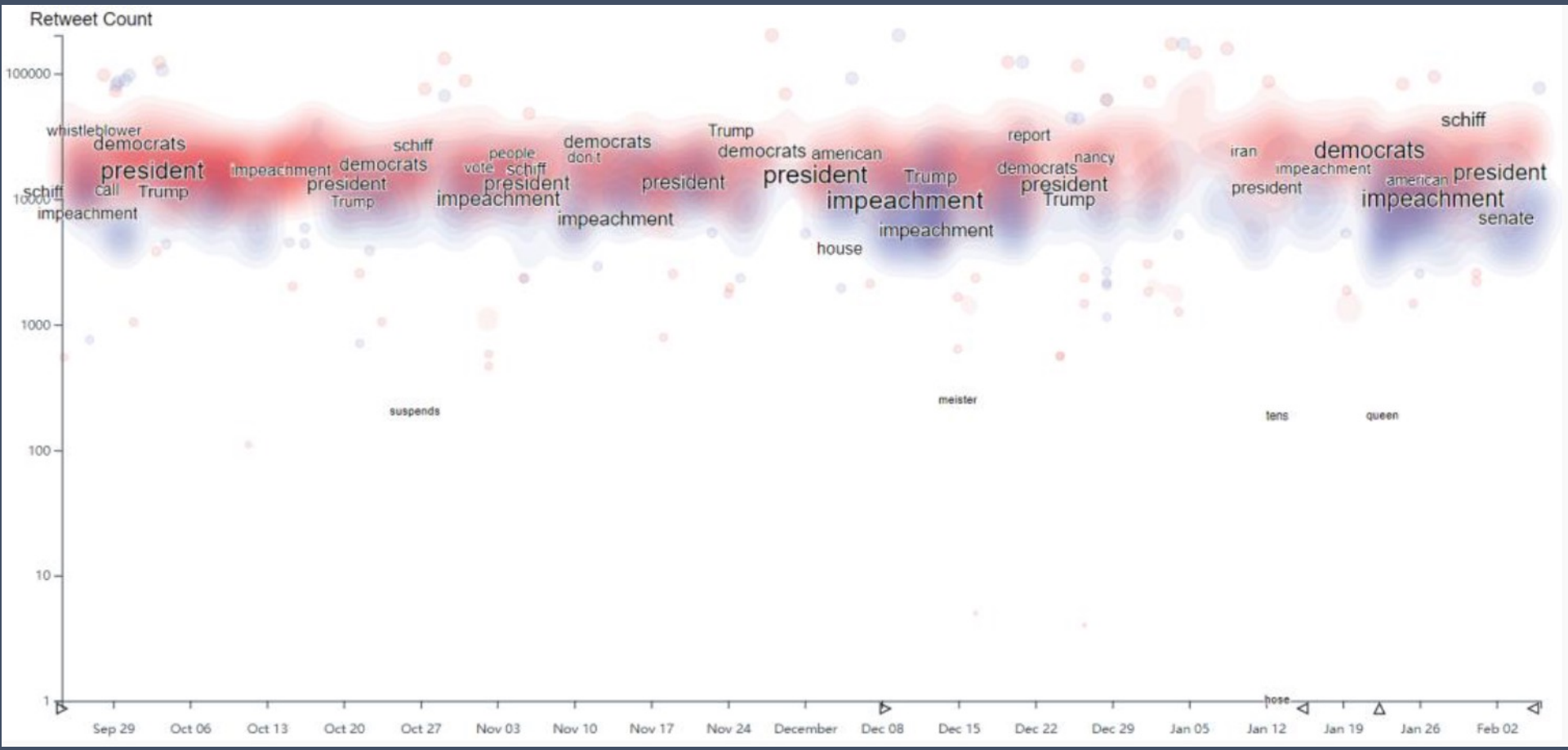
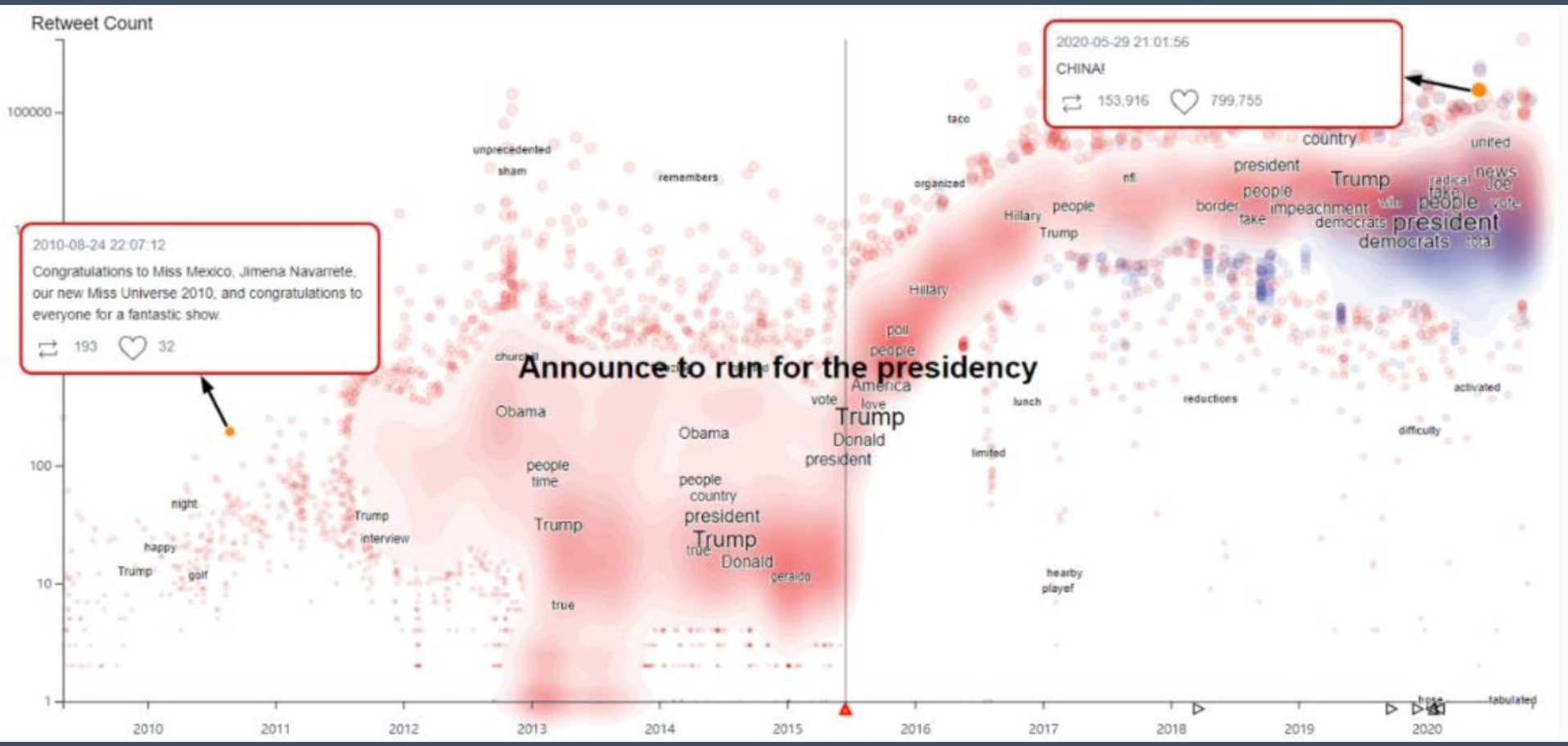
Interactive Systems

Interaction in Visualization

Lingyun Yu

Visualization




Retweet Count
100000
100
10
1
2010-08-24 22:07:12
Congratulations to Miss Mexico, Jimena Navarrete, our new Miss Universe 2010, and congratulations to everyone for a fantastic show.
193
32
2020-05-29 21:01:56
CHINA!
153,916
799,755
Announce to run for the presidency
unprecedented
sham
remembers
taco
organized
nfl
Hillary
people
Trump
border
take
impeachment
democrats
president
Trump
country
united
news
joe
vote
people
democrats
Obama
people
time
Trump
Obama
people
country
president
Trump
true
Donald
poll
people
America
vote
love
Trump
Donald
president
lunch
reductions
activated
difficulty
limited
night
Trump
interview
happy
Trump
golf
true
hearby
playef
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Retweet Count
10000
100
10
1
2015-05-27 03:21:39
Entrepreneurs. Realize that persistence can go a long way. Being stubborn is often an attribute.
187
266
2015-06-16 23:57:23
I am officially running for President of the United States. #MakeAmericaGreatAgain https://t.co/Ct0lNu7kz0
11,230
10,400
2015-06-17 03:15:54
Today I officially declared my candidacy for President of the United States. Watch the video of my full speech- https://t.co/gonTk0o9Dt
6,537
10,408
2015-06-30 20:57:28
I love the Mexican people, but Mexico is not our friend. They're killing us at the border and they're killing us on jobs and trade. FIGHT!
4,151
4,219
May 24
May 31
Jun 07
Jun 14
Jun 21
Jun 28
Jul 05
Jul 12


Retweet Count
10000
100
10
1
2020
February
March
April
May
June
July
August
September
October
2020-01-25 05:18:15
China has been working very hard to contain the Coronavirus. The United States greatly appreciates their efforts and transparency. It will all work out well. In particular, on behalf of the American People, I want to thank President Xi!
22,967 124,909
2020-02-26 15:19:49
"U.S. acted on the Coronavirus very, very quickly." Gordon Chang @IngrahamAngle
11,378 54,817
2020-03-12 02:50:10
Someone needs to tell the Democrats in Congress that CoronaVirus doesn't care what party you are in. We need to protect ALL Americans!
35,525 165,578
2020-05-28 22:34:10
All over the World the CoronaVirus, a very bad "gift" from China, marches on. Not good!
62,675 306,777
2020-10-09 02:59:59
Joe Biden has no plan for Coronavirus - ALL TALK! He was a disaster in his handling of H1N1 Swine Flu. He didn't have a clue, with his own Chief of Staff so saying. If he were in charge, perhaps 2.2 million people would have died from this much more lethal disease!
33,200 146,031

Once Upon A Time

- Sketchpad Ivan Sutherland 1963

Interactions in Visualization

- "Overview first, zoom and filter, and details on demand."
  - Ben Schneiderman

Representation and Interaction

There are two major components of visualization:

- **Representation** of objects users pay attention to, and
- **Interactions** which are operations users can apply.

Outline

- Fundamental Interaction methods
- Interaction models
- Tasks, Techniques and Devices
- Take-away Messages

Fundamental Interaction methods

Fundamental Interaction Methods

- Yi et al. (TVCG 2007)
  - Select
  - Explore
  - Reconfigure
  - Encode
  - Abstract/Elaborate
  - Filter
  - Connect

Fundamental Interaction Methods

- Yi et al. (TVCG 2007)
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Select

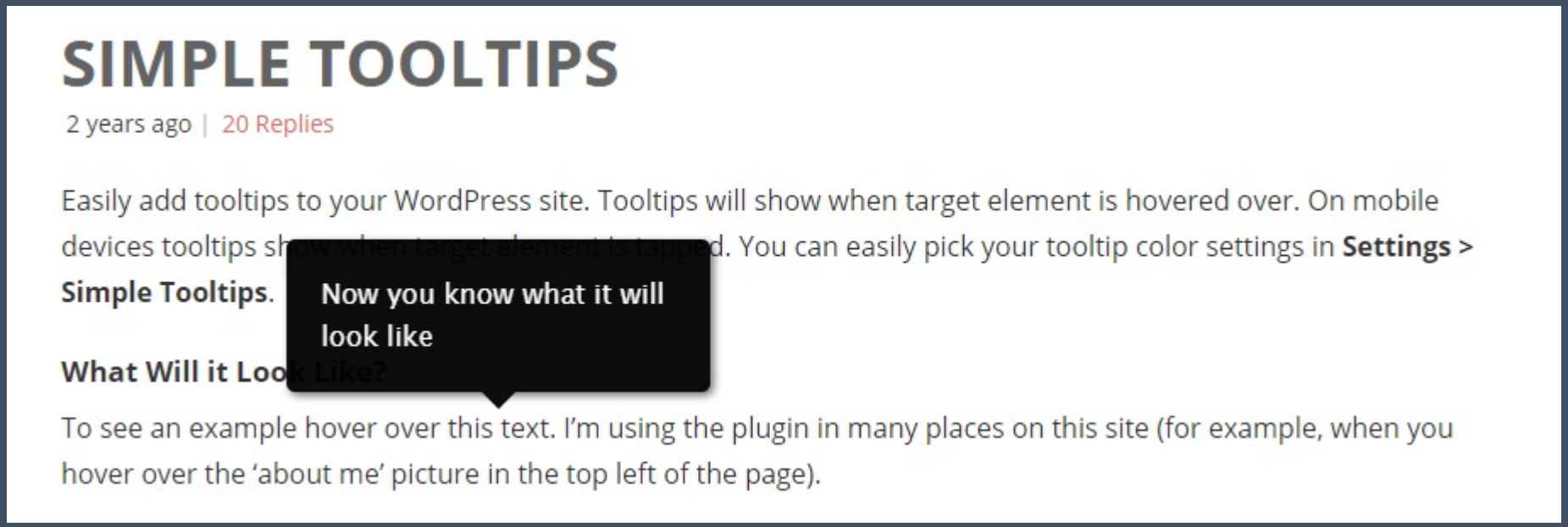
- “Mark something as interesting.”
- Mark items of interest to keep track.
- Seems to often work as a preceding action to subsequent operations.

Examples

- Select a landmark in Google Map.
- Select the Focus feature in TableLens.

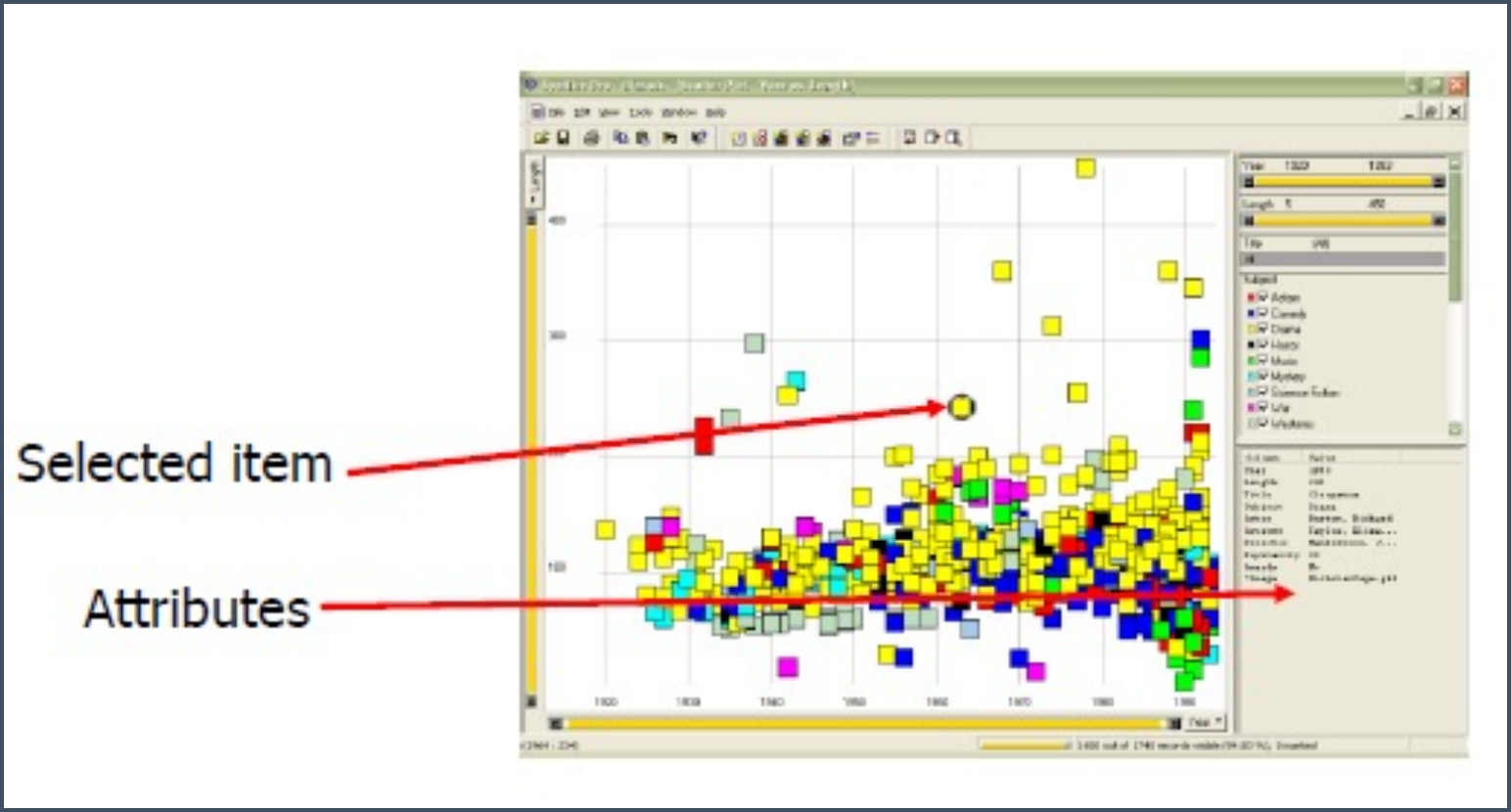
Method 1: Pop-up Tooltips

- Hovering mouse cursor brings up details of item.



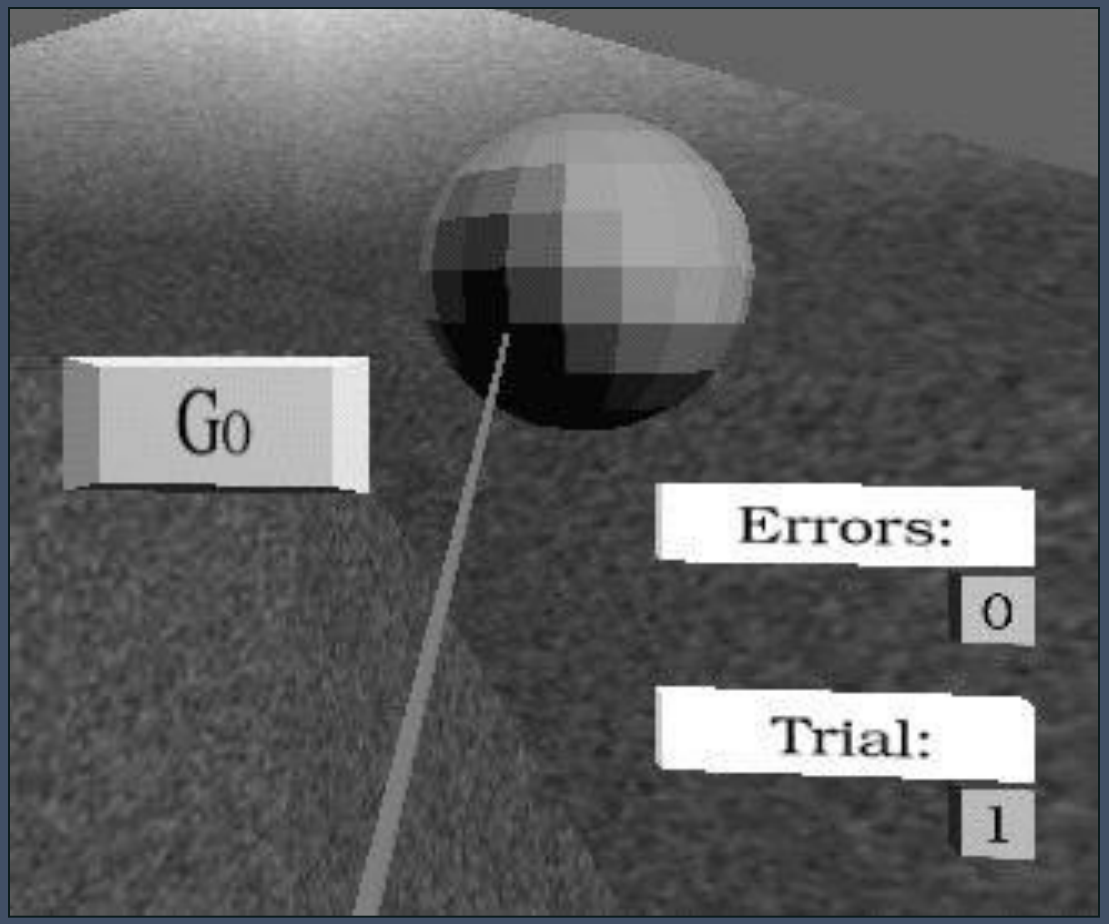
Method 2: Picking (in 2D)

- Clicking on an item on a 2D projection: selects it, attributes of the selected item are shown.



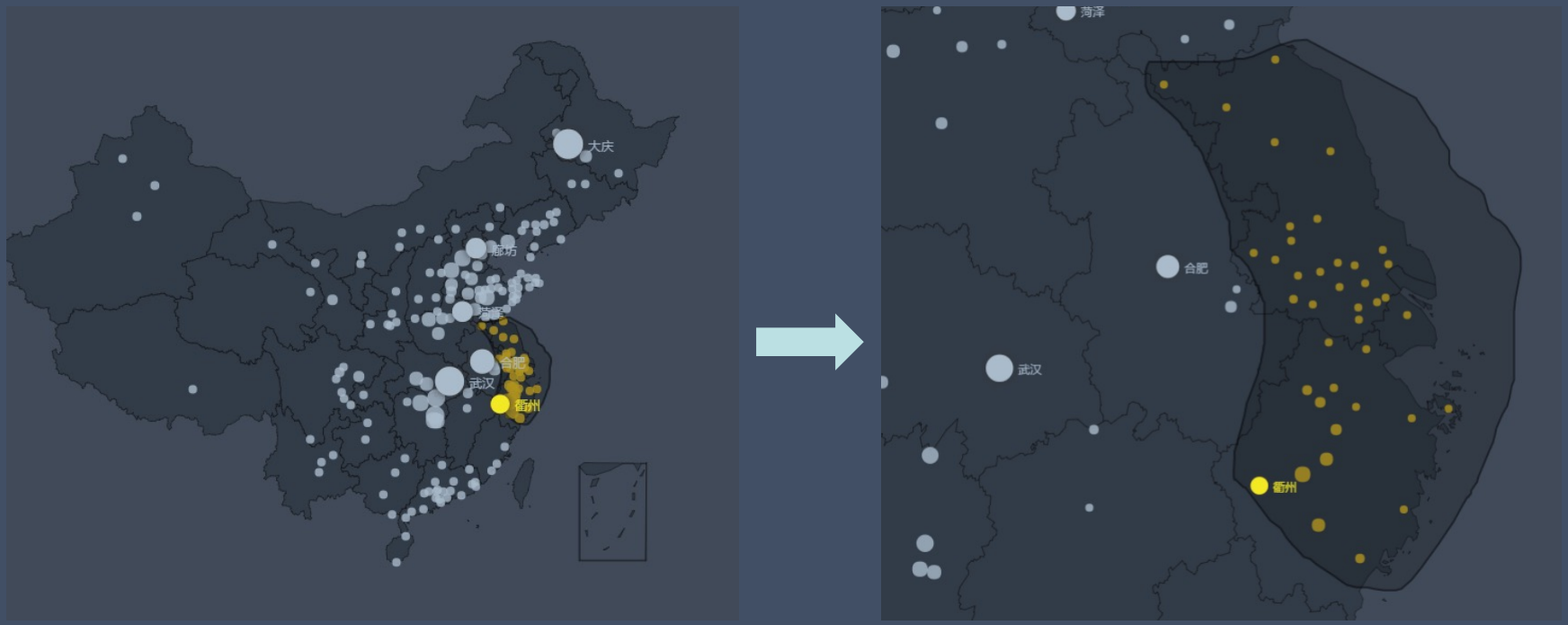
Method 2: Picking (in 3D)

- Picking an item in a 3D space:



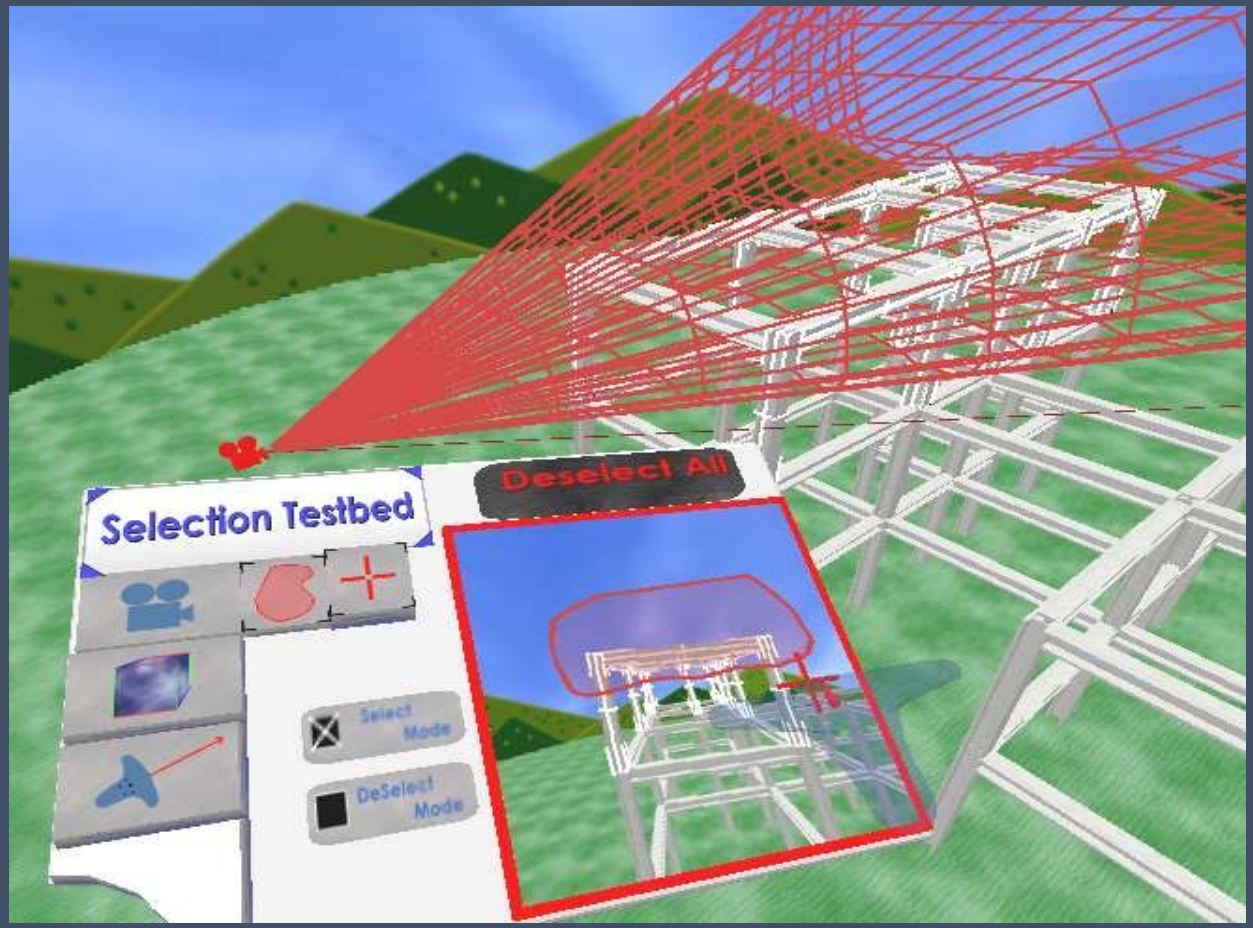
Method 3: Lasso (in 2D)

- Select a region on the map and use amplification technology to visualize clusters in the selection.



http://www.echartsjs.com/examples/#chart-type-map

Method 3: Lasso (in 3D)



Design and Evaluation of 3D Multiple Object Selection Techniques. Report, Virginia Polytechnic Institute and State University, USA, 2005.

Fundamental Interaction Methods

- Yi et al. (TVCG 2007)
  - Select
  - Explore
  - Reconfigure
  - Encode
  - Abstract/Elaborate
  - Filter
  - Connect

Explore

- "Show me something different."
  - Exploration enable users to examine a different subset of data.
  - Exploration overcome the limitation of display size.
- Examples
  - Panning in Google Earth
  - Navigation in 3D space

Direct Walk

Linkages between cases : Exploring one may lead to another.

- Follow the hyperlinks on web pages.

http://www.zju.edu.cn/

3D Navigation

https://www.youtube.com/watch?v=tI_sJuA2LWg

Fundamental Interaction Techniques

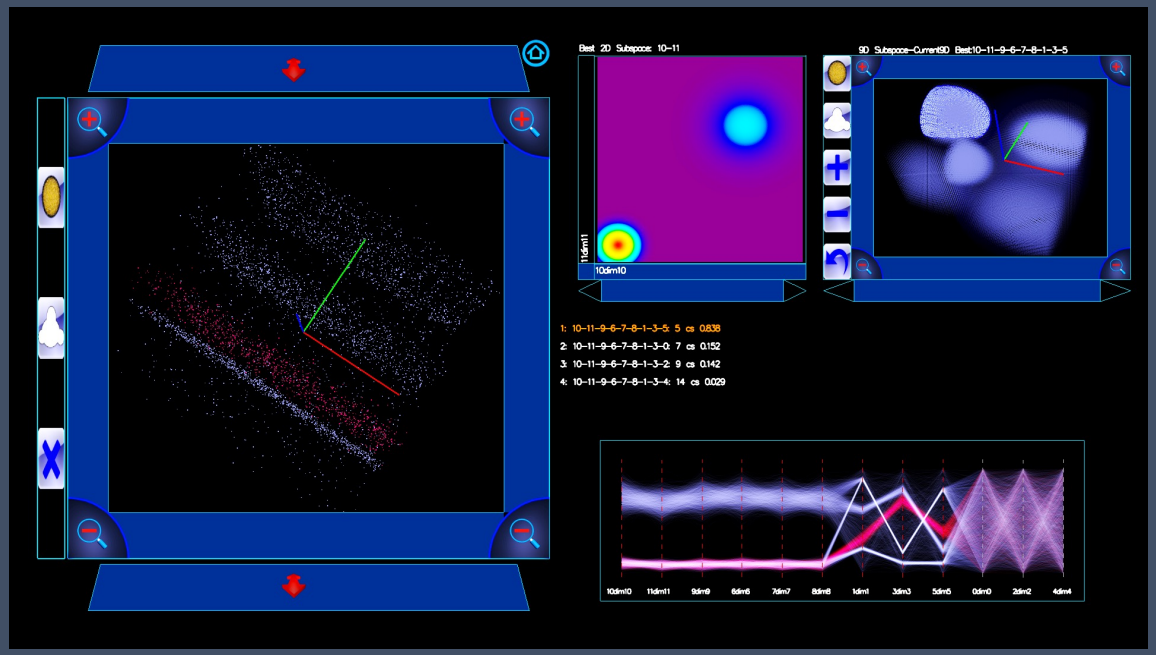
- Select
- Explore
- **Reconfigure**
- Encode
- Abstract / Elaborate
- Filter
- Connect

Reconfigure

- "Show me a different arrangement."
- Reconfiguring provides different perspectives by changing the spatial arrangement of representation.
- Examples
  - Sorting and rearranging columns in TableLens.
  - Changing the attributes in a scatter plot.

Method 1: Rearrange View

- Keep same fundamental representation and what data is being shown, but rearrange elements by:
  - Alter positioning
  - Sort



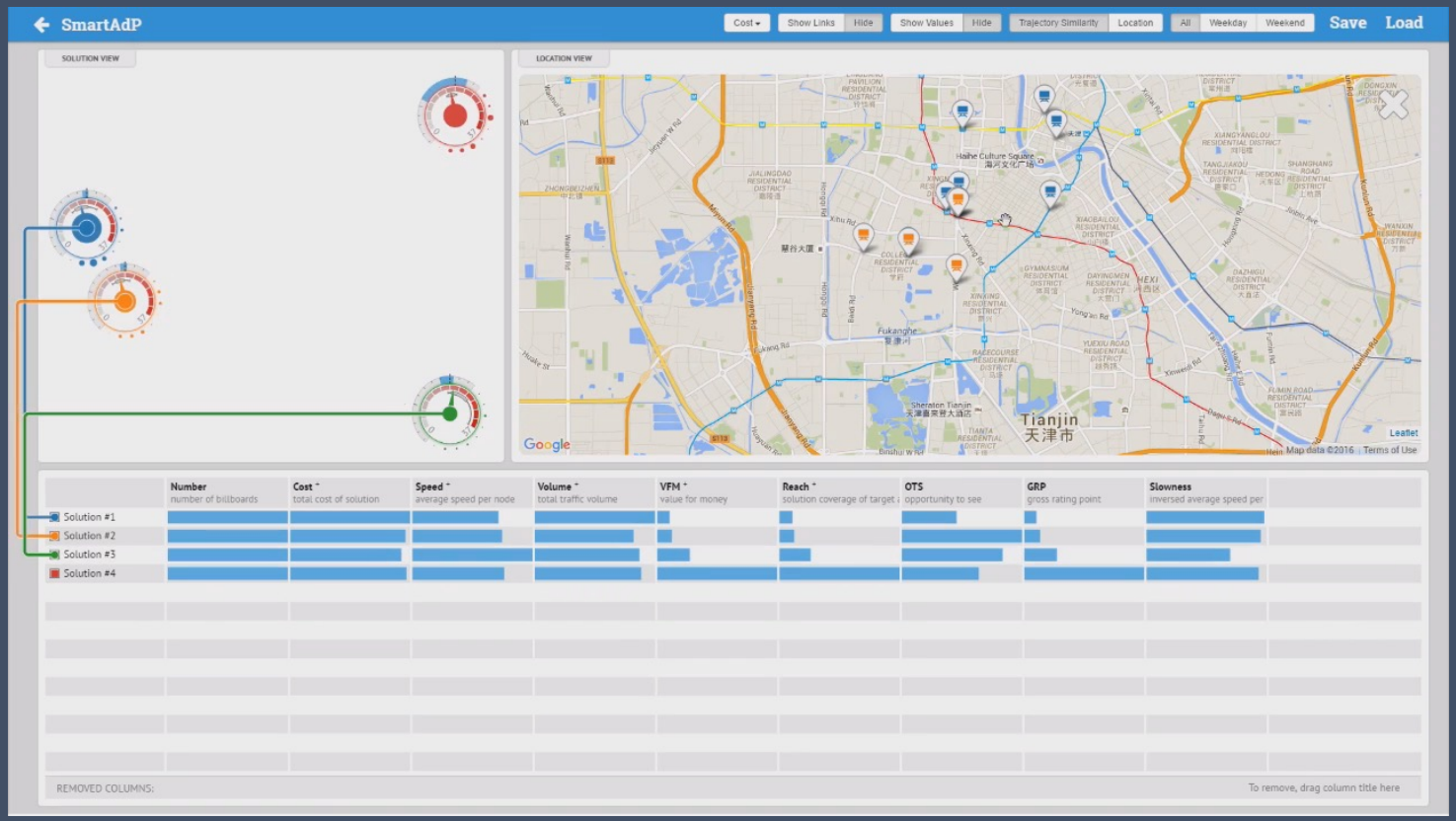
You can change the attributes in the scatter plots

You can move columns (attributes) left and right.

Touching 3D data. Interactive visualization of cosmological simulations. PhD thesis. University of Groningen.

Method 2: Sorting

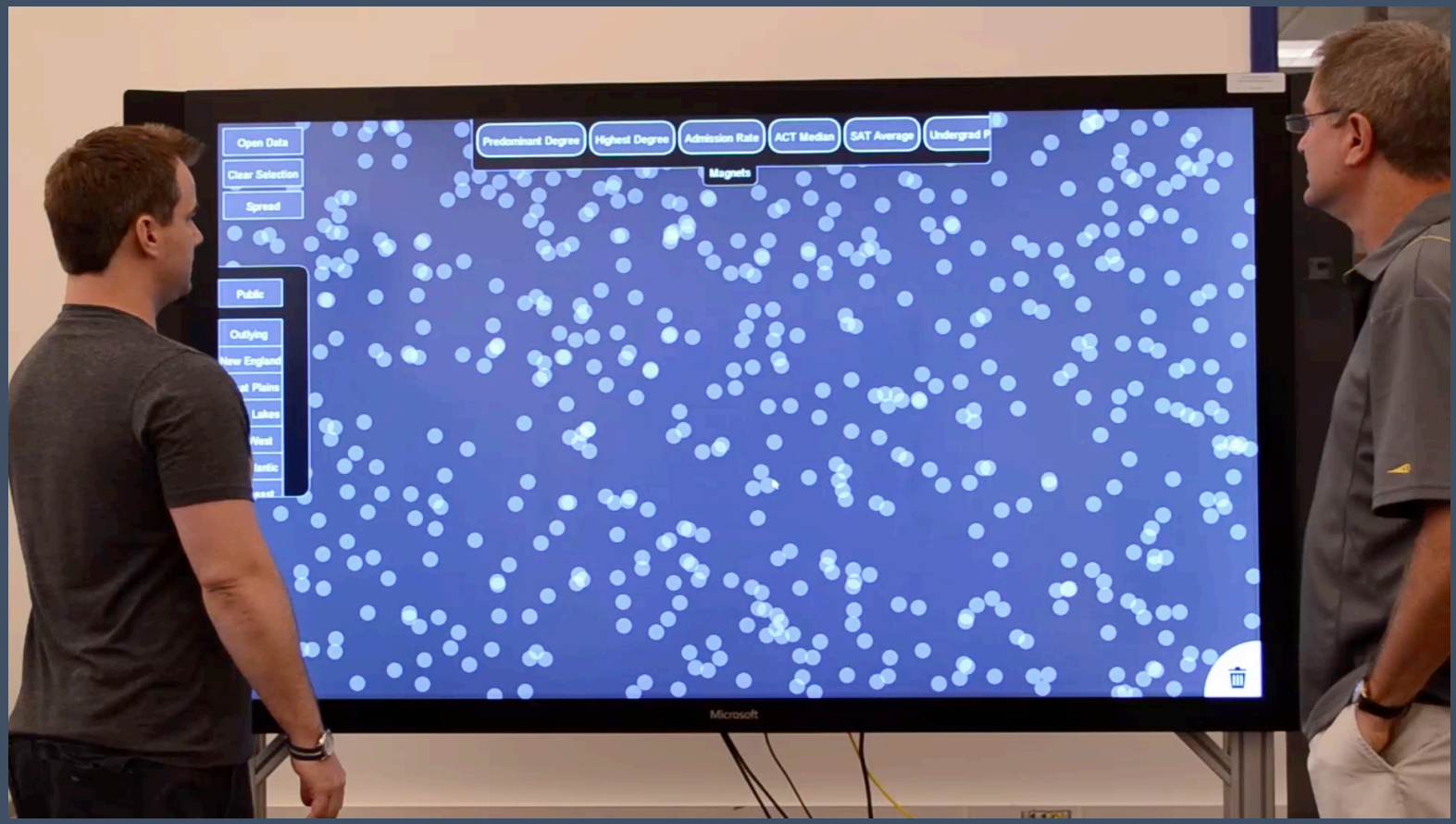
- Sort data with respect to a particular attribute.



Liu, Dongyu, et al Smartadp: Visual analytics of large-scale taxi trajectories for selecting billboard locations. IEEE TVCG 2017. https://www.youtube.com/watch?v=7vkYubflVuo

Method 3: Reposition

- Dust & Magnet



https://www.youtube.com/watch?v=laGJ4v7DEU0

Example

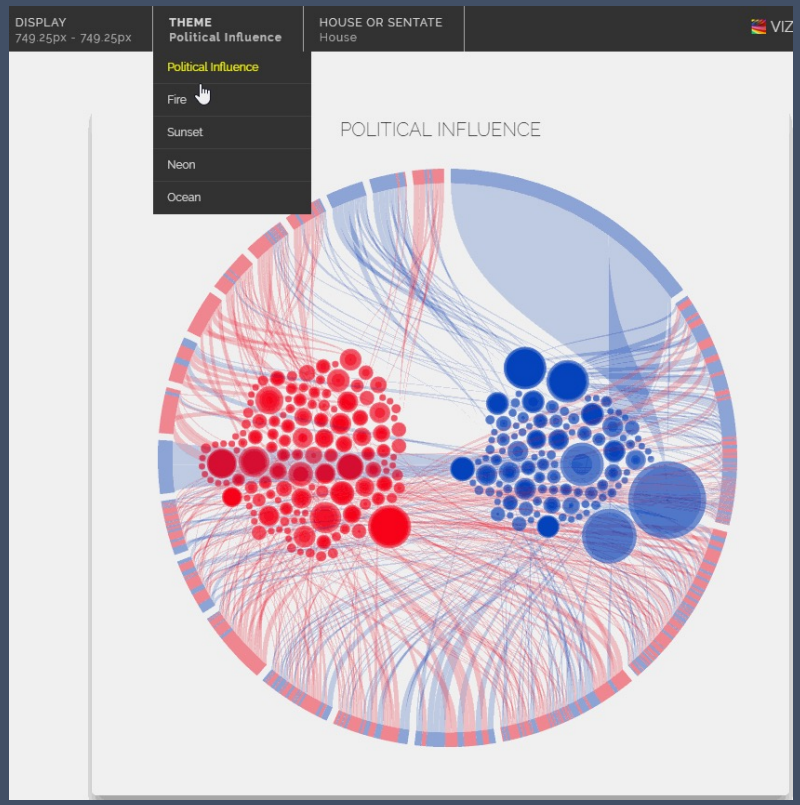
Rolling the Dice: Multidimensional Visual Exploration using Scatterplot Matrix Navigation. TVCG. 2008

Fundamental Interaction Techniques

- Select
- Explore
- Reconfigure
- **Encode**
- Abstract / Elaborate
- Filter
- Connect

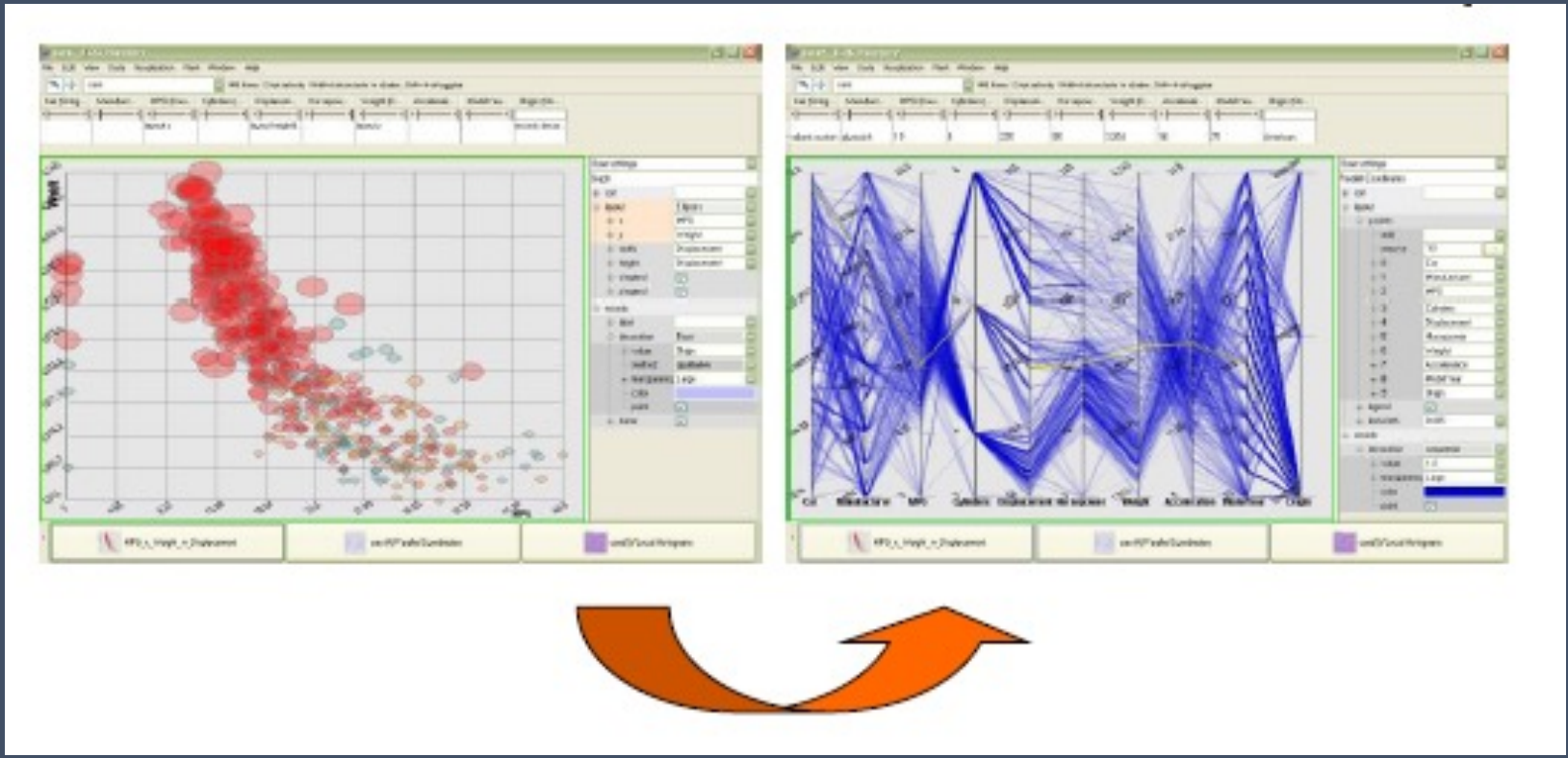
Encode

- "Show me a different representation."
- Change visual appearances.
- Examples
  - Changing color encoding
  - Changing size
  - Changing orientation
  - Changing shape



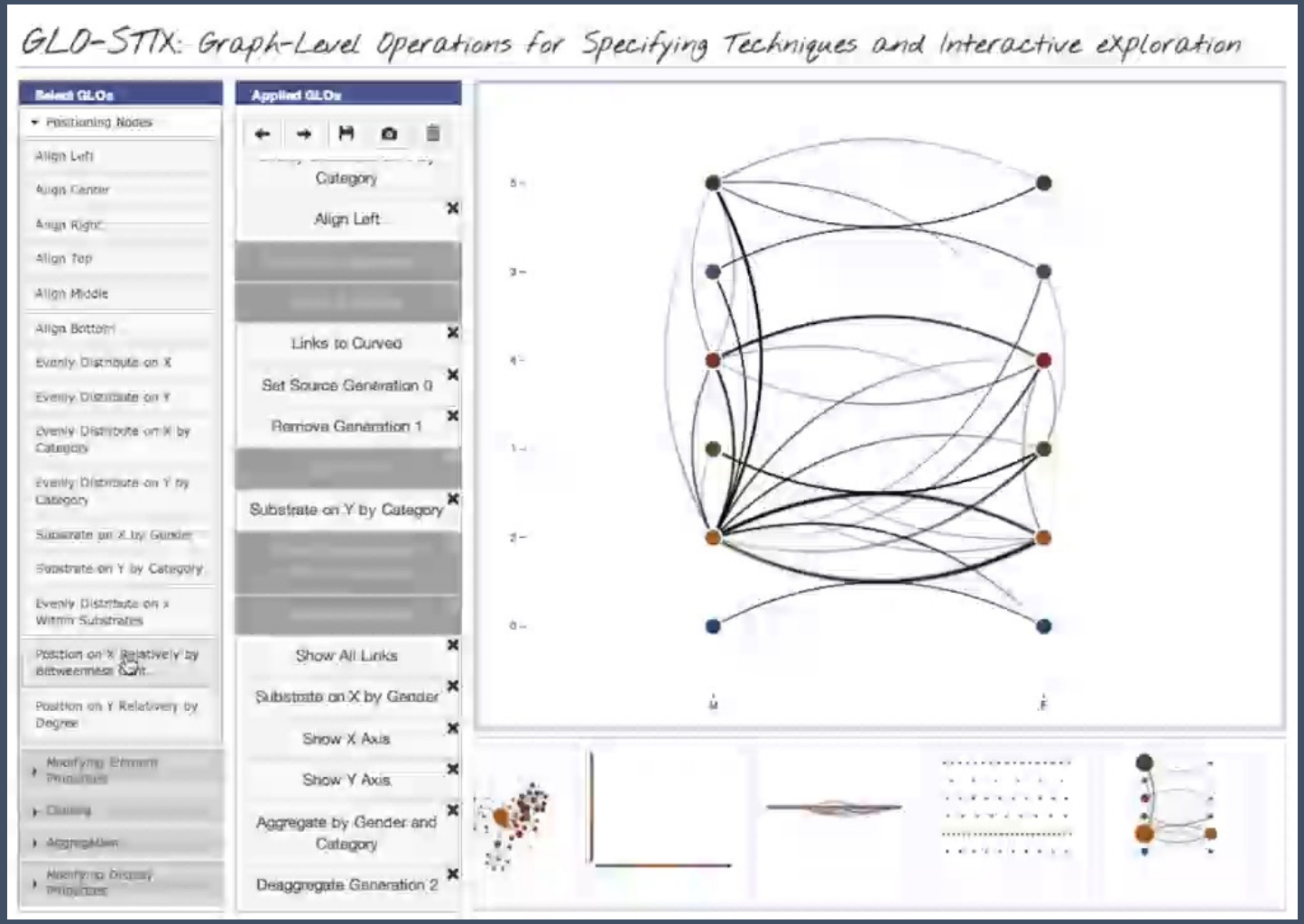
https://github.com/d3/d3/wiki/Gallery

Examples



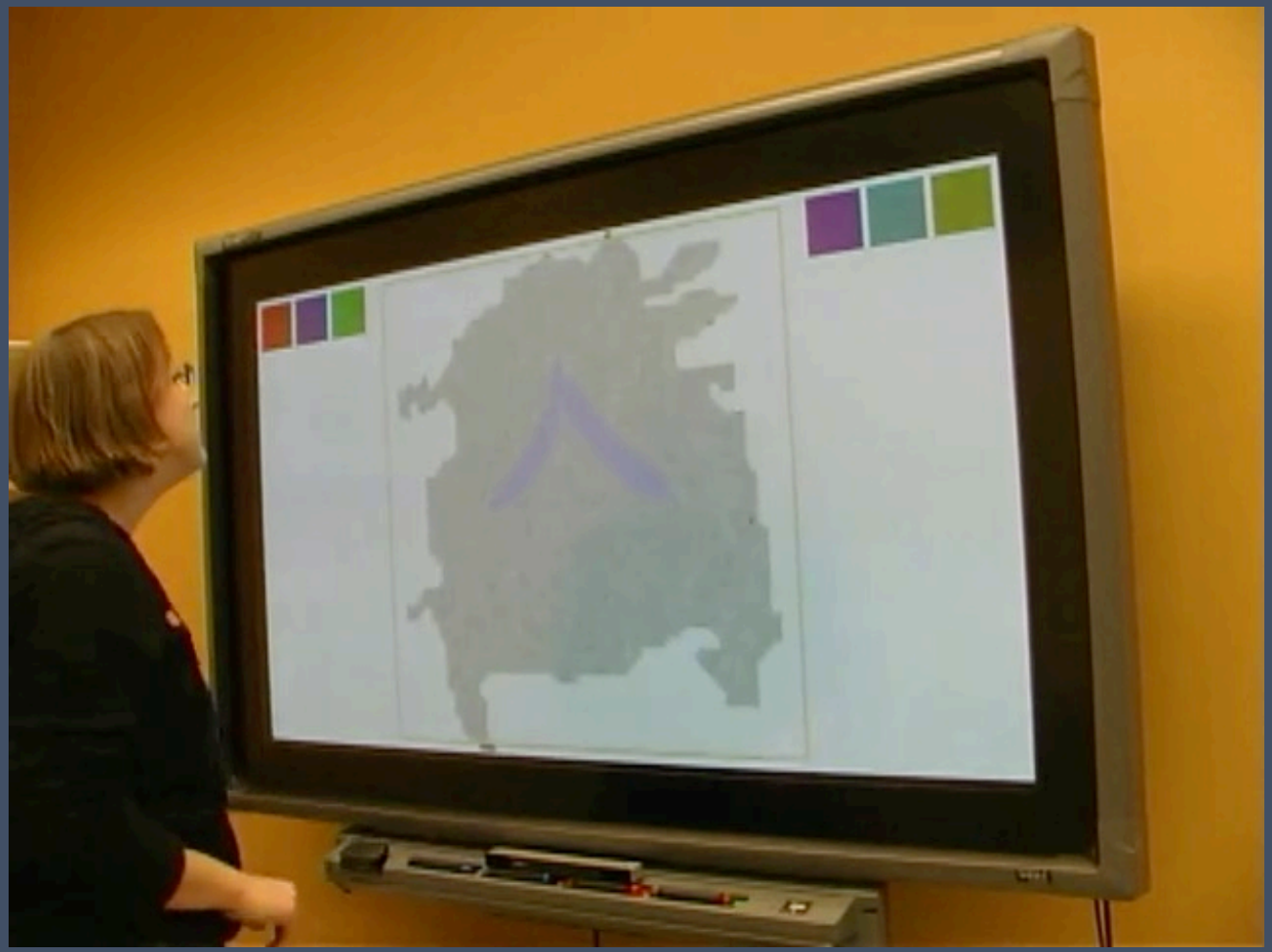
Selecting different representation from options at the bottom.

Examples



Stolper et al. Glo-stix: Graph-level operations for specifying techniques and interactive exploration. IEEE TVCG, 2014
https://www.youtube.com/watch?v=a7ZkZRU6VBM

Examples



Interactive Exploratory Visualization of 2D Vector Fields. Computer Graphics Forum, 2008
https://www.youtube.com/watch?v=yHX2__wnUJg

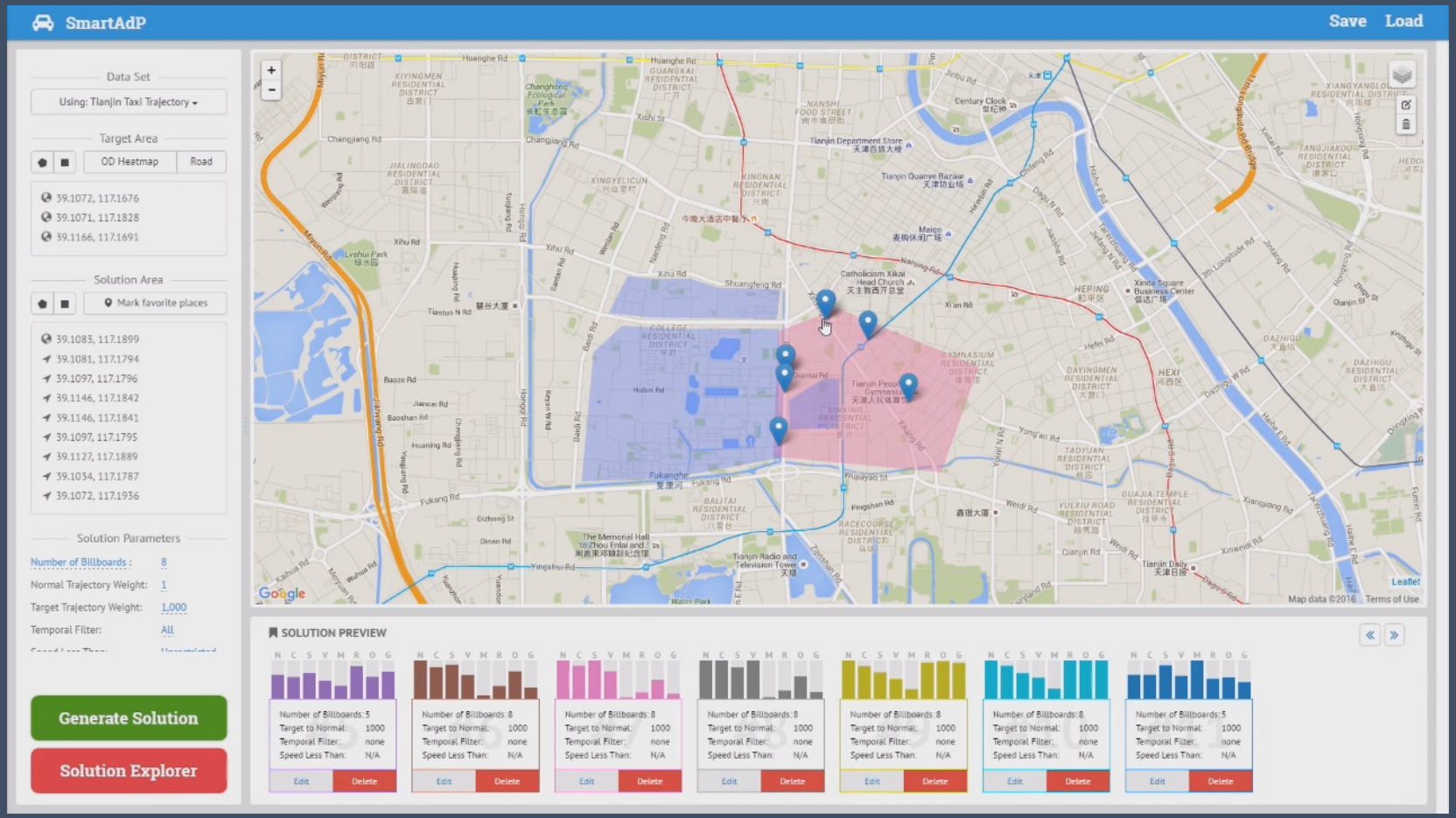
Fundamental Interaction Techniques

- Select
- Explore
- Reconfigure
- Encode
- **Abstract / Elaborate**
- Filter
- Connect

Abstract/Elaborate

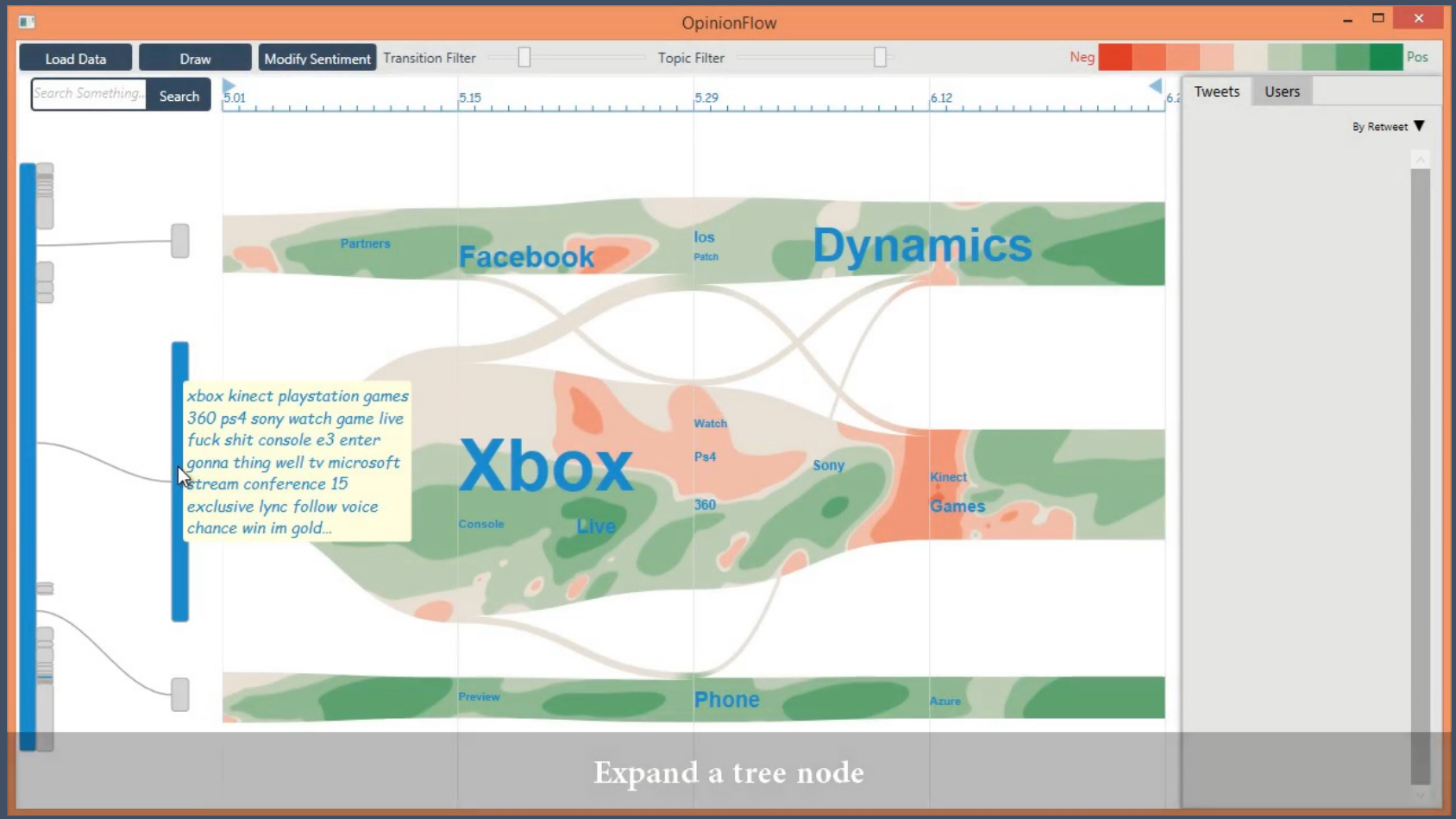
- “Show me more or less detail”.
- Adjust the level of abstraction (overview and details)
- Examples
  - Zooming (geometric zooming)
  - Unfolding sub-categories in an interactive pie chart
  - Details-on-demand

Examples



SmartAdP: Visual Analytics of Large-scale Taxi Trajectories for Selecting Billboard Locations, VAST, 2016

Examples



OpinionFlow: Visual Analysis of Opinion Diffusion on Social Media, TVCG, 2014

Fundamental Interaction Techniques

- Select
- Explore
- Reconfigure
- Encode
- Abstract / Elaborate
- **Filter**
- Connect

Filter

- “Show me something conditionally.”
- Change the set of data items being presented based on some specific conditions.
- Examples
  - Dynamic query

Dynamic Query

- Probably best-known and one of most useful infovis techniques
- Let's explore more details...

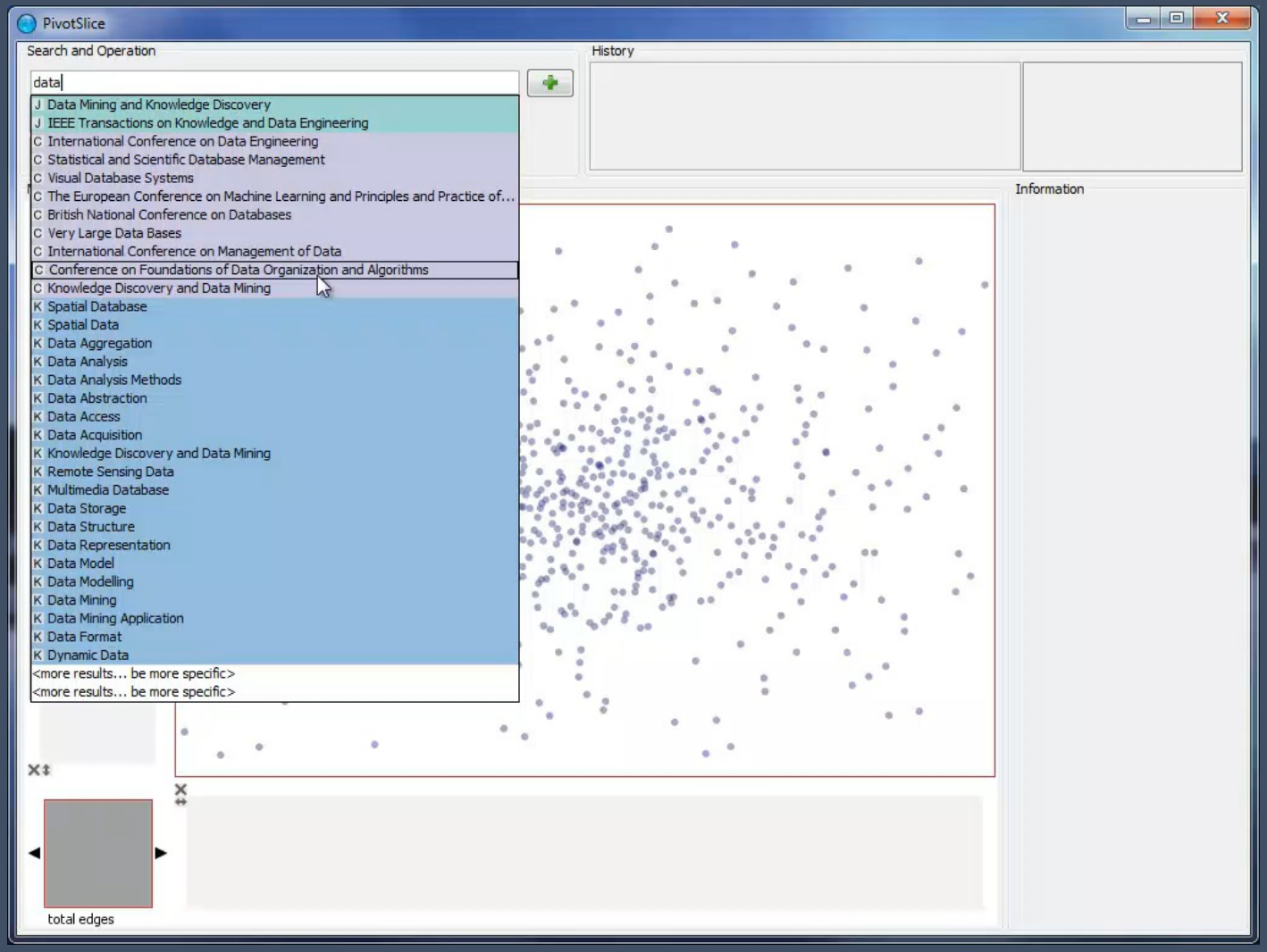
DB Query

Query language
- **Select** house-address
  From atl-realty-db
  Where price >= 200,000 **and**
  price <= 400,000 **and**
  bathrooms >= 3 **and**
  garage == 2 **and**
  bedrooms >= 4

Usually we will get

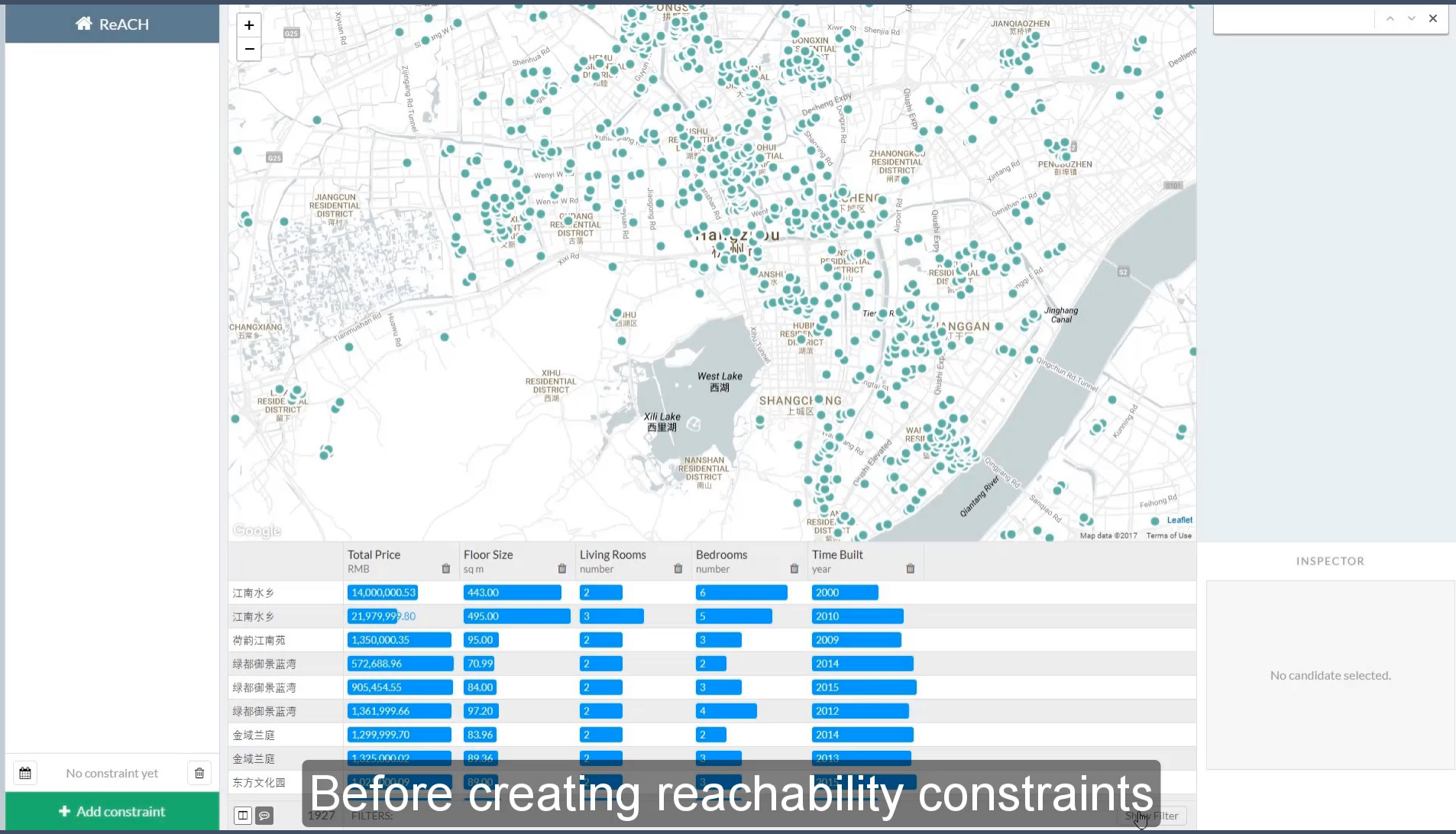
- 124 hits found
  - 1. 748 Oak St. - a beautiful ...
  - 2. 623 Pine Ave. -
  - ...
- 0 hits found

Dynamic Query

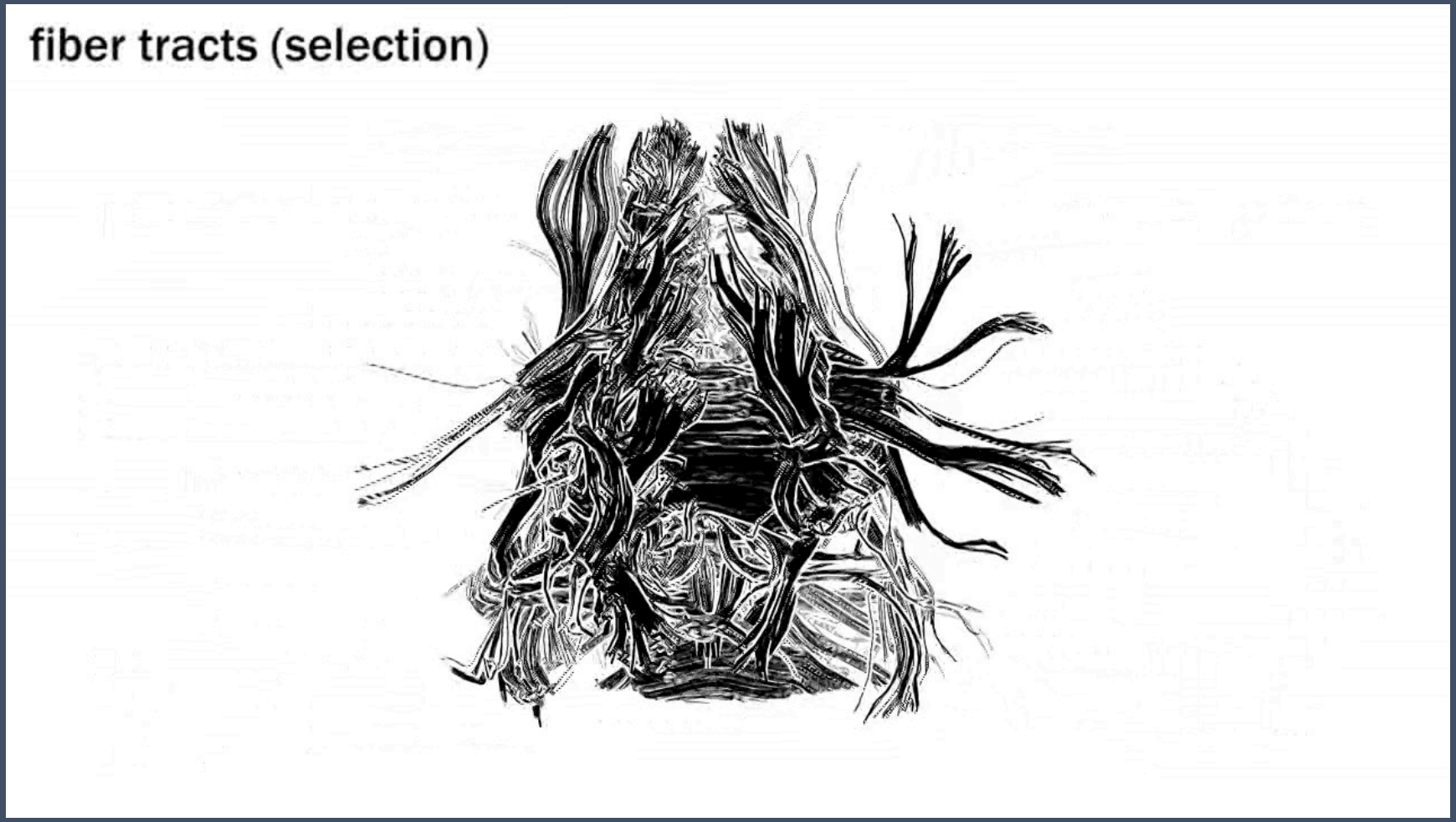


http://vialab.science.uoit.ca/portfolio/pivotslice

Example


ReACH
No constraint yet
Add constraint
West Lake
西湖
Xili Lake
西里湖
Qiantang River
Jinghang Canal
Leaflet
Map data ©2017
Terms of Use
Total Price
RMB
Floor Size
sq m
Living Rooms
number
Bedrooms
number
Time Built
year
江南水乡 14,000,000.53 443.00 2 6 2000
江南水乡 21,979,999.80 495.00 3 5 2010
荷韵江南苑 1,350,000.35 95.00 2 3 2009
绿都御景蓝湾 572,688.96 70.99 2 2 2014
绿都御景蓝湾 905,454.55 84.00 2 3 2015
绿都御景蓝湾 1,361,999.66 97.20 2 4 2012
金域兰庭 1,299,999.70 83.96 2 2 2014
金域兰庭 1,325,000.02 89.36 2 3 2013
1927
FILTERS:
INSPECTOR
No candidate selected.
Before creating reachability constraints

Example



Depth-Dependent Halos: Illustrative Rendering of Dense Line Data. IEEE Transactions on Visualization and Computer Graphics, 15(6):1299–1306, November/December 2009.

Fundamental Interaction Techniques

- Select
- Explore
- Reconfigure
- Encode
- Abstract / Elaborate
- Filter
- **Connect**

Connect

- “Show me related items.”
- Highlight associations and relationships.
- Show hidden data items that are relevant to a specified item.
- Examples:
  - Highlighting directly connected nodes
  - Brushing

Linked Views

- Viewer may wish to examine different attributes of a data case simultaneously.
- Alternatively, viewer may wish to view data case under different perspectives or representations.
- But need to keep straight where the data case is.

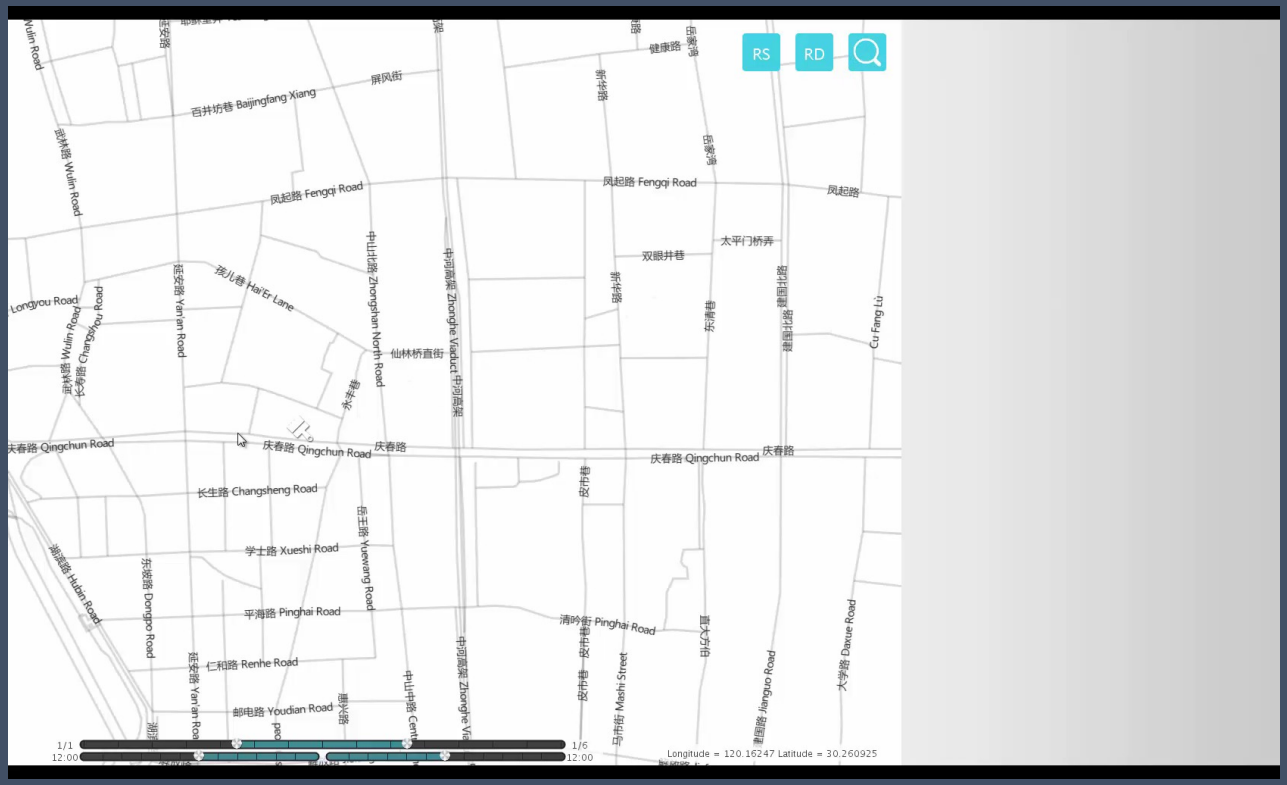
Linked Views

- Very common technique in InfoVis
- Applies when you have multiple views about the same data

Selecting or brushing a case in one view generates highlighting the case in the other views

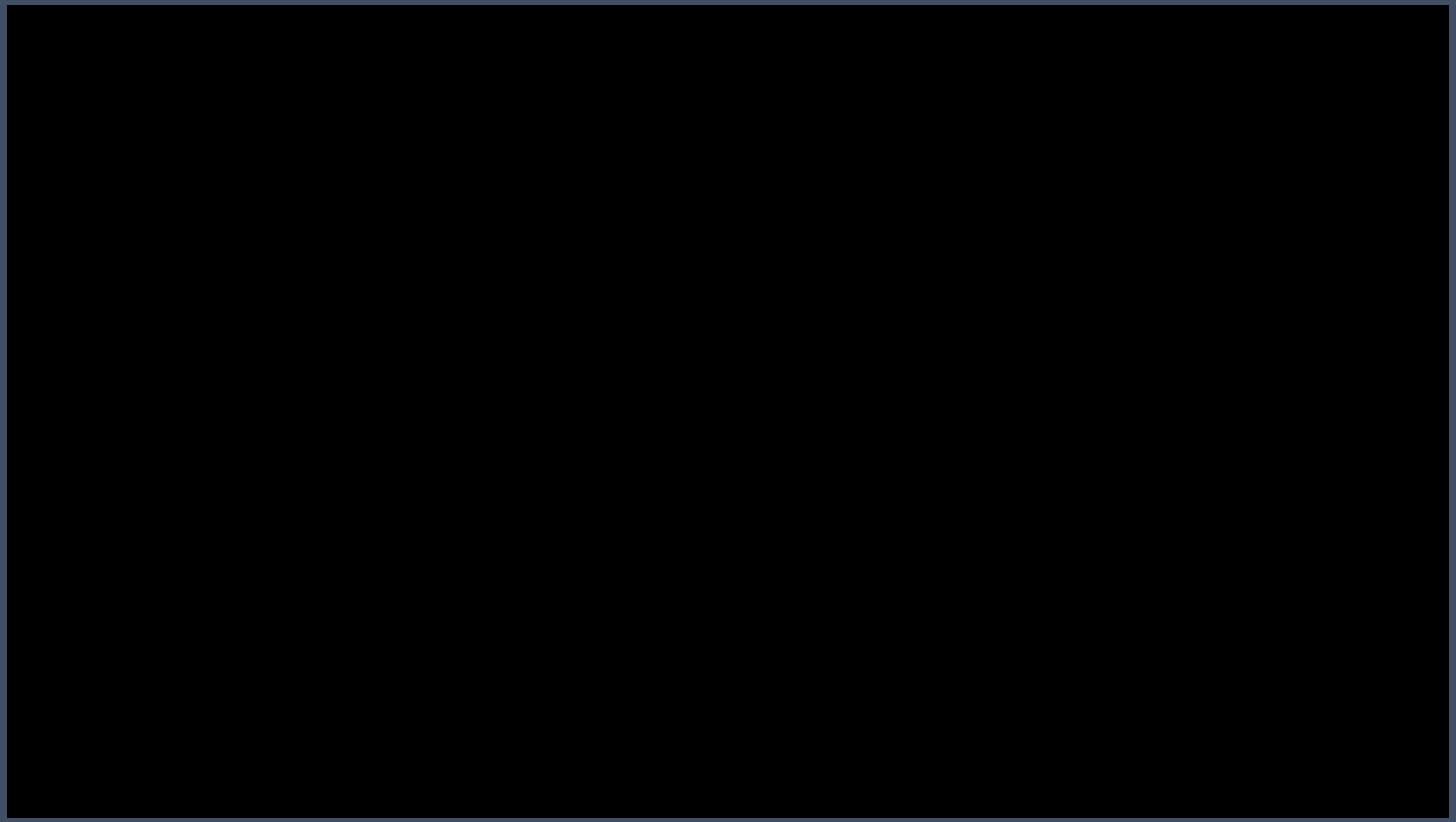
Brushing

- Very common technique in InfoVis
- Applies when you have multiple views of the same data



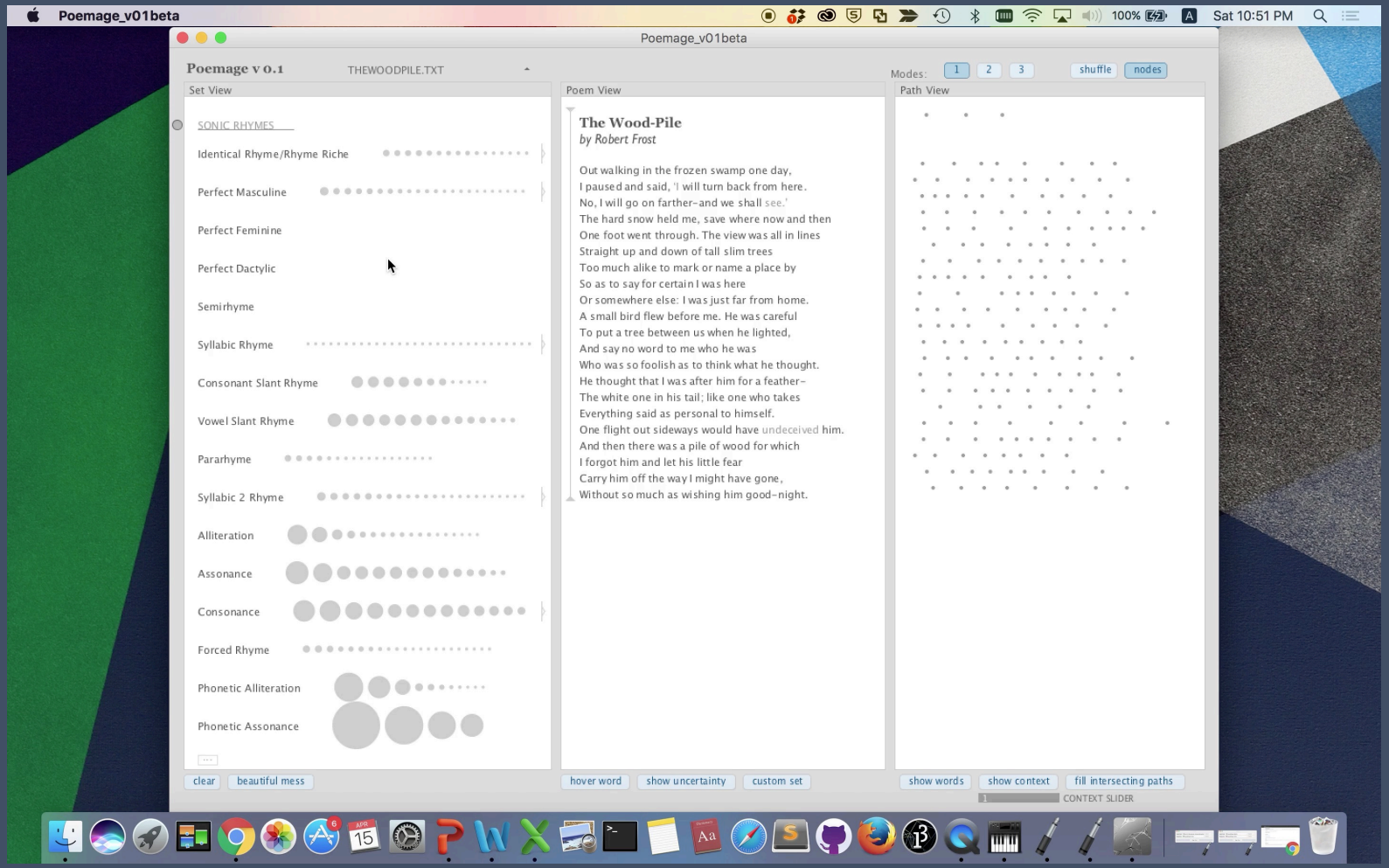
A visual reasoning approach for data-driven transport assessment on urban roads. IEEE TVCG 2014.
http://www.cad.zju.edu.cn/home/vagblog/VAG_Work/IEEEVis2014/TaxiHash_Wangfei/wang%20(1).mp4

Example



Yalcin et al. AggreSet: Rich and scalable set exploration using visualizations of element aggregations. IEEE TVCG 2016. https://www.youtube.com/watch?v=cSSAvDAre-E

Example



Poemage: Visualizing the Sonic Topology of a Poem. IEEE Transactions on Visualization and Computer Graphics (Proceedings of InfoVis 2015), pages 439-448, January 2016.

Interaction models

Interaction models

- Overview + Details
- Focus + Context

Interaction models

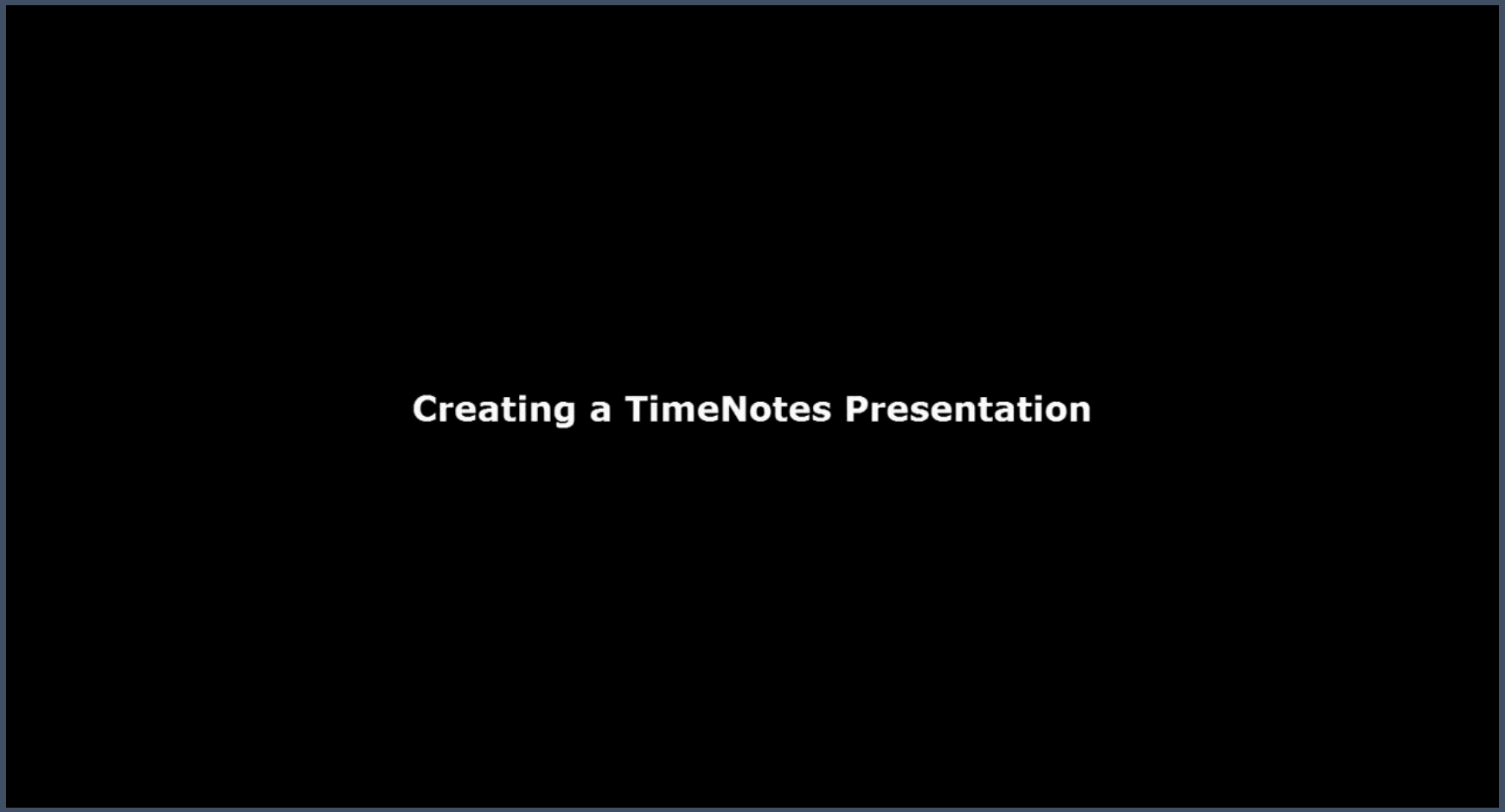
- **Overview + Details**
- Focus + Context

Overview + Details

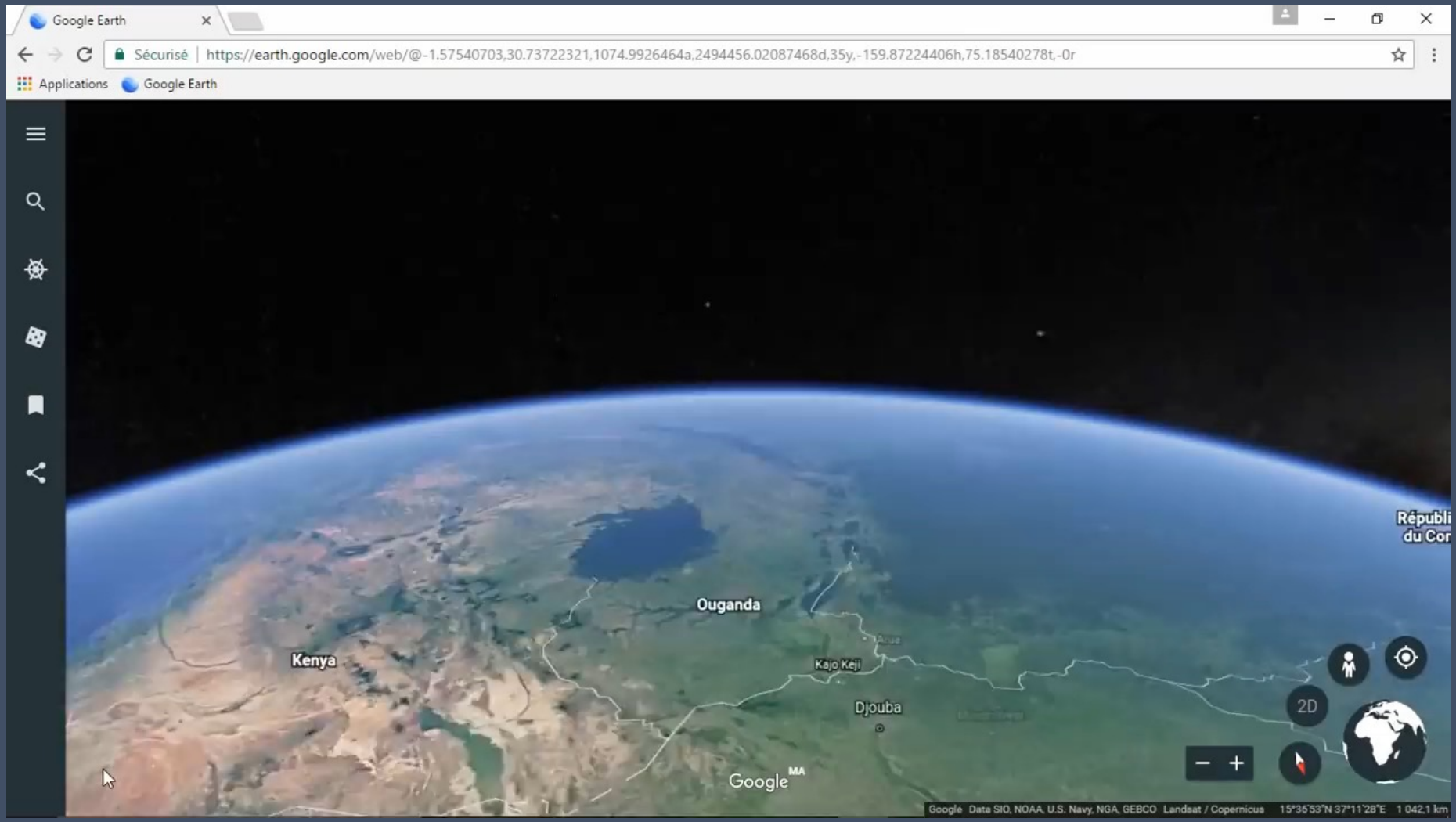
- Scale-Many data sets are too large to visualize on one screen.
  - Too many cases.
  - Too many variables.
  - May only be able to highlight particular cases or particular variables, but viewer's focus may change from time to time.

- Potential solutions lie in:
  - Data representation,
  - Interaction,
  - Or both.

Examples



Examples



https://www.youtube.com/watch?v=paqB4FrJN0w

Interaction models

- Overview + Details
- **Focus + Context**

Why is it called Fisheye?

Fisheye Camera Lens

Fisheye 1992

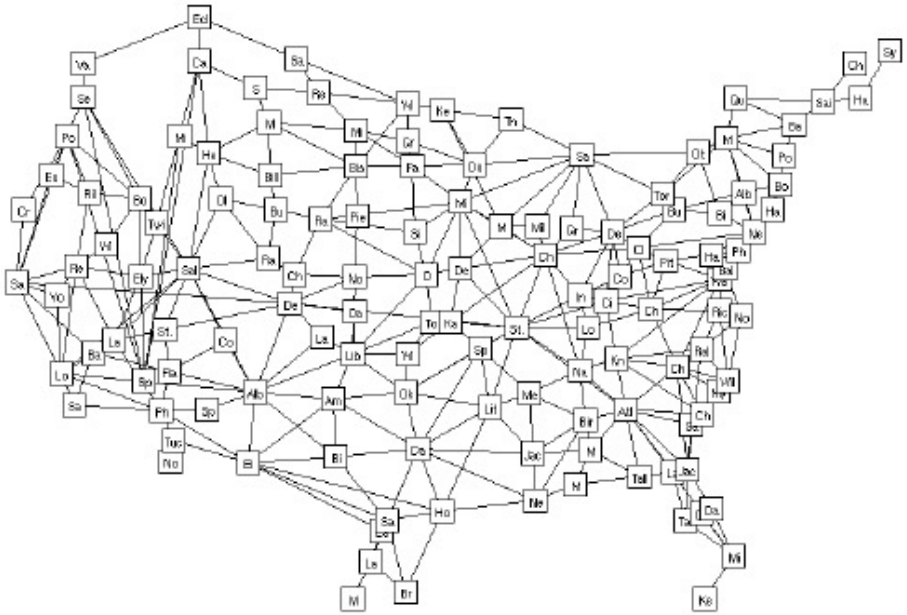


Figure 1: A graph with 134 vertices and 338 edges. The vertices represent major cities in the United States, and the edges represent paths between neighboring cities. (Typically, the edges would be annotated with the distance and driving time between the cities.) The *a priori importance* value assigned to each vertex is proportional to the population of the corresponding city. Fisheye views of this graph appear in Figures 2–6

Sarkar et al. Graphical fisheye views of graphs. SIGCHI ACM, 1992.

Fisheye 1992

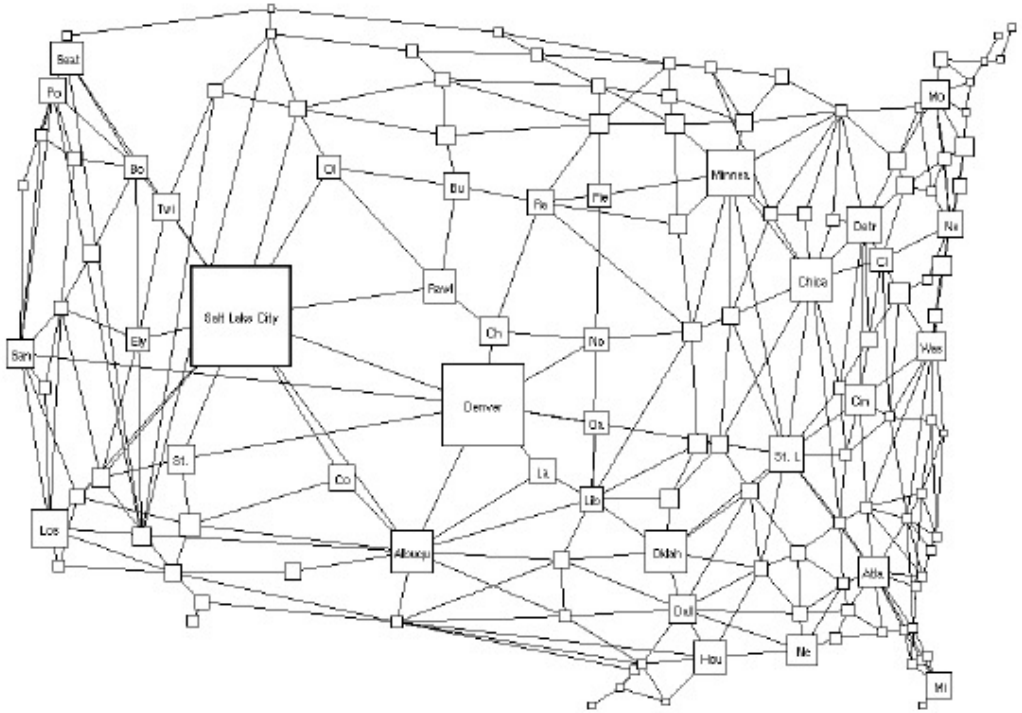
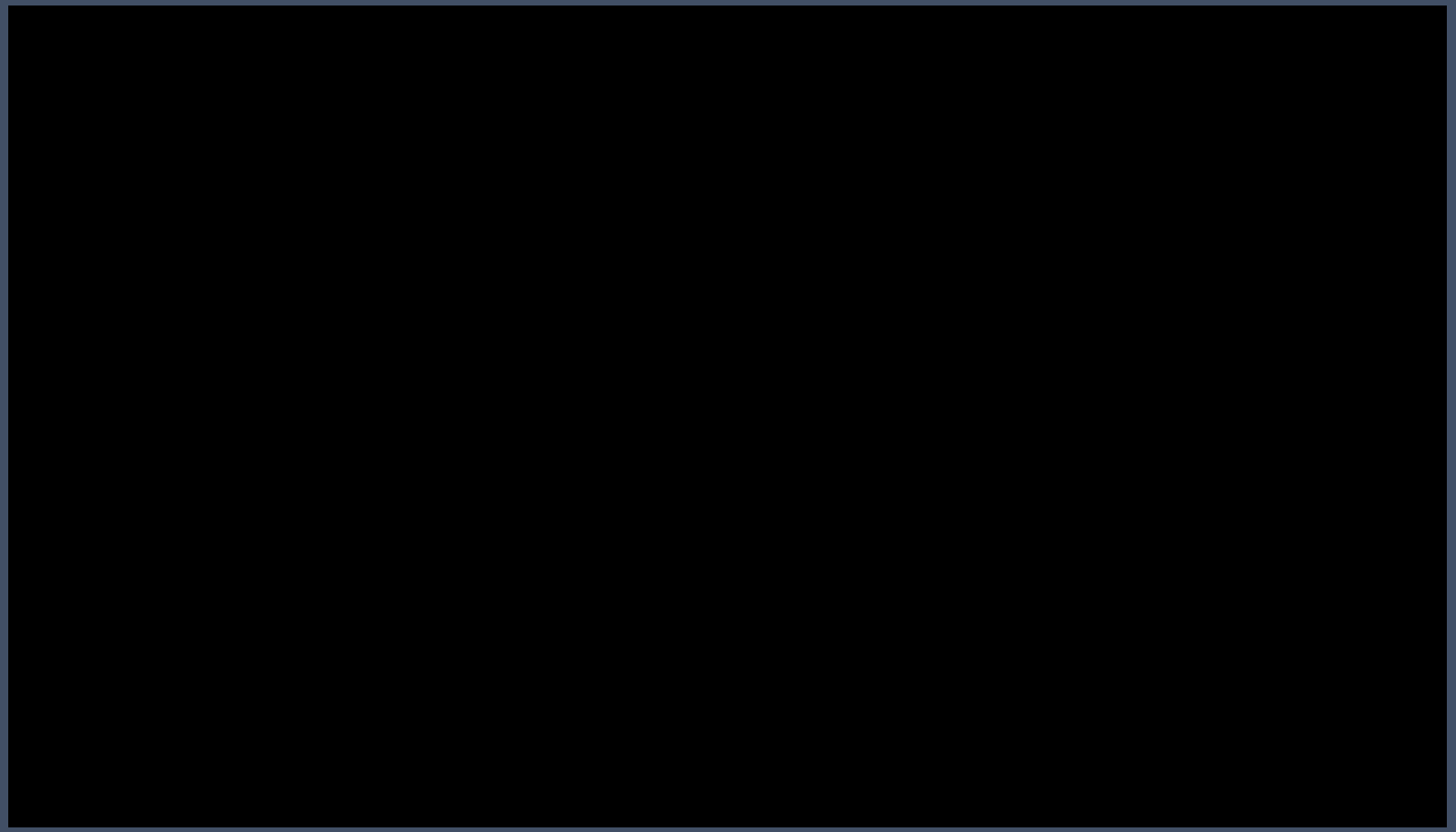


Figure 4: A fisheye view of the graph in Figure 1, with the focus on Salt Lake City. The level of distortion is the same as in Figure 3; only the location of the focus has changed. The values of the fisheye parameters are $d = 2, c = 0.5, e = 0.5, VWcutoff = 0$.

Sarkar et al. Graphical fisheye views of graphs. SIGCHI ACM, 1992.

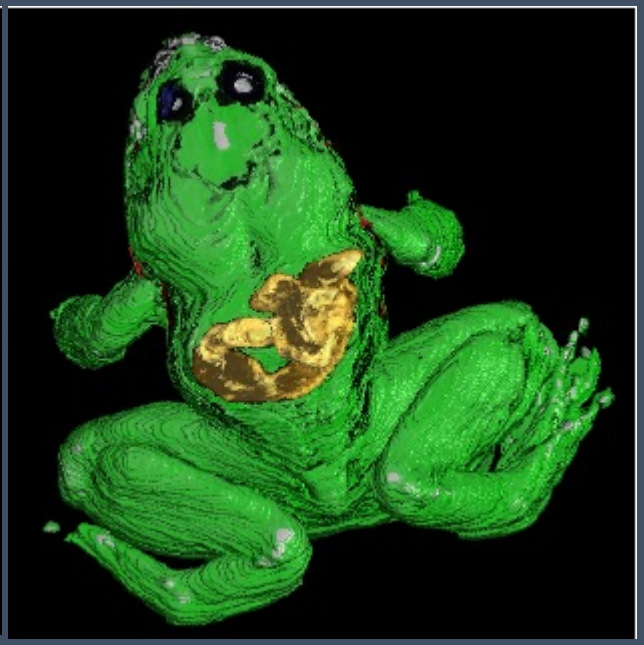
Example

- Maps

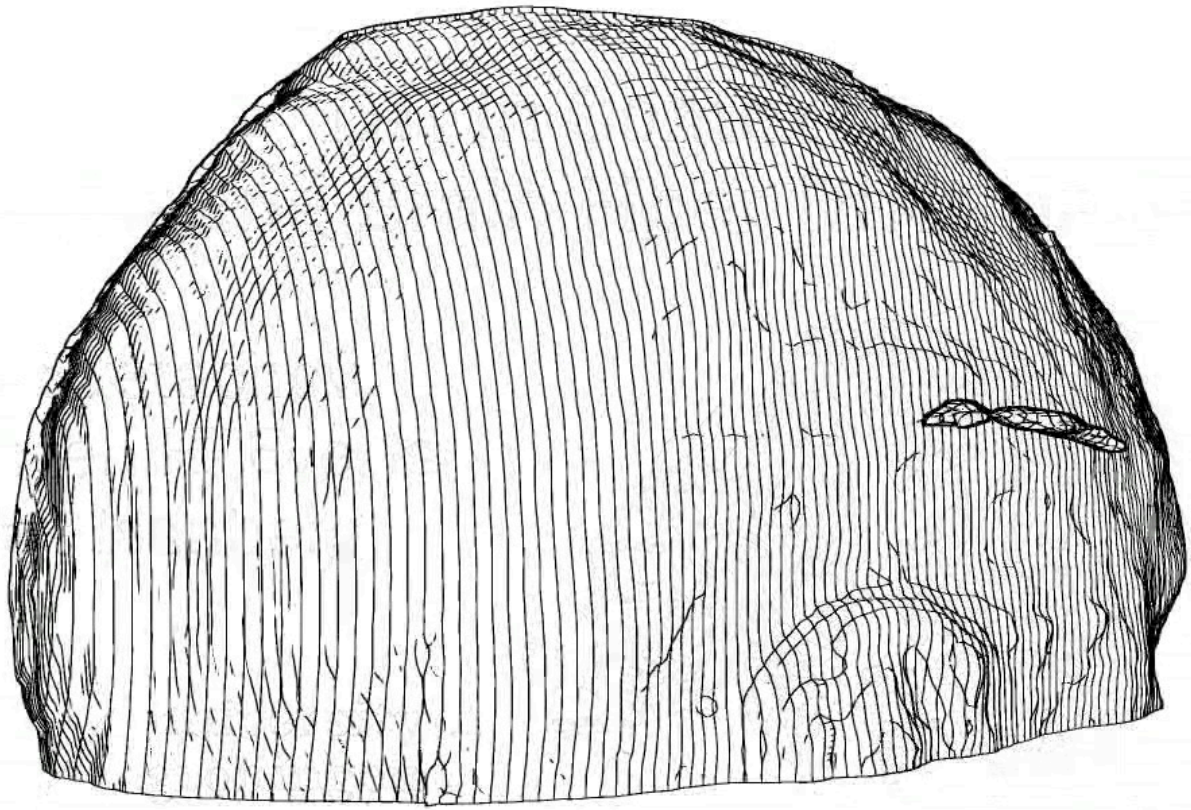


Tominski et al. 3d information visualization for time dependent data on maps. International Conference on Information Visualisation , 2005.

The magic volume lens



Focus & Context



DTI in Context: Illustrating Brain Fiber Tracts In Situ. Computer Graphics Forum, 29(3):1024–1032, June 2010.
http://tobias.isenberg.cc/VideosAndDemos/Svetachov2010DCI

Outline

- Fundamental Interaction methods
- Interaction models
- Tasks, Techniques and Devices
- Take-away Messages

Tasks, Techniques and Devices

Tasks, Techniques and Devices

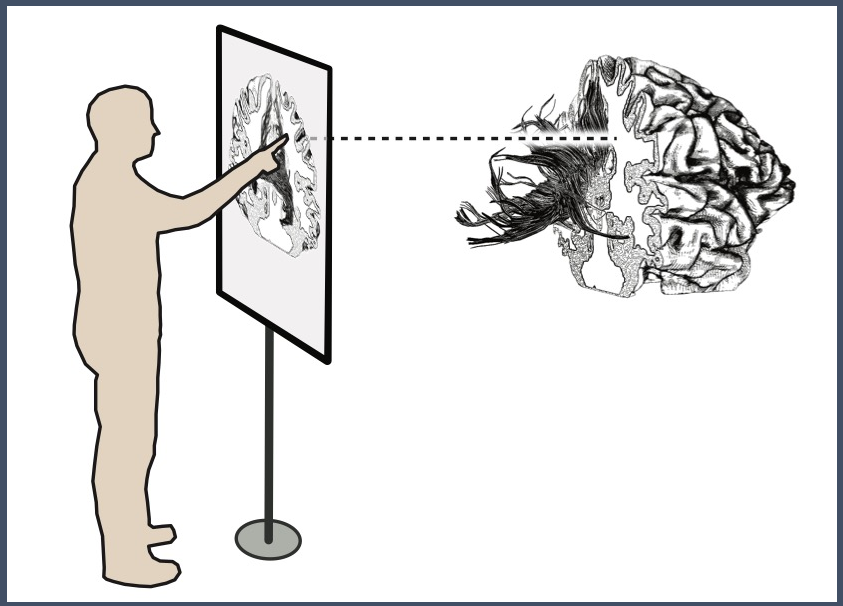
- Interaction Tasks for Visualization
  - View and Object Manipulation
  - Visualization Widgets Manipulation
  - 3D Data Selection and Annotation
- Interaction Techniques and Devices
  - Touch Interaction
  - Tangible Interaction
  - Mid-air Interaction
  - Hybrid Interaction

Spatial Interaction

- Touch Interaction
- Tangible Interaction
- Mid-air Interaction
- Hybrid Interaction

Touch / Pen-based Interaction

- Pros:
  - fast, precise, direct
  - increase the user's impression they are making direct manipulations
- Cons:
  - limited: used as a discrete interaction mechanism
  - limiting: many complex tasks (in particular for 3D manipulations) require input/control with more than three degrees of freedom



Large vs Small Displays

(1)

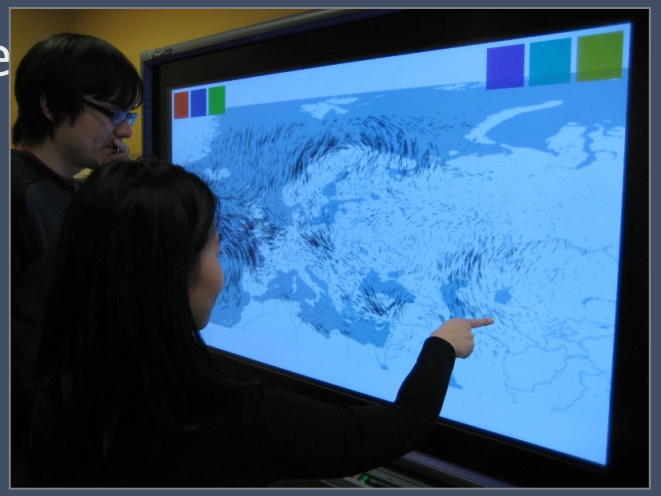
(2)

1. OpenSpace: Bringing NASA missions to the public. IEEE Computer Graphics and Applications, 2018

2. Glanceable Visualization: Studies of Data Comparison Performance on Smartwatches. IEEE Transactions on Visualization and Computer Graphics, 25(1):616–629, 2019.

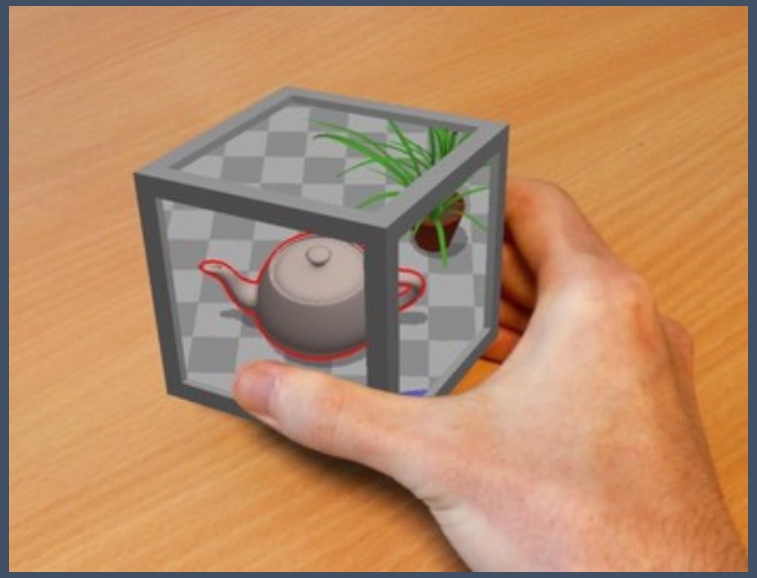
Horizontal vs. Vertical Displays

- PC: display oriented vertically
  - (Horizontal) desktop shown on a (ve
- Wall displays: vertical orientation
  - White/black board
- Tabletop displays:
  - Tabletop
- Other orientations: tilted
  - Drafting boards



Tangible Interaction

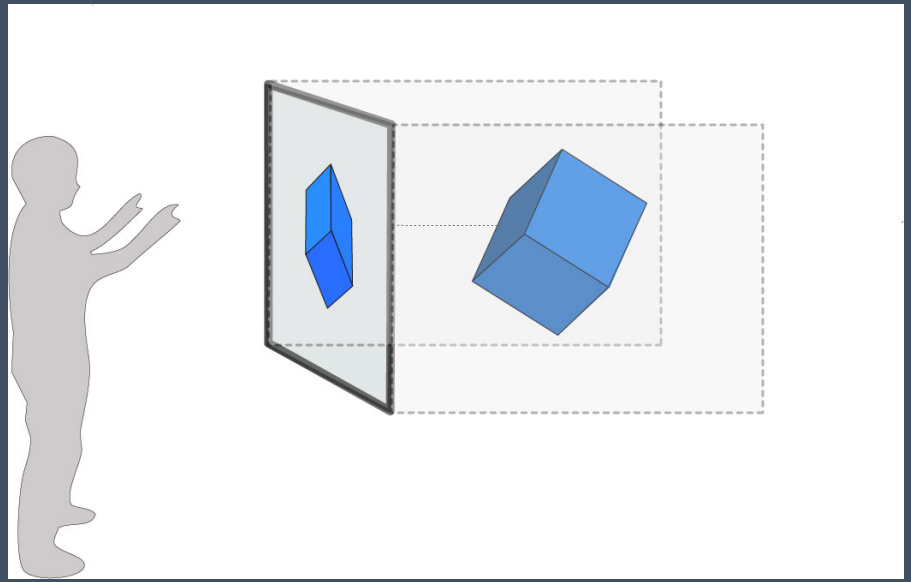
- allow users to achieve complex 3D manipulations with simple real-world style gestures
- more flexible than other interaction paradigms
- Manipulations with these devices can be programmed to feel realistic, as they would in the real world



Issartel et. al. *A Tangible Volume for Portable 3D Interaction.* In Adjunct Proceedings of the International Symposium on Mixed and Augmented Reality pages 215–220, 2016.

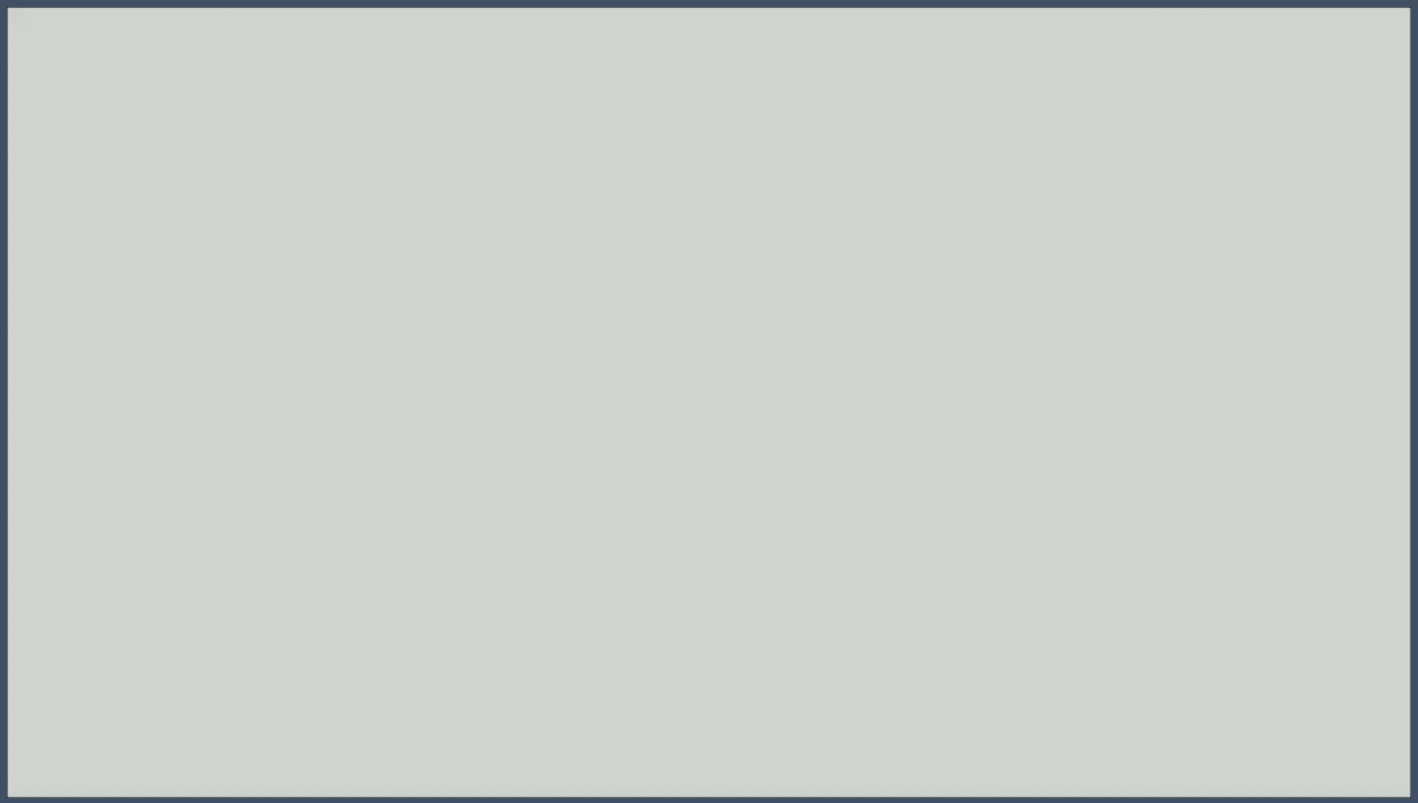
Mid-air gestural interaction

- touchless interaction
- mimics the physical actions we make in the real world



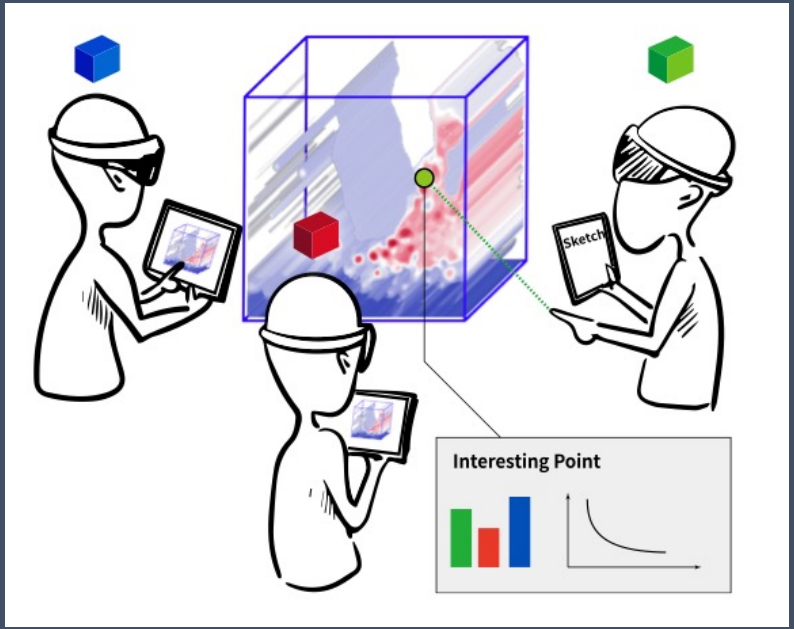
Mid-air Interaction

- Finger-Level 3D Input: Leap Motion
  - 3D sensing on a smaller scale, smaller space
  - More precision: finger-accurate tracking



Hybrid Interaction

- combine multiple interaction paradigms together
- overcome the inherent limitations of a device
  - augmenting the number of DOF that can be manipulated
  - reduce the occlusion limitation with tactile interaction
- combine the benefits of two interaction paradigms
- simply tackle complicated tasks



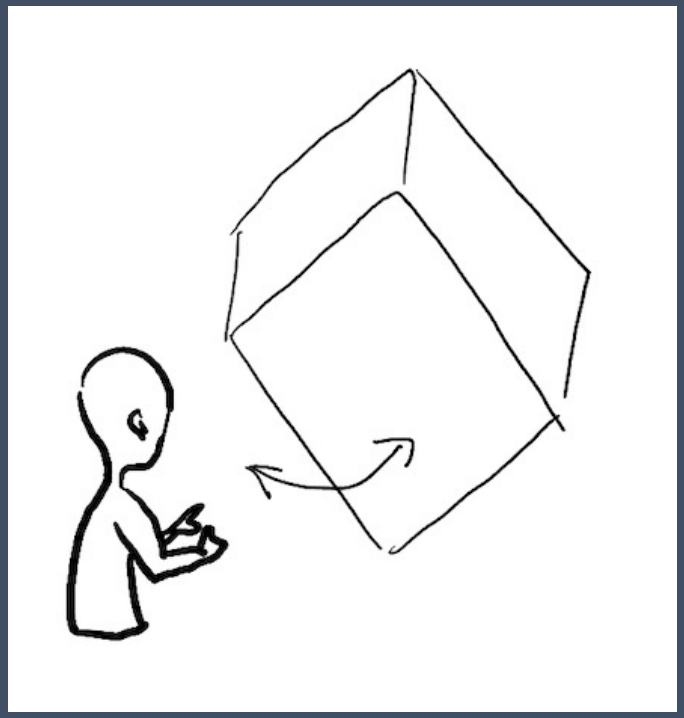
Sereno et. al Supporting Volumetric Data Visualization and Analysis by Combining Augmented Reality Visuals with Multi-Touch Input. In Posters at the Eurographics/IEEE VGTC Annual Visualization Conference (EuroVis), pages 21–23, 2019.

Interaction Tasks for Visualization

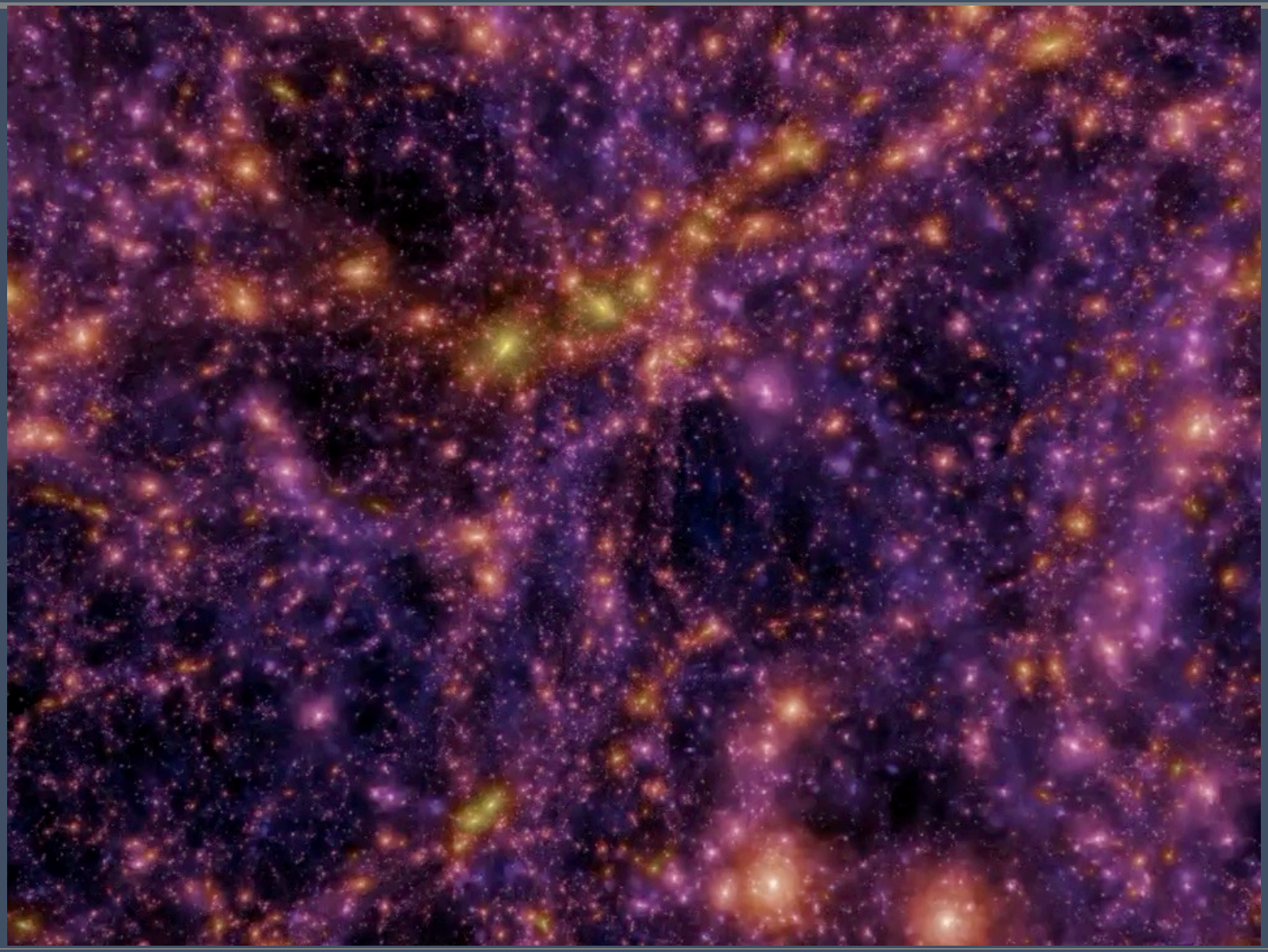
- View and Object Manipulation
- Visualization Widgets Manipulation
- 3D Data Selection and Annotation

Volumetric view & object manipulation

- Volumetric view and clipping manipulation tasks are fundamental to visualize spatial 3D data effectively
  - a single viewpoint, all of the important aspects of the data may be analyzed
  - adjust the viewpoint of the rendering(s) or to manipulate clipping planes within the data
- Manipulation of cutting planes or transfer function editors.



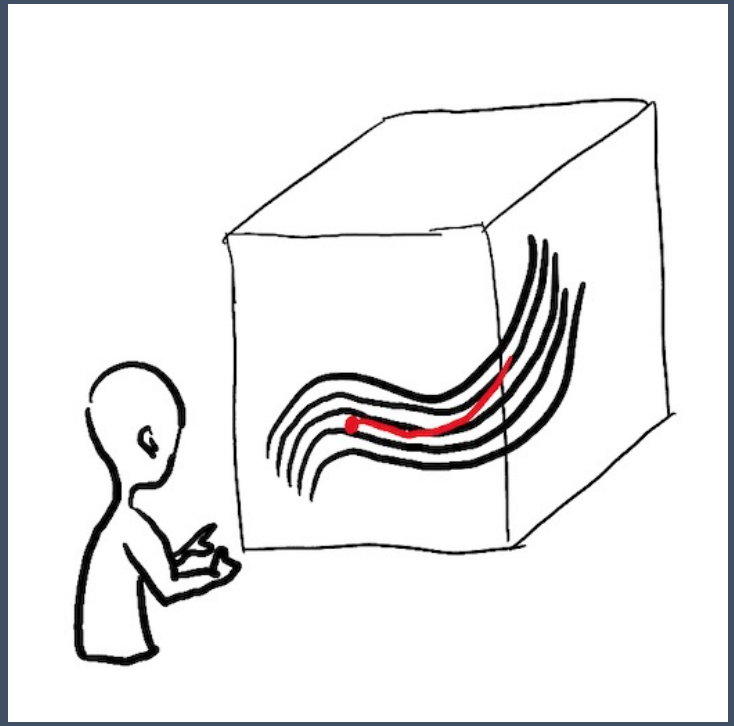
Astronomical visualization



Medical visualization

Defining, placing, & manipulating visualization widgets

- visualization widgets is required to more deeply explore and interrogate the data
- virtual tools that are manipulable by users in much the same way as any traditional 2D or 3D user interface widget
- Cutting plane, particle seeding, 3D placement, magic lens, measurement widgets



Flow visualization

Continuous Navigation of Nested Abstraction Levels

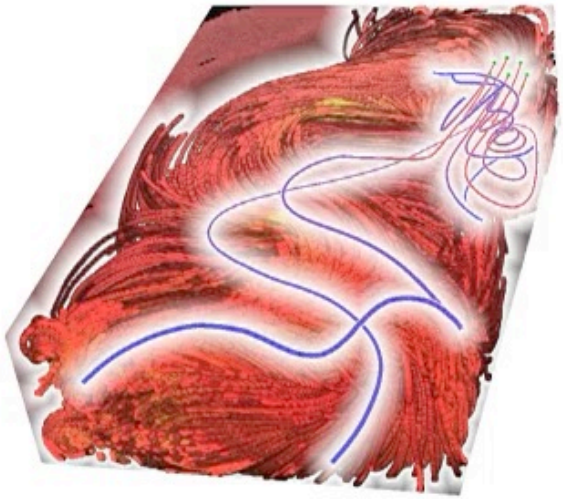
Matthew van der Zwan Alexandru Telea Tobias Isenberg

university of groningen

digiteo
Research in science and technology of information

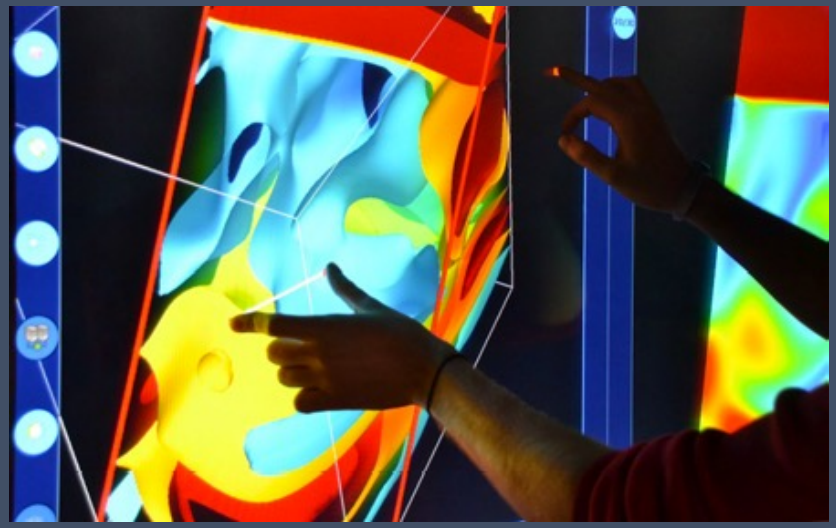
cnrs

informatics mathematics
Inria

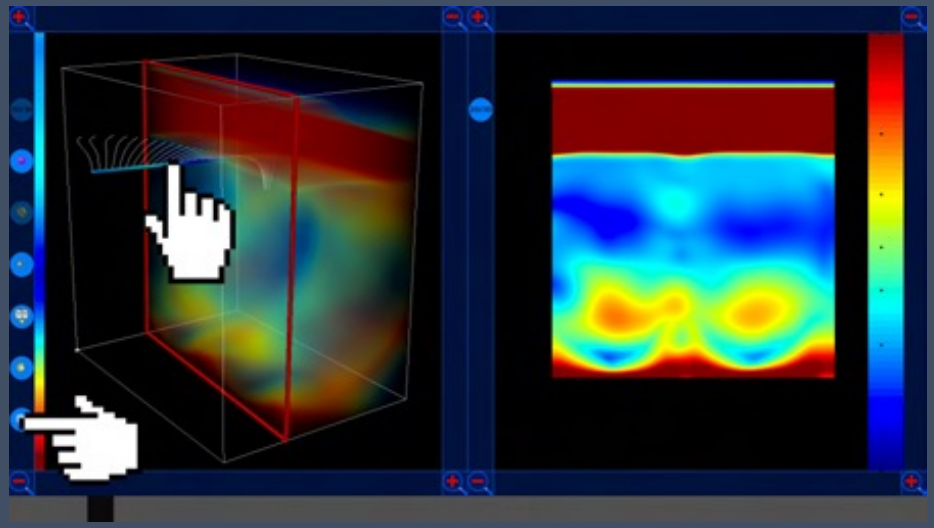


Matthew van der Zwan, Alexandru Telea, and Tobias Isenberg (2012) *Continuous Navigation of Nested Abstraction Levels.* In Miriah Meyer and Tino Weinkauf, eds., Short Paper Proceedings of the EG/IEEE VGTC Conference on Visualization (EuroVis, June 5-8, Vienna, Austria). Goslar, Germany. Eurographics Association, pages 13–17, 2012.

Touch & Manipulation of Visualization Widgets



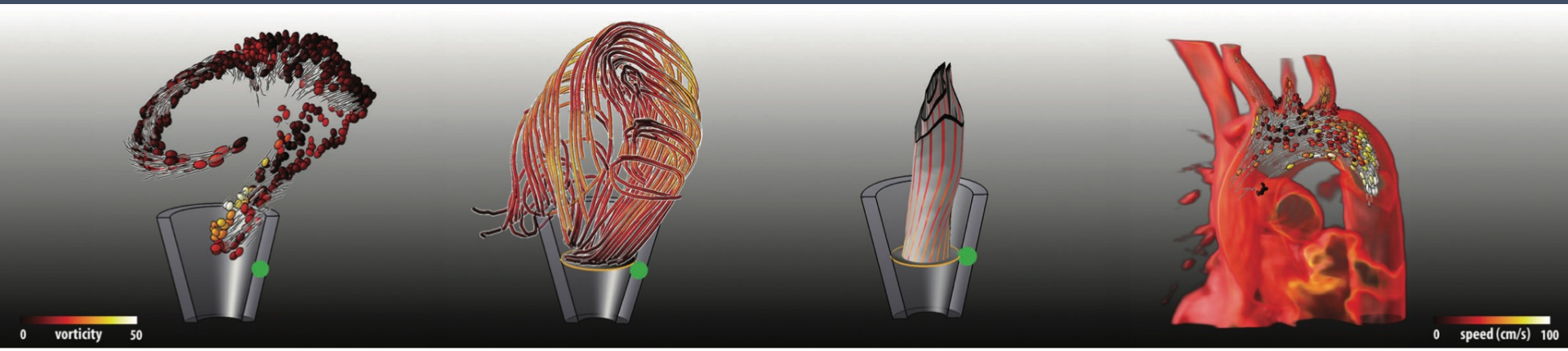
Cutting plane interaction



Drilling interaction

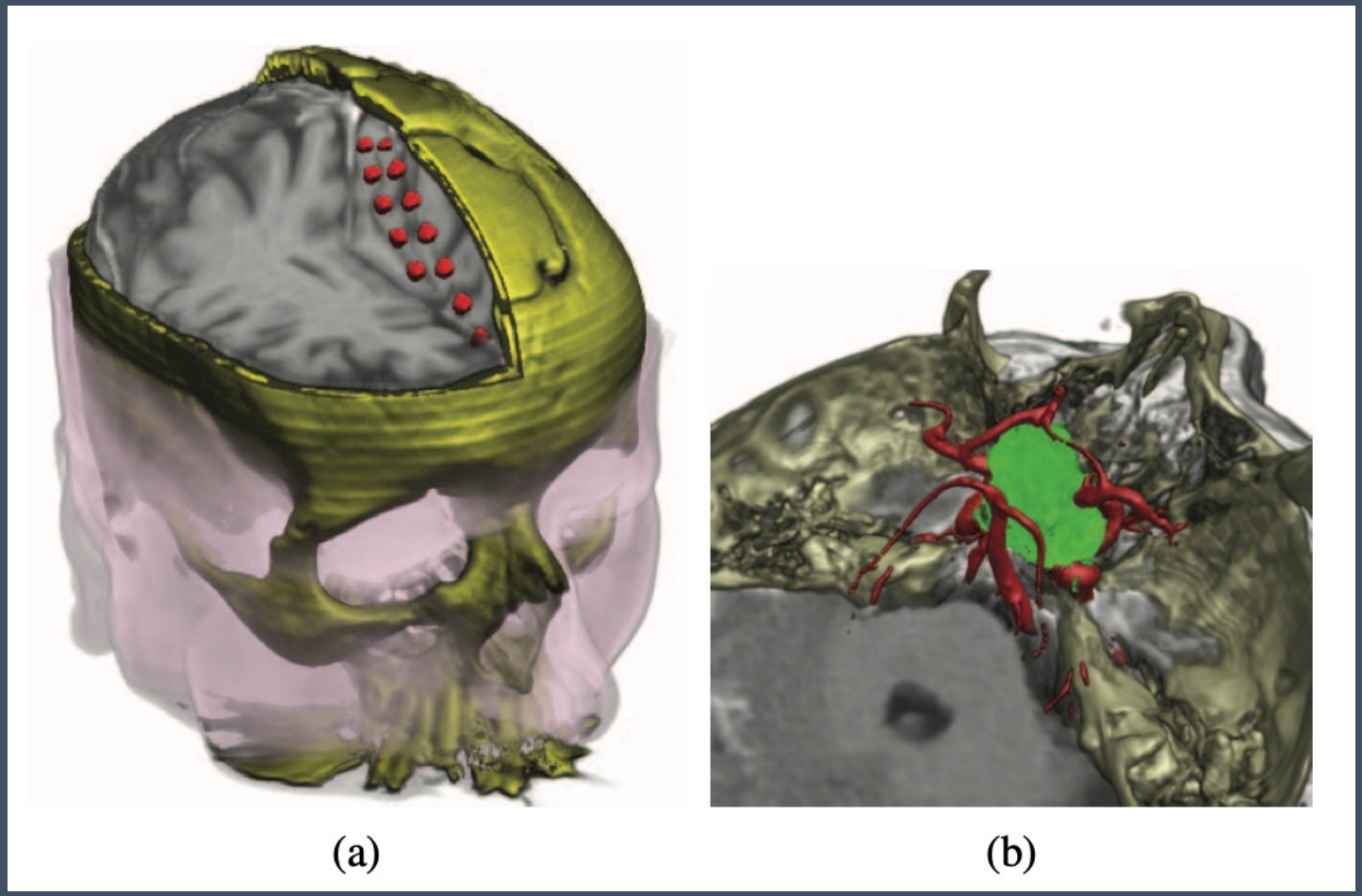
A design study of direct-touch interaction for exploratory 3D scientific visualization. Computer Graphics Forum 31, 3 (June 2012), 1225–1234

Defining, placing, & manipulating visualization widgets



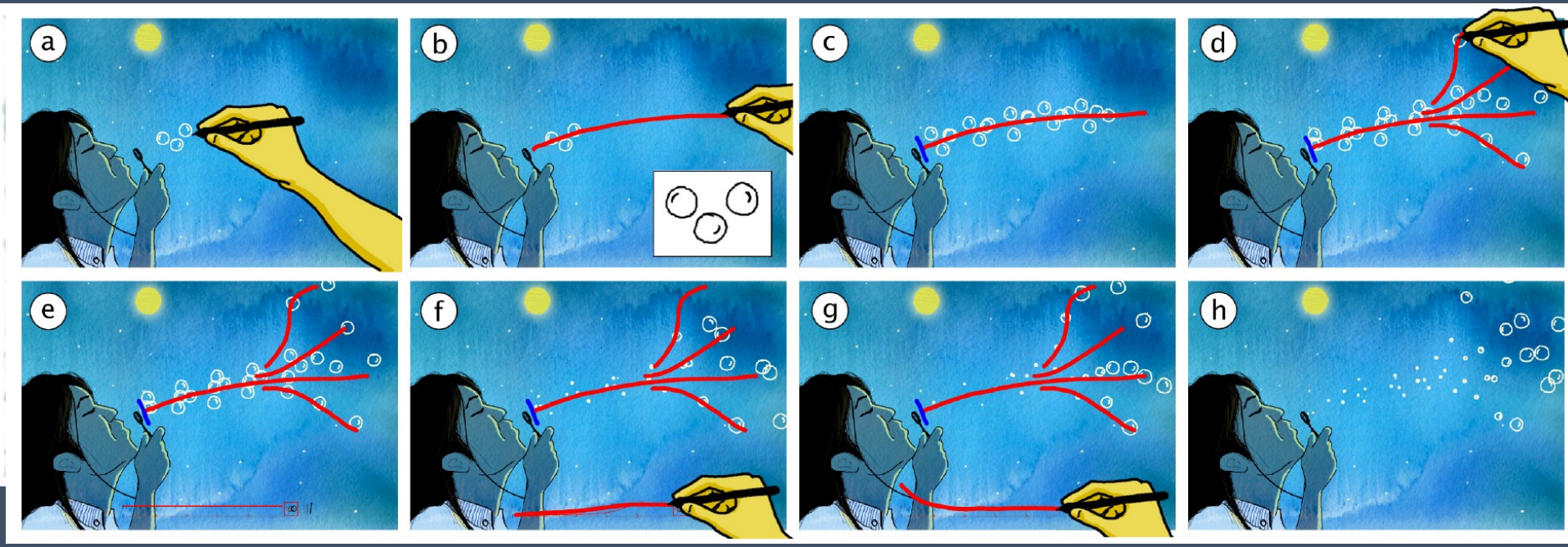
R. van Pelt *et al*., "Interactive Virtual Probing of 4D MRI Blood-Flow," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 17, no. 12, pp. 2153-2162, Dec. 2011, doi: 10.1109/TVCG.2011.215.

Defining, placing, & manipulating visualization widgets



J. Beyer, M. Hadwiger, S. Wolfsberger and K. Bühler, "High-Quality Multimodal Volume Rendering for Preoperative Planning of Neurosurgical Interventions," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 13, no. 6, pp. 1696-1703, Nov.-Dec. 2007, doi: 10.1109/TVCG.2007.70560.

Transfer function



Draco: Bringing Life to Illustrations with Kinetic

Transfer function

Semantics by Analogy for Illustrative Volume Visualization

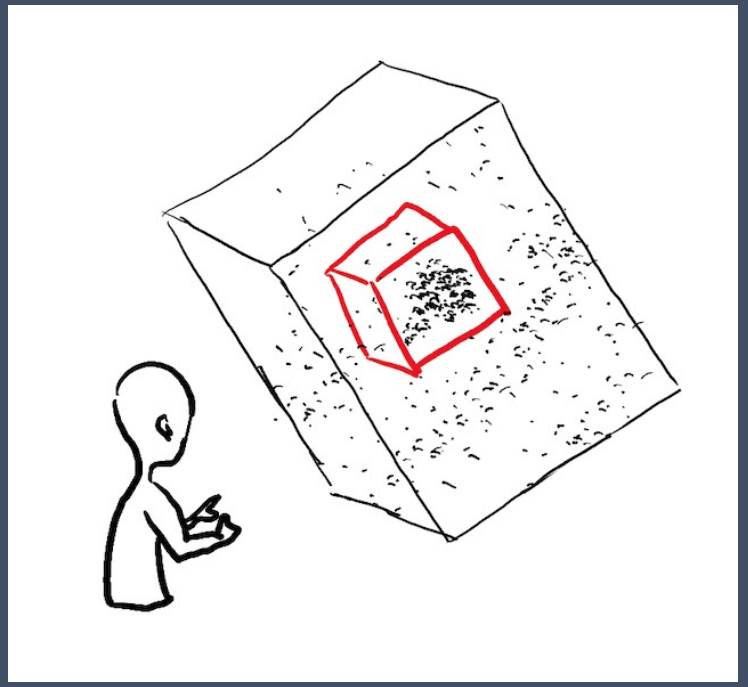
Moritz Gerl
Peter Rautek
Tobias Isenberg
M. Eduard Gröller

university of groningen

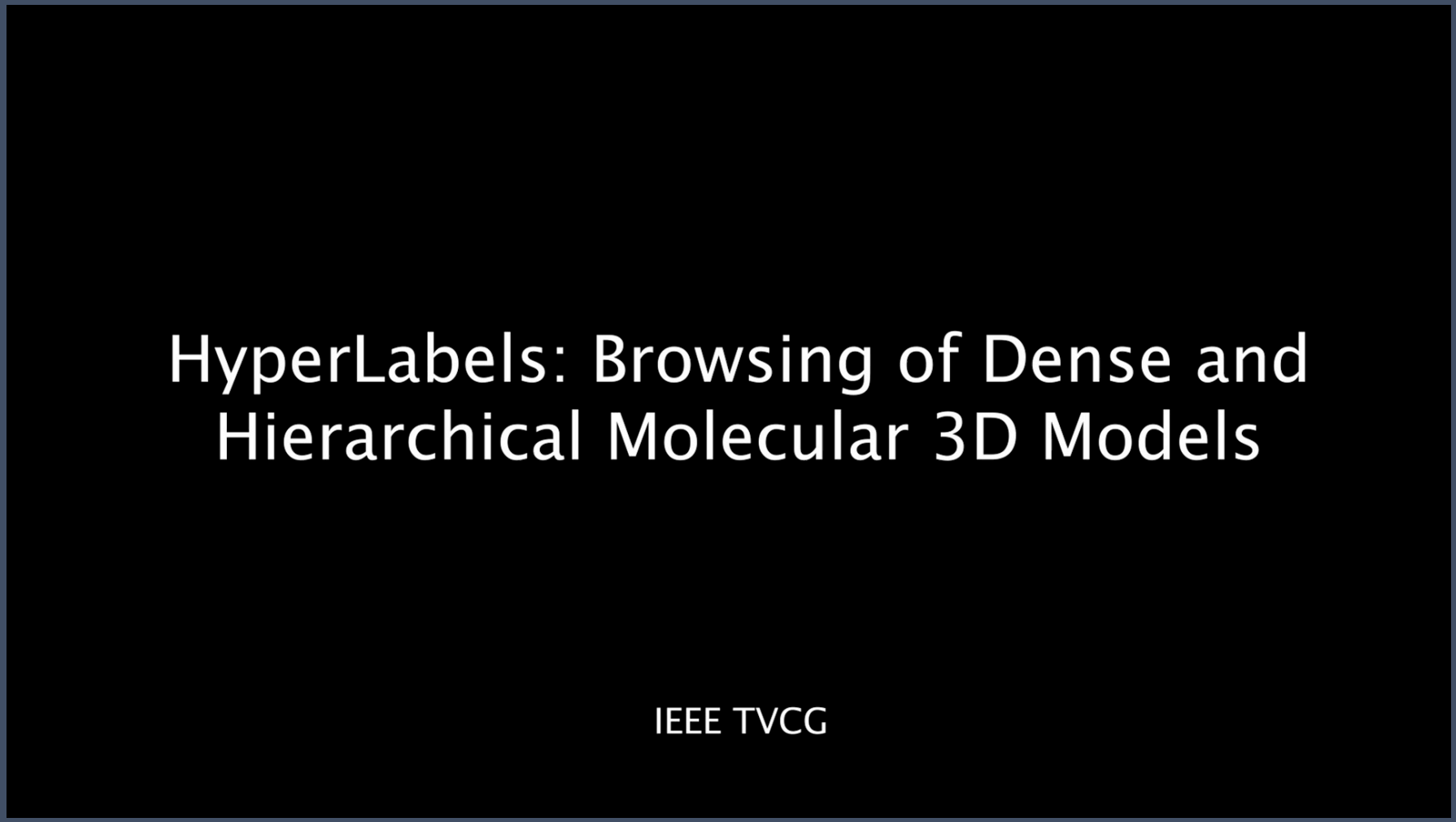
TU WIEN
TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

3D data selection & annotation

- Selection: the first step in accessing deeper information about some subset or feature of the 3D spatial data
- Annotation: insights or questions

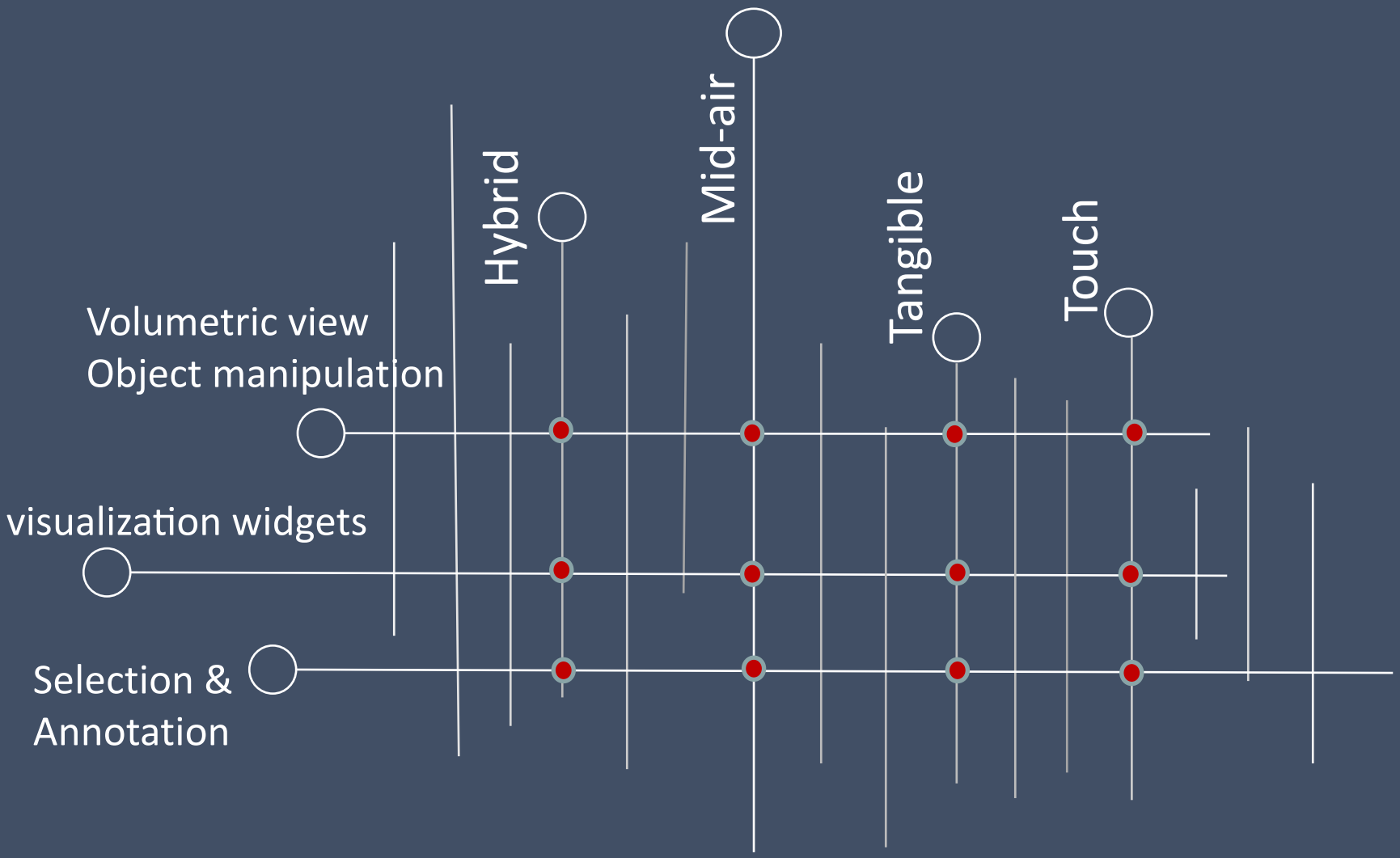


Annotation



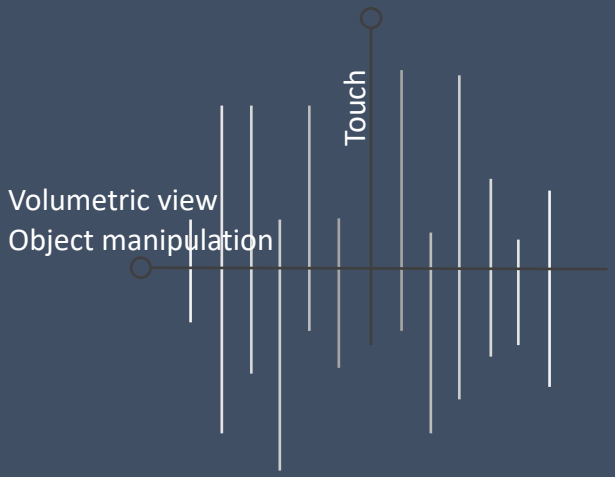
David Kouřil, Tobias Isenberg, Barbora Kozlíková, Miriah Meyer, M. Eduard Gröller, and Ivan Viola (2021) *HyperLabels—Browsing of Dense and Hierarchical Molecular 3D Models*.IEEE Transactions on Visualization and Computer Graphics, 27, 2021. *To appear*.

Spatial interaction for 3D visualization



Touch/pen Interaction & Volumetric view / object manipulation

- Separate and constrain DOFs
- Precise control
- Combine with pressure



Supporting Sandtray Therapy on an Interactive Tabletop. CHI 2010

Touch/pen Interaction & Volumetric view / object manipulation

- Separate and constrain DOFs
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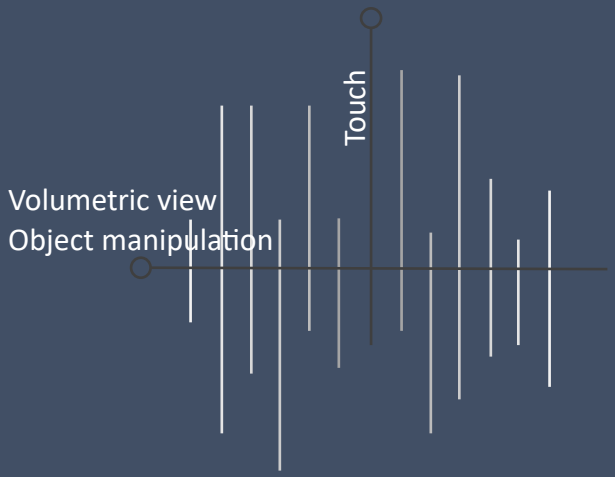
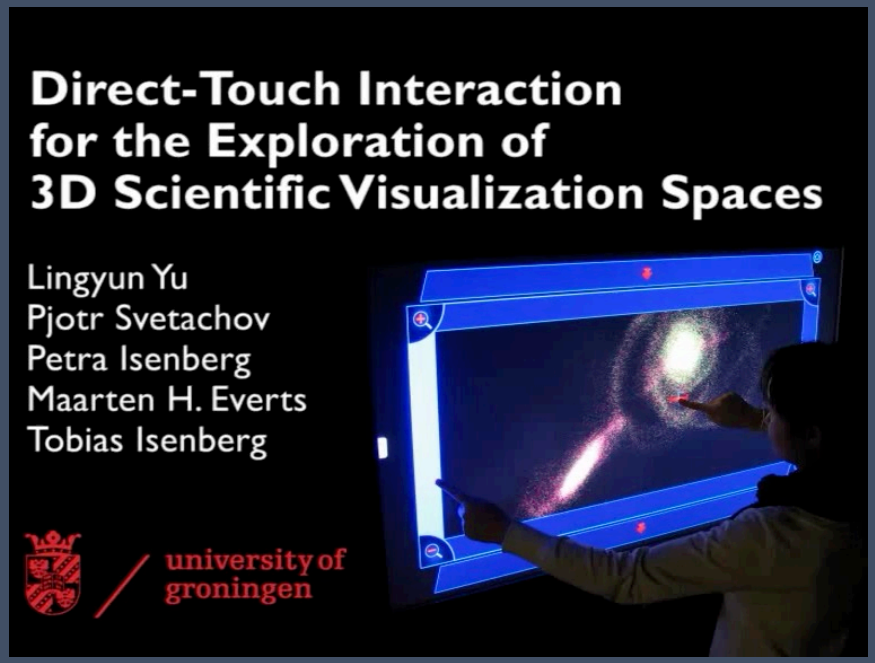
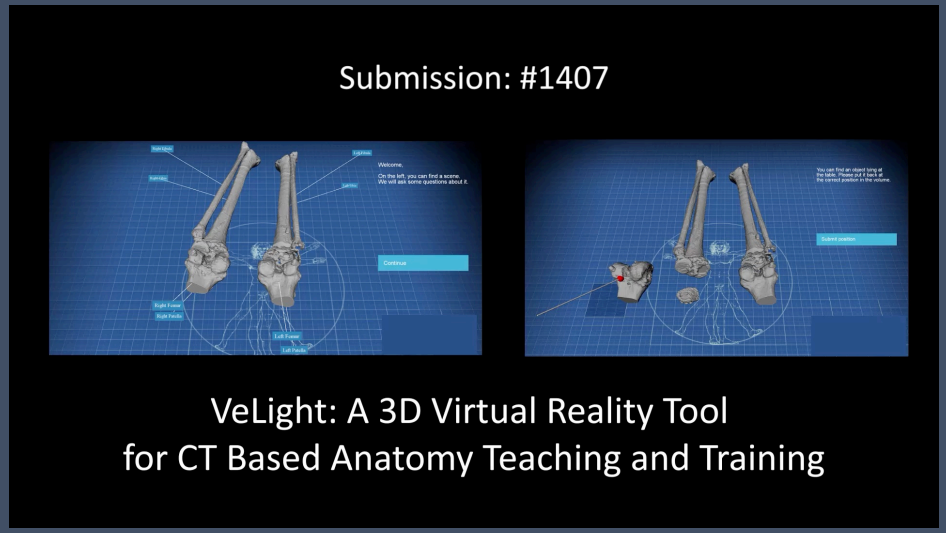


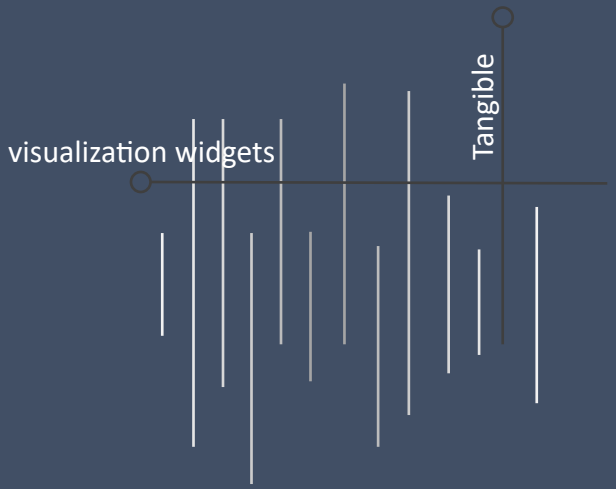


Yu et.al. FI3D: Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces. IEEE Transactions on Visualization and Computer Graphics, 16(6):1613–1622, November/December 2010.

Tangible interaction & Volumetric view / object manipulation

- props used as intuitive proxies for manipulating data and slicing planes
- constraining the interaction (not utilizing all 6-DOF) can often be useful



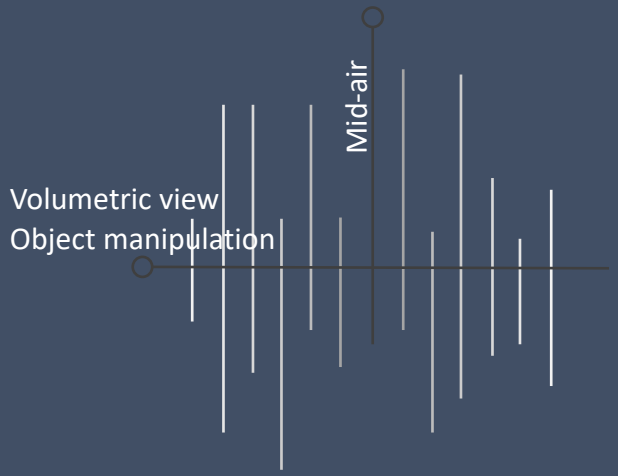


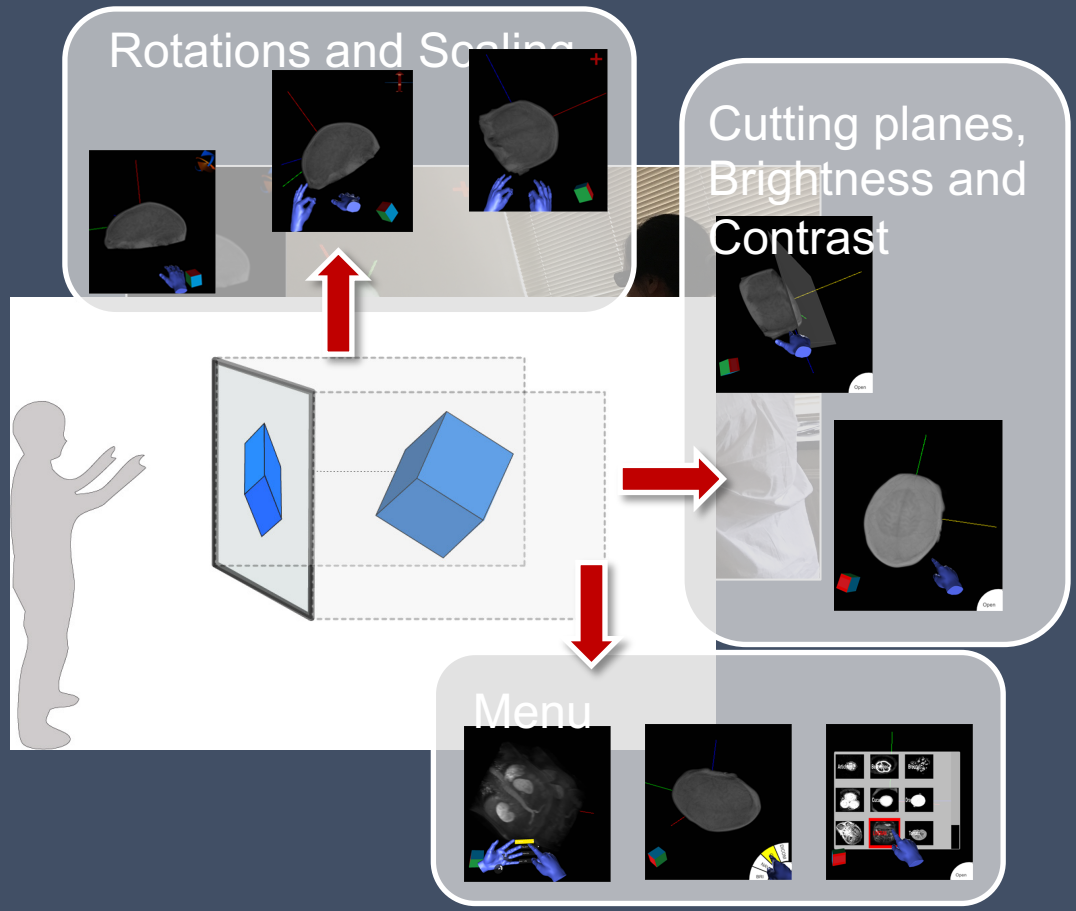
Hybrid Interaction

- The idea to combine different interaction techniques and devices was suggested and investigated in the 1990s and 2000s.
- The combinations of techniques: pressure and touch interaction, touch and tangible interaction, mid-air interaction and touch interaction, mid-air interaction and tangible interaction, etc.
- The **benefits** includes:
  - reduce the occlusion issue of touch interaction;
  - combine the benefits of two (or many) interaction paradigms;
  - tackle complicated tasks.

Mid-air interaction & Volumetric view / object manipulation

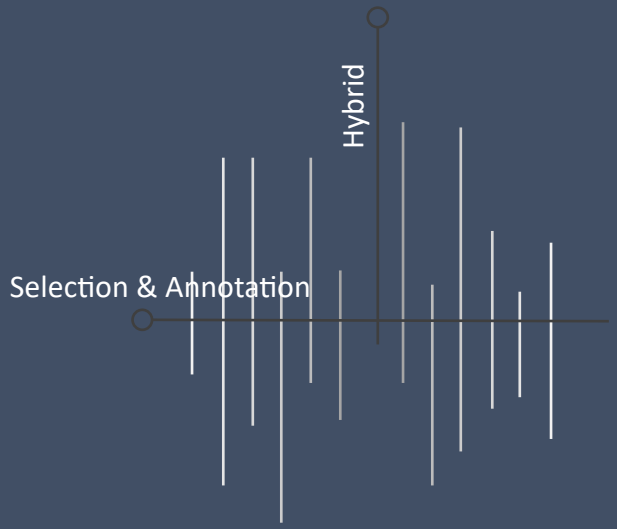
- natural 3D manipulations
- constrained by the application domain
- Receive little attention

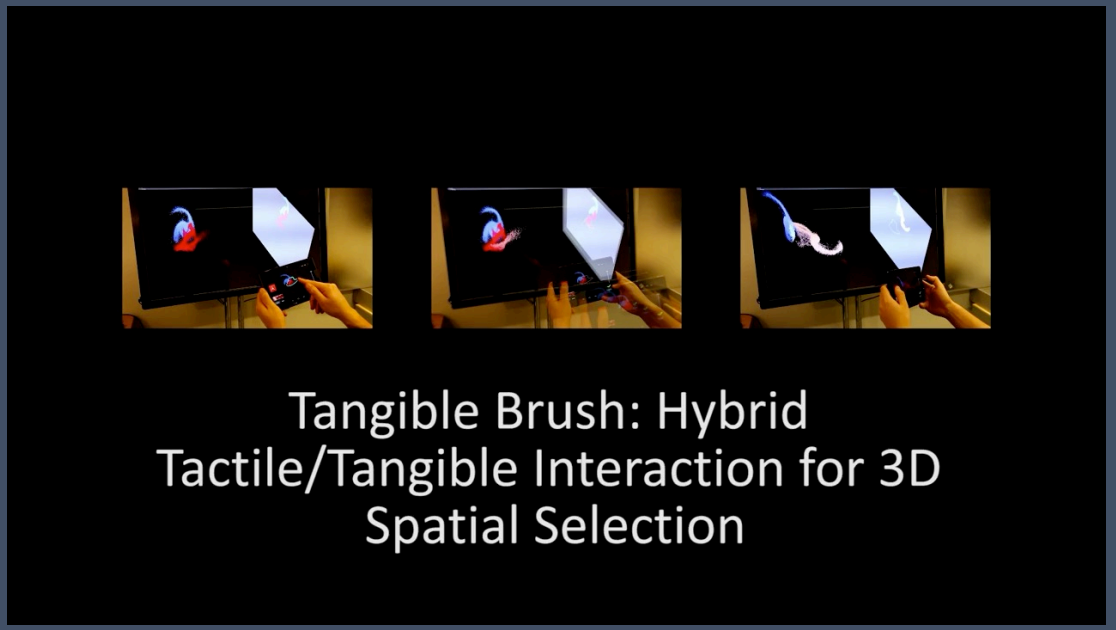




Hybrid interaction & Selection / Annotation

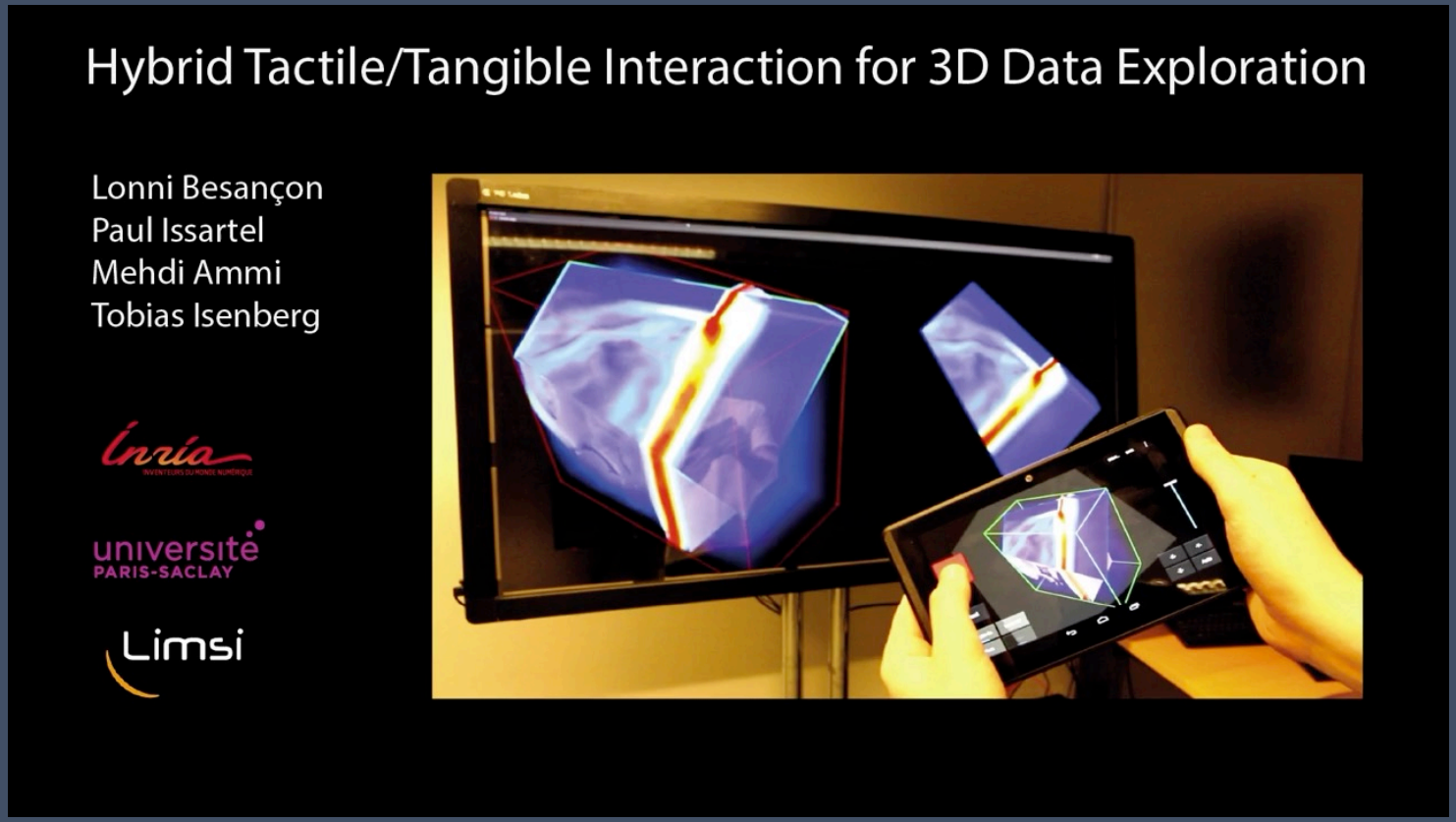
- More flexible





BESANÇON L., SERENO M., YU L., AMMI M., ISENBERG T.: Hybrid touch/tangible spatial 3D data selection. Computer Graphics Forum 38, 3 (June 2019), 553–567.

Hybrid Interaction & Manipulation of Visualization Widgets



Hybrid tactile/tangible interaction for 3D data exploration. IEEE Transactions on Visualization and Computer Graphics 23, 1 (Jan. 2017), 881–890.

Future work

Opportunities for future research

Previously…

- A lot of work has been done in 2D data interaction.
- 3D interaction is more challenging when applied to complex features or structures of 3D datasets.
- 3D interaction becomes more interesting when taking users' intention into consideration.

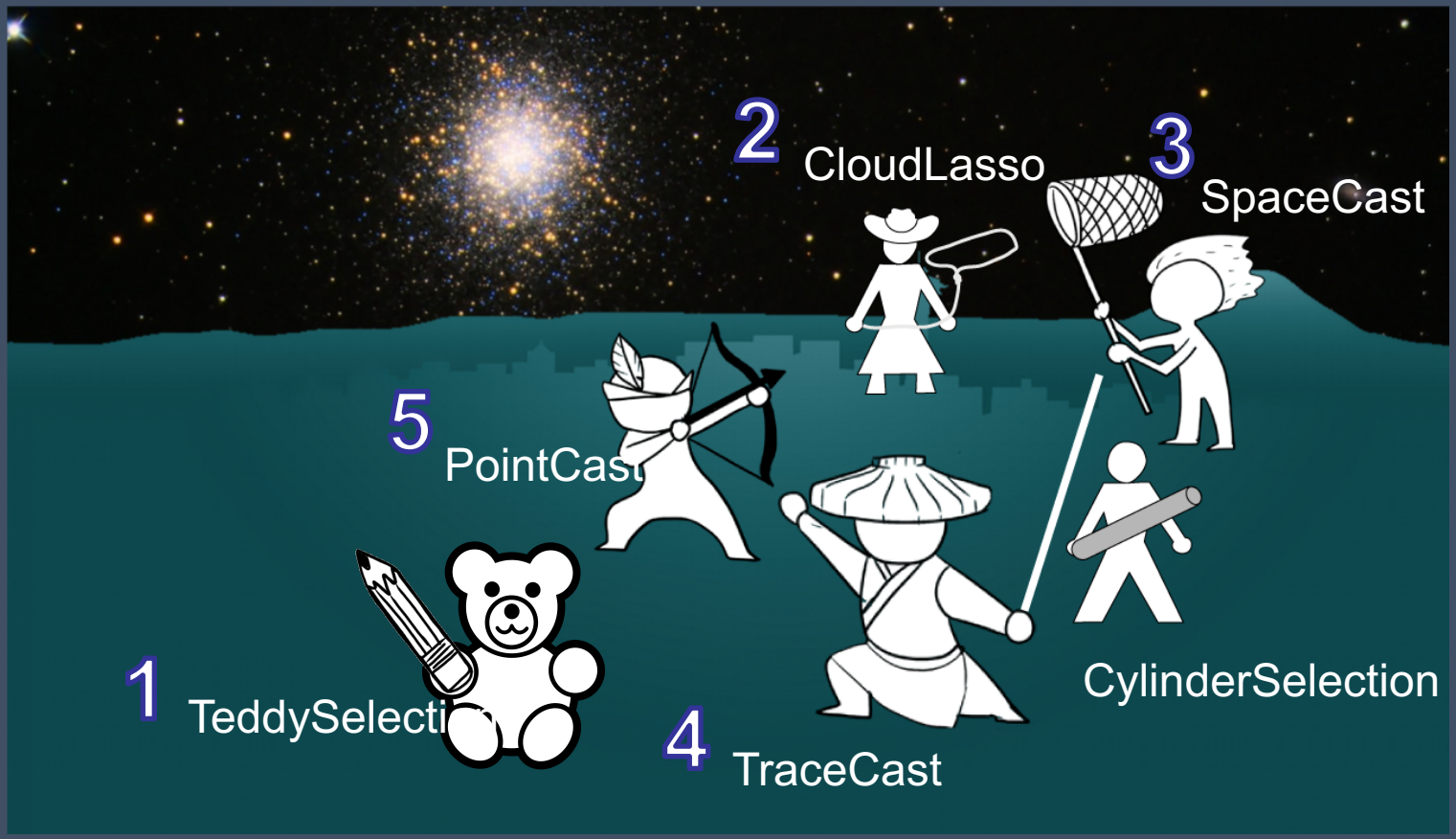
Context/Structure aware Interactions

Point cloud selection methods

Teddy


Teddy:
A Sketching Interface
for 3D Freeform Design
Takeo Igarashi
Hidehiko Tanaka
Satoshi Matsuoka

Particle selection techniques

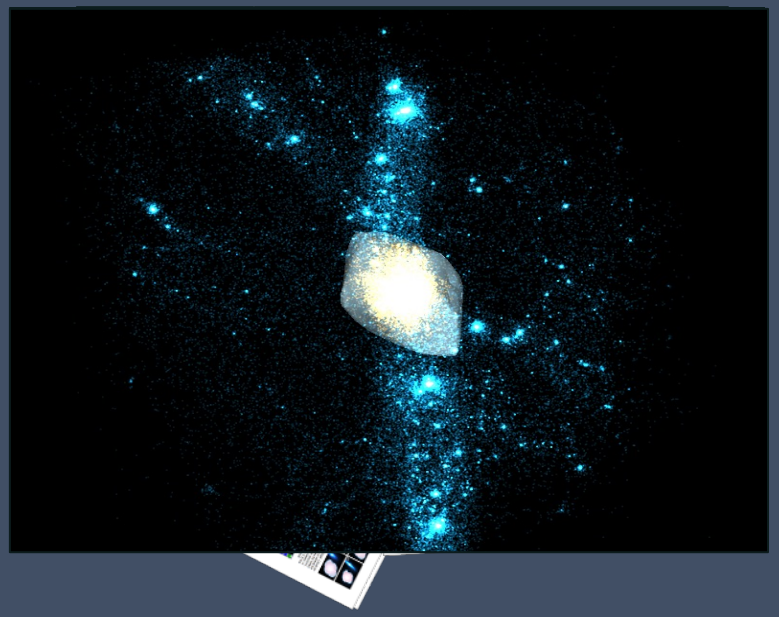


- Efficient Structure-Aware Selection Techniques for 3D Point Cloud Visualizations with 2DOF Input [Yu et al., 2012].
- CAST: Effective and Efficient User Interaction for Context-Aware Selection in 3D Particle Clouds. [Yu et al., 2016].

The Problem: Selection of 3D Subspaces

- 3D spatial data - basis of many visualization research questions

- **problem:** why/how to efficiently select subspaces in 3D?
  - raycasting requires large objects
  - want spatial selection from 2D (Tablet Freehand Lasso)
  - iterative selection too tedious

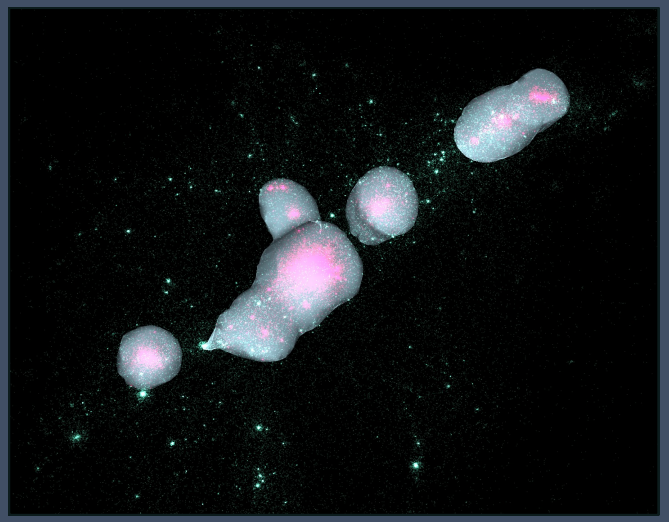


Interactive Selection Techniques

- ***spatial selection*** rather than object-based selection
- ***two-dimensional input*** (PC, touch displays)
- ***2D lasso*** interaction: ***intended*** selection
- ***structure-aware selection*** in 3D depth

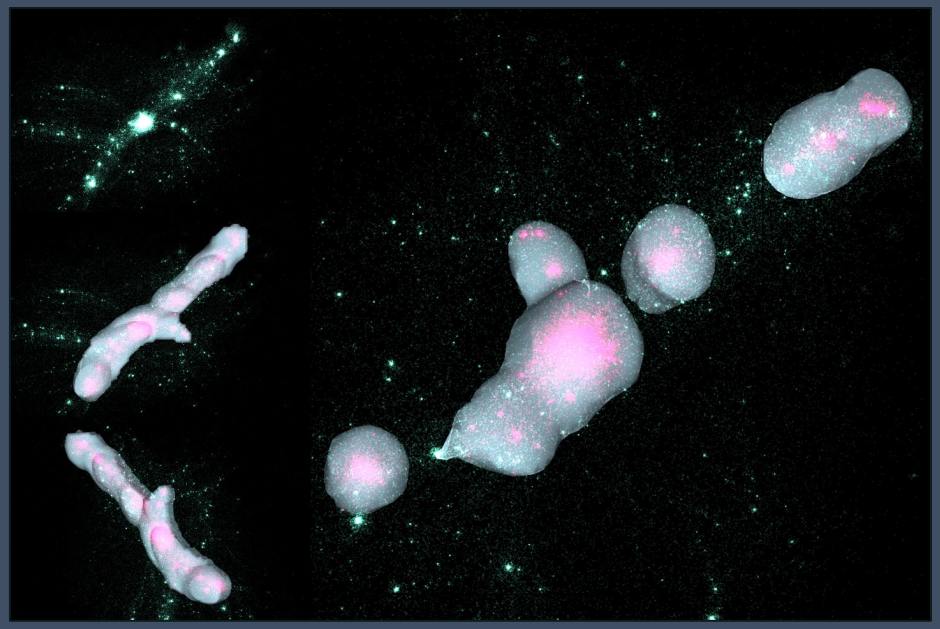
Cloudlasso

- ***spatial, structure-aware*** 3D selection techniques
- ***2D lasso*** interaction:
  - particle density or the scalar properties of volume data
  - Select all dense clusters through the 3D space that is enclosed by the drawn lasso



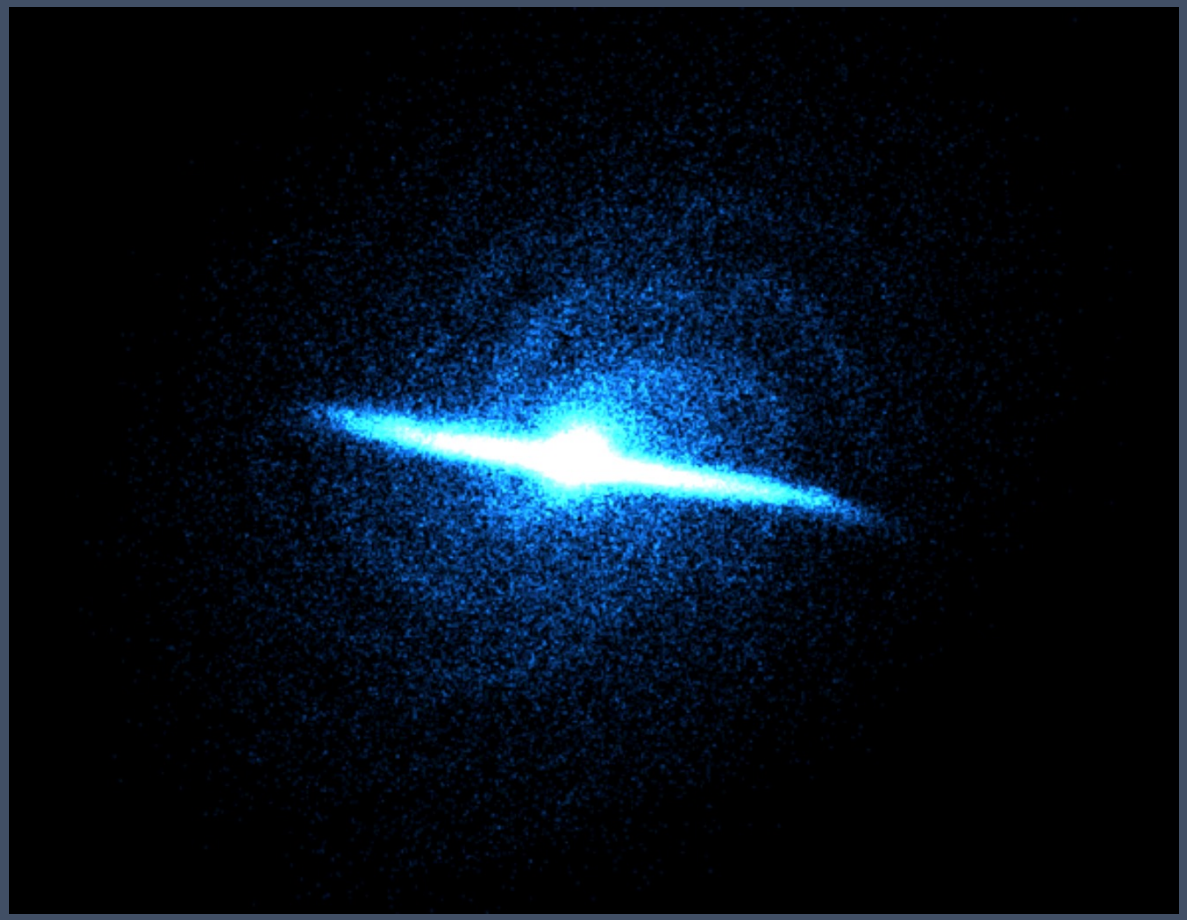
Cloudlasso

- structure-aware selection
- separate clusters
- interactive adjustment o selection threshold



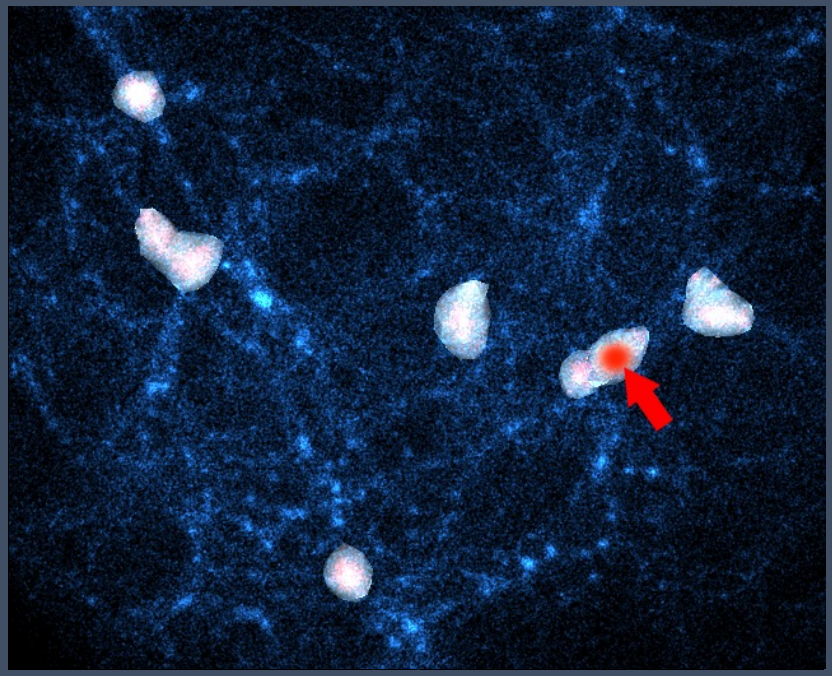
- performance:
  Marching Cubes: ≈ 0.4 sec.
  density estimation:
  4–6 sec. for ≈ $2 \bullet 10^5$ particles

Video: CloudLasso Selection & Interaction



Cast family

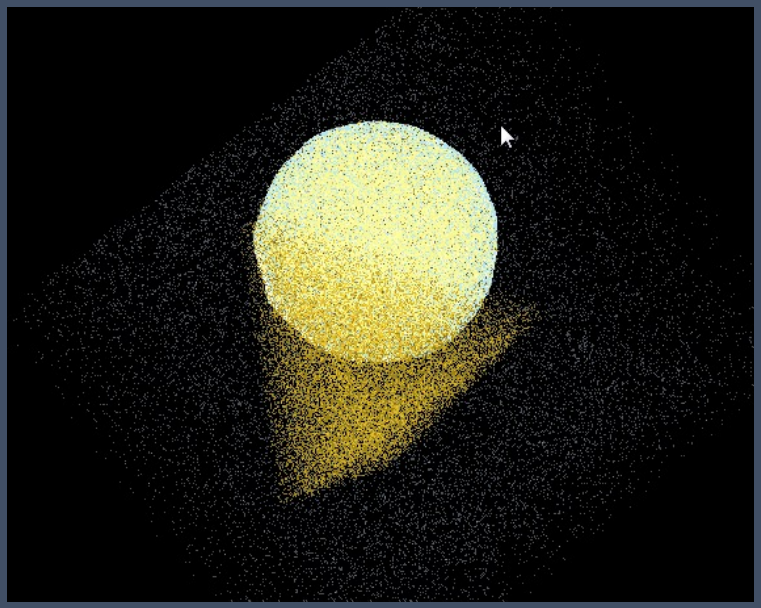
- ***spatial, context-aware*** selection techniques
  - Input : 2D lasso / point
  - Location or shape
  - Output: ***intended*** 3D selection



SpotCast

SpaceCast

- the idea: Selecting only the part that has the best overlap with the input lasso.
- principle:
  - identify the volume set V where the density ρ is above the threshold ρ0 (only consider the regions inside of the lasso)
  - project each volume *Vk* to an area *Sk* on the screen
  - compare to the *SL*, compute the overlap
  - identify *SkM* that has the maximal overlap and determine the selection volume to be *VkM*

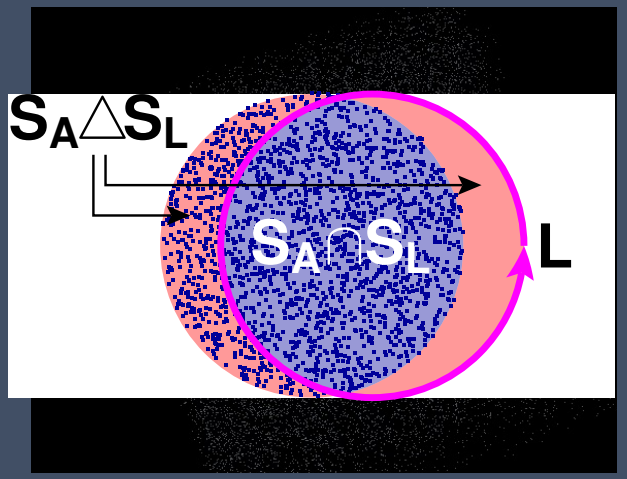


Video: SpaceCast

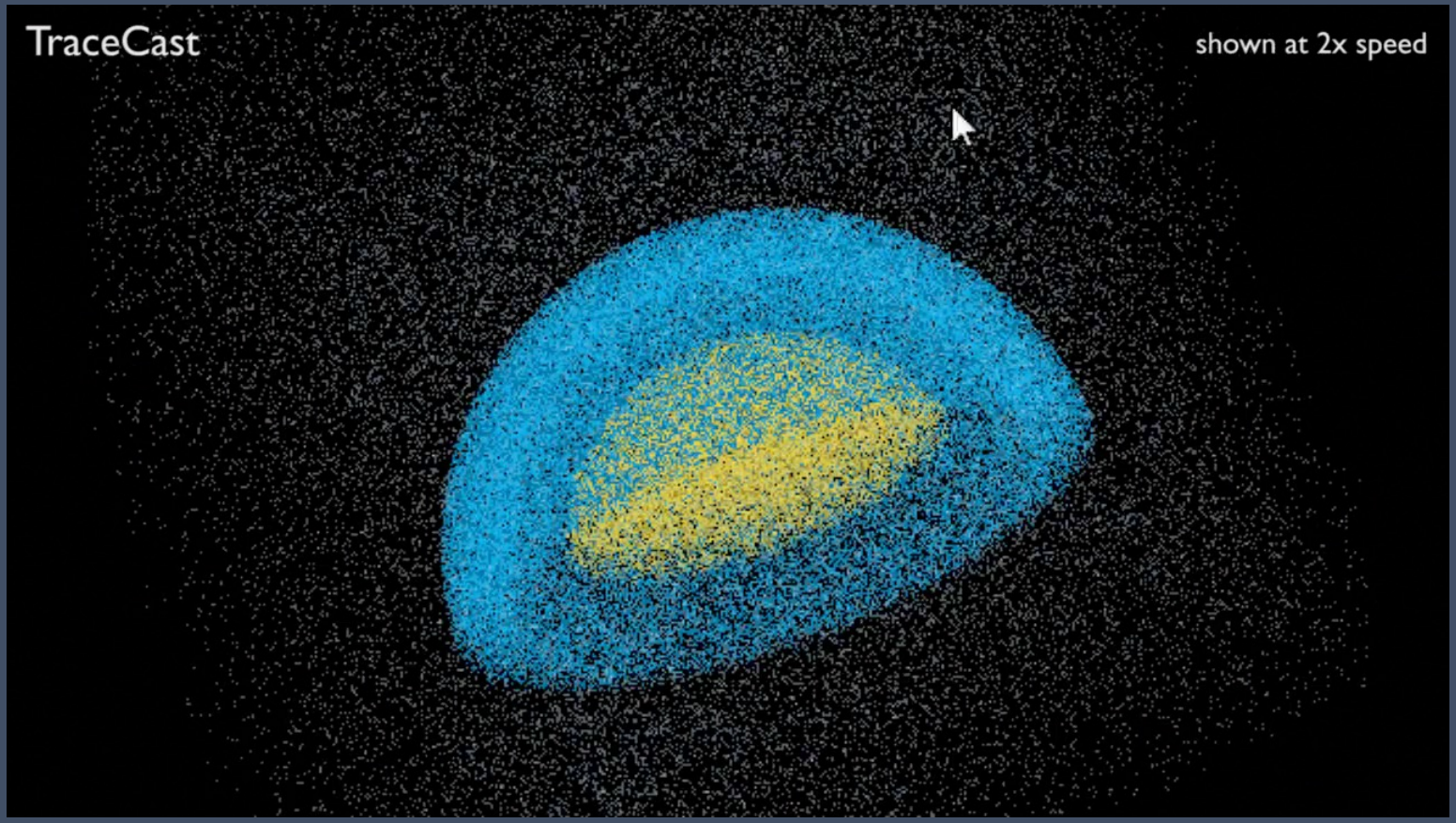
TraceCast

- the idea: Selecting the candidate cluster whose 2D projection is best approximated by the drawn stroke.
- principle:
  - identify the volume set V (consider the regions outside F).
  - project each volume *Vk* to an area *Sk* on the screen
  - compare to the *SL*, compute the overlap

  $Mk = \text{area}(Sk \cap SL) - \text{area}(Sk \triangle SL)$
  - identify *MkM* that has the maximal overlap and determine the selection volume to be *VkM*

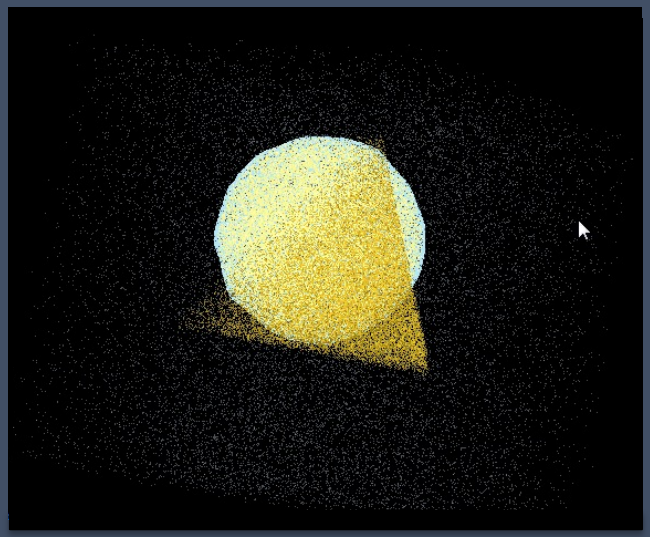


Video: TraceCast

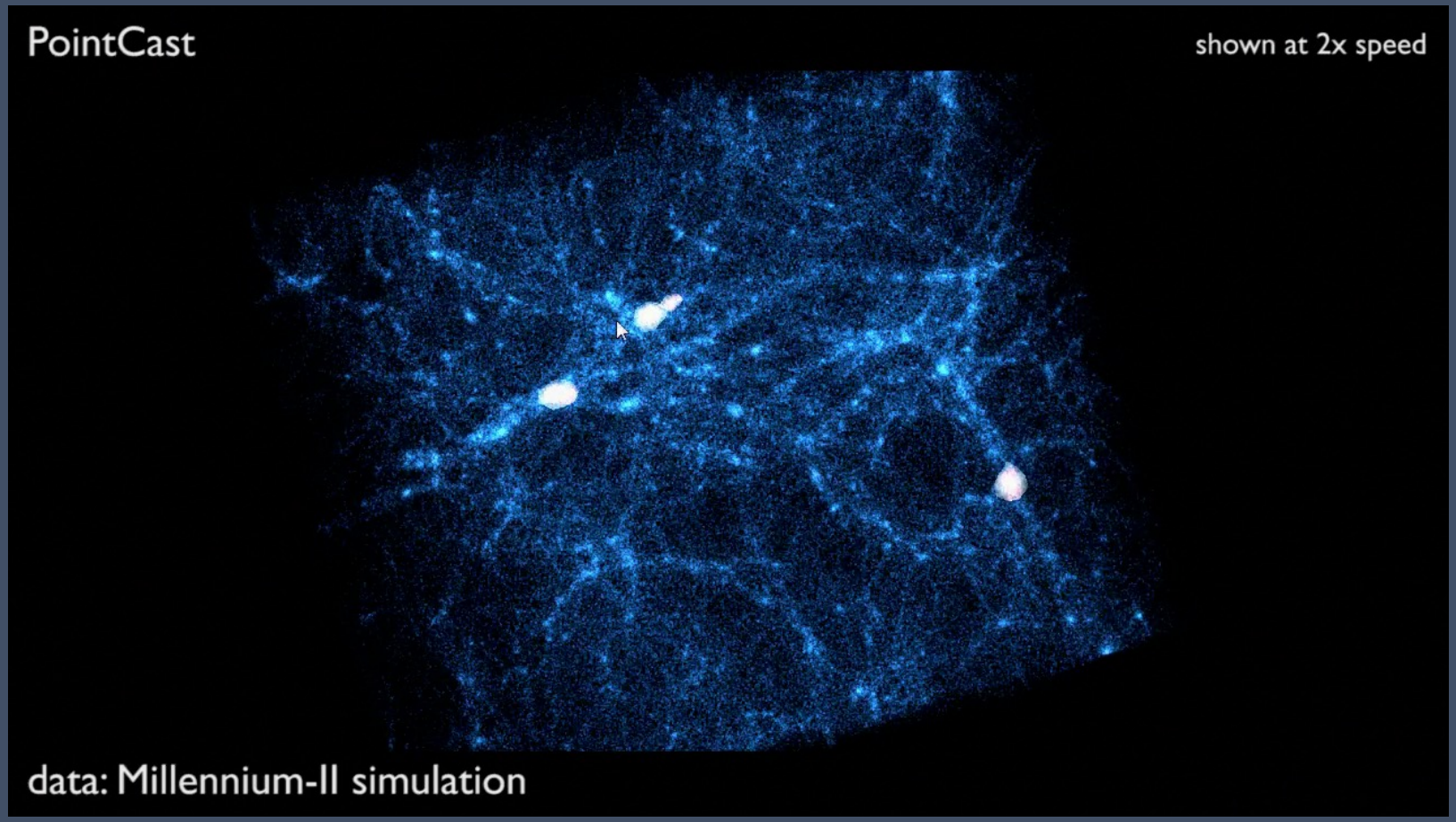


PointCast

- the idea: a single click or touch action to mark a cluster.
- principle:
  - project a ray into the dataset.
  - sample the particle density ρ at equally spaced points along the ray.
  - identify clusters along this ray.
  - select the closest one.



Video: PointCast

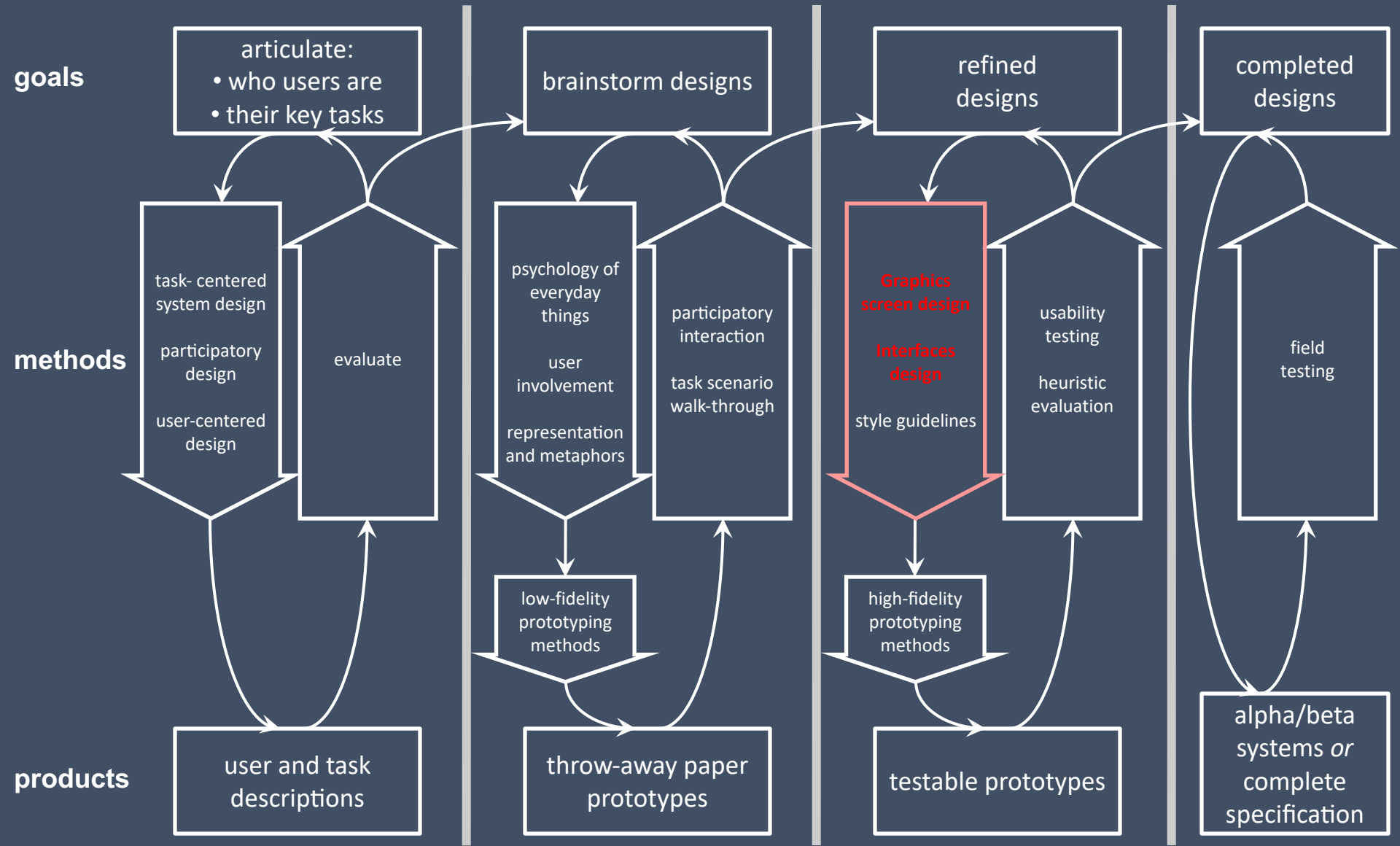


WYSIWYP

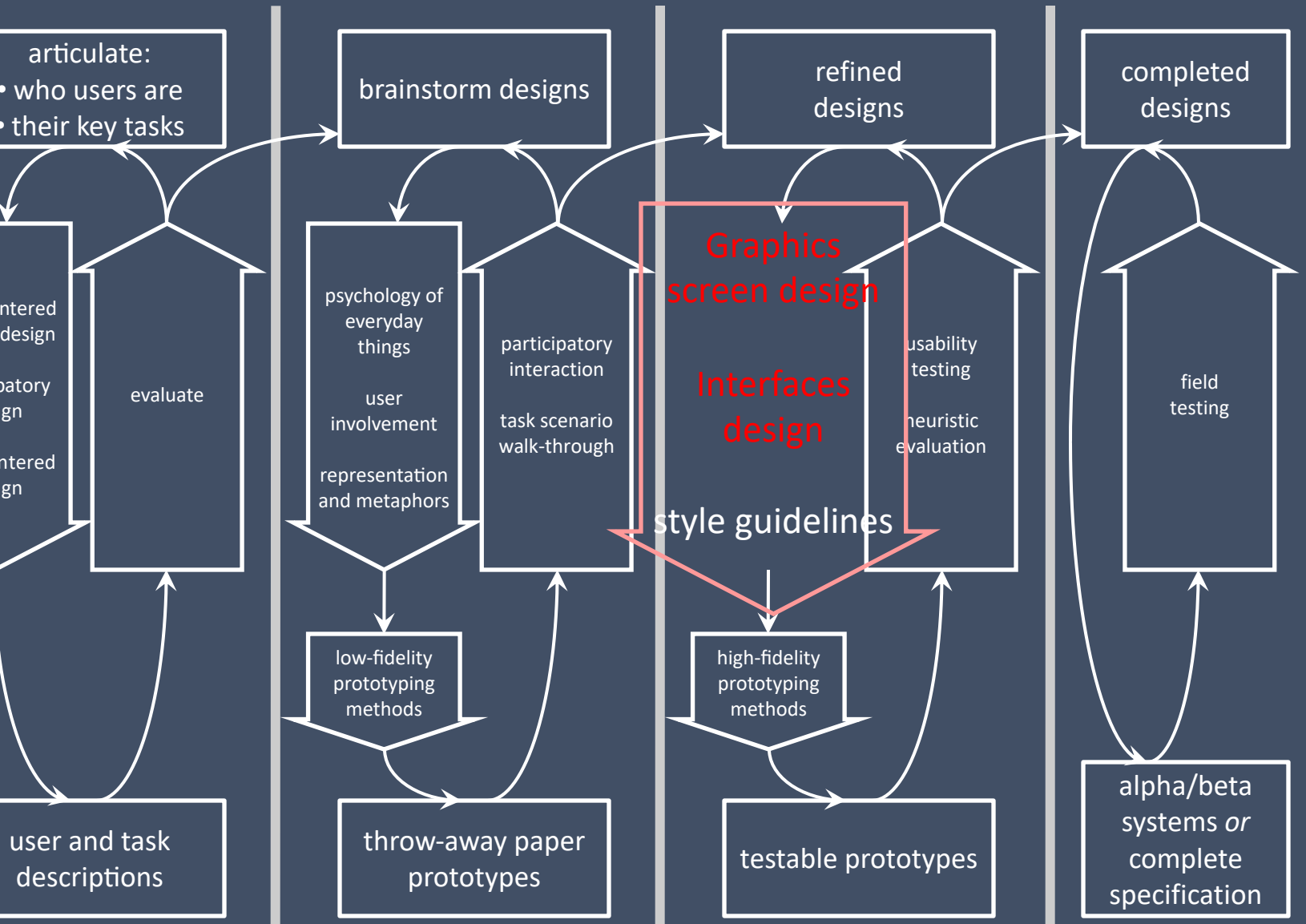
Comparison between WYSIWYP and picking most contributing position

MRI scan of the abdomen

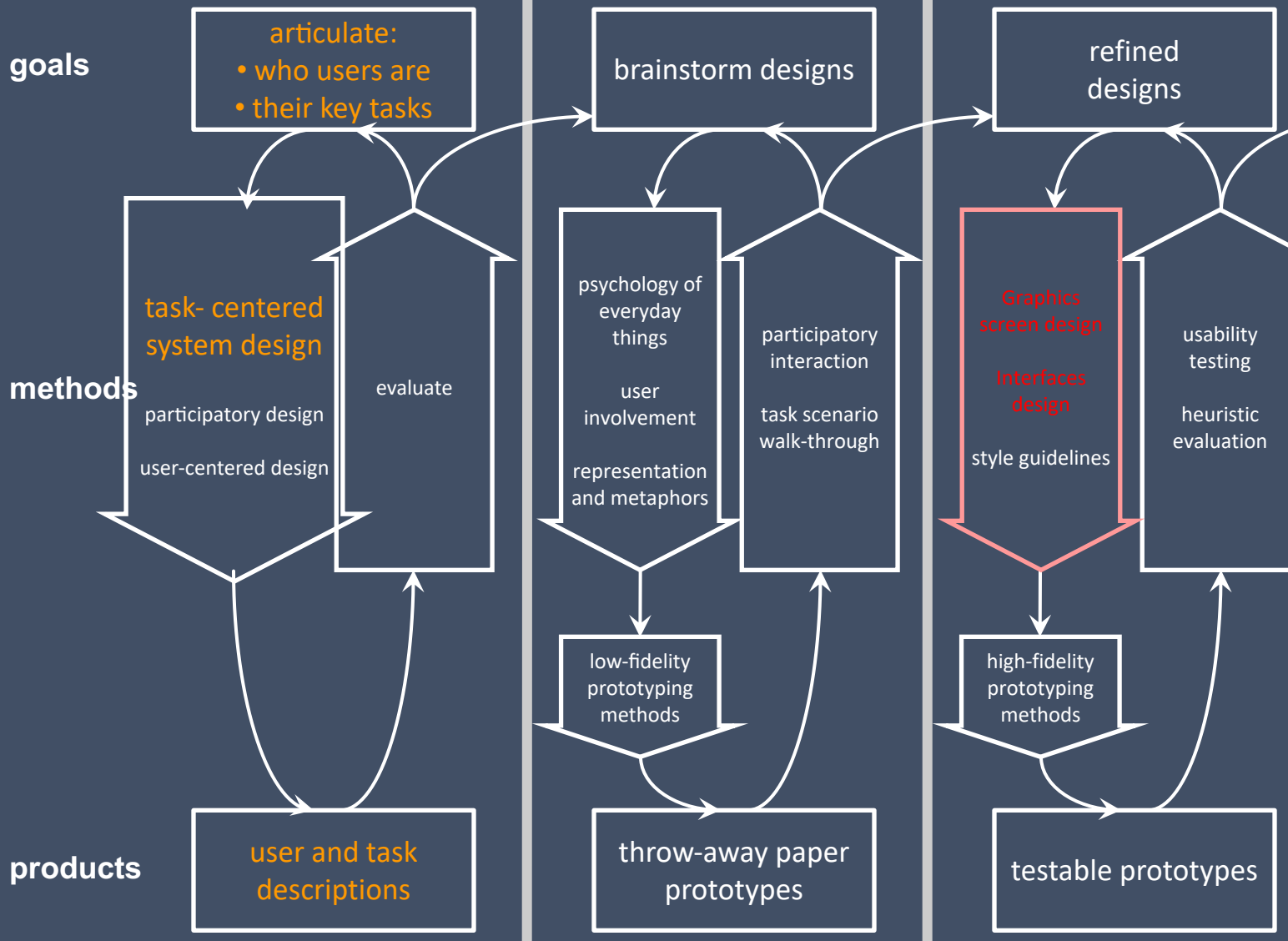
An Interface Design Process



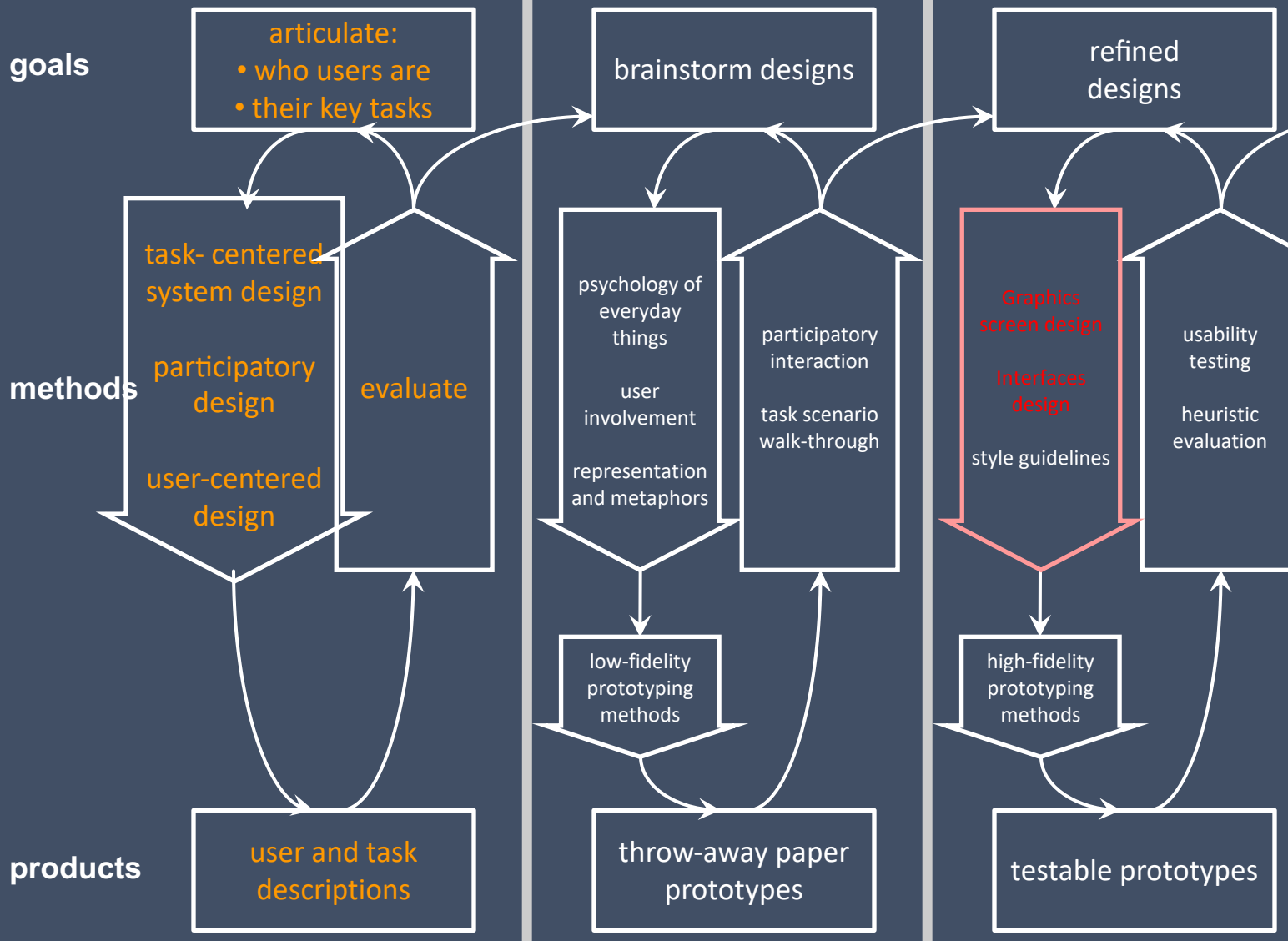
erface Design Process



An Interface Design Process



An Interface Design Process



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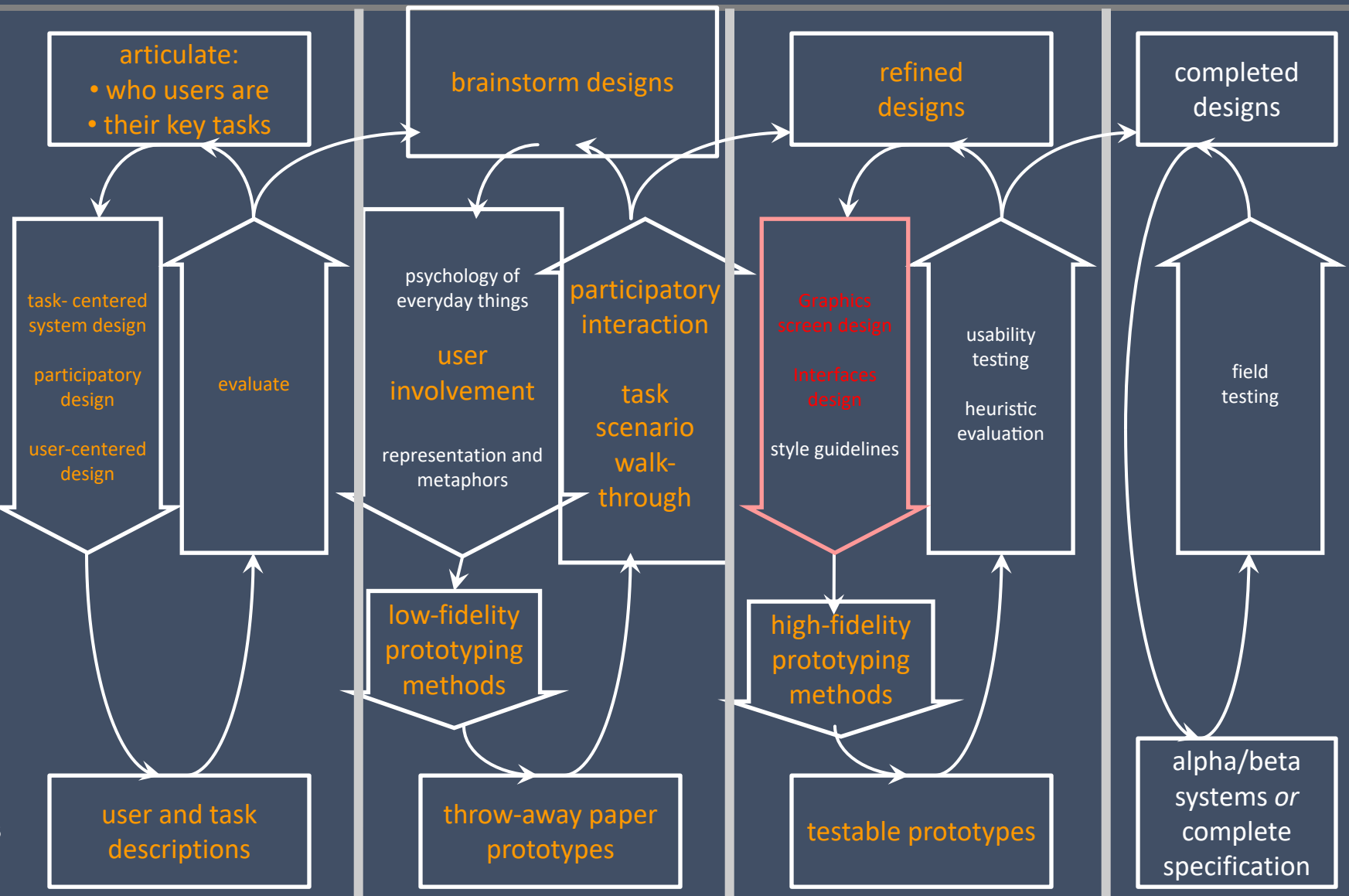
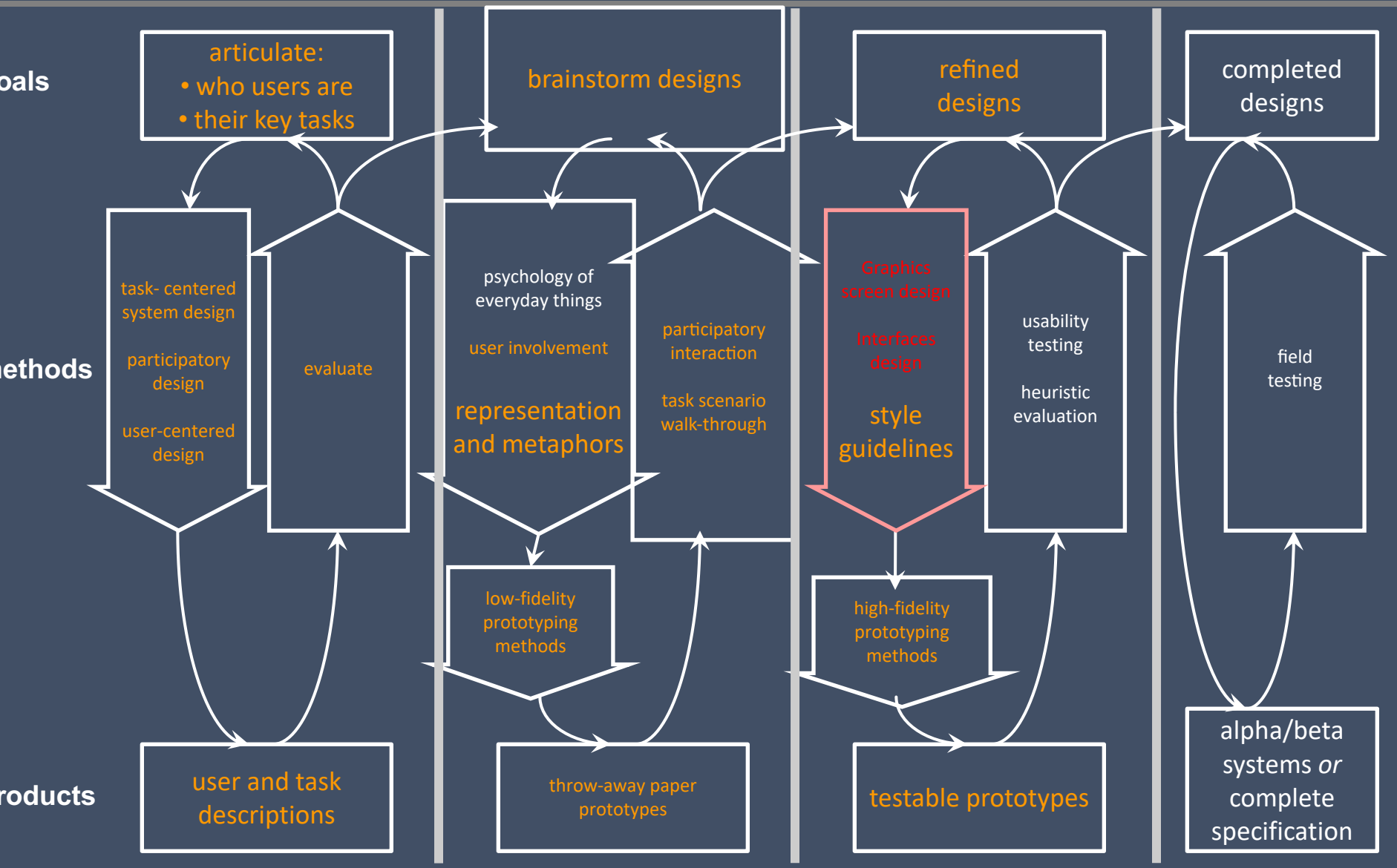
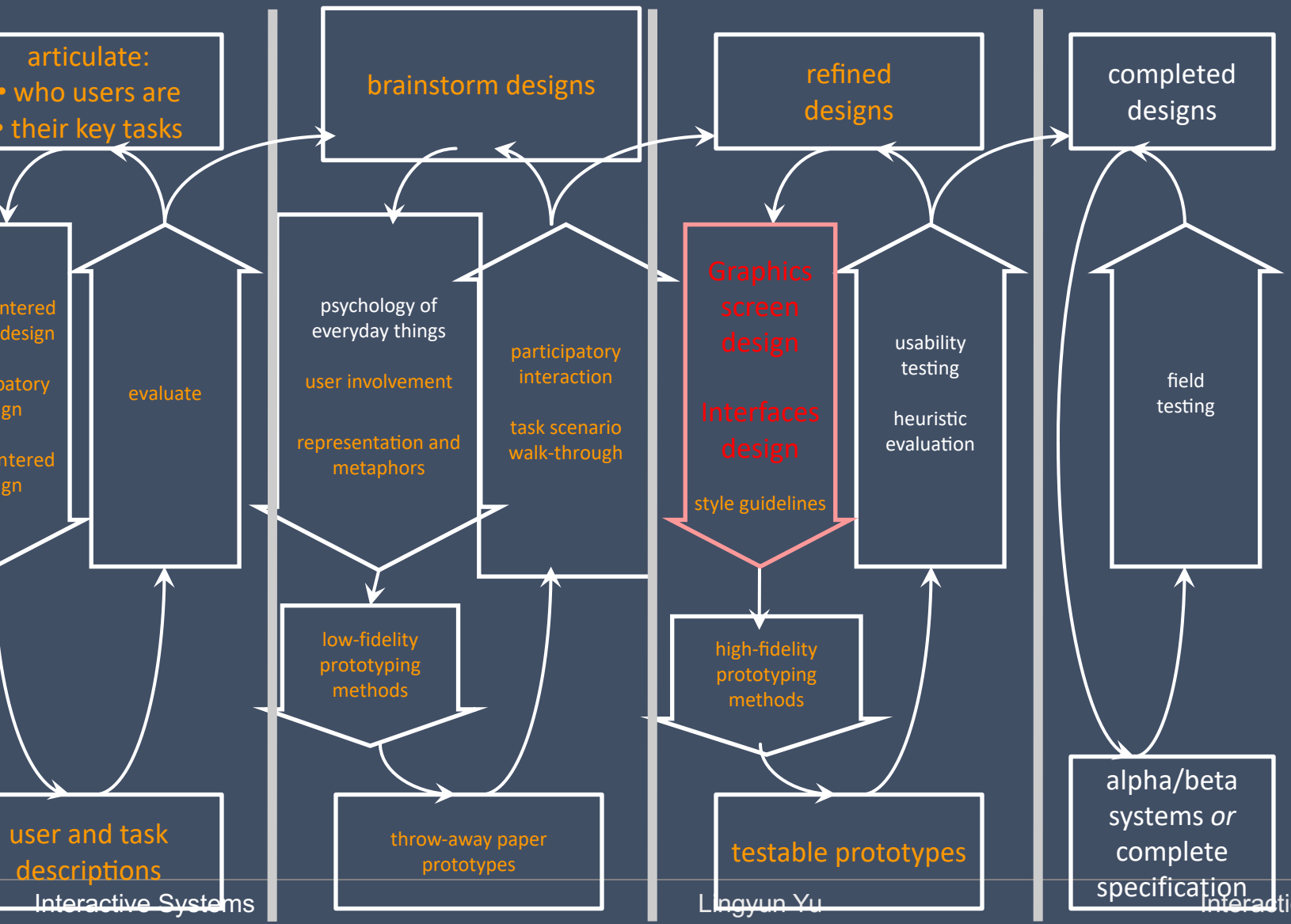


An Interface Design Process



An Interface Design Process



An Interface Design Process