Tools & Techniques for Direct Volume Interaction

3. Interaction with Non-Standard Input and Output Devices

traditional setups:

- one or more displays
- input through mouse and keyboard

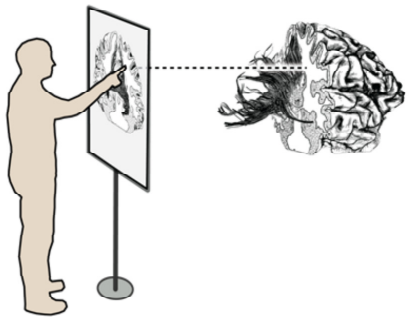
non-traditional setups:

- a lot more variety
- potentially larger or smaller displays, potentially capable of stereoscopic viewing
- variety of input devices
- combinations of multiple displays and input devices

Outline

- general considerations
  - output type: stereoscopic vs. monoscopic
  - input type: direct vs. indirect
  - tactile interaction feedback type: none, somesthetic, haptic
  - benefits and challenges
  - various combinations
- some specific interaction techniques
  - dataset navigation
  - data selection

- some of the applications are not volume rendering, but the mentioned interaction techniques apply to most 3D data in general



Interaction with Non-Standard Input and Output Devices

Part 1: General Considerations

- first part: general considerations
- what makes novel interface environments novel?
- several aspects to consider

Monoscopic vs. Stereoscopic Display

Images: Univ. Groningen, LG, A. Wiebel

less immersion

→ good stereo perception only w/ interaction

high visual immersion

→ stereo perception w/o interaction
→ ppl. can understand 3D data well

- first aspect: type of display
- (a) monoscopic displays, i.e., the 3D content is projected onto the 2D surface of the display
- (b) stereoscopic displays, i.e., the 3D content is shown using immersive technology
    - different options: passive, active
    - typically combined with 3D tracking
- monoscopic displays with less visual immersion
    - perception of stereo content through the projection (difficult in volumetric data)
    - perception of stereo content largely through interaction (navigation)
- stereoscopic displays produce higher visual immersion
    - 3D perception w/o interaction
    - but problems with input devices

Indirect vs. Direct Input

input location ≠ data location

→ always mental mapping necessary

input location = data location

→ no mental mapping necessary
→ ppl. feel more in control

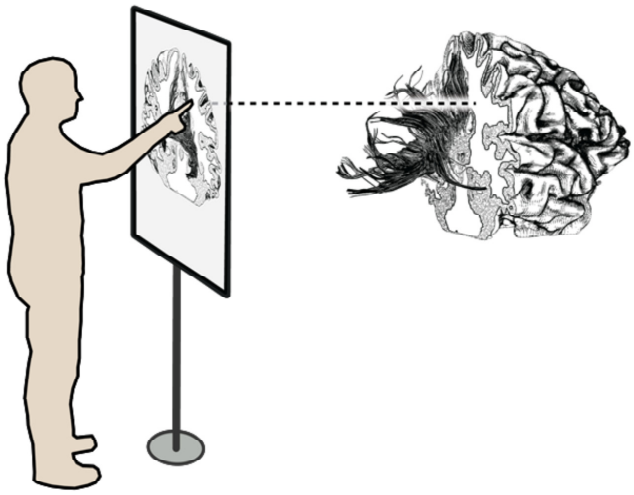
e.g., pen, touch, 3D tracking

images: Logitech, Univ. Calgary

second aspect: type of input

- (a) indirect input: input location is different from data location
- (b) direct input: input location the same as data location
- for indirect input
    - a mental mapping from input to data/manipulation location necessary
- for direct input
    - no mental mapping necessary
    - ppl. tend to feel more in control
    - different types of direct input: pen, touch, 3D tracking

Direct Input for 3D Data? Input vs. Data Domain



- but what does direct input for 3D data mean?
- depends on the type of display
- stereoscopic displays:
    - input directly at the 3D location of the data element
- projected (monoscopic) displays:
    - input directly on the 2D projection on of the data element
    - still some form of indirection due to different input and data domains

Tactile Feedback

images: Wikipedia user GRPH3838, SCI institute, NASA, [Caffrey et al. 2011/2012], Univ Calgary, 3D Systems

third aspect: type of tactile feedback

- important information for interaction, corrections
- people do not get lost in space
- resting position, thus more precise input
- (passive) somesthetic vs. (active) haptic feedback

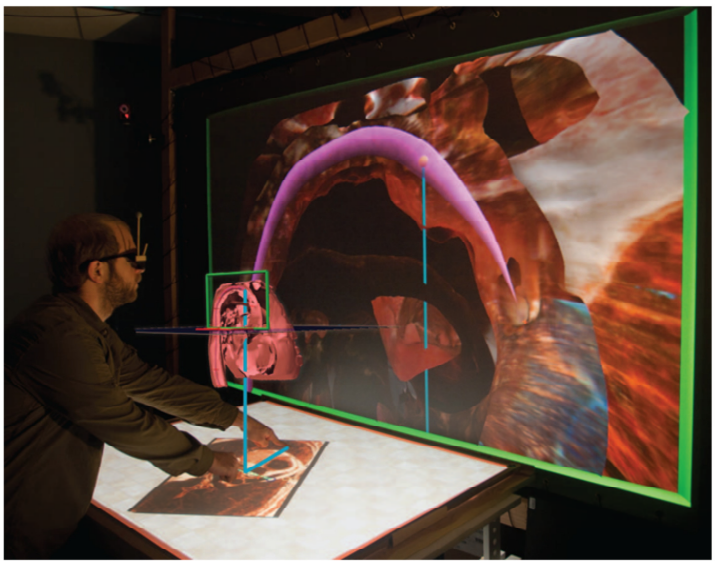
Tactile Feedback

images: Wikipedia user GRPH3838, SCI institute, NASA, [Caffrey et al. 2011/2012], Univ Calgary, 3D Systems

third aspect: type of tactile feedback

- important information for interaction, corrections
- people do not get lost in space
- resting position, thus more precise input
- (passive) somesthetic vs. (active) haptic feedback

Tactile Feedback



images: Wikipedia user GRPH3838, SCI institute, NASA, [Caffrey et al. 2011/2012], Univ Calgary, 3D Systems

third aspect: type of tactile feedback

- important information for interaction, corrections
- people do not get lost in space
- resting position, thus more precise input
- (passive) somesthetic vs. (active) haptic feedback

Tactile Feedback

Images: Wikipedia user GRPH3818, SCI Institute, NASA, [Coffey et al. 2011/2012], Univ Calgary, 3D Systems

third aspect: type of tactile feedback

- important information for interaction, corrections
- people do not get lost in space
- resting position, thus more precise input
- (passive) somesthetic vs. (active) haptic feedback

Taxonomy of Input/Output Environments

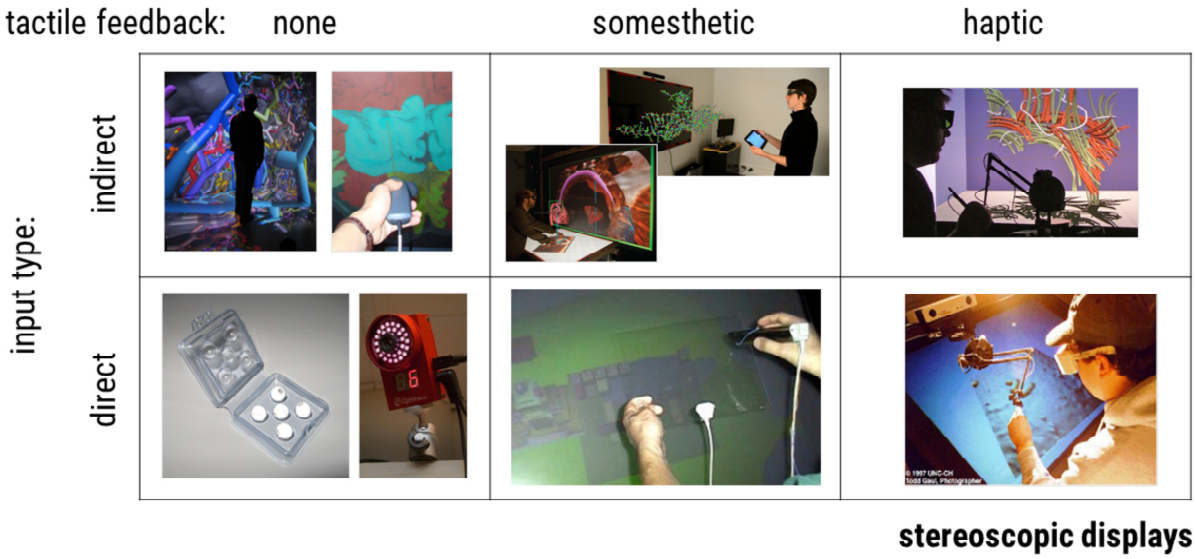
input type:	tactile feedback: none	somesthetic	haptic
indirect			
direct	(except hover)		(for 3D content)

monoscopic displays

images: Logitech, IG, Microsoft, D. Keefe, Google

- based on the three aspects we can formulate a three-dimensional taxonomy of input devices
- first for monoscopic displays
- the table shows some examples for input devices

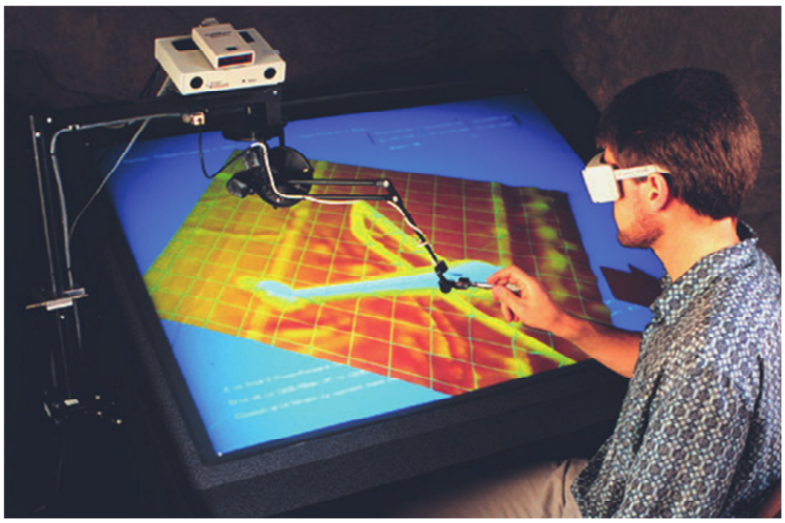
Taxonomy of Input/Output Environments



images: Univ. Groningen, Purdue Univ., Coffey et al. 2012, D. Keefe, Google, Schmalstieg et al. 1998, UNC Charlotte

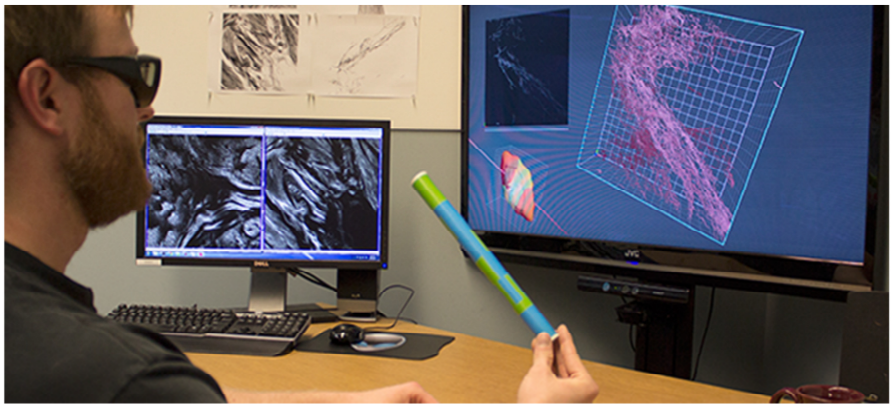
- then for stereoscopic displays
- the table shows some examples for input devices

Direct Input plus Stereo? → Complex HW



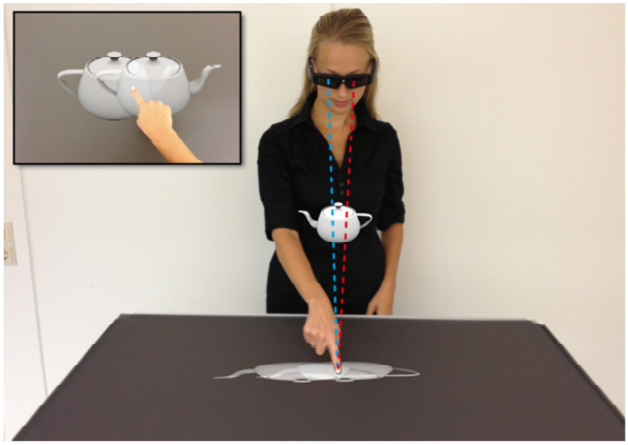
- are there ideal input/output situations?
- stereo plus direct input plus haptic feedback?
- problematic, complex hardware setup

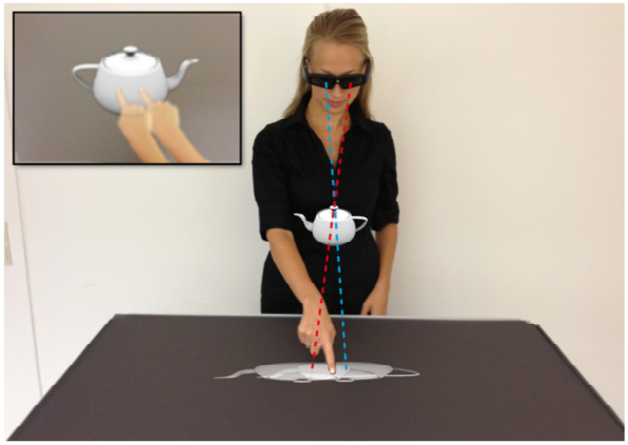
Direct Input plus Stereo? → Special Control



- or, with easier setups, limited types of control (yet cool)

Direct Touch plus Stereo? → Fundamental Issues

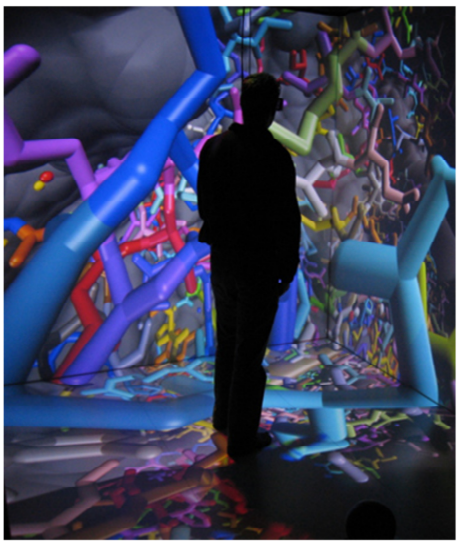


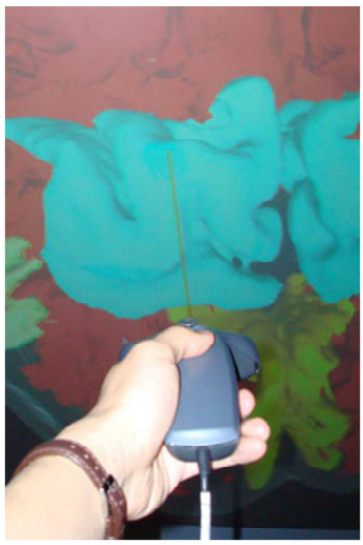


[Bruder et al. 2013]

- compromise: stereo plus somesthetic feedback, i.e. touch input?
- less complex setup, more types of control
- there are fundamental issues:
    - touch plus stereo display on the same output device does not work

Compromise: Stereo View + Indirect Input





Images: Univ. Groningen, Purdue Univ.

- compromise: stereo view plus indirect input:
  - precision issues
  - lost in space issues
  - issues due to the indirectness of the input

Compromise: Stereo View + Indirect Input

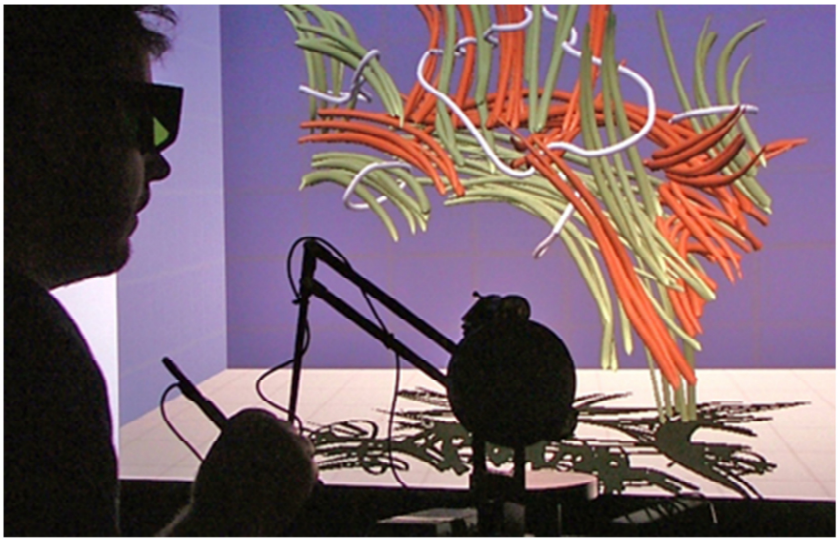
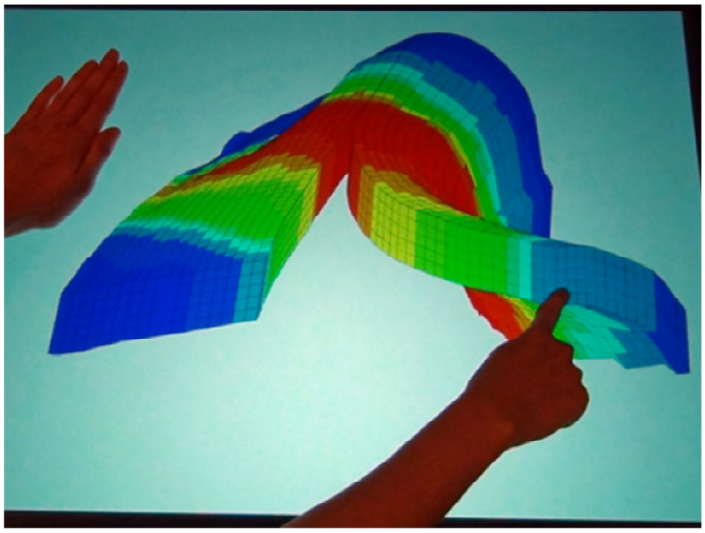


image: Daniel F. Keefe

- adding haptic (yet indirect) feedback is better, yet still complex and not so common hardware setup

Compromise: Mono View + Direct Input



[Sultanum et al. 2010/2011]

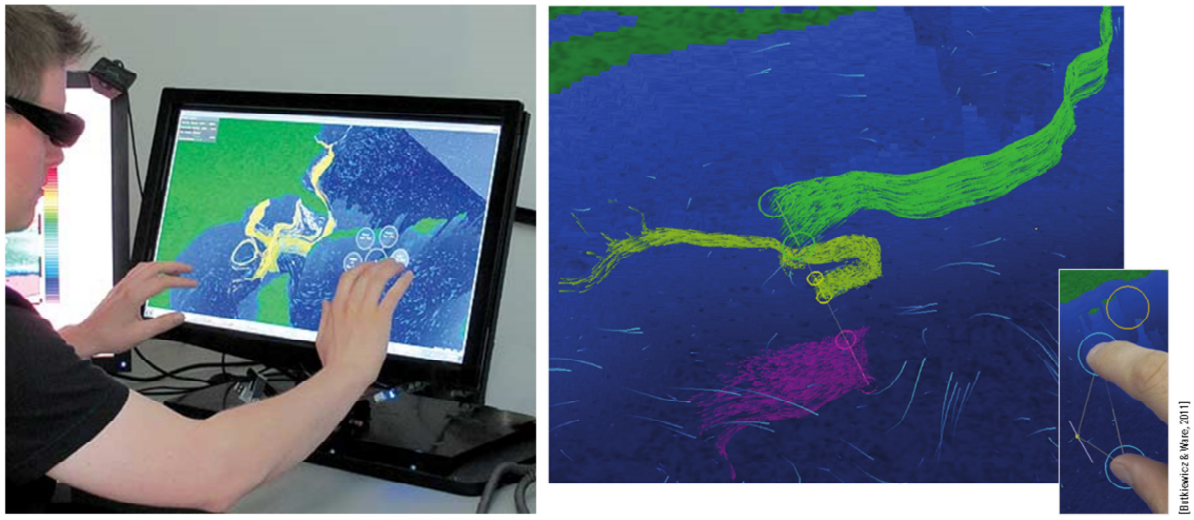
- other compromise: monoscopic view plus direct (touch) input
- loosing the stereo immersion, but gaining immersion through interactive direct manipulation

Compromise: Mono View + Direct Input

[Lundström et al., 2011]

- another example for monoscopic view plus direct input

Direct Input + Stereo View – Shallow 3D



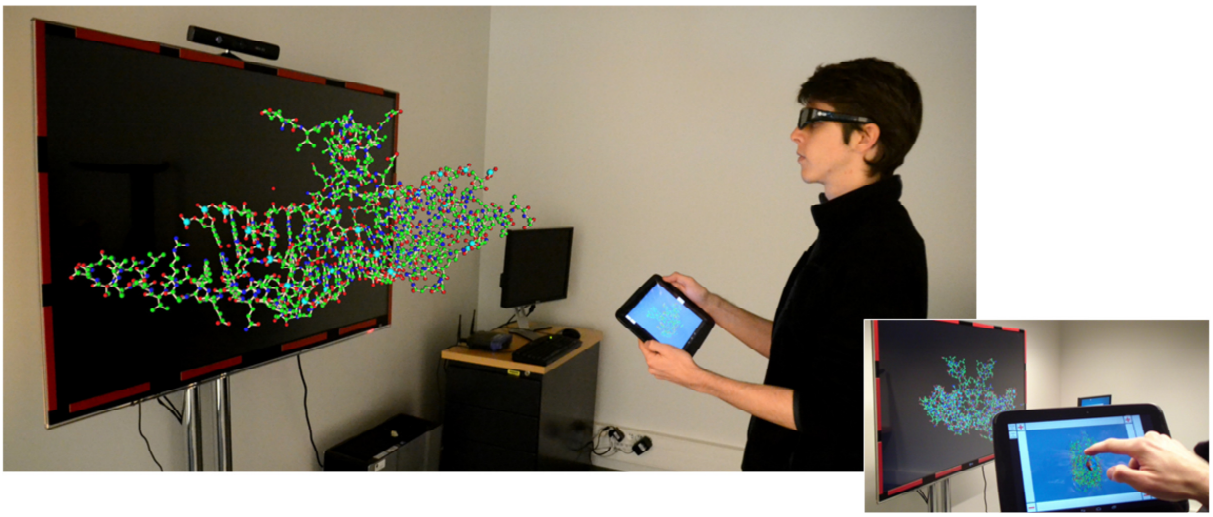
Tutorial "Tools & Techniques for Direct Volume Interaction" 21

- only in very few cases do touch plus stereoscopic viewing work on the same device
- oceanographic visualization
    - comparatively shallow depth of data
    - inherent surface that works as the default touch surface and which can be placed at zero parallax
    - projection and display orientation match

Direct Input + Stereo View – Separate Views

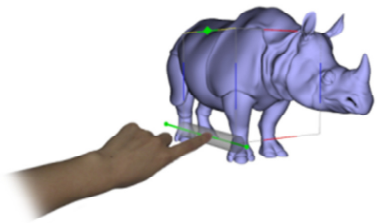
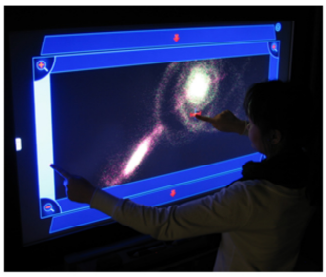
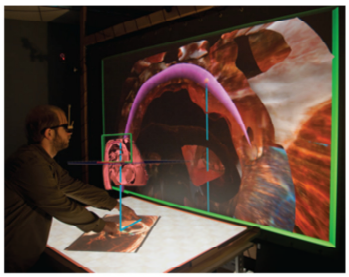
- another compromise: separate the stereo display from the input surface
- the input surface uses a monoscopic view and is direct in that sense
- functions as an indirect input device for the stereo projection, with somesthetic feedback
- the setup can be stationary …

Direct Input + Stereo View – Mobile Touch



- … or can use a mobile touch surface (tablet)
- in that case one has to take the possible orientation mappings between the tablet and the stereo view into account

now: break

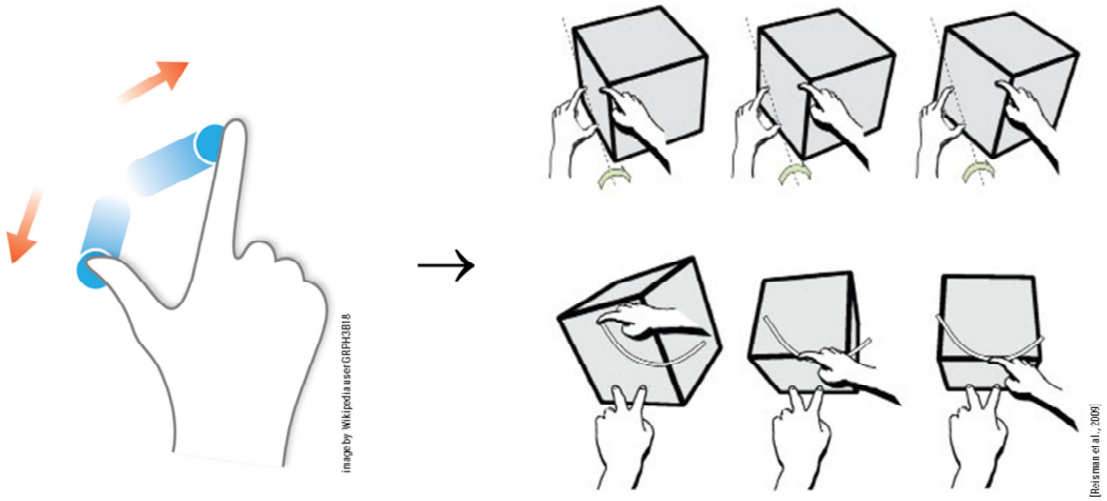




Interaction with Non-Standard Input and Output Devices

Part 2: Fundamental Interaction Techniques for Direct(-Touch) Input: Navigation & Selection

- in the second part, let’s look at some specific interaction techniques
- specifically for touch input and to initiate navigation and selection operations

Navigation using Touch Input: 3D RST



Tutorial "Tools & Techniques for Direct Volume Interaction" 25

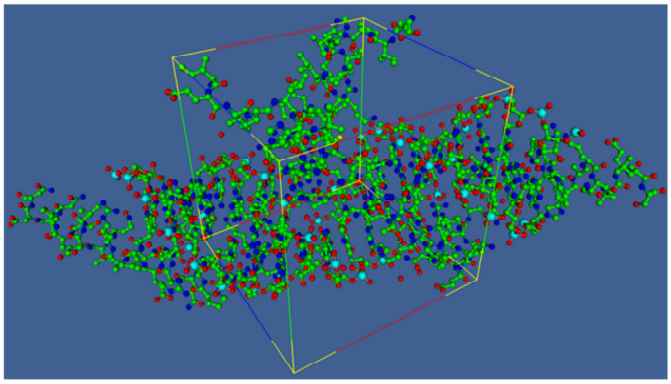
- RST stands for rotation-scale-translate
- known as the pinch gesture in 2D interaction (not invented by Apple)
- two input points, i.e., 2 x 2DOF
- can produce 4DOF control: 2DOF position, 1DOF orientation, and 1DOF uniform scale
- more complex for 3D case: we need >= 7DOF; but as humans we are limited to 4DOF **simultaneous** input (maybe 5DOF)
- 3D RST gesture set by Reisman et al. [2009]
- see the video

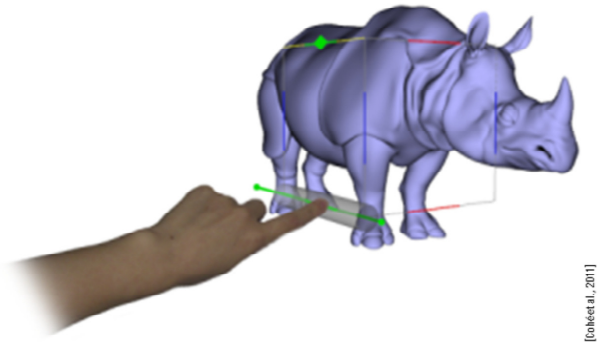
Navigation using Touch Input: 3D RST

[Reisman et al., 2009]

3D RST video

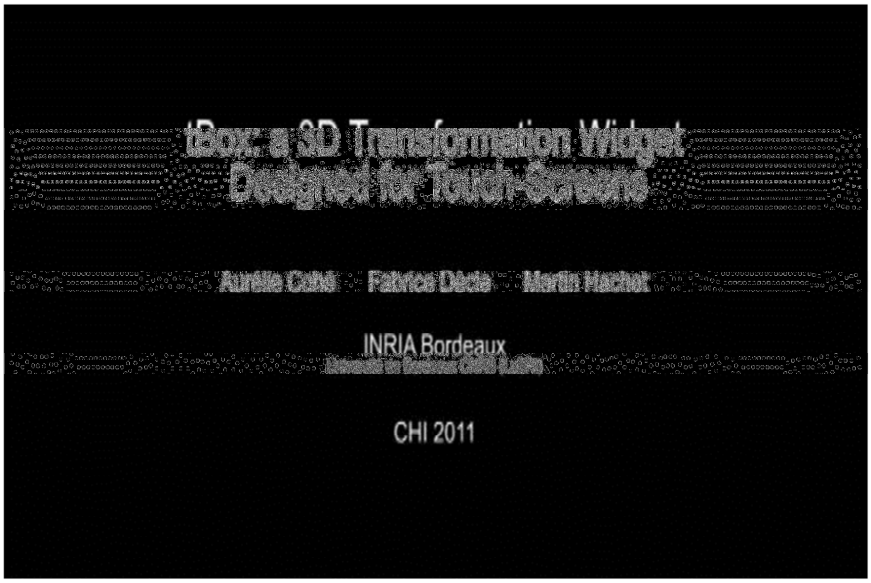
Navigation using Touch Input: tBox





- problem with (3D) RST: all controlled DOF always connected
- to be able to isolate the control of single DOF: tBox by [Cohé et al., 2011]
- virtual interaction handles in form of box
- input possible on sides and along axes
- full 9DOF control possible (of data objects or data space)
- see video

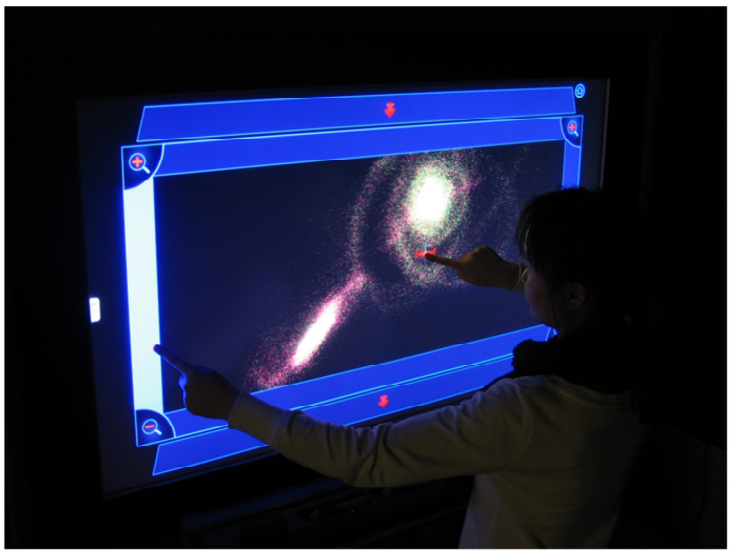
Navigation using Touch Input: tBox



[Cohé et al., 2011]

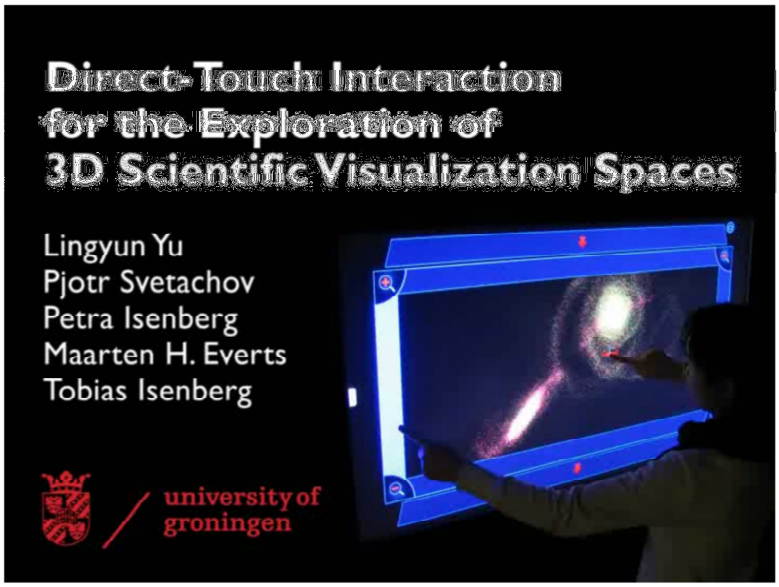
tBox video

Navigation using Touch Input: FI3D



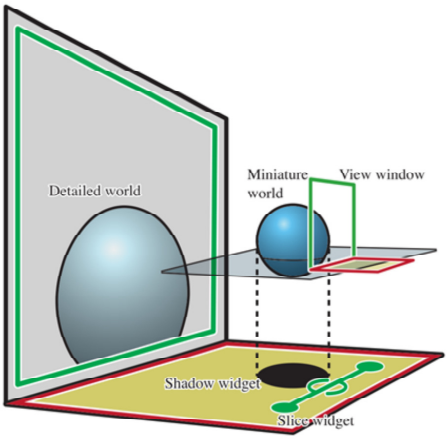
- other form of isolating the input DOF: permanent widget set – FI3D
- widget around the data view
- direction of input selects rotation in frame
- 7DOF control of data space
- see video

Navigation using Touch Input: FI3D



FI3D video

Navigation using Touch Input: Slice WIM



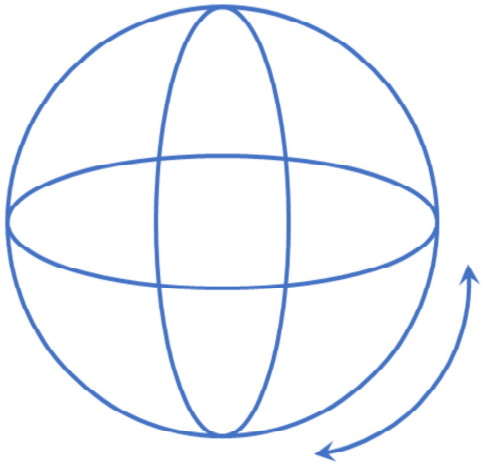
- example for data navigation on separated stereo view and mono input: Slice WIM by Coffey et al. [2012]
- dedicated interaction widget on the touch surface
- uses a small miniature world to connect input and stereo view
- can also provide control for more than navigation
- see video

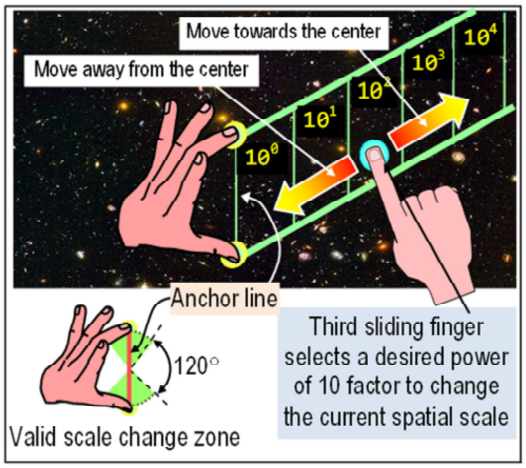
Navigation using Touch Input: Slice WIM

[Coffey et al. 2011/2012]

Slice WIM video

Navigation using Touch Input: Powers of 10



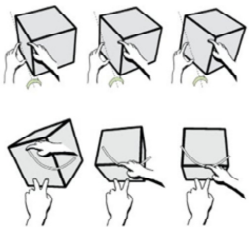


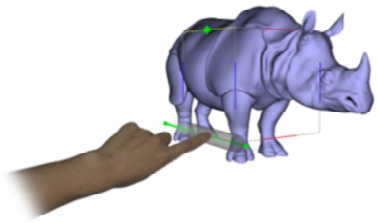
- sometimes also dedicated scale navigation needed
- special gesture for this scale navigation: Powers of 10 input by Fu et al. [2010]
- see video

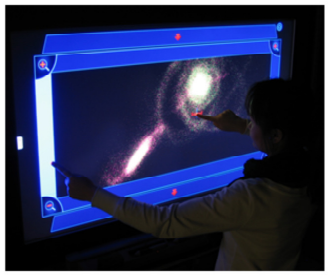
Navigation using Touch Input: Powers of 10

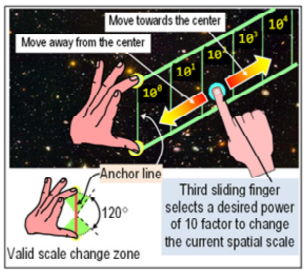
powers of 10 video

Which navigation to use? – It depends …





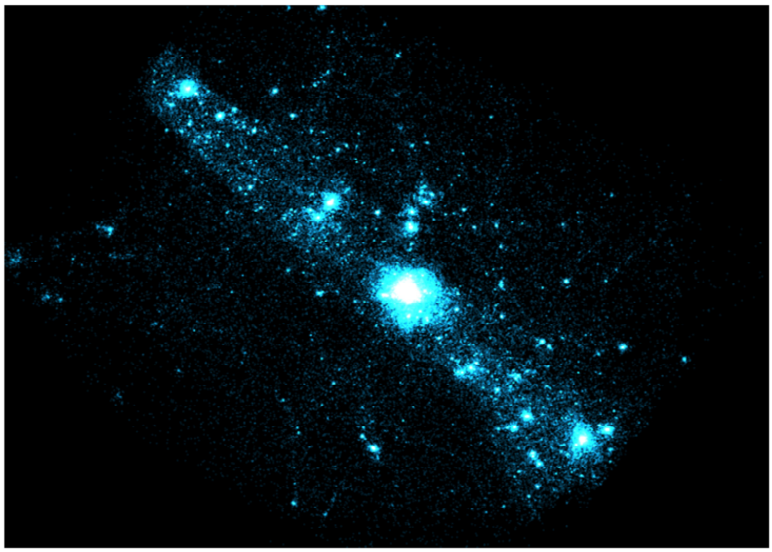




[Reisman et al., 2009], [Cohé et al., 2011], [Fu et al. 2010], [Coffey et al. 2011/2012], [Fu et al., 2010]

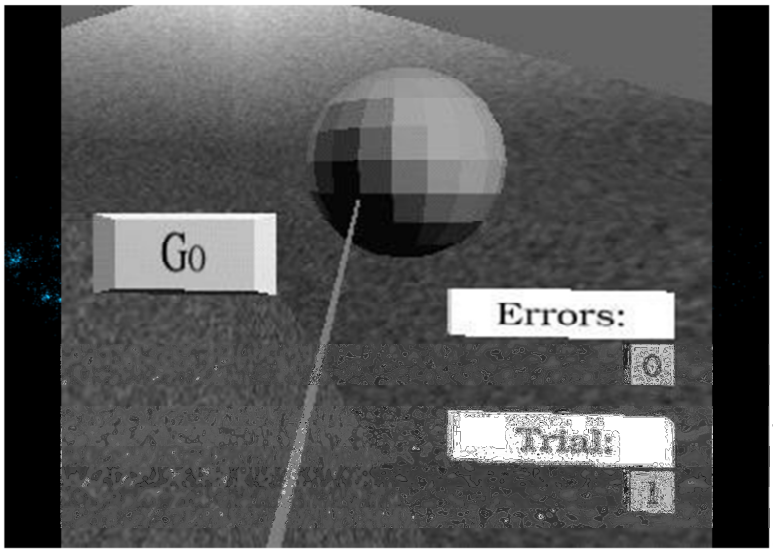
- but which one to to use?
- depends on application and its constrains for
  - type of control
  - precision vs. flexibility
  - hardware setup available
  - etc.

Selection using Direct Input



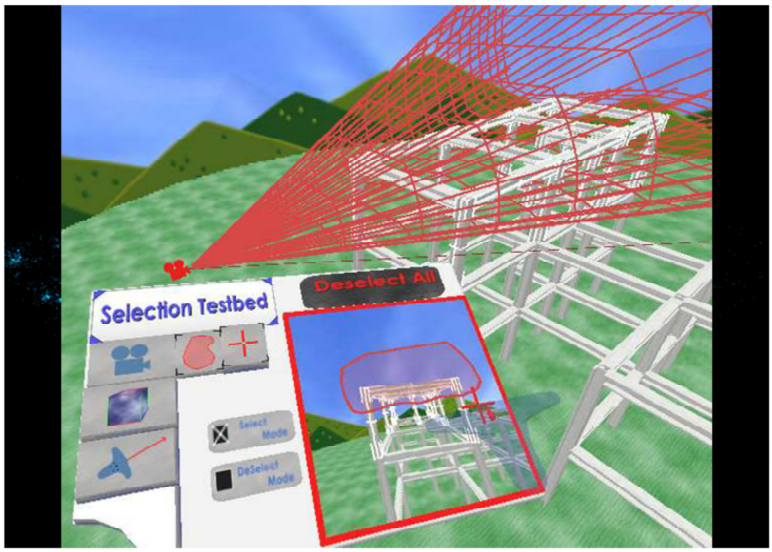
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input

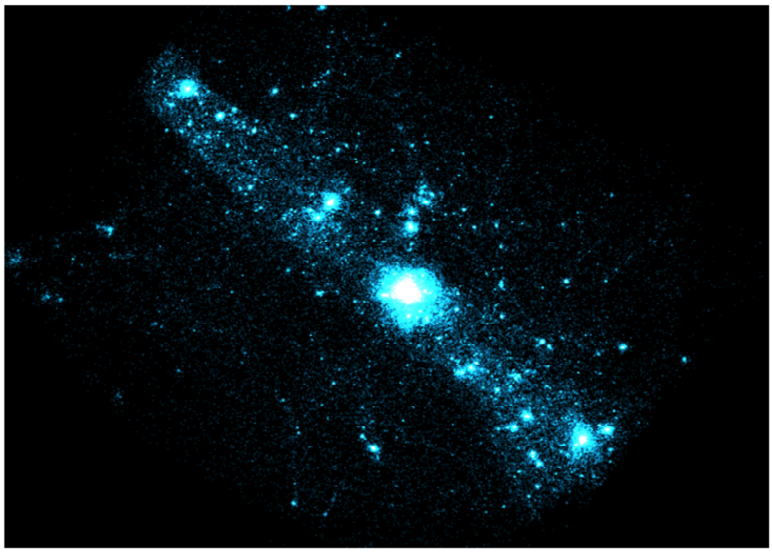


[Lucas & Bowman, 2005]

Tutorial "Tools & Techniques for Direct Volume Interaction" 30

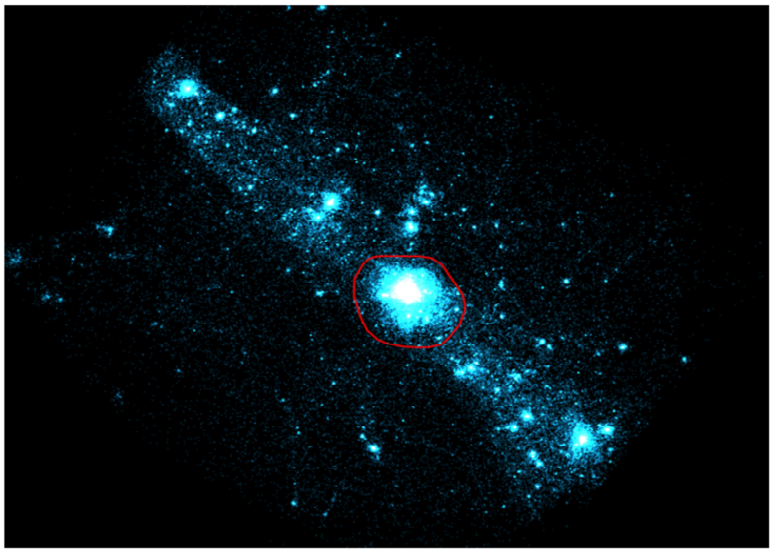
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



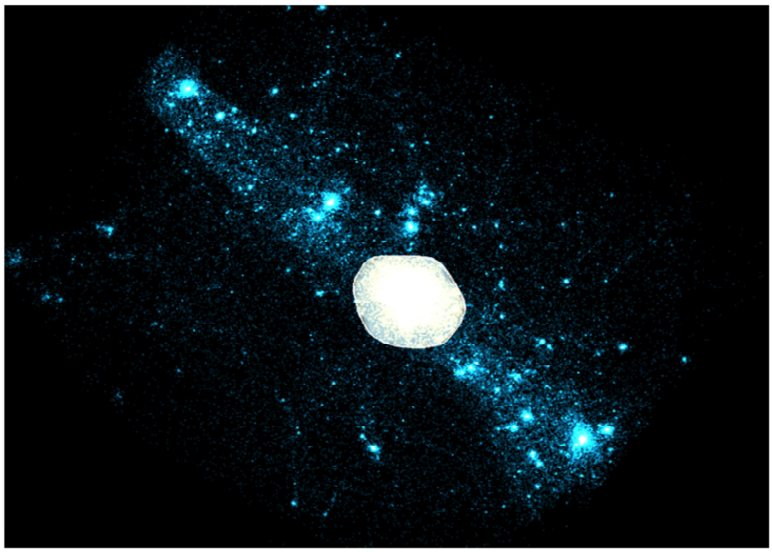
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



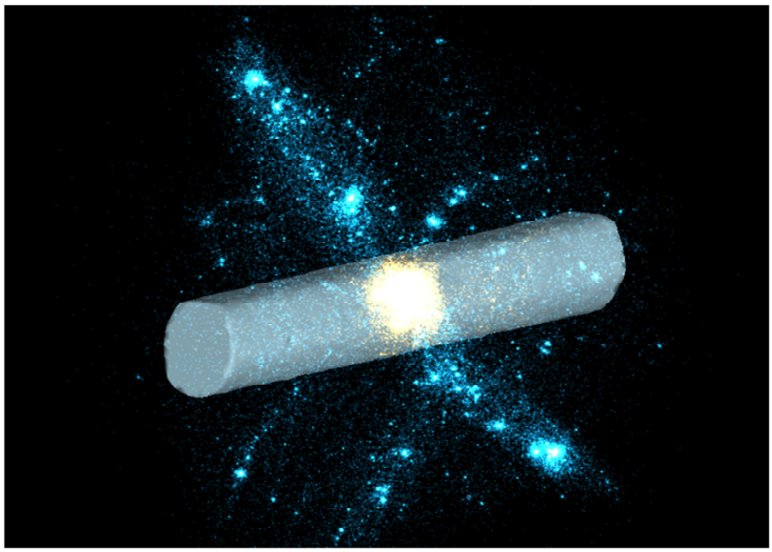
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



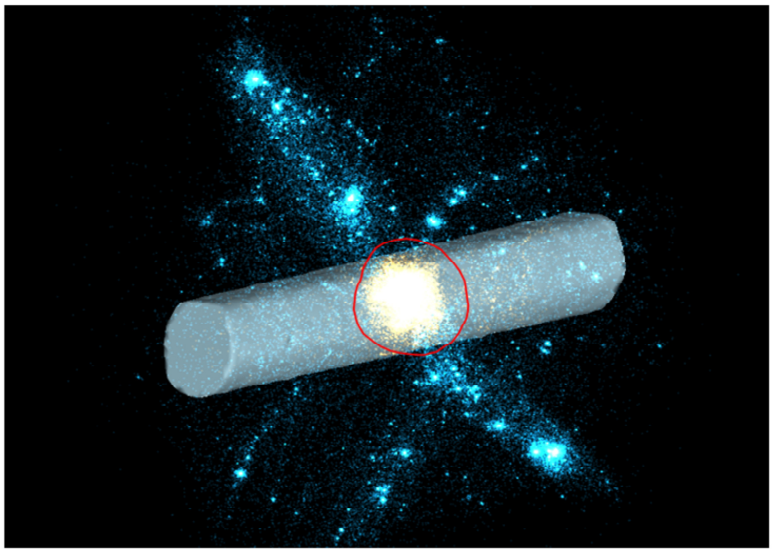
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



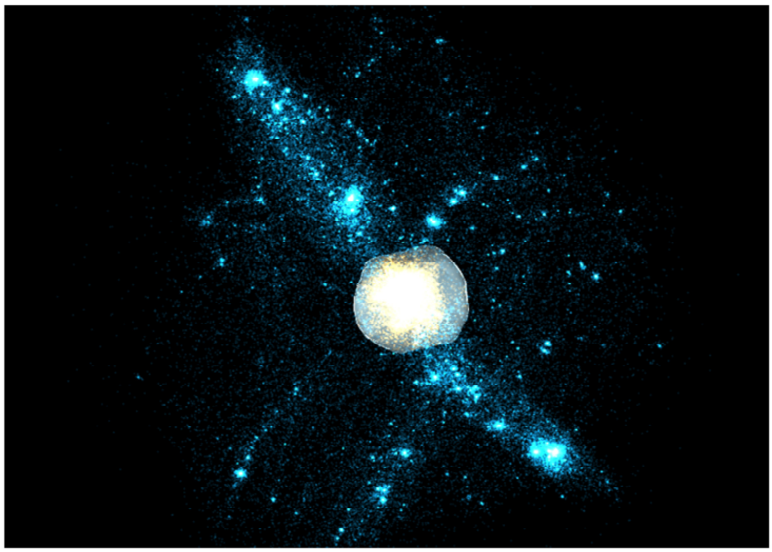
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



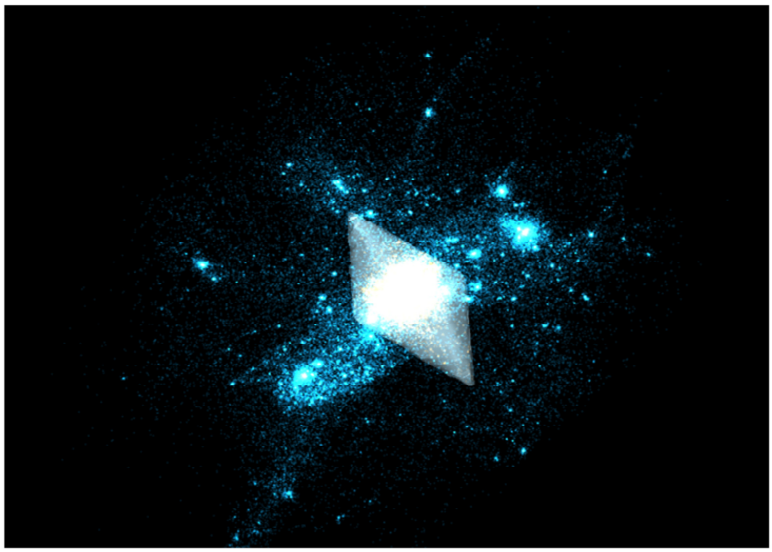
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



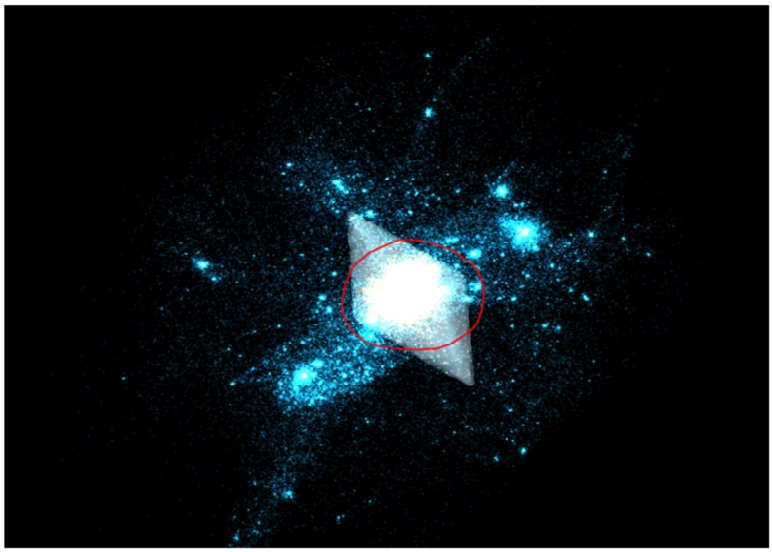
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



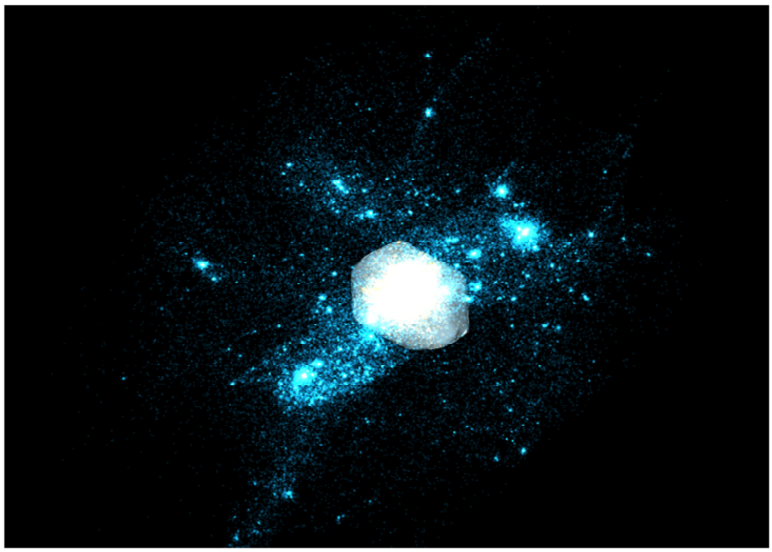
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



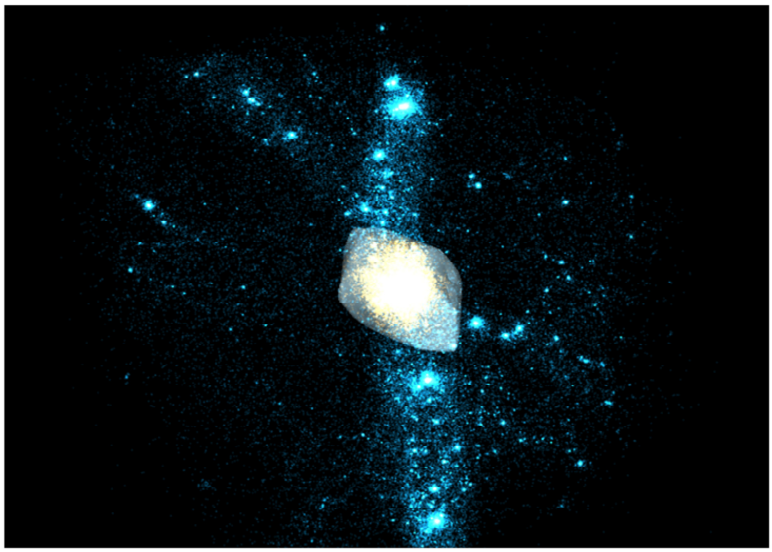
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



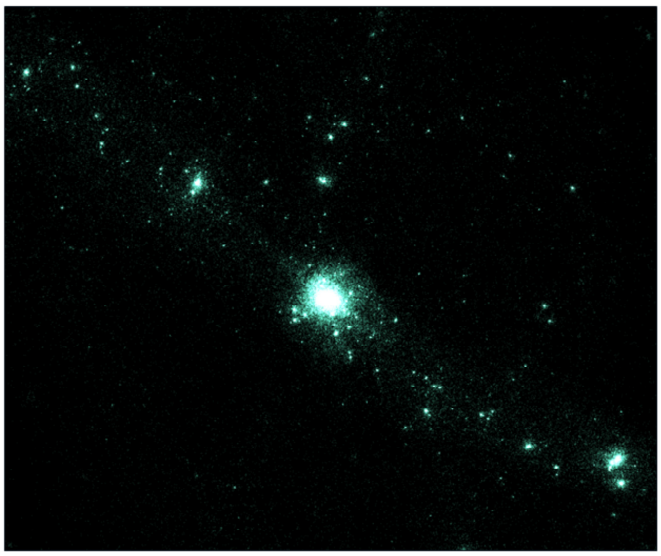
- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

Selection using Direct Input



- final interaction technique: selection using direct touch input
- problem with the indirectness of projected surfaces for 3D data selection
- under-constrained problem

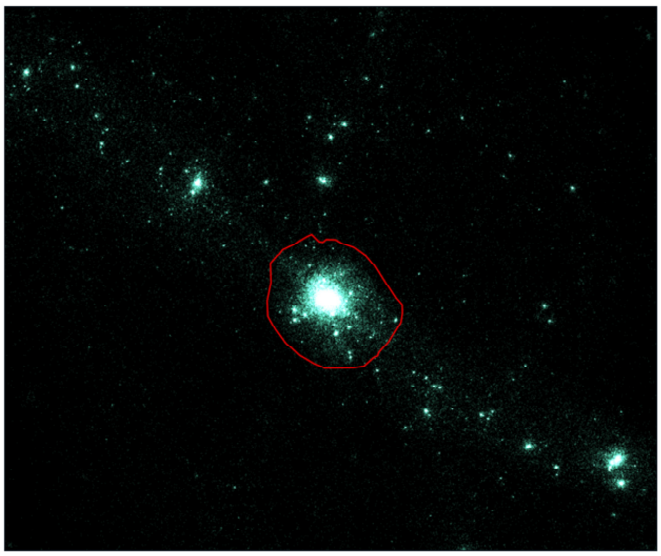
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

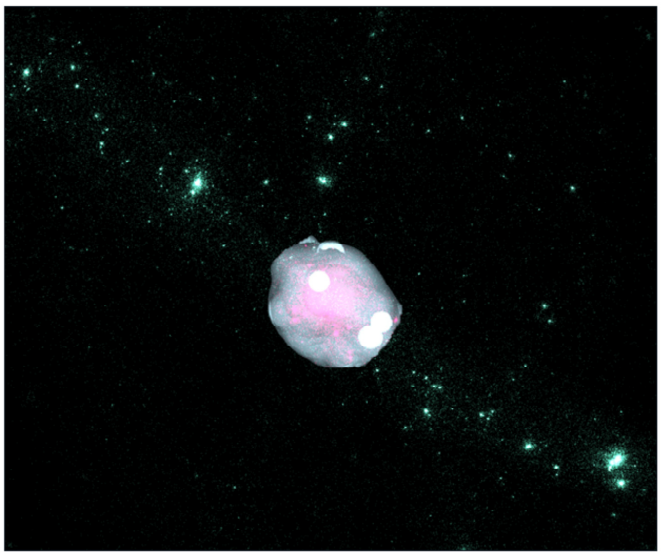
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

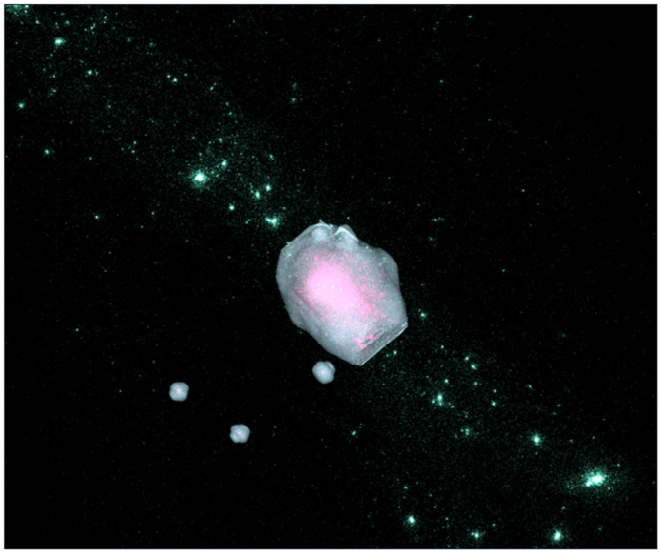
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

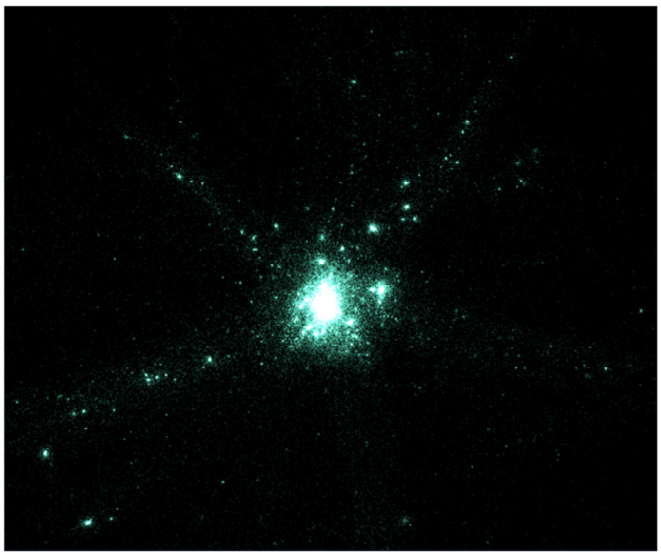
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

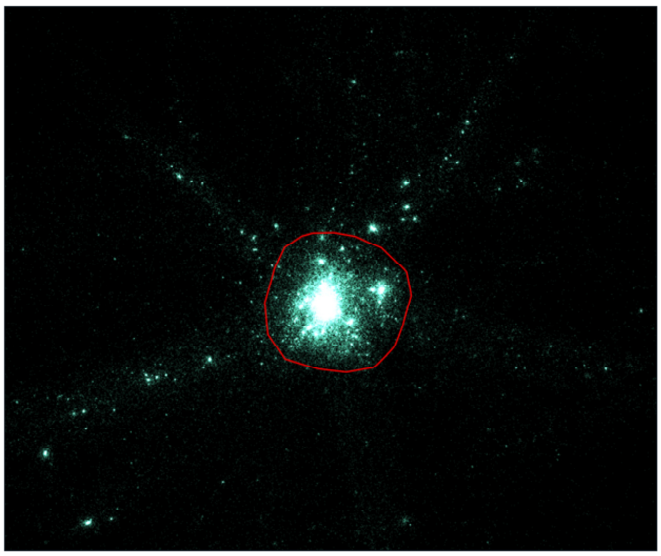
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

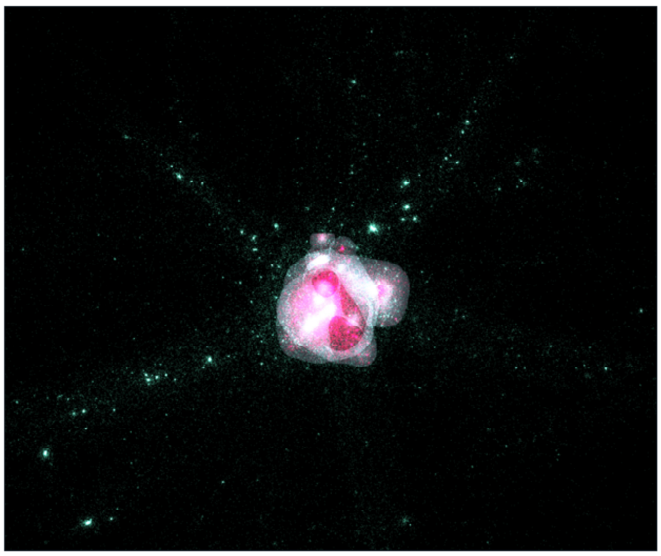
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

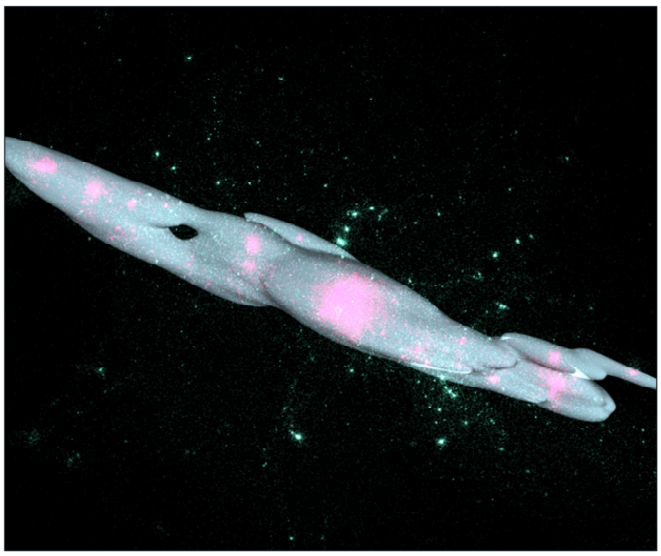
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

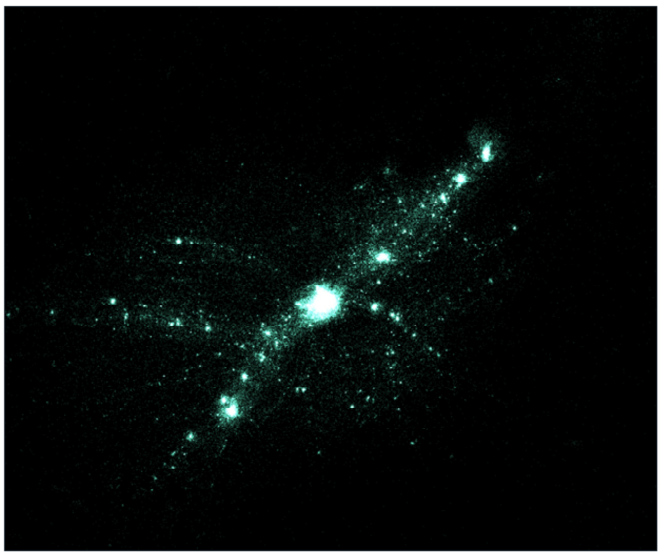
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

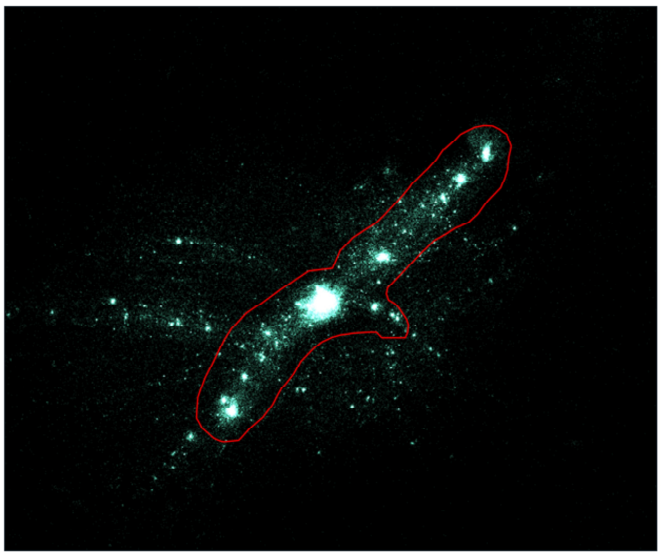
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

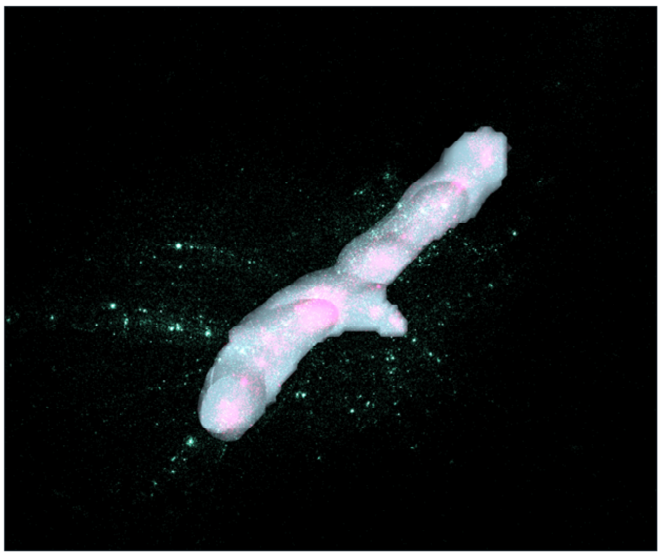
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

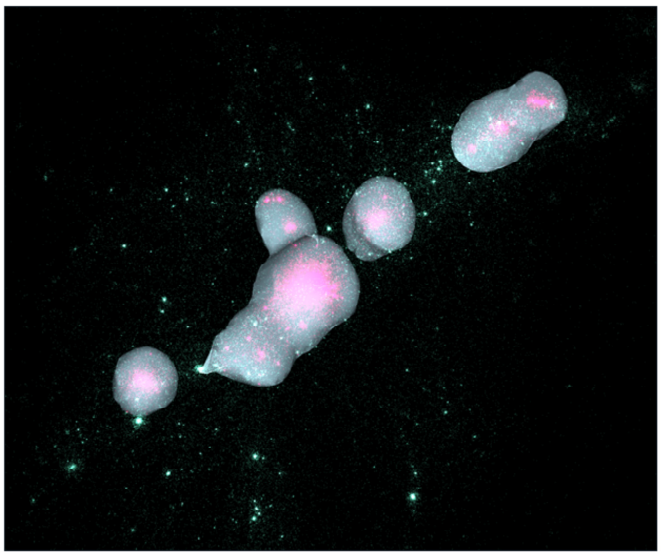
Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

- envisioned selection output: depending on structure of the data space – structure-aware selection

Envisioned Spatial Selection in 3D Space



[Yu et al. 2013]

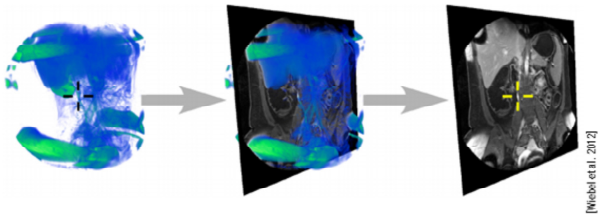
- envisioned selection output: depending on structure of the data space – structure-aware selection

Structure-Aware Selection of Data: CloudLasso

- example technique: CloudLasso by Yu et al. [2012]
- video

Other Interaction Techniques for Direct Input

- two generic types discussed
- many others exist: special tasks, special hardware
- challenges & advantages: precision, speed, effectiveness



[Wiebel et al., 2012]

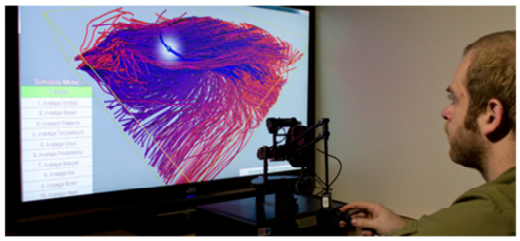


Image: Daniel F. Keefe

- only discussed two generic types of 3D interaction, for volumetric data and other forms
- others exist as well
    - for special interaction tasks (we already heard about picking)
    - using special hardware
    - depending on the specific data
- challenges and advantages are similar:
    - precision of input/control
    - speed of interaction
    - effectiveness of interaction

- the end

References

- D. A. Bowman, E. Kruijff, J. J. LaViola, Jr., and I. Poupyrev. 3D User Interfaces: Theory and Practice. Addison-Wesley, Boston, 2005.
- S. Bryson. Virtual reality in scientific visualization. Communications of the ACM 39(5):62–71, May 1996. http://dx.doi.org/10.1145/229459.229467
- D. Coffey, N. Malbraaten, T. Le, I. Borazjani, F. Sotiropoulos, A. G. Erdman, D. F. Keefe. Interactive slice WIM: Navigating and interrogating volume datasets using a multi-surface, multi-touch VR interface. IEEE TVCG 18(10):1614–1626, 2012. http://dx.doi.org/10.1109/TVCG.2011.283
- A. Cohé, F. Dècle, and M. Hachet. tBox: A 3D transformation widget designed for touch-screens. In Proc. CHI, pp. 3005–3008, ACM, New York, 2011. http://dx.doi.org/10.1145/1978942.1979387
- C.-W. Fu, W.-B. Goh, and J. A. Ng. Multi-touch techniques for exploring large-scale 3D astrophysical simulations. In Proc. CHI, pp. 2213–2222, ACM, New York, 2010. http://dx.doi.org/10.1145/1753326.1753661
- T. Isenberg. Position Paper: Touch Interaction in Scientific Visualization. In Proc. DEXIS, pp. 24–27, Inria, Le Chesnay, France. http://tobias.isenberg.cc/VideosAndDemos/Isenberg2012DTV
- P. Isenberg, T. Isenberg. Visualization on interactive surfaces: A research overview. i-com 12(3):10–17, 2013. http://dx.doi.org/10.1524/icom.2013.0020
- J. Jankowski, M. Hachet. A survey of interaction techniques for interactive 3D environments. In Eurographics State of the Art Reports, pp. 65–93, Eurographics Assoc., Goslar, 2013. http://dx.doi.org/10.2312/conf/EG2013/stars/065-093

References

- D. F. Keefe, T. Isenberg. Reimagining the scientific visualization interaction paradigm. IEEE Computer 46(5):51–57, 2013. http://dx.doi.org/10.1109/MC.2013.178
- T. Klein, F. Guéniat, L. Pastur, F. Vernier, T. Isenberg. A design study of direct-touch interaction for exploratory 3D scientific visualization. Computer Graphics Forum 31(3):1225–1234, 2012. http://dx.doi.org/10.1111/j.1467-8659.2012.03115.x
- J. L. Reisman, P. L. Davidson, and J. Y. Han. A screen-space formulation for 2D and 3D direct manipulation. In Proc. UIST, pp. 69–78, ACM, New York, 2009. http://dx.doi.org/10.1145/1622176.1622190
- N. Sultanum, S. Somanath, E. Sharlin, and M. C. Sousa. "Point it, split it, peel it, view it": Techniques for interactive reservoir visualization on tabletops. In Proc. ITS, pp. 192–201, ACM, New York, 2011. http://dx.doi.org/10. 1145/2076354.2076390
- D. Valkov, F. Steinicke, G. Bruder, K. Hinrichs. 2D touching of 3D stereoscopic objects. In Proc. CHI. New York: ACM, 2011, pp. 1353–1362. http://dx.doi.org/10.1145/1978942.1979142
- L. Yu, P. Svetachov, P. Isenberg, M. H. Everts, T. Isenberg. FI3D: Direct-touch interaction for the exploration of 3D scientific visualization spaces. IEEE TVCG 16(6):1613–1622, Nov.–Dec. 2010. http://dx.doi.org/10.1109/TVCG.2010.157
- L. Yu, K. Efstathiou, P. Isenberg, T. Isenberg. Efficient structure-aware selection techniques for 3D point cloud visualizations with 2DOF input. IEEE TVCG, 18(12):2245–2254, Dec. 2012. http://dx.doi.org/10.1109/TVCG.2012.217