A Direct Manipulation Interface for Time Navigation in Scientific Visualizations

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Motivation

When have the particles passed the diffuser?
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Goals:

• Enable direct manipulation of objects to navigate in time
• Drag visualization objects along their trajectory
• Motivation

• Basics

• Techniques
  • General Curved Trajectories
  • Loopled Trajectories

• Evaluation
Visualization Objects

Objects with trajectories:

• Particle traces
• Features
• Simulation objects
Occlusion Management

- Geometry can occlude visualization object
- Taxonomy-based selection of occlusion management technique*

→ Irregular cutaway
  - Interactive
  - Maintains depth cues well

*Elmqvist and Tsigas „A Taxonomy for 3D Occlusion Management for Visualization“, TVCG 14(5) 2008
• Motivation
• Basics
• Techniques
  • General Curved Trajectories
  • Loopled Trajectories
• Evaluation
General Curved Trajectories

- Set of spatio-temporal points
- 3D image is ambiguous

\[ p = (x, y, z, t) \]
• Select object
  • Variant of IntenSelect*

- Select object
- Confirm object
  - Show focus point
  - Show trajectory
  - Color trajectory according to distance
• Select object
• Confirm object
  • Show focus point
  • Show trajectory
  • Color trajectory according to distance
• Select object
• Confirm object
• Drag object
  • Move focus point
  • Rubber band
  • Determine best candidate on trajectory
• Select object
• Confirm object
• Drag object
  • Move focus point
  • Rubber band
  • Determine best candidate on trajectory

\[
D = \sqrt{(c_x - f_x)^2 + (c_y - f_y)^2 + (c_z - f_z)^2}
\]
• Select object
• Confirm object
• Drag object
  • Move focus point
  • Rubber band
  • Determine best candidate on trajectory*

\[
D = \sqrt{(c_x - f_x)^2 + (c_y - f_y)^2 + (c_z - f_z)^2 + k \cdot a}
\]

*adapted from Dragicevic et al. „Video Browsing by Direct Manipulation“, SIG CHI 2008, for 2D dragging
• Select object
• Confirm object
• Drag object
  • Move focus point
  • Rubber band
  • Determine best candidate on trajectory*

\[ D = \sqrt{(c_x - f_x)^2 + (c_y - f_y)^2 + (c_z - f_z)^2 + k \cdot a + k_{dir}} \]

*adapted from Dragicevic et al. „Video Browsing by Direct Manipulation“, SIG CHI 2008, for 2D dragging
• Select object
• Confirm object
• Drag object
• Change time

\[ p = (x, y, z, t) \]
• Motivation
• Basics
• Techniques
  • General Curved Trajectories
  • Looped Trajectories
• Evaluation
Looped Trajectories

• Common in engineering simulations

• Uniform rotational movement
  \[ \alpha_t = t \cdot \omega \]

• Use handle to interact with element
• Select handle
• Select handle
• Rotate handle
  • Real-world
• Select handle
• Rotate handle
  • Real-world
  • Ray-based
• Select handle
• Rotate handle
  • Real-world
  • Ray-based
  • Constraint
• Select handle
• Rotate handle
  • Real-world
  • Ray-based
  • Constraint
• Change time

\[ \Delta t = \frac{\Delta \alpha}{\omega} \]
• Motivation
• Basics
• Techniques
  • General Curved Trajectories
  • Looped Trajectories
• Evaluation
Technical Evaluation

- Occlusion Management
  - > 30 fps
- Trajectory Dragging
  - Kd-tree for each trajectory on selection
  - build up 2 ms, evaluate < 1 ms
- Rotation Widget
  - virtually no effort

Measured on system with 2 AMD Opteron 2218 dual core CPUs at 2 GHz, 8 GB main memory, Quadro FX 5600 graphics board.
Comparative Evaluation

- Slider vs. dragging and rotation techniques
- Space-centered tasks

Hypotheses:
- Dragging is faster than slider (H1)
- Dragging is more accurate than slider (H2)
- Rotation is faster than slider (H3)
- Rotation is more accurate than slider (H4)
Comparative Evaluation

- 8 participants (2 female, 6 male, avg. 26 years)
- all simulation scientists

![Bar chart showing comparison between Virtual Reality and Simulation Science users by experience level.](image-url)
Quantitative Results

- 60 tasks for dragging („Move particle to marked target!“)
- 20 tasks for rotation („Rotate impeller by 45° degrees!“)

![Graph showing performance times for different techniques with p-values]
Quantitative Results

- Rotation tasks: „Rotate by 45°, 90°, 180°, 360°, 720° degrees“
Quantitative Results

- 60 tasks for dragging ("Move particle to marked target!")
- 20 tasks for rotation ("Rotate impeller by 45° degrees!")

![Error Percentage Graph]

- Slider Dragging: p=.019
- Traj. Dragging: p=.009
- Slider Rotation
- Rotation Handle
Comparative Evaluation

- Slider vs. dragging and rotation widgets
- Space-centered tasks

- Hypotheses:
  - Dragging is faster than slider (H1)  accepted
  - Dragging is more accurate than slider (H2) accepted
  - Rotation is faster than slider (H3) rejected
  - Rotation is more accurate than slider (H4) accepted
Qualitative Results

- 8 participants (2 female, 6 male, avg. 26 years)
- all simulation scientists
Qualitative Results

Positive Feedback
• Occlusion management highly beneficial
• Very intuitive
• No reported fatigue

Negative Feedback
• Manipulation of single objects only
• Fixed distance between device and focus point
• Ray-based rotation „jumps“ at plane center
Conclusion

• Alternative approach to time navigation
• Direct manipulation of visualization objects

• General trajectories
• Rotational elements

• Faster and more accurate than slider
• High user acceptance
Thank you for your attention!

Questions?

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