A Design Study of Direct-Touch Interaction for Exploratory 3D Scientific Visualization

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Introduction and Motivation

- benefits of touch interaction
  - direct interaction
  - somesthetic feedback
  - “intuitive” & “natural”
  - being “in control” of data

- constraints of visualization
  - datasets defined in 3D
  - diverse sets of data types (volumes, iso-surfaces, particles, lines, etc.)
  - need for control of interaction & precise input
  - support for many different exploration strategies needed (navigation, selection, cutting planes, drilling, seeds, time, ...)

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Related Work: Touch-Based Visualization

- [Fu et al. 2010]
- [Coffey et al. 2011/2012]
- [Sultanum et al. 2010/2011]
Goal and Problem Domain

• goals:
  – design study of touch-based interactive visualization system
  – understanding of how to integrate many different exploration techniques, all working in the same input space
  – understanding of how touch-based interaction can benefit visualization

• application domain:
  – fluid mechanics
  – visualization of turbulent flow
  – vector & scalar data
Design Approach: Participatory Design

• 2 experts in fluid mechanics research
  – look for Lagrangian Coherent Structures (barriers that particles cannot cross) in time-dependent, turbulent 3D flow
  – want to understand dynamic flow behavior, e.g. mixing
  – typically use 2D visualizations (Matlab & ParaView as tools)

• direct involvement in the design
  – specifications of requirements
  – suggestions for new interface
  – feedback on intermediate results

• regular meetings
  – approx. once every two weeks
  – total of about 15 meetings
Derived Requirements for Design

- combination of vector and scalar data, time-dependent
- volumetric and iso-surface modalities for scalar field
- 3D navigation and zoom
- cutting planes: free placement, orientation, translation
- 2D visualization and interaction
- seeding in 3D for streamlines to show the vector field
- drilling to explore the scalar values along a 3D line
- data not obstructed, intuitive interaction; interface design to suggest function
- support for at least 2 people interacting simultaneously
Visualization and Hardware Setup

- vector data: direction & velocity
- scalar data: FTLE – Finite Time Lyapunov Exponent field (neighbors’ rate of divergence)

- display & touch hardware:
  - 55” full-HD display
  - PQLabs touch overlay (IR-based)
  - up to 32 simultaneous inputs
  - display height-adjustable
  - angle from horizontal to vertical
General Interface Design and 3D Navigation

- visuals based on VTK (due to familiarity with ParaView)
- support for both iso-surfaces and volumetric views
- two views for potential independent work
- modal control through bi-manual interaction
- navigation interaction based on FI3D [Yu et al. 2010]
3D Navigation: Video

general 3D interaction
Cutting Plane Interaction

- cutting planes: one of the most frequent analysis tools to see inside of 3D volume
- need for orientation and translation
- same input space for the interaction as for the navigation
- two touch points to specify rotation axis
- motion of third point to rotate cutting plane
- motion of third point on frame to translate
Parameter Control: Adjusting Iso-Surfaces

- scalar scale on the right; color scale specified by experts
- points on the scale can be added, moved, and removed through touch interaction
Adjusting Iso-Surfaces: Video
Drilling

- investigation of scalar values along a line
- initially planned as drilling core along viewing direction
- based on expert feedback changed design to drilling perpendicularly to the current cutting plane
- bi-manual and single-point control
- addition of streamlines seeded from drilling core
Drilling: Video
3D vs. 2D Views

- traditional ways of exploration based on 2D views
- addition of 2D view, specified by current cutting plane
3D vs. 2D Views: Video
Placing Seed Points in 3D

- use of 2D view to specify 3D locations for seed particles
- three modes: single point, two points, three or more
Placing Seed Points in 3D: Video

working with 2D view: seeding
Controlling Seed Point Density: Video

"working with 2D view: changing the seeding density"
Temporal Interaction

- addition of time bar for exploring temporal changes
- animation of seeded streamlines
Temporal Interaction: Video
Connected & Separated Views

- support for both individual & collaborative exploration
- each view can be switched between 3D and 2D
- two 3D views can be connected or remain separate
Connected & Separated Views: Video

using 3D views connected & separately
Evaluation

• quantitative vs. qualitative methodologies
• goal **not** to compare method A with method B
• goal to get fundamental understanding of **complex interactive system**

• choice of qualitative, observational study design
  – 7 experts in fluid mechanics; 3 groups of 2, 1 person by himself
  – first tutorial of system with test data, then real dataset
  – observation, think-aloud + video, semi-structured interview
  – 1.5 – 2 hours per session
Evaluation Results, Discussion, and Criticism

- four categories of findings: usability issues, possible extensions, interaction concepts, implications for design

- interaction concepts
  - need for interaction precision
  - need to isolate interactions
  - need to easily achieve well-defined views
  - evident, in particular, in cutting plane interaction; its interaction design not ideal
  - interaction not perceived to be imprecise in general, exploratory nature of interface
Evaluation Results, Discussion, and Criticism

- implications for design, benefits of direct touch
  - direct manipulation and fluidity of interaction valued highly
  - combination of 3D and 2D elements for 3D data exploration
  - need for some learning of direct-touch interaction is accepted
  - touch interfaces not to replace existing visualization tools, but going back & forth between traditional & touch-based

- support of collaboration beneficial and valued
- different collaboration styles
- vertical setup accepted in collaboration;
  3D nature of data? inherent “up” and “down”?
Conclusion

- design study of integration of touch interactions
- participatory design approach with experts
- part of the design worked well, other parts need to be improved
- complex system, evaluation by observational approach
- holistic insights on how to design touch-based systems, not if one method is, e.g., 2% faster than another one
Thanks for your attention