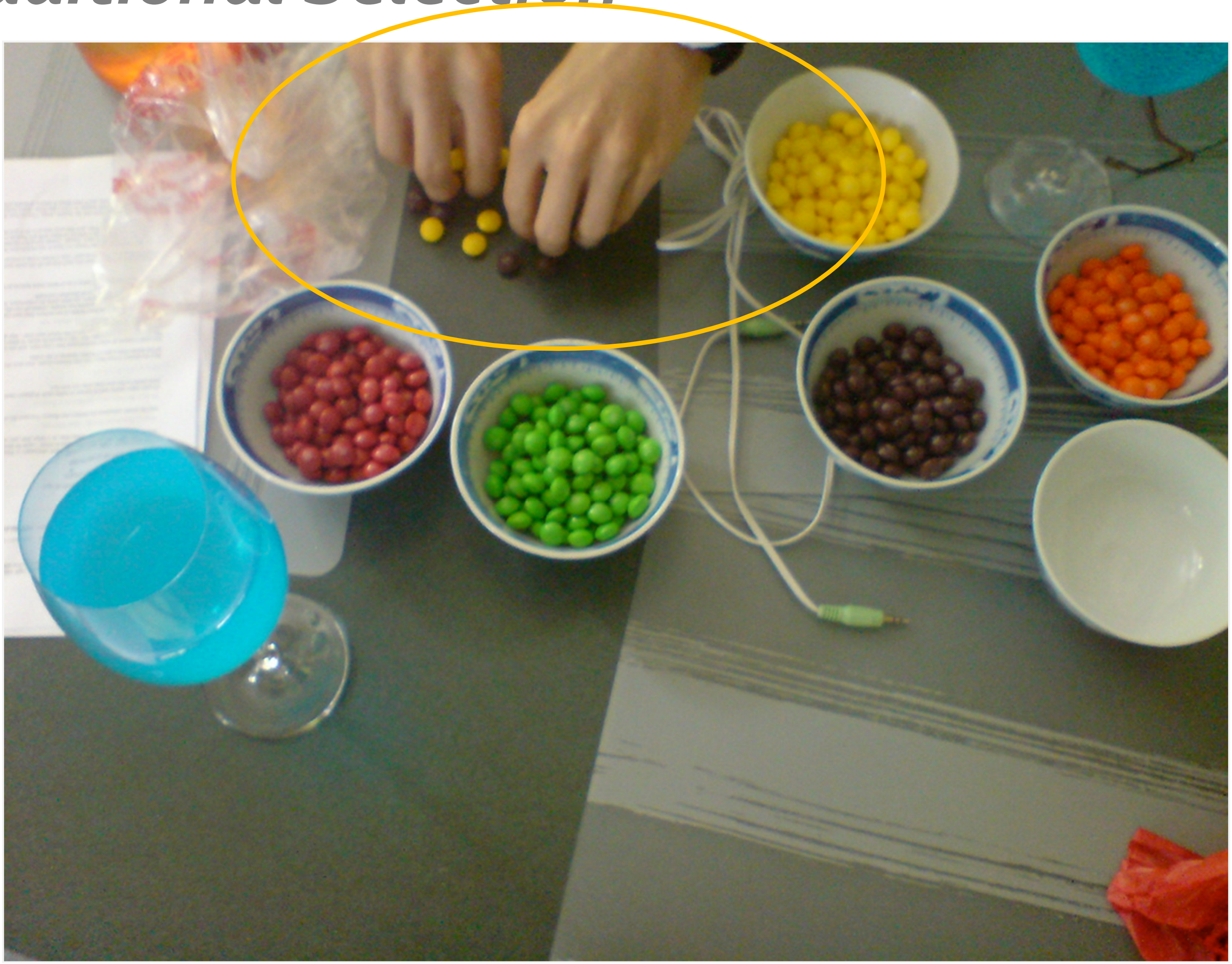
Gestures

- What if we want to make use of the true power of multi-touch?

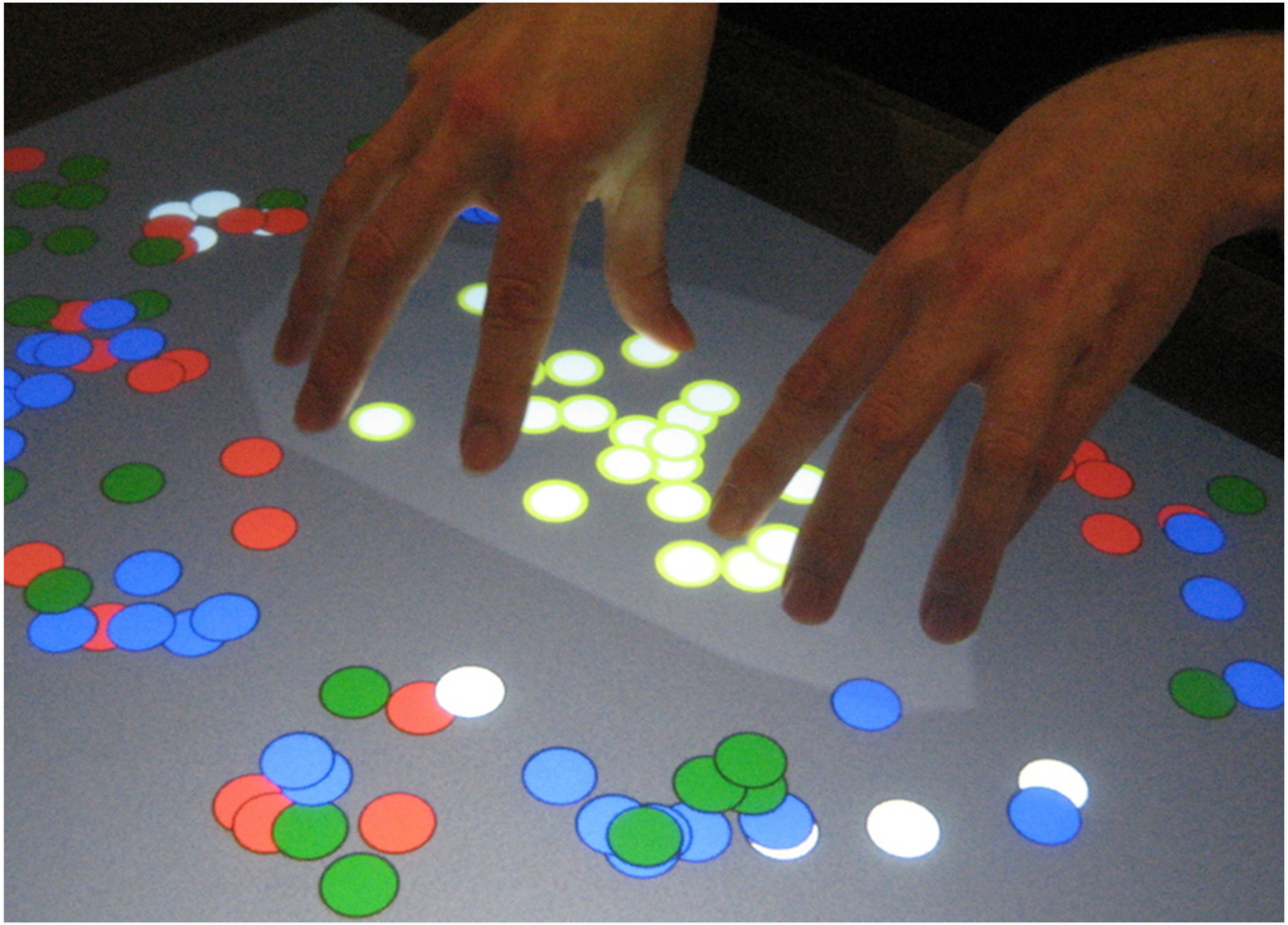
Desktop Selection



Traditional Selection

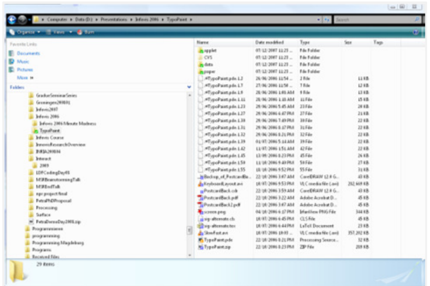


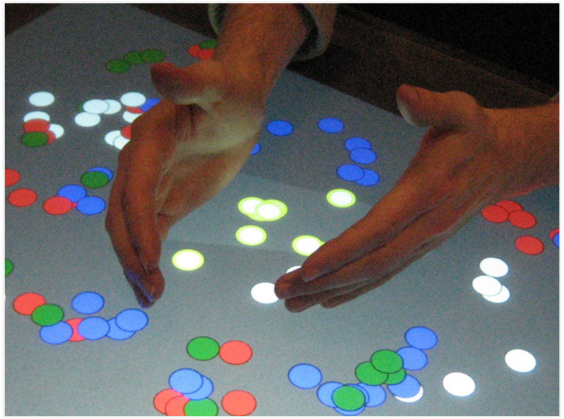
Multi-touch Selection



Multi-touch Selection

- How do virtual and physical techniques carry over?
- How will people use hands and fingers?
- How dextrous will they be?
- Will they focus on single objects or groups?





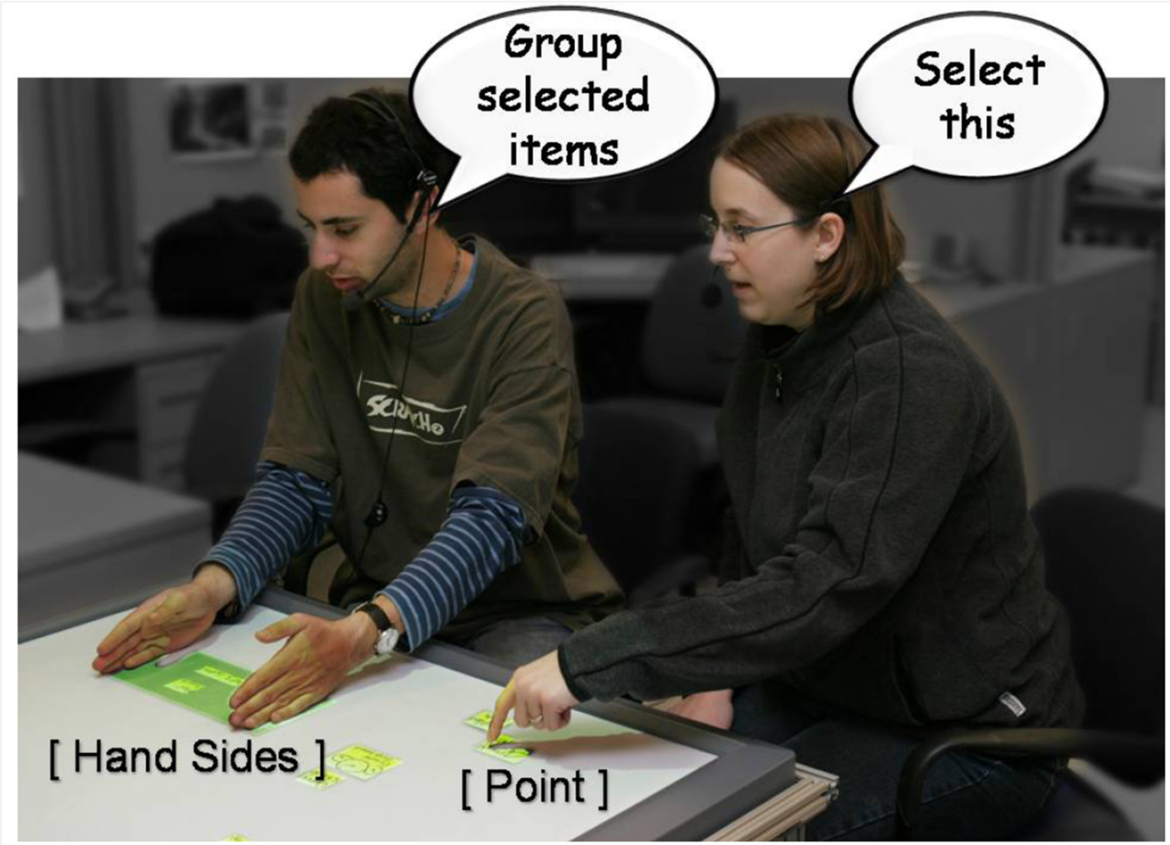
HCI Solutions

Pile-N-Browse

From (Wu et al., 2006)

HCI Solutions

Multi-modal interaction



From (Tse et al., 2008)

HCI Solutions

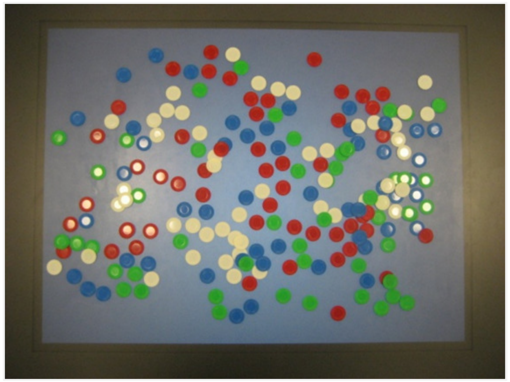
Physics -based

From (Wilson et al., 2008)

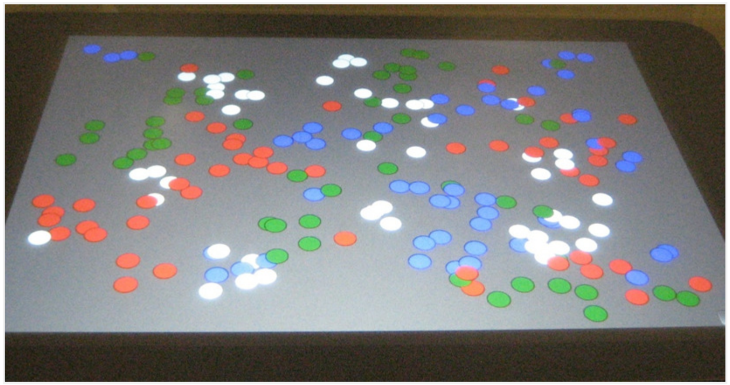
Study

Goals

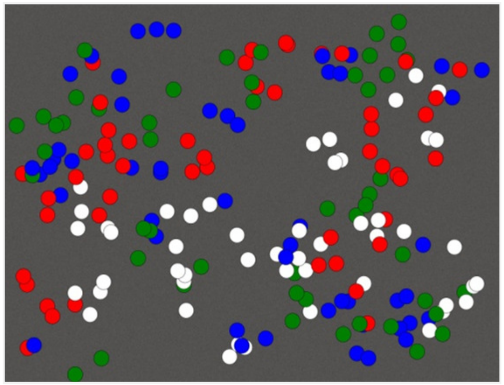
- Study tasks with manipulation of large number of small objects
- Compare gestures from physical/mouse to surface
- Derive gesture vocabulary



Physical



Surface

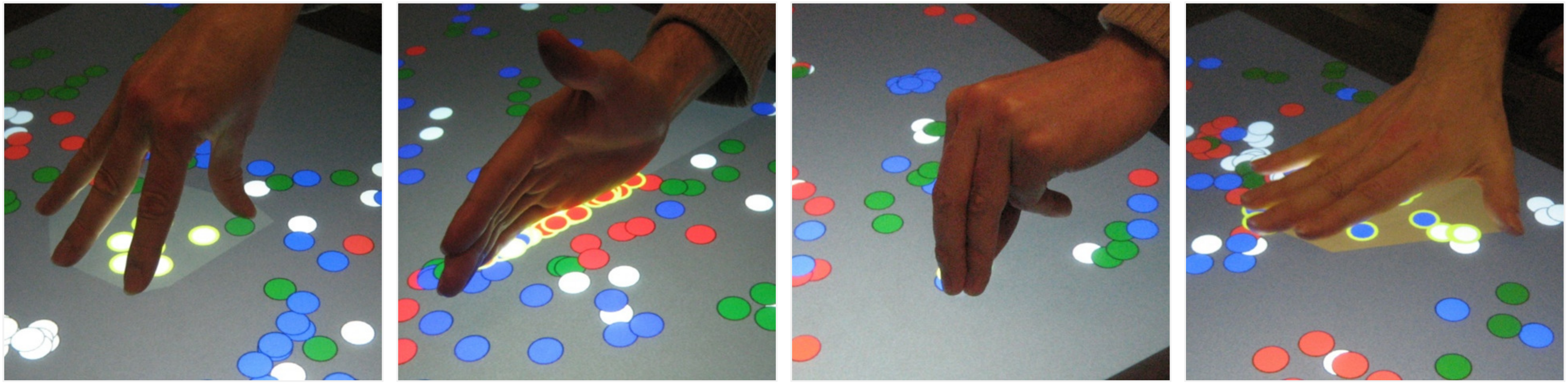


Mouse

Gesture Classes

1.) One handed – applied to a group

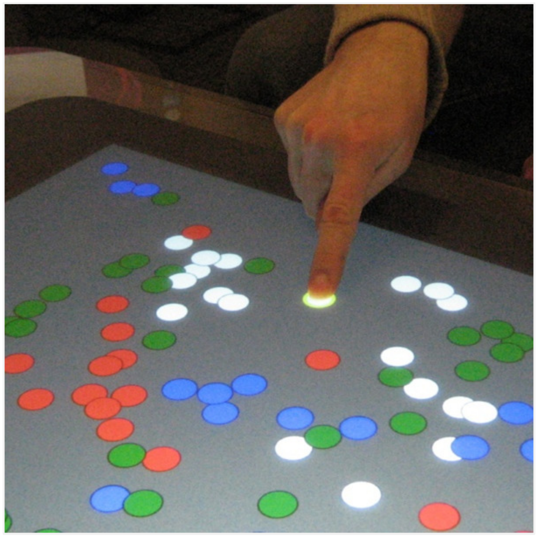
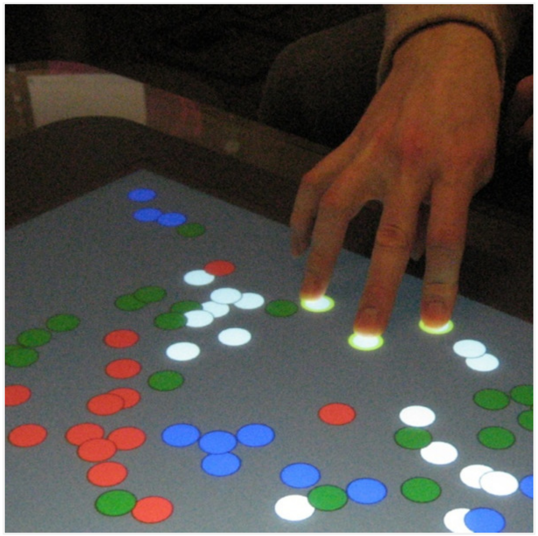
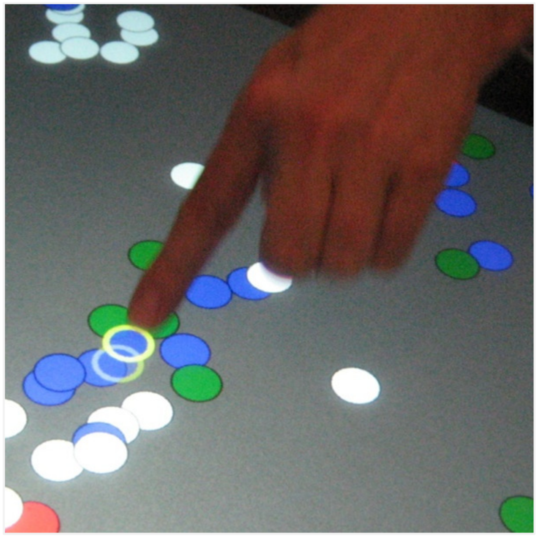
- Splayed hand pushes pieces
- One hand shove
- Pinch
- Hand and palm



Gesture Classes

2.) One handed – applied to single item

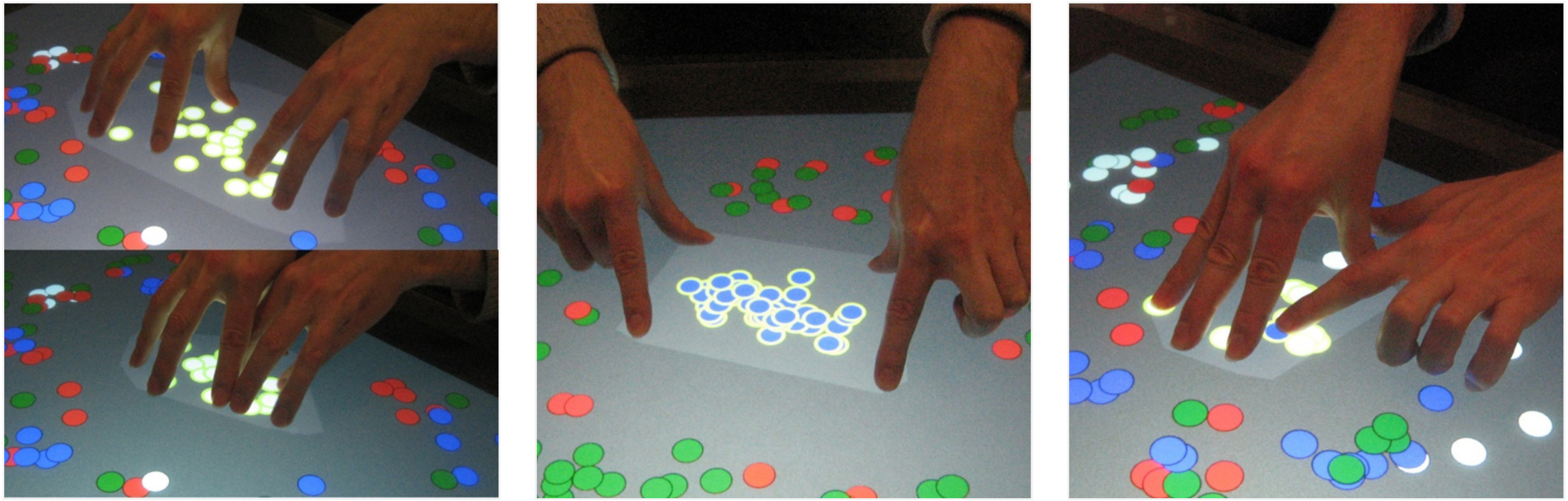
- Drag single item
- Select single items with multiple fingers
- Toss single object

Gesture Classes

3.) Two handed – applied to single group

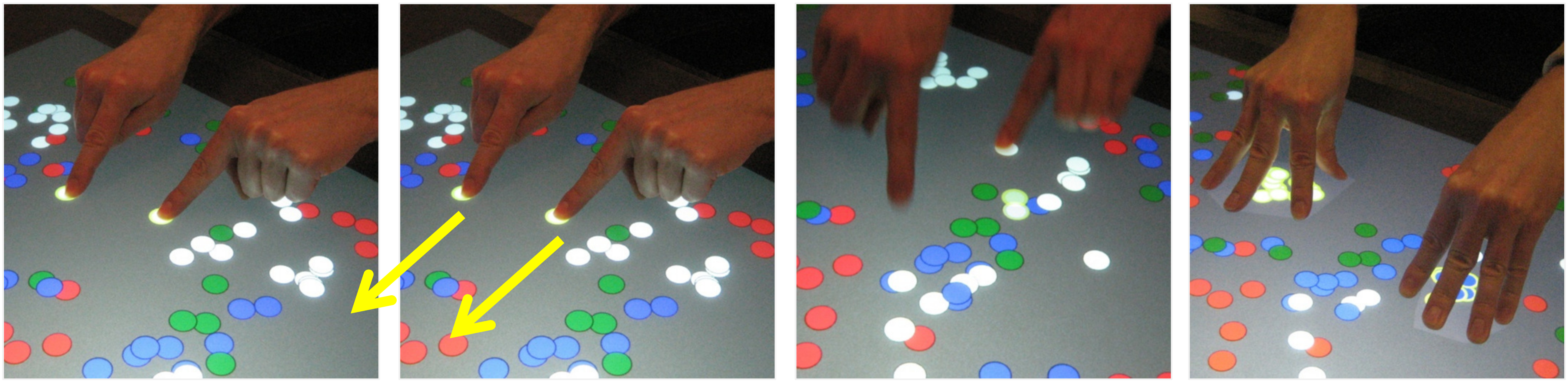
- Both hands coalesce large group to small
- Two-hand transport
- Add/remove from selection



Gesture Classes

4.) Two handed – applied to > 1 group

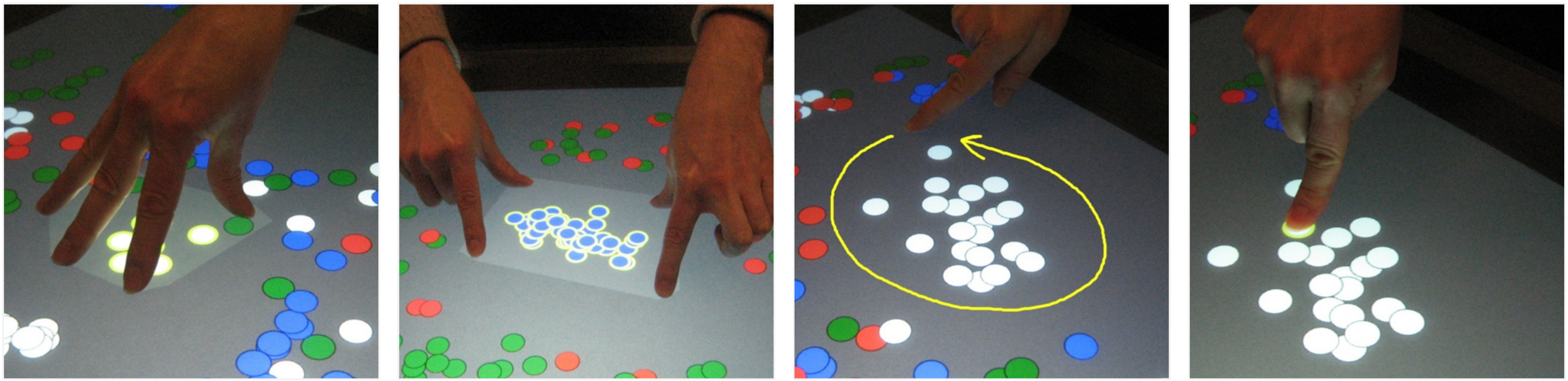
- Drag two objects with pointer fingers
- Two hands grab points in sync
- Rhythmic use of both hands
- Two hands grab groups



Gesture Classes

5.) Surface Only

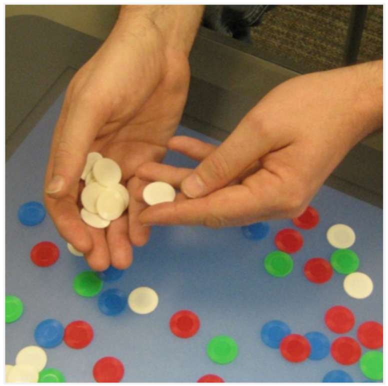
- One hand hull manipulation
- Two-hand hull manipulation
- Treat finger like a mouse
- Push hard to multi-select



Gesture Classes

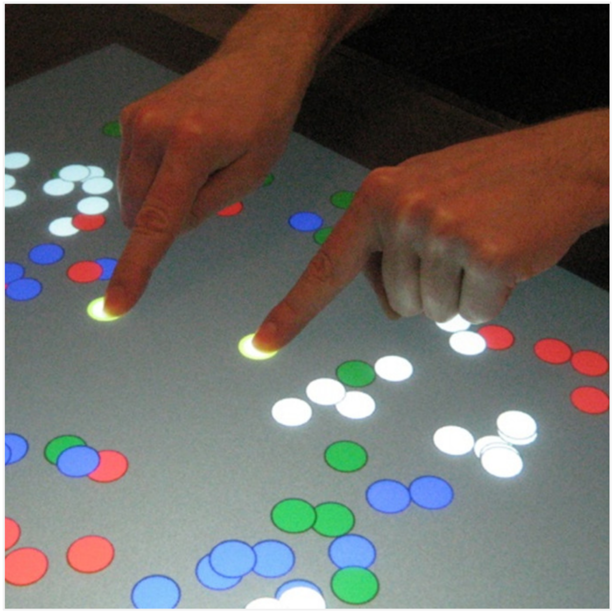
6.) Physical Only

- Lift up
- Go outside the lines
- Slide around objects
- Texture-based
- Toss chips between hands
- Drag and drop some chips on the way

High-level Summary

- Participants showed influence of previous condition
  - Gestures sets and work speed influenced
- Multi-touch grouping was common
- Two-handed interaction common
  - Wide variety of coordinations (in sync, in parallel, ...)

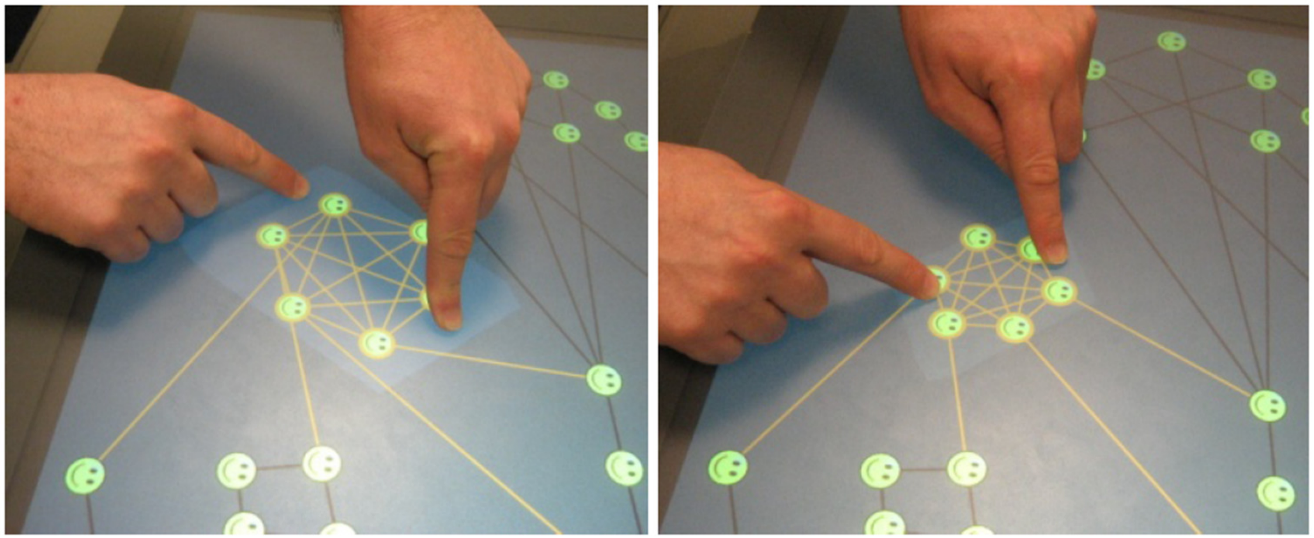


Take-Away

- Grouping gestures and group operations often required
- Possibly most valuable: ephemeral operations (e.g. open-hand grab & move)
- Design of grouping gesture requires great care
  - Wide variety of gestures
  - Wide variety of coordination strategies
  - Expectations differed

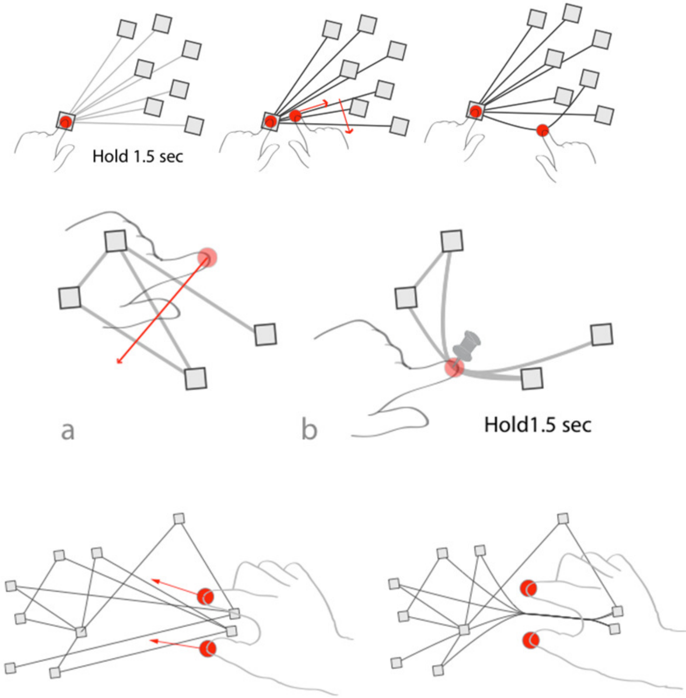
Application Graph Manipulatiom

- Touch used for “testing connection”, moving single nodes
- Dual touch to “move edge”
- Convex Hull + Rotate & Translate
  - To organize long chains & cliques



(InfoVis ‘09)

MT Graph Interaction



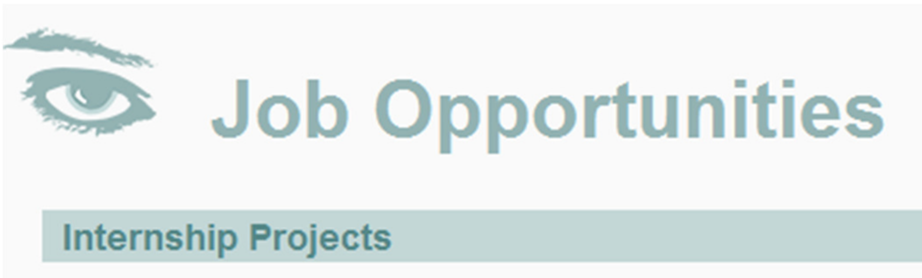
Sebastian Schmidt, Miguel Nacenta, Raimund Dachselt and Sheelagh Carpendale. **A Set of Multi-touch Graph Interaction Techniques**. In *Proceedings of Interactive Tabletops and Surfaces - ITS'10*. ACM Press, 2010

MT Parallel Coordinates Interaction

Robert Kosara,
Poster: Indirect Multi-Touch Interaction for Brushing in Parallel Coordinates,
IEEE Information Visualization Posters, 2010.

Summary

- Many more types of interaction in visualization
- Unified mapping needed to MT



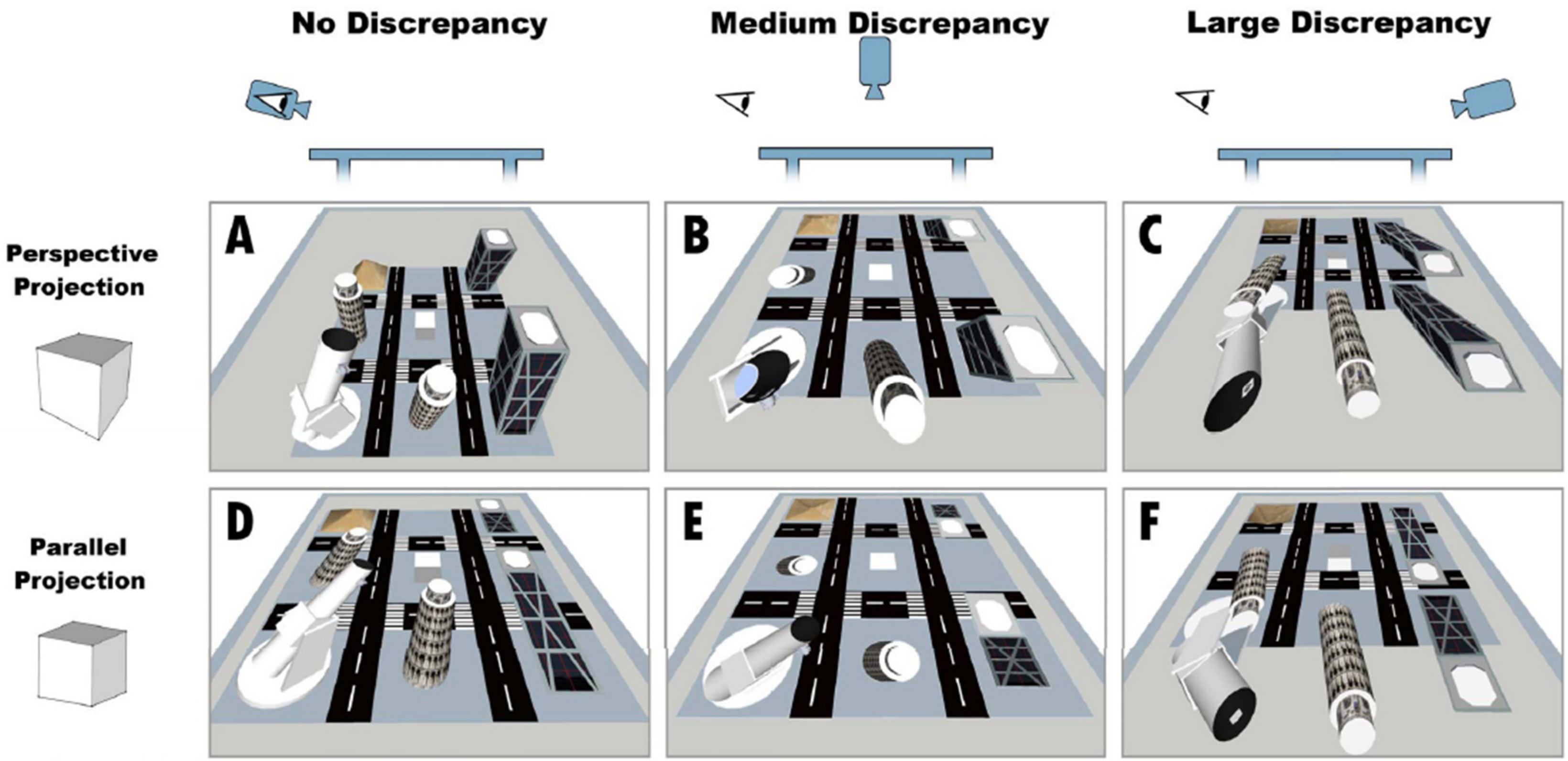
www.aviz.fr/jobs.html

part II.II:

representation challenges

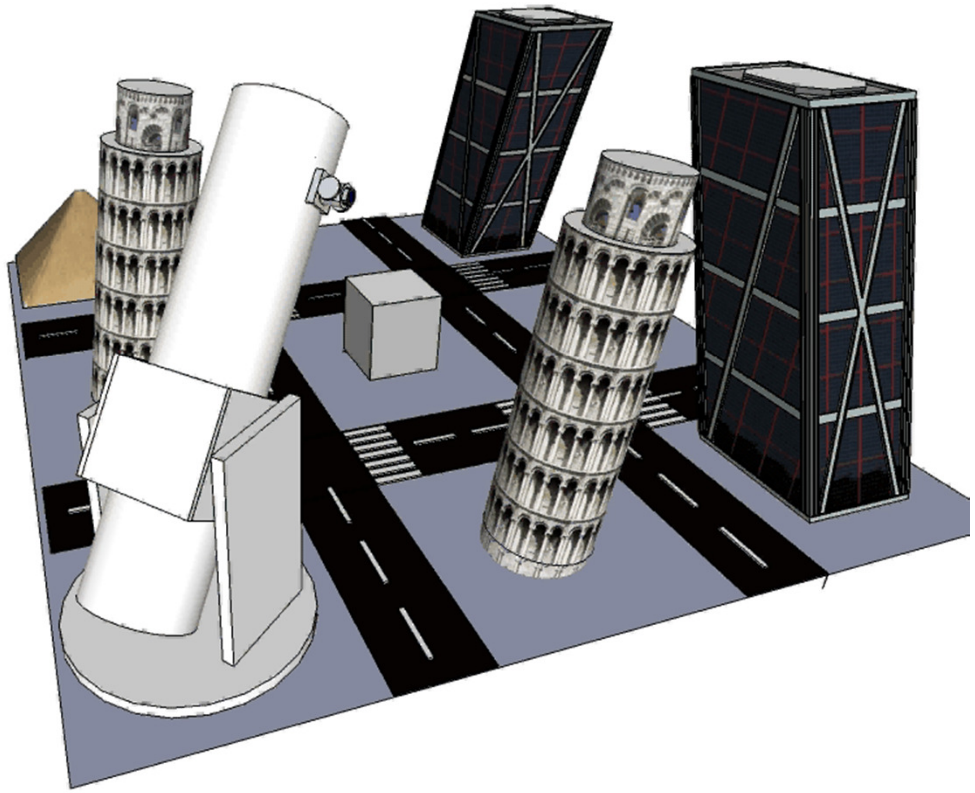
Visual Variables & Point of View

Distortion to 3D visual elements



The effects of changing projection geometry on the interpretation of 3D orientation on tabletops. Mark Hancock, Miguel Nacenta, Carl Gutwin, and Sheelagh Carpendale. In *Proc. ITS*, pp. 175-182, 2009

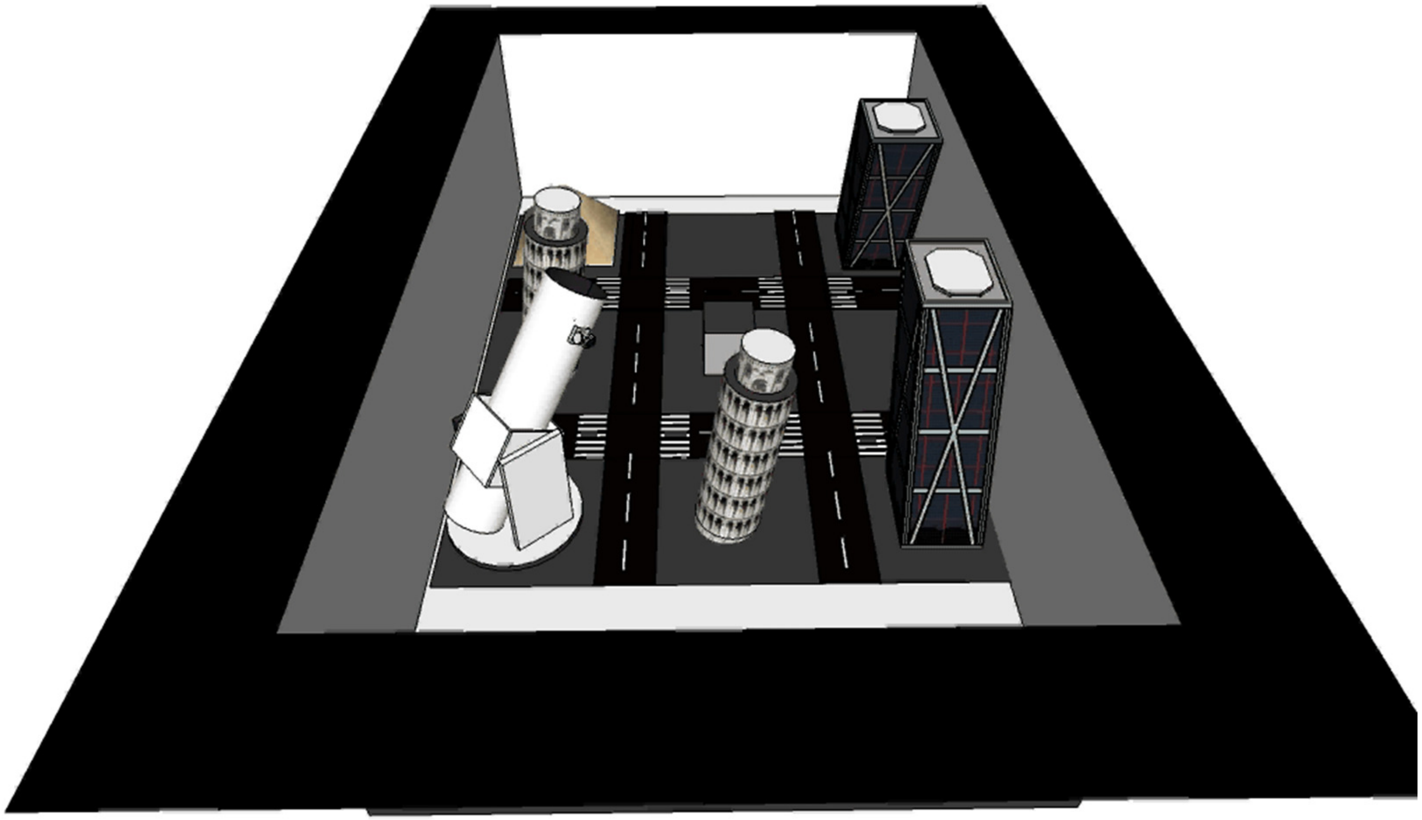
Example



assume we have a 3D model

Video by Miguel Nacenta

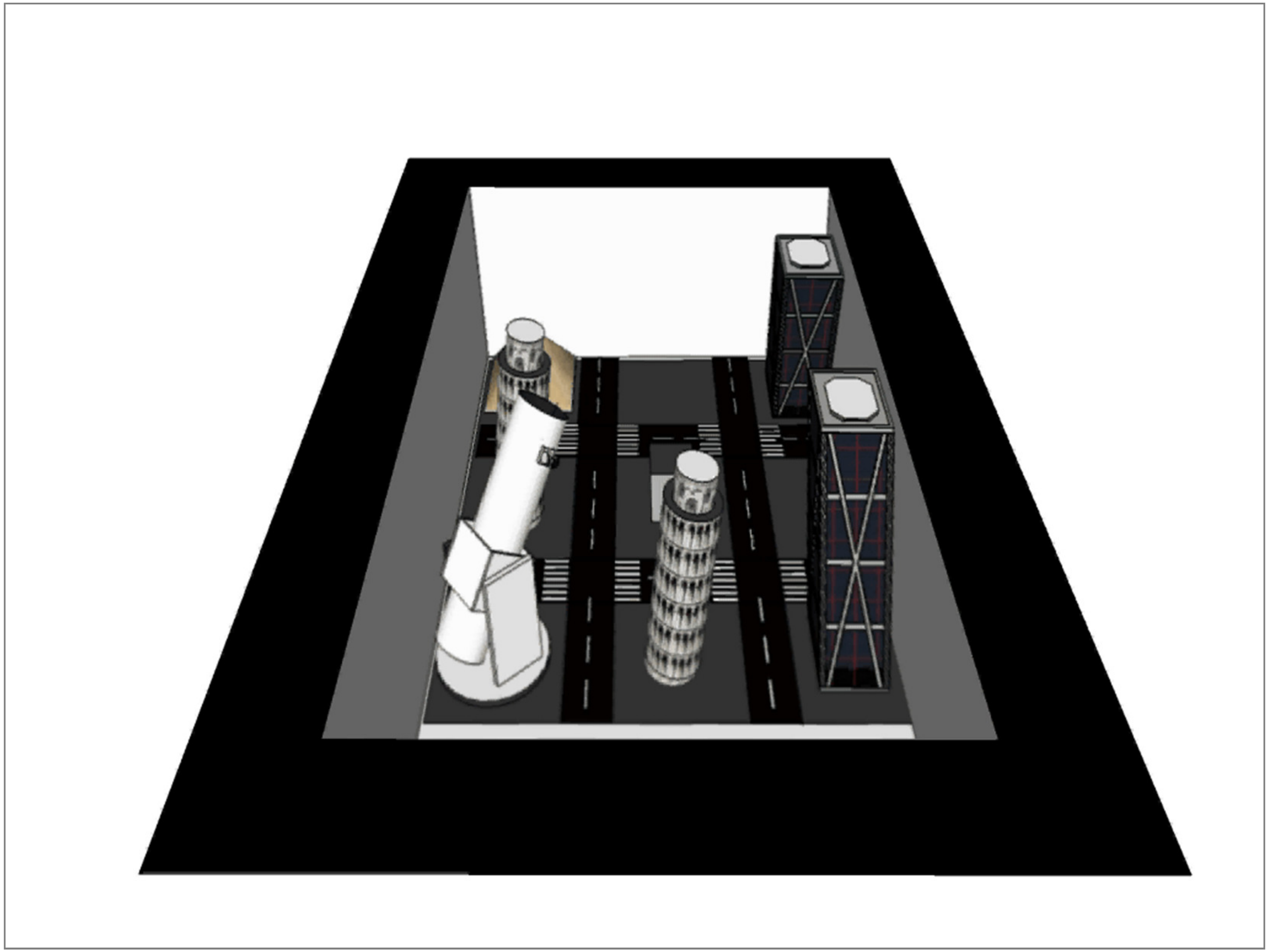
Example



this is what we would expect to see on the table

Video by Miguel Nacenta

Example



this is what we would actually see on the table

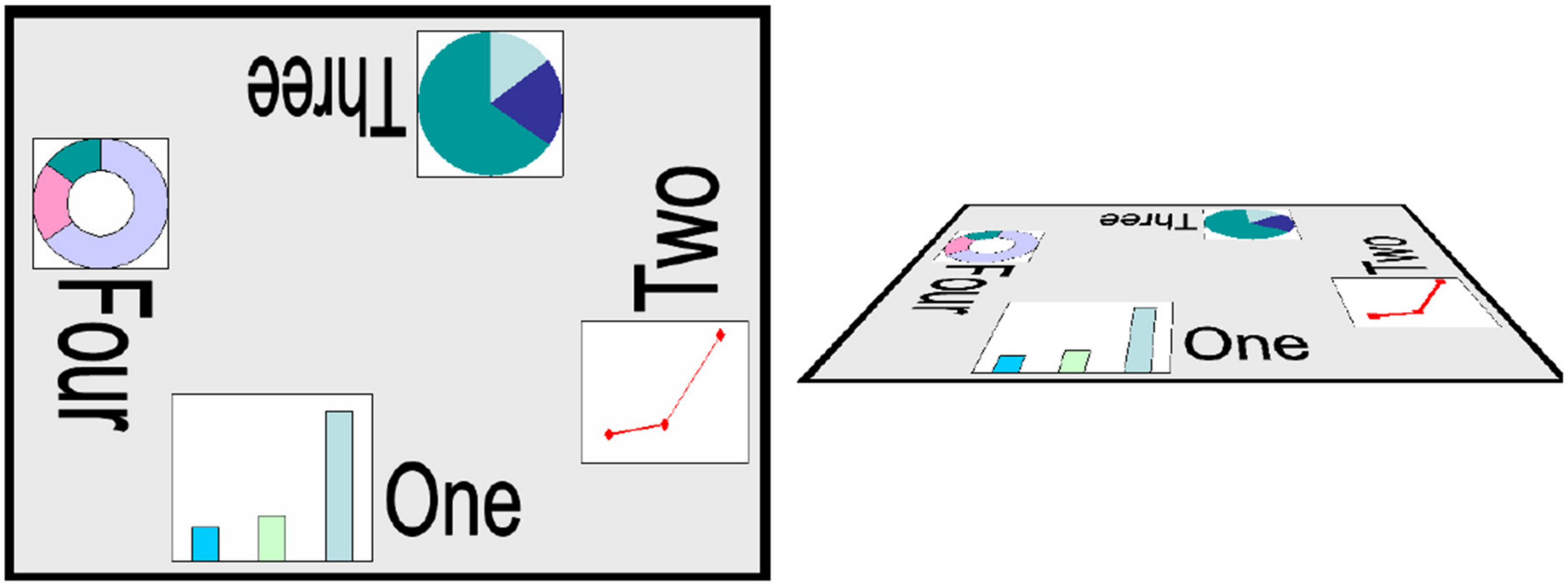
Video by Miguel Nacenta

Recommendation

- If you have 3D information:
  - use parallel projection
  - with camera above center of the tabletop

Visual Variables & Point of View

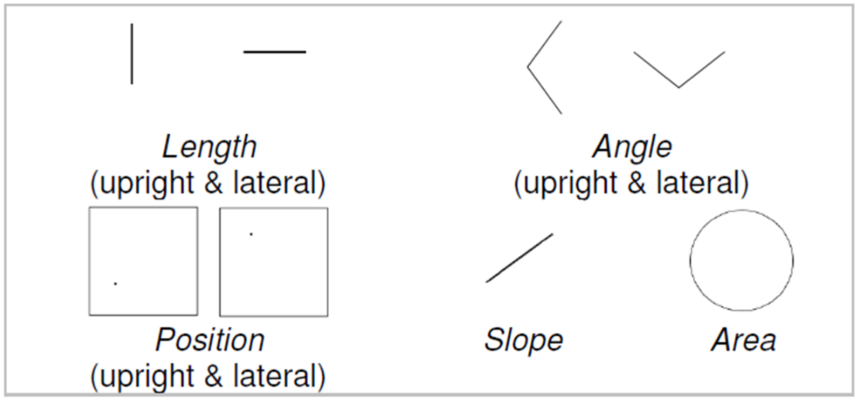
Distortion to 2D visual elements



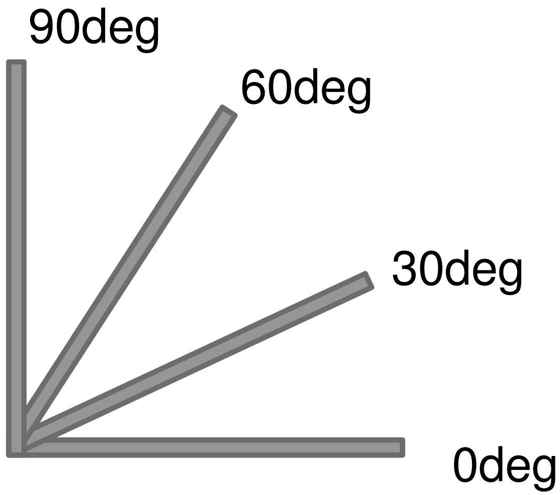
Wigdor, D., Shen, C., Forlines, C., Balakrishnan, R. (2007). Perception of Elementary Graphical Elements in Tabletop and Multi-Surface Environments. Proceedings of the 2007 SIGCHI conference on human factors in computing systems (CHI 2007)

Visual Variables & Point of View

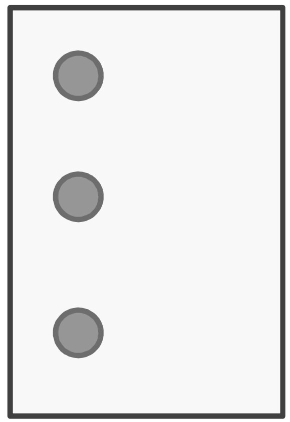
Visual variables tested on range of orientations



Visual Variables



Display Angle



Variable Pos.

Wigdor, D., Shen, C., Forlines, C., Balakrishnan, R. (2007). Perception of Elementary Graphical Elements in Tabletop and Multi-Surface Environments. Proceedings of the 2007 SIGCHI conference on human factors in computing systems (CHI 2007)

Visual Variables & Point of View

Recommendations from this study **for tables**:

- Relative comparison of values is less accurate when they are not at similar up/down distance
- Some visual variables are more accurately compared:
  - length > position (lateral) > angle (lateral) > area > position (upright), angle (upright), slope
  - most robust: position, angle should be display laterally
  - if both upright & lateral display required: use position

Wigdor, D., Shen, C., Forlines, C., Balakrishnan, R. (2007). Perception of Elementary Graphical Elements in Tabletop and Multi-Surface Environments. Proceedings of the 2007 SIGCHI conference on human factors in computing systems (CHI 2007)

Visual variables in context

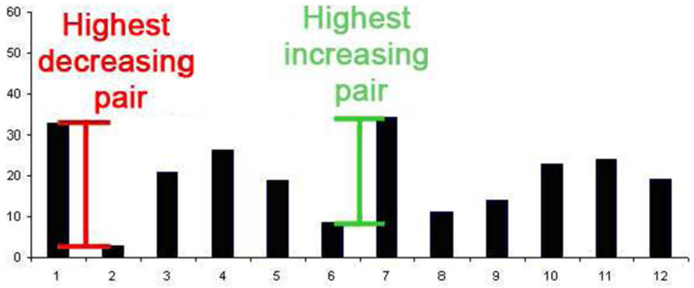
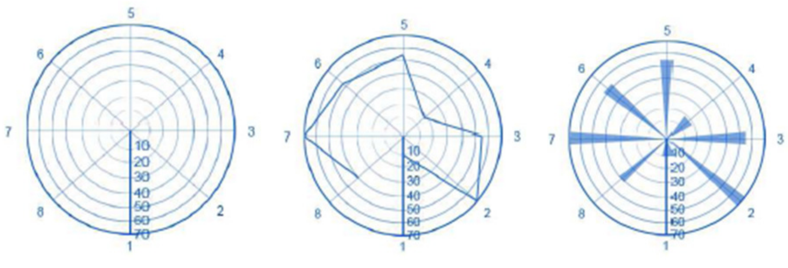
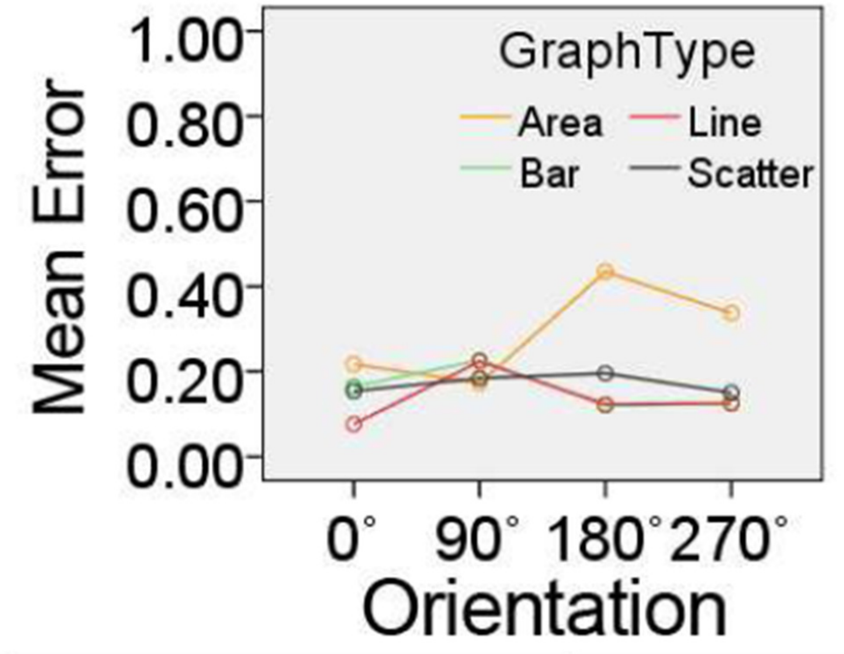


Figure 2: A chart could have one of two types of questions. Each participant was asked to identify the maximal decreasing pair (shown as points 1 to 2) or maximal increasing pair.





OA-Graphs: Orientation Agnostic Graphs for Improving the Legibility of Charts on Horizontal Displays
Fouad Alallah Dean Jin Pourang Irani, ITS 2010

Perceptual Scalability

- how much data can a person effectively perceive?
- visual scalability = the ability of visualizations to effectively display large amounts of data (affected by human perception, visual metaphor, display, algorithms, computation) [Eick & Karr]
- a visualization that is perceptually scalable should not result in an increase in task completion time or error
  - when time is normalized to the amount of data

Yost, B., and C. North, "The Perceptual Scalability of Visualization", *IEEE Transactions on Visualization and Computer Graphics*, vol. 12, no. 5, pp. 837-844, 2006

Perceptual Scalability

They tested:

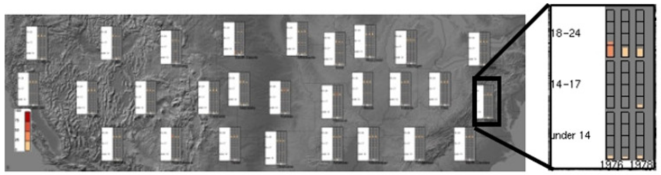


Fig. 2. BARS embedded visualization.

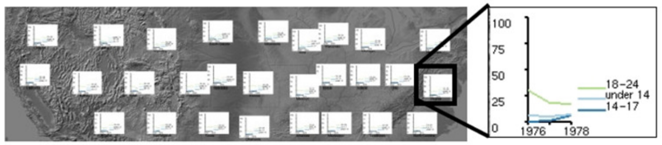
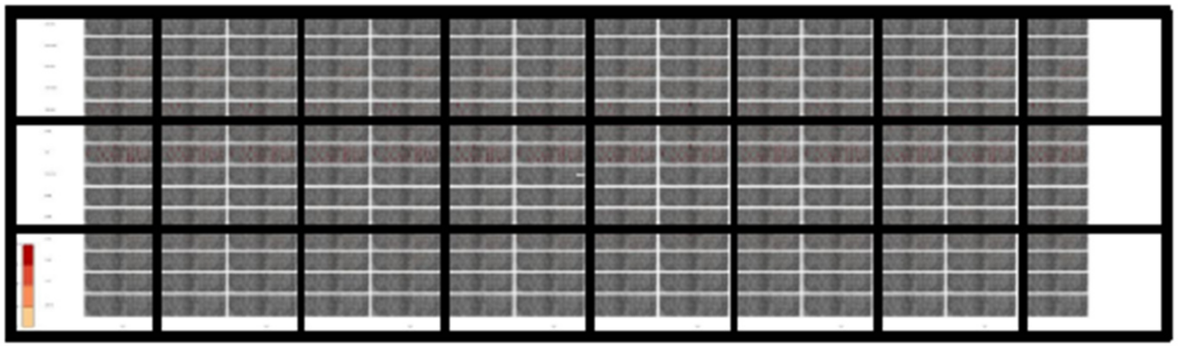


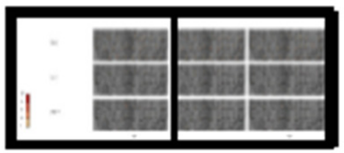
Fig. 3. GRAPHS embedded visualization.

Bars & Graphs

Large Display



Small Display



Yost, B., and C. North, "The Perceptual Scalability of Visualization", *IEEE Transactions on Visualization and Computer Graphics*, vol. 12, no. 5, pp. 837-844, 2006

Perceptual Scalability - Result

- Data increased 20x from small to large
  - Task completion time increased 3x
  - Accuracy did not decrease significantly
- Users navigated physically & gained overview
- On large display spatial grouping seemed more important than visual encoding (small multiples vs. data embedded on a map)

Summary

- perception may be affected when displaying visualizations on large displays
- what visual representations work best?
- what is the cognitive limit?

part II.III:

collaboration challenges

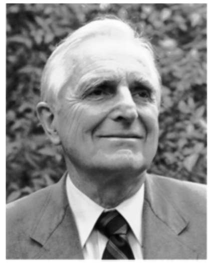
Collaboration

Acquire Information → Analyze & Interpret → Share Results of Analysis → Make Decisions & Take Action


COLUMBIA
UNIVERSITY

First we need to learn about …

COMPUTER SUPPORTED COOPERATIVE WORK



The Problem

The world is getting more complex, and problems are getting more urgent. These must be dealt with **collectively**. However, human abilities to deal collectively with complex / urgent problems are not increasing as fast as these problems.

If you could do something to improve human capability to deal with these problems, then you'd really contribute something basic.

...Doug Engelbart

The early 1950s

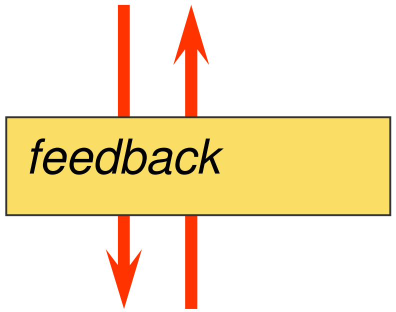
Ack. Saul Greenberg

CSCW

1987

Groupware

- software that supports group work
- investigate algorithms & architectures for multi-user systems



Computer Supported Cooperative Work

- knowledge about the context of groupware design
- investigate individual/group/organizational requirements for multi-user systems

Research Goals

Ack. Saul Greenberg

"is about groups of users – **how to design systems** to support their work *as a group* and how to understand the effect of technology on their work patterns"

Dix, Finlay, Abowd & Beale
Human Computer Interaction, 2nd Ed. Prentice Hall. 1998

"is the **study of the electronic workplace** – an organization-wide system that integrates information processing and communication activities"

Ellis, Gibbs & Rein
Groupware: some issues and experiences, Comm ACM 34(1) 1991

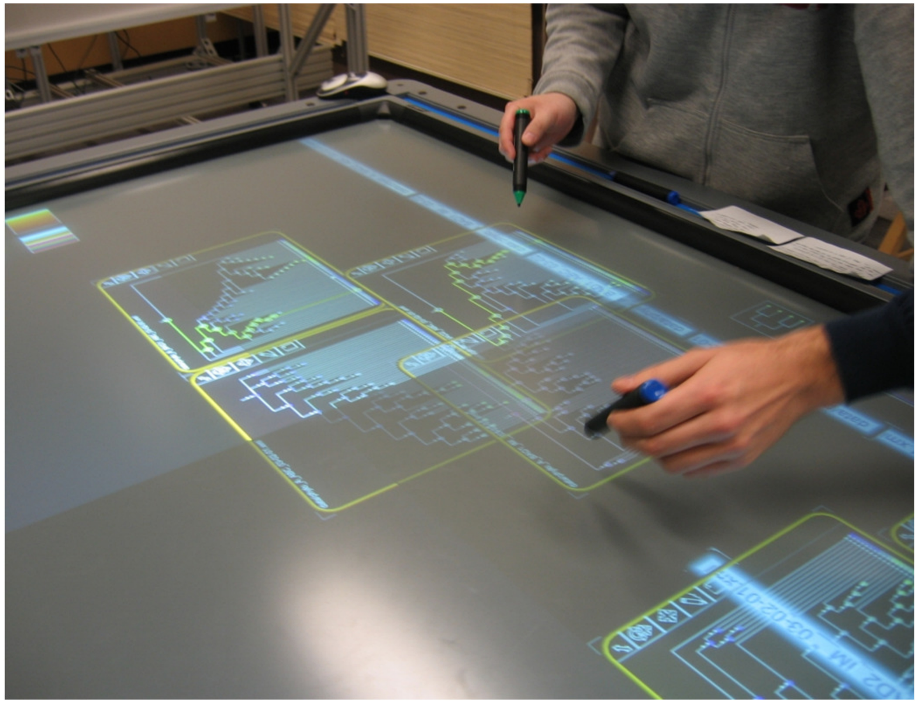
Definitions

	same time synchronous	**different times** asynchronous
same place co-located	face to face interactions decision rooms single display groupware shared table / wall displays roomware...	**continuous task**
different places remote	**remote interactions**	**communication+coordination**

Space/Time Matrix

Multiple people using a single display

- multiple input devices
- simultaneous input
- new interaction widgets
- technical issues (O/S)
- conflict with conventional applications
- supporting social conventions of simultaneous work
- mice vs. direct touch



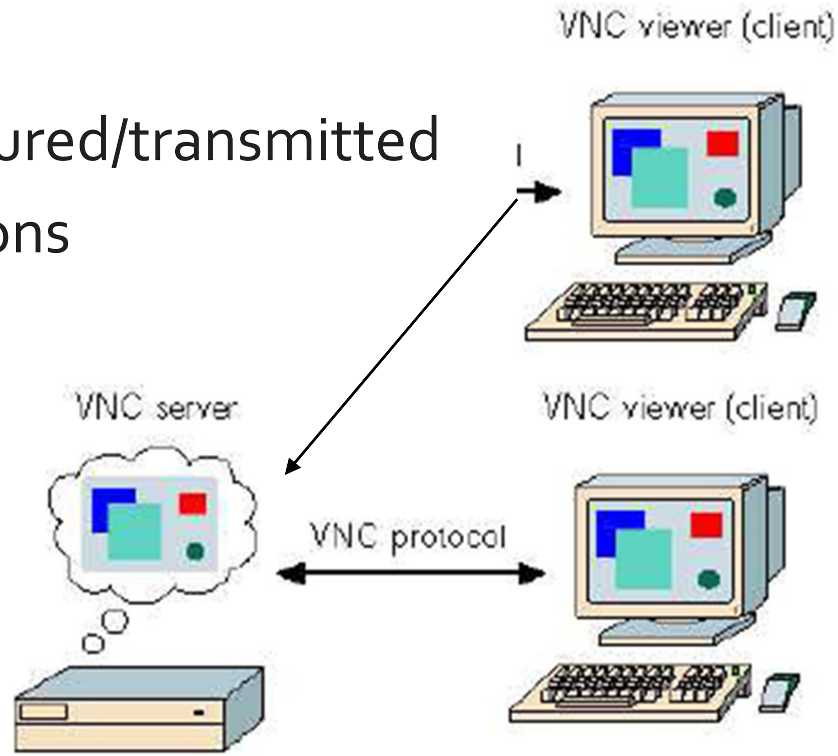
Single-Display Grouware

Ack. Saul Greenberg

	same time synchronous	**different times** asynchronous
same place co-located	**face to face interactions**	**continuous task**
different places remote	remote interactions video conferencing instant messaging chats/virtual worlds shared screens multi-user editors	**communication+coordination**

Space/Time Matrix

- Share unaltered single user applications
  - technical concerns
    - how regions are captured/transmitted
    - architectural limitations
    - controlling input
    - access control…
  - social limitations
    - turntaking
    - control
    - privacy



Richardson, T., Stafford-Fraser, Q., Wood, K. and Hopper, A.
Virtual Network Computing. IEEE Internet Computing. Vol. 2, No. 1. p33-39. January/February, 1998.

Shared Screens / Windows

Ack. Saul Greenberg

	same time synchronous	**different times** asynchronous
same place co-located	**face to face interactions**	**continuous task**
different places remote	**remote interactions**	**communication+coordination** email bulletin boards, blogs asynchronous conferencing group calendars workflow version control wikis

Space/Time Matrix

Email

- Many styles
  - threaded mail
  - intelligent mail (routing / sorting)
  - structured mail (by speech acts)
  - multimedia mail
  - object-oriented mail
  - distribution lists / elist servers

- Social
  - managing complexity and overloads
  - spam
  - archiving

Ack. Saul Greenberg

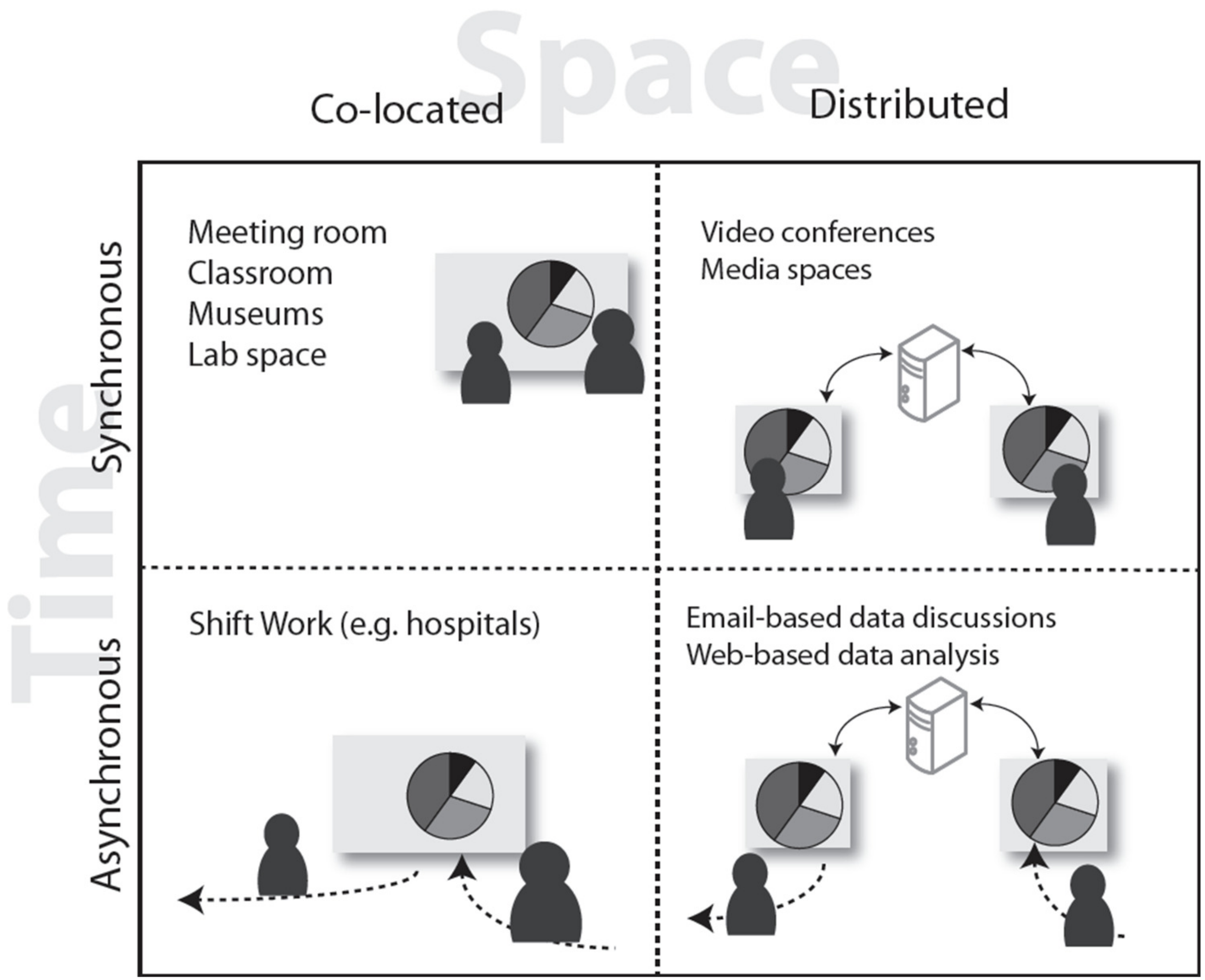
	same time synchronous	**different times** asynchronous
same place co-located	**face to face interactions**	continuous task team rooms large public displays shift work groupware project management
different places remote	**remote interactions**	**communication+coordination**

Space/Time Matrix

Information that goes across shifts

Control Rooms

Visualization/Data Analysis Spaces



	co-located	remote
concurrent synchronized *people intentionally active at the same time*	meeting rooms	video conferences, video wall, etc.
	shared work surfaces and editors, shared PCs and windows	
semi-synchronized *people active in near real time*	rapid email exchanges, delayed IM exchanges	
Mixed *may include active and serial activity*	co-authoring systems, shared calendars	
Serial *forces turntaking*	argumentation tools	
Unsynchronized people use tools at different times	email and structured messages, electronic conferences	

Modified from Figure 13.9 in Dix, Finlay, Abowd & Beale, Human Computer Interaction, 2nd Ed. Prentice Hall. 1998

Organization according to time/space is not always clean

Ack. Saul Greenberg

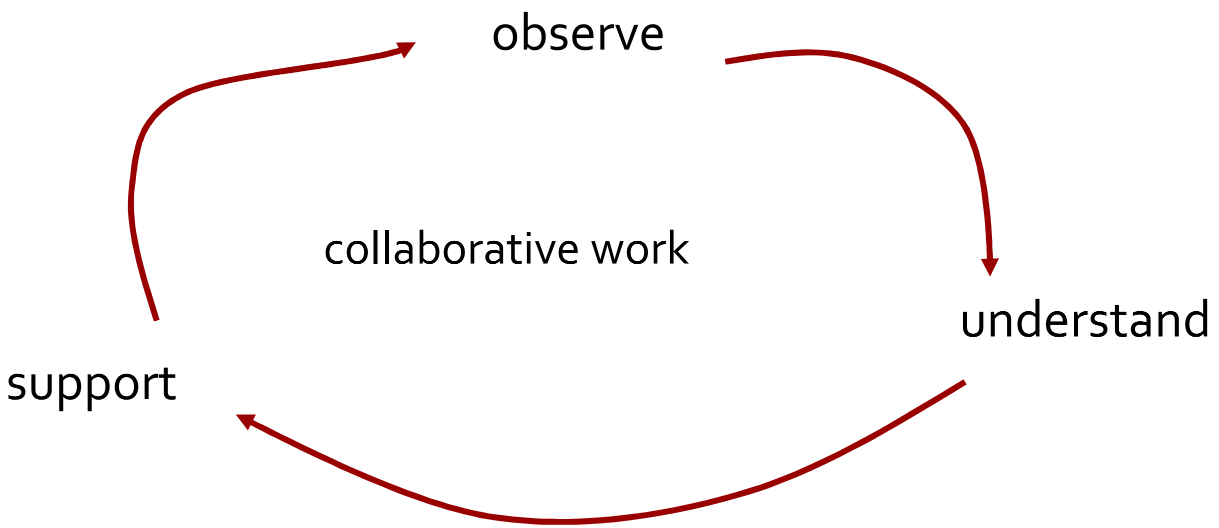
Designing & Studying CSCW Systems

- Needs of a group are different

→Should be reflected in technology

→Need to examine what IS different

→Need to understand differences



Specific Challenges

The intersection of (Visualization and CSCW)

Aspect	Specific Focus in Visualization	Specific Focus in Core CSCW
Users	multiple participants	specific data-related background
Tasks	collaborative activity-centric	information artifact-centric
Cognition	collaborative foraging	information foraging
	collaborative sensemaking	information sensemaking
Results	consensus, shared insight	insights (no actual product)
Interaction	multiple inputs	data-centric interactions
Visual Representations	multiple displays	multiple visual representations
	novel display hardware	high rendering performance
Evaluation	social interaction	analytical sensemaking

Table 1: Specific challenges and focus of collaborative visualization within the broader scope of visualization and CSCW research.

Task Analysis for Groupware Usability Evaluation … (Pinelle et al., 2003)

Motivation:

- What are the essential components to design & study?

Group activity

Taskwork vs. Teamwork

Actions needed to complete task

Actions needed to complete task as a group

Task Analysis for Groupware Usability Evaluation … (Pinelle et al., 2003)

Mechanics of Collaboration

Basic operations of teamwork - the small-scale actions and interactions that group members must carry out in order to get a task done collaboratively

Task Analysis for Groupware Usability Evaluation …
(Pinelle et al., 2003)

Mechanics of Collaboration

Explicit Communication – intentional & planned

Task Analysis for Groupware Usability Evaluation …
(Pinelle et al., 2003)

Mechanics of Collaboration

Explicit Communication – intentional & planned

Spoken Messages

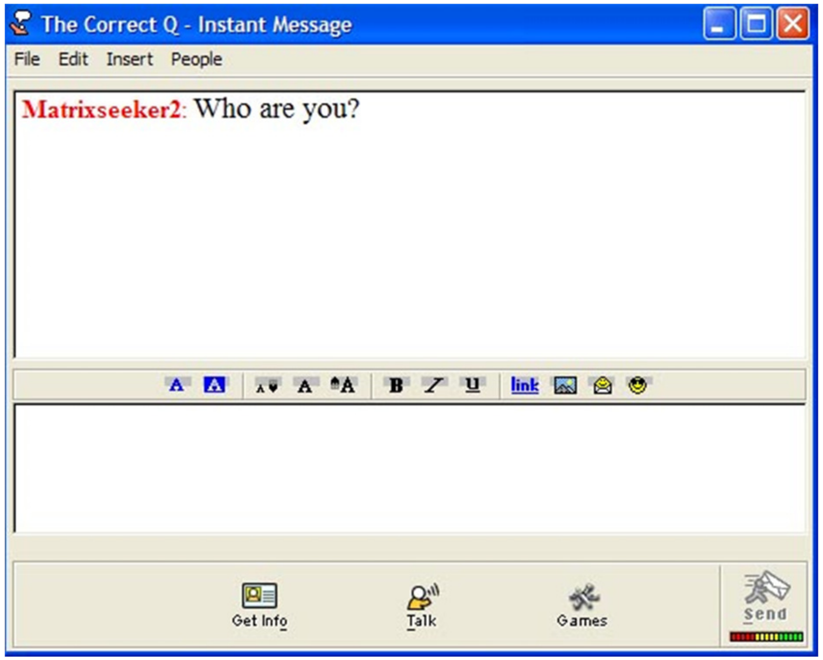
Task Analysis for Groupware Usability Evaluation … (Pinelle et al., 2003)

Mechanics of Collaboration

Explicit Communication – intentional & planned

Spoken Messages

Written Messages



Task Analysis for Groupware Usability Evaluation … (Pinelle et al., 2003)

Mechanics of Collaboration

Explicit Communication – intentional & planned

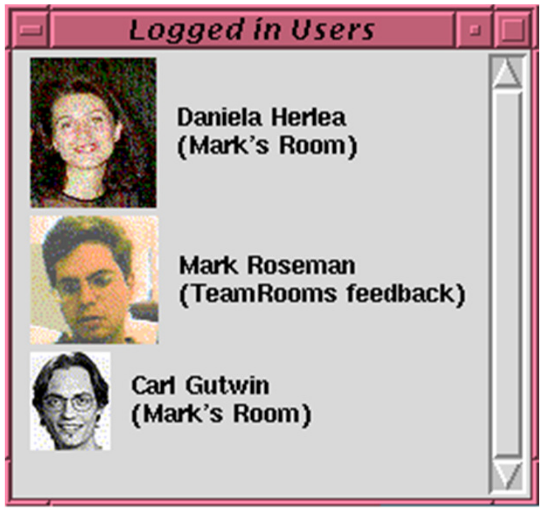
- Spoken Messages
- Written Messages
- Gestural Messages
- Deictic Messages
- Manifesting Messages

Mechanics of Collaboration

Explicit Communication – intentional & planned

Information Gathering – decoupled communication

Basic Awareness



Task Analysis for Groupware Usability Evaluation …
(Pinelle et al., 2003)

Mechanics of Collaboration

Explicit Communication – intentional & planned

Information Gathering – decoupled communication

Basic Awareness

Feedthrough

Task Analysis for Groupware Usability Evaluation … (Pinelle et al., 2003)

Mechanics of Collaboration

Explicit Communication – intentional & planned

Information Gathering – decoupled communication

- Basic Awareness
- Feedthrough
- Consequential Communication
- Overhearing
- Visual Evidence

Task Analysis for Groupware Usability Evaluation …
(Pinelle et al., 2003)

Mechanics of Collaboration

Communication

Coordination

Shared Access

- Tools
- Objects
- Space
- Time

Task Analysis for Groupware Usability Evaluation …
(Pinelle et al., 2003)

Mechanics of Collaboration

Communication

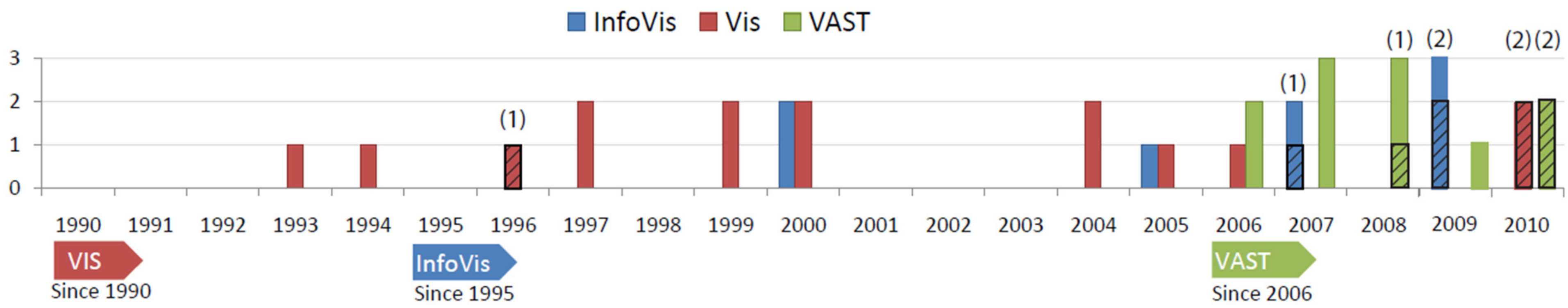
Coordination

Shared Access

Transfer

A very short history of:

COLLABORATIVE VISUALIZATION



shaded bars and (numbers): co-located collaboration

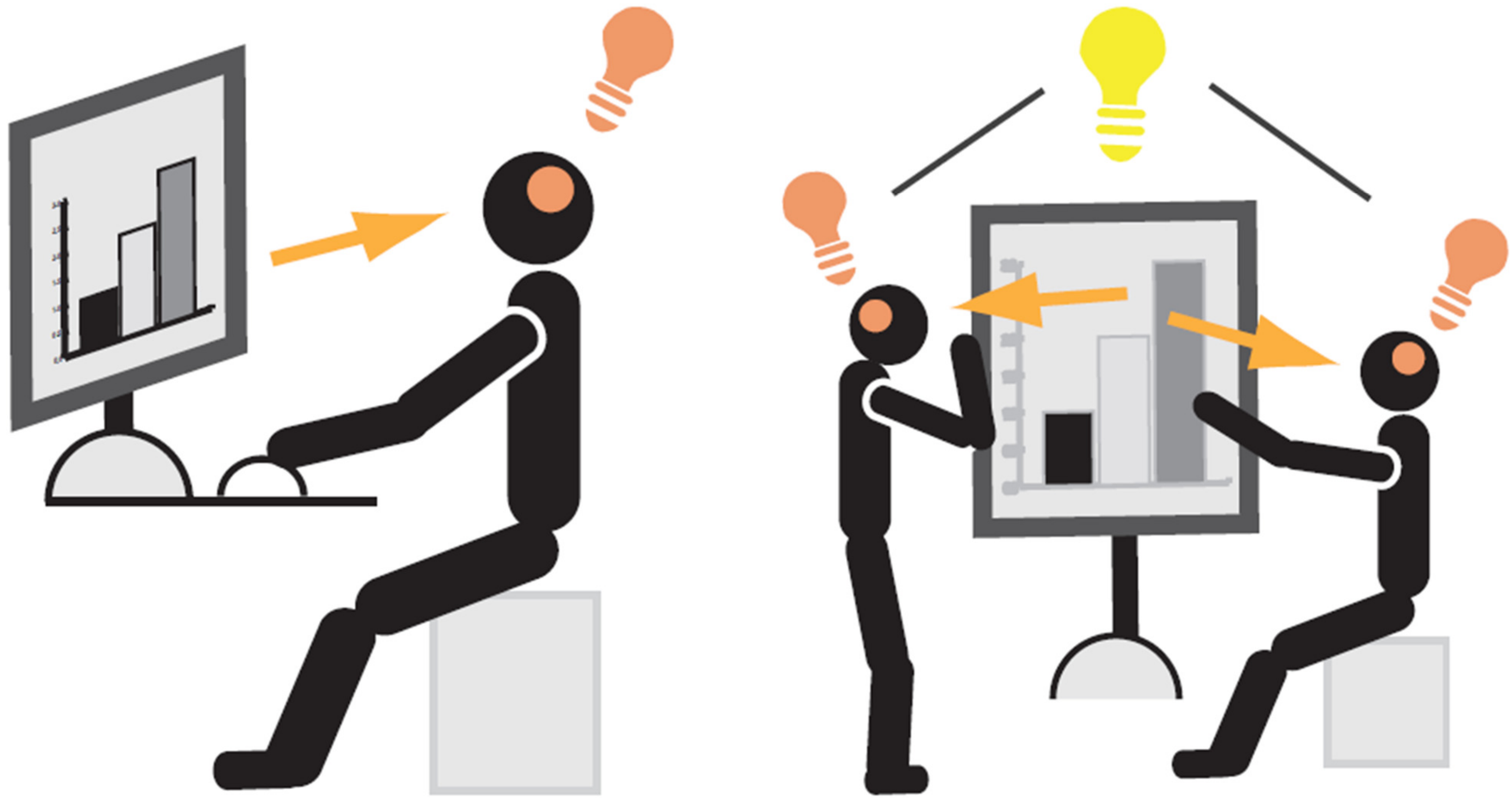
Definition

Collaborative visualization is the shared *use of computer-supported, (interactive,) visual representations of data by more than one person with the common goal of contribution to joint information processing activities.*

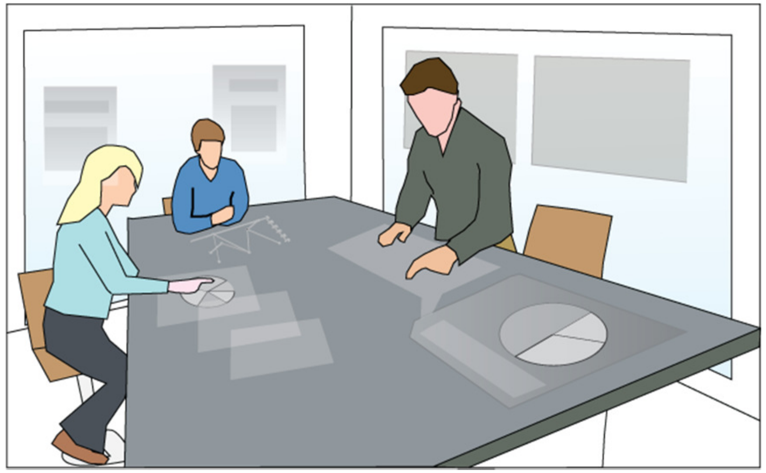
Isenberg, Elmqvist, Scholtz, Cernea, Ma, Hagen: **Collaborative Visualization: Definition, Challenges, and Research Agenda** to appear in Information Visualization: State of the Field and New Research Directions. Oct 2011

Large MT displays for:

CO-LOCATED COLLABORATIVE VISUALIZATION



Goal



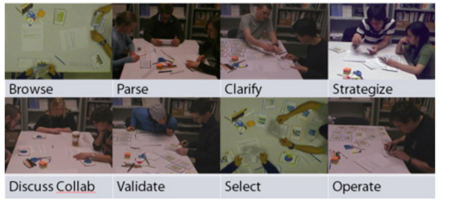
Challenges:

1. How do people conduct face-to-face analysis?
2. Do we need to redesign visualizations?
3. What data/tasks for collaborative analysis?

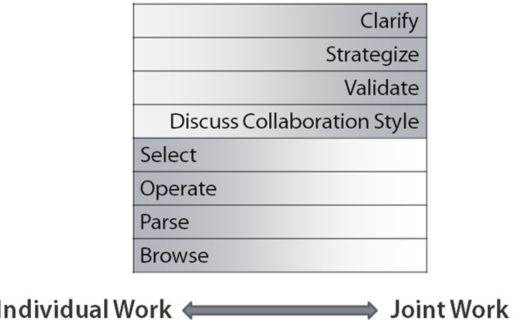
1. How do people conduct face-to-face analysis?

analysis work processes of teams

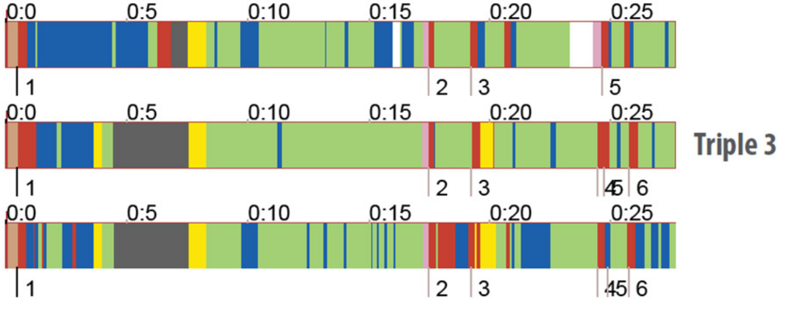
- Petra Isenberg, Anthony Tang, and Sheelagh Carpendale. **An Exploratory Study of Visual Information Analysis**. In *Proc. CHI 2008*, ACM Press.
- Identified processes



- Processes used in collaboration



- Processes used over time

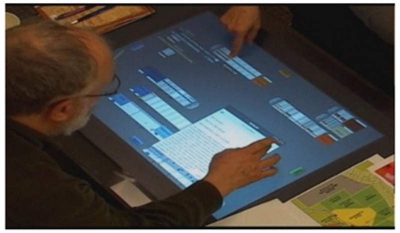


analysis work processes of teams

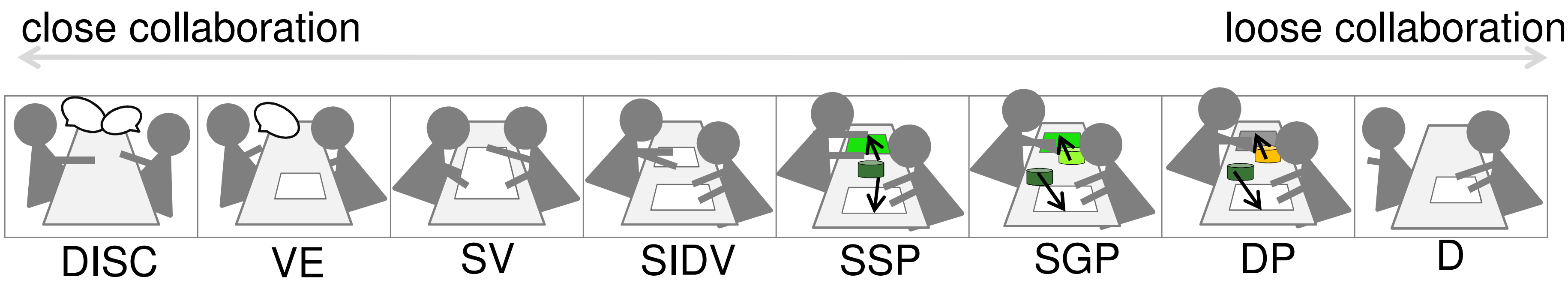
Recommendations:

1. Support flexible temporal sequence of processes
2. Support unique approaches
3. Activities differ wrt parallel/joint work

collaboration / sharing in a tabletop setting



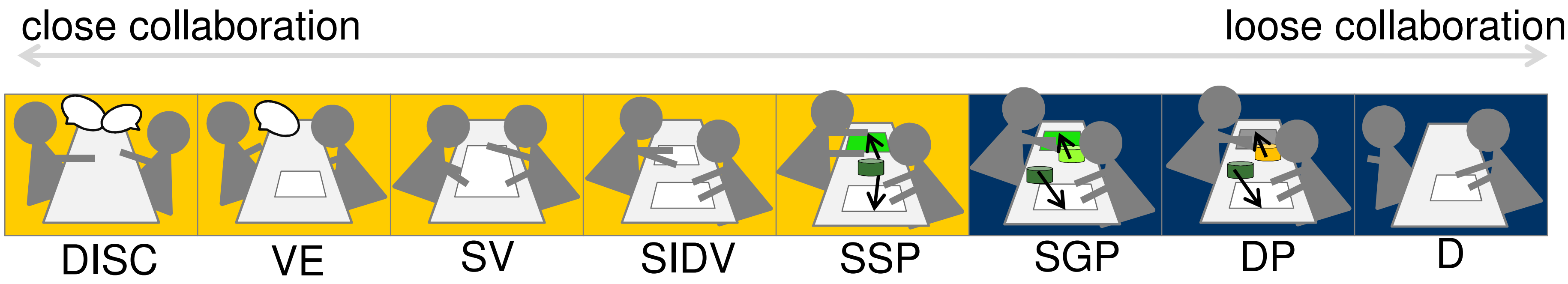
- different collaboration styles adopted
- influenced what data/views were shared
- allowed flexible investigation based on emerging information

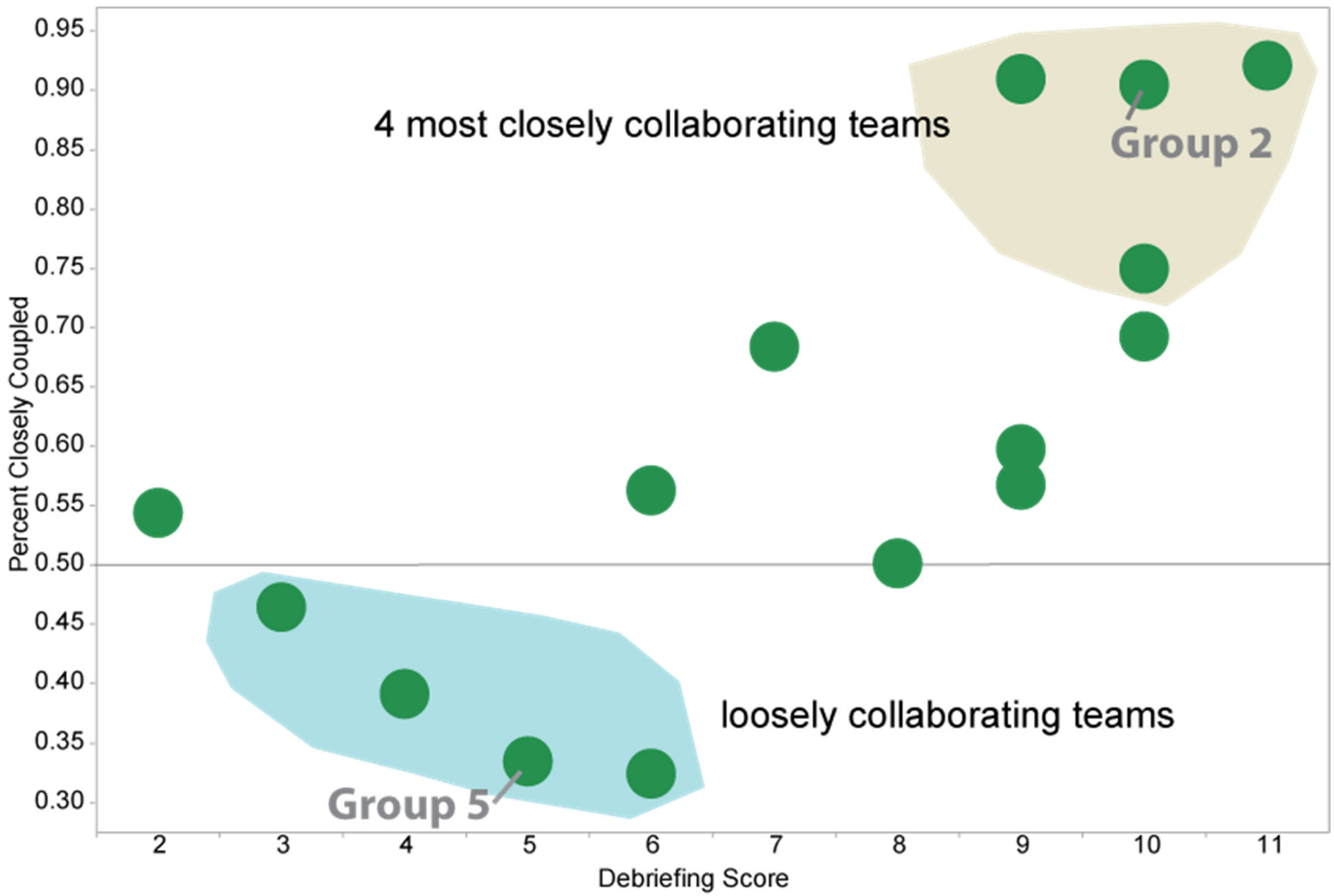


[extended fromTang et al., 2006]

Petra Isenberg, Danyel Fisher, Meredith Ringel Morris, Kori Inkpen, and Mary Czerwinski. **An Exploratory Study of Co-located Collaborative Visual Analytics around a Tabletop Display**. In *Proceedings of Visual Analytics Science and Technology (VAST)*, pages 179–186, Los Alamitos, CA, USA, 2010. IEEE

temporal analysis





4 most closely collaborating teams
Group 2
loosely collaborating teams
Group 5
Percent Closely Coupled
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
2
3
4
5
6
7
8
9
10
11
Debriefing Score

implications for design

- design for transient behavior
  - strategies change & interfaces need to accommodate
  - design system features to support different styles
- encourage closely coupled work
  - awareness features possibly not strong enough for loosely-coupled teams
  - make common information even more obvious

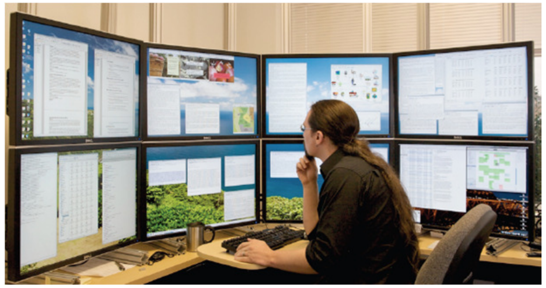
collaborative synthesis

- how do individual analysts combine results from individual analysis results?

- Results:
  - Help create common ground
  - Wide variety of organization styles (timeline, network, groups, ...)
  - Annotation/tagging important
  - Flexible organization required
  - Customization to roles required of tools

Robinson, A.C. 2008 ***Collaborative Synthesis of Visual Analytic Results***. *IEEE Visual Analytics, Science Technology Conference*. Columbus, OH, October 19-24

space to think



- how is information spatially organized on a large display (in visual analytics task)?
- Results:
  - space encodes meaning, task advancement
  - tools needed to manage information in space
  - search across space/time needed

Andrews et al., CHI 2010

Summary

- collaborative visualization requires knowledge about how people interact with one another
- teamwork != taskwork
- how people interact with one another affects how they (want to) use software

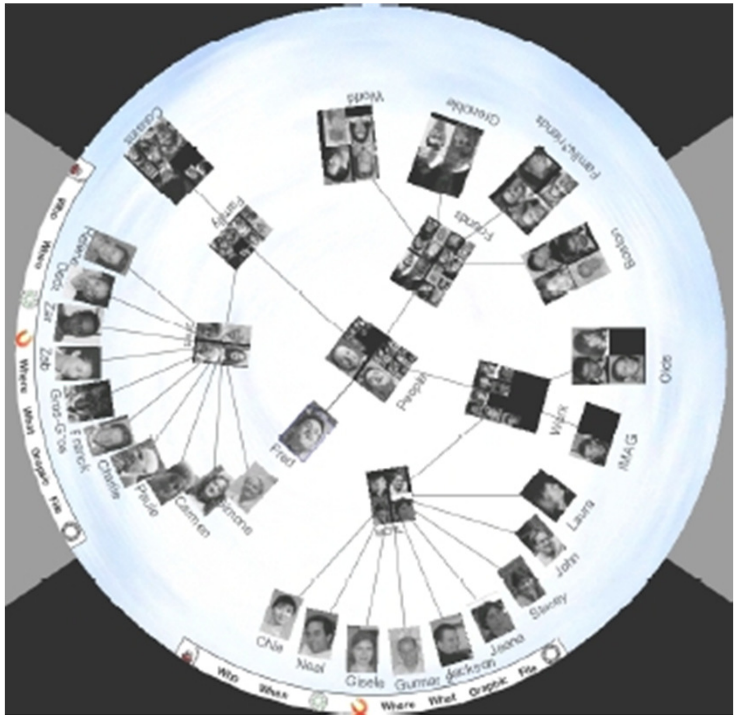
Additional resources

- Book Chapter:
  - Digital Tables for Collaborative Information Exploration. *Tabletops—Horizontal Interactive Displays*
  - Creation and collaboration: Engaging new audiences for information visualization. *Information Visualization—Human-Centered Issues and Perspectives*
- PhD Thesis (mine, Jeff Heer, Jo Wood, …)
- Overview articles (several depending on focus)

Now what about

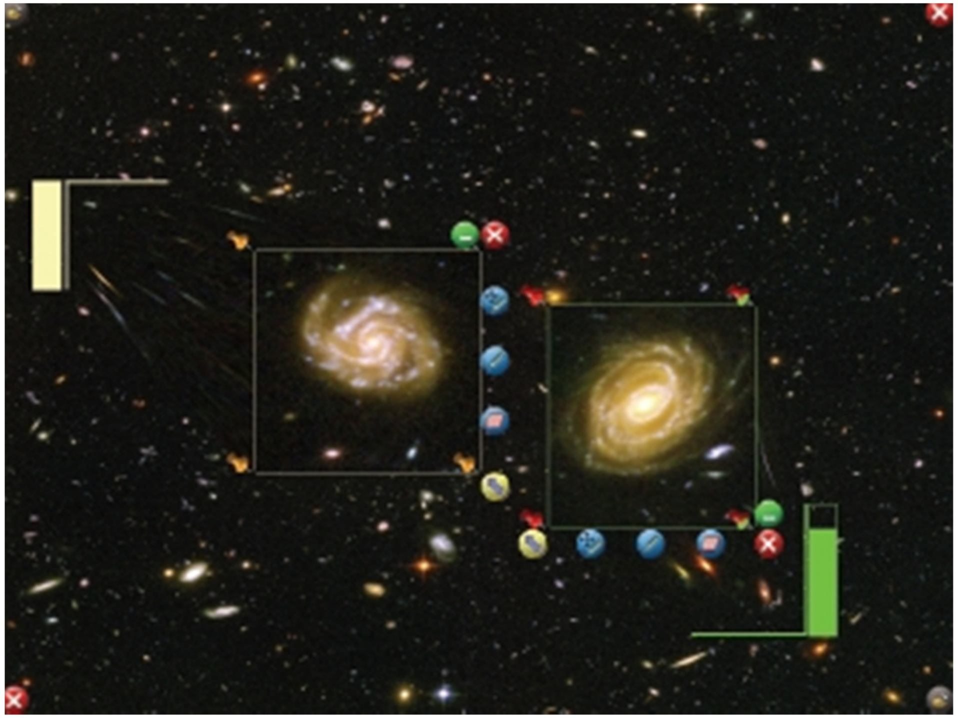
APPLICATIONS

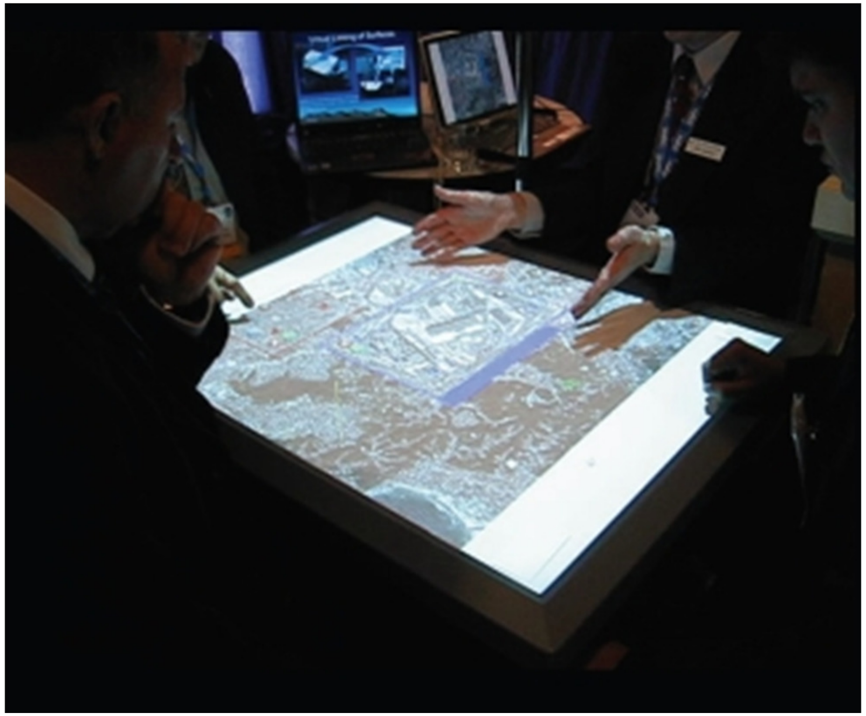
Personal Digital Historian



Shen et al., 2002

DTLens



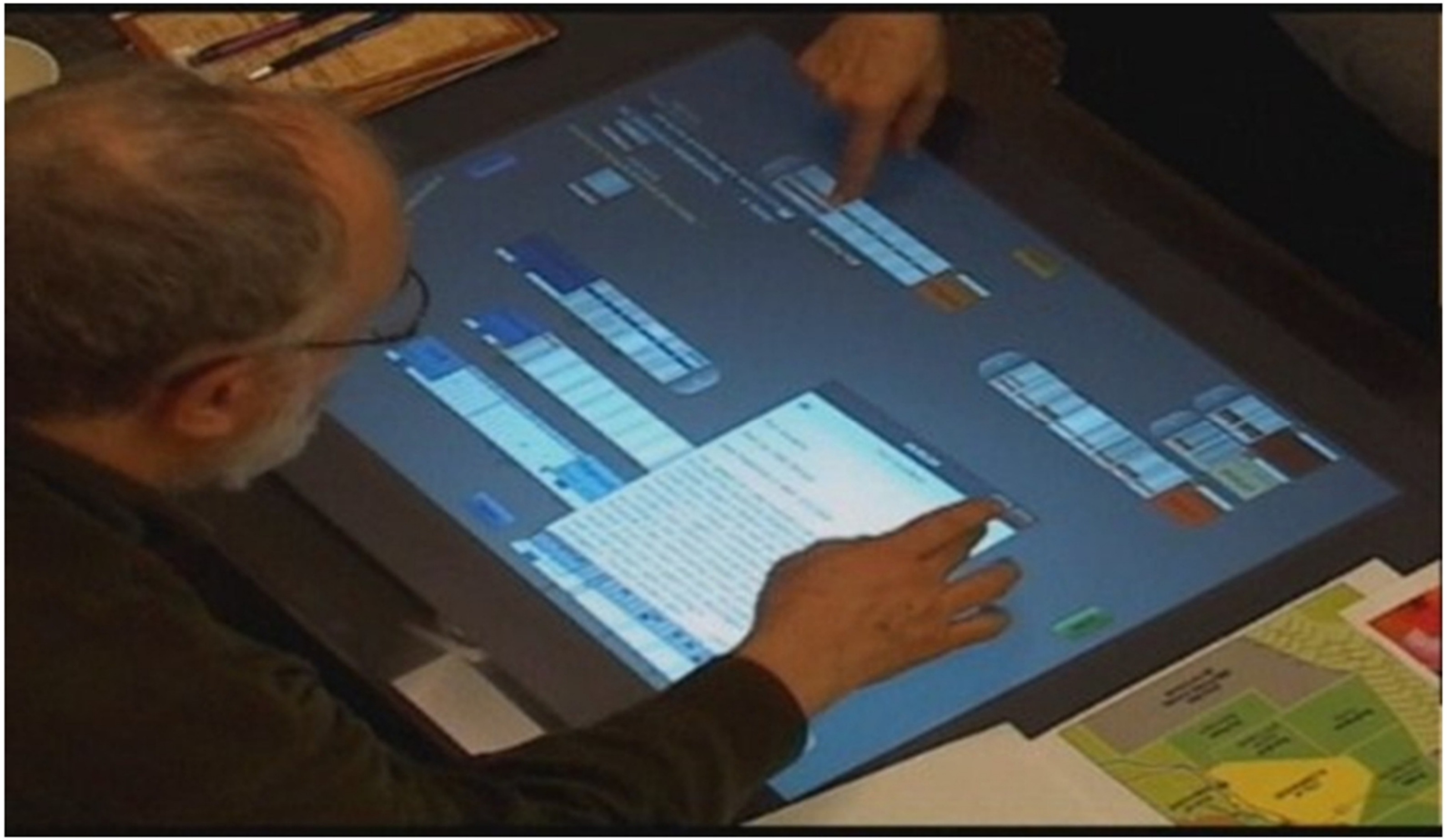


Forlines & Shen et al., 2005

Molecular Visualization

Forlines et al., 2006, 2008

Cambiera



[Isenberg & Fisher, EuroVis 2009]

EMDialog

[Hinrichs et al., InfoVis '08]

Summary

- a multitude of application areas exist for large multi-touch applications
- collaborative data analysis is one very promising one
- supporting data analysis with interactive displays is not trivial!
  - interaction challenges (MT input)
  - representation challenges (size, resolution)
  - social challenges (collaboration!)

Wrap-up

Today you learned about:

- different types of multi-touch technologies
- software frameworks
- interaction challenges
- representation challenges
- collaboration challenges

where to go from here?

engage new audiences

- multi-touch data analysis is a huge field: different needs, goals, questions, challenges exist
- go study them!

where to go from here?

make interaction a standard

- interaction is important at all stages of data analysis
- retrofitting visualization tools for multi-touch is possible but not always easy
- build tools with diverse input methods in mind from the ground up
- offer visualization toolkits which offer diverse interaction support

where to go from here?

evaluation

- evaluation of traditional interaction is already difficult
- how do we assess the value of touch or other input methods to cognition with data?
- how do we assess collaborative data analysis?
- how do we assess the added value of large-screen environments?

where to go from here?

derive higher-level understanding

- build iterative understanding of possibilities of interactive large displays for visualization, data analysis
- in a variety of audiences, spatial/temporal settings, tasks, goals, …

Petra Isenberg

INRIA

Visualization for Large Multi-touch Interactive Surfaces

Tutorial PacificVis 2011