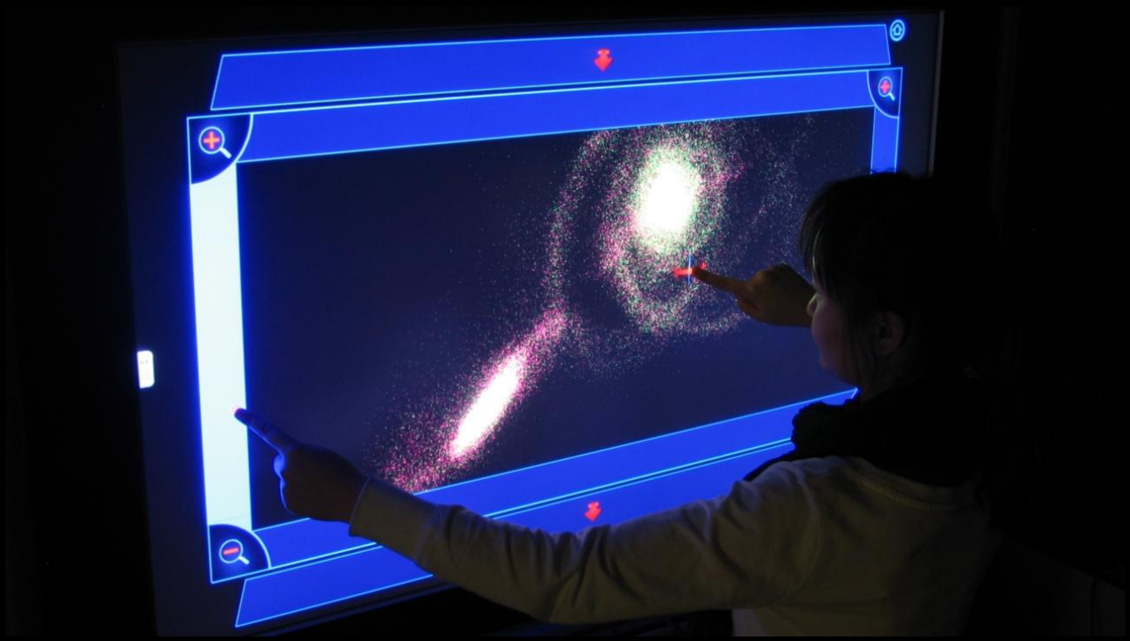


FI3D: Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces

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

university of
groningen

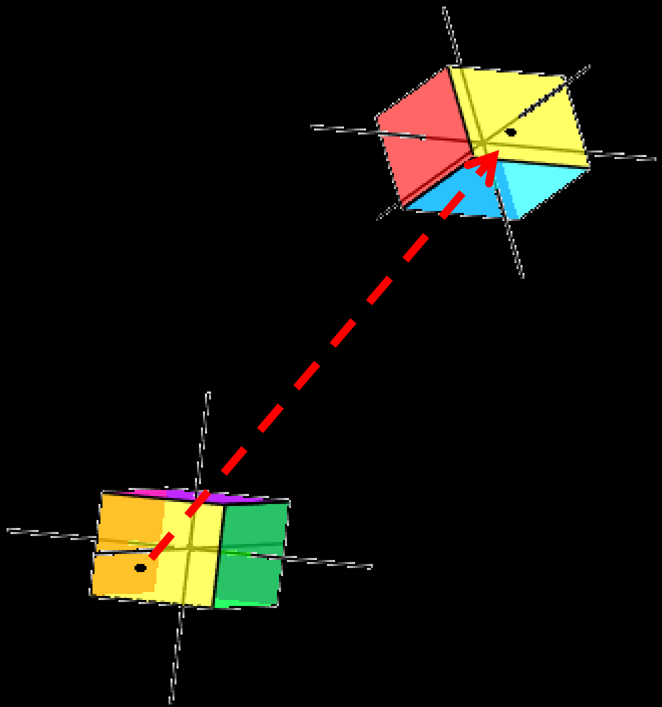
Motivation: Direct-Touch Interaction

Useful for scientific visualization?

Efficient for selection
[Kin et al., 2009]

Intuitive and natural
[North et al., 2009]

Challenges of 2D to 3D Mapping



[Hancock et al., 2007]

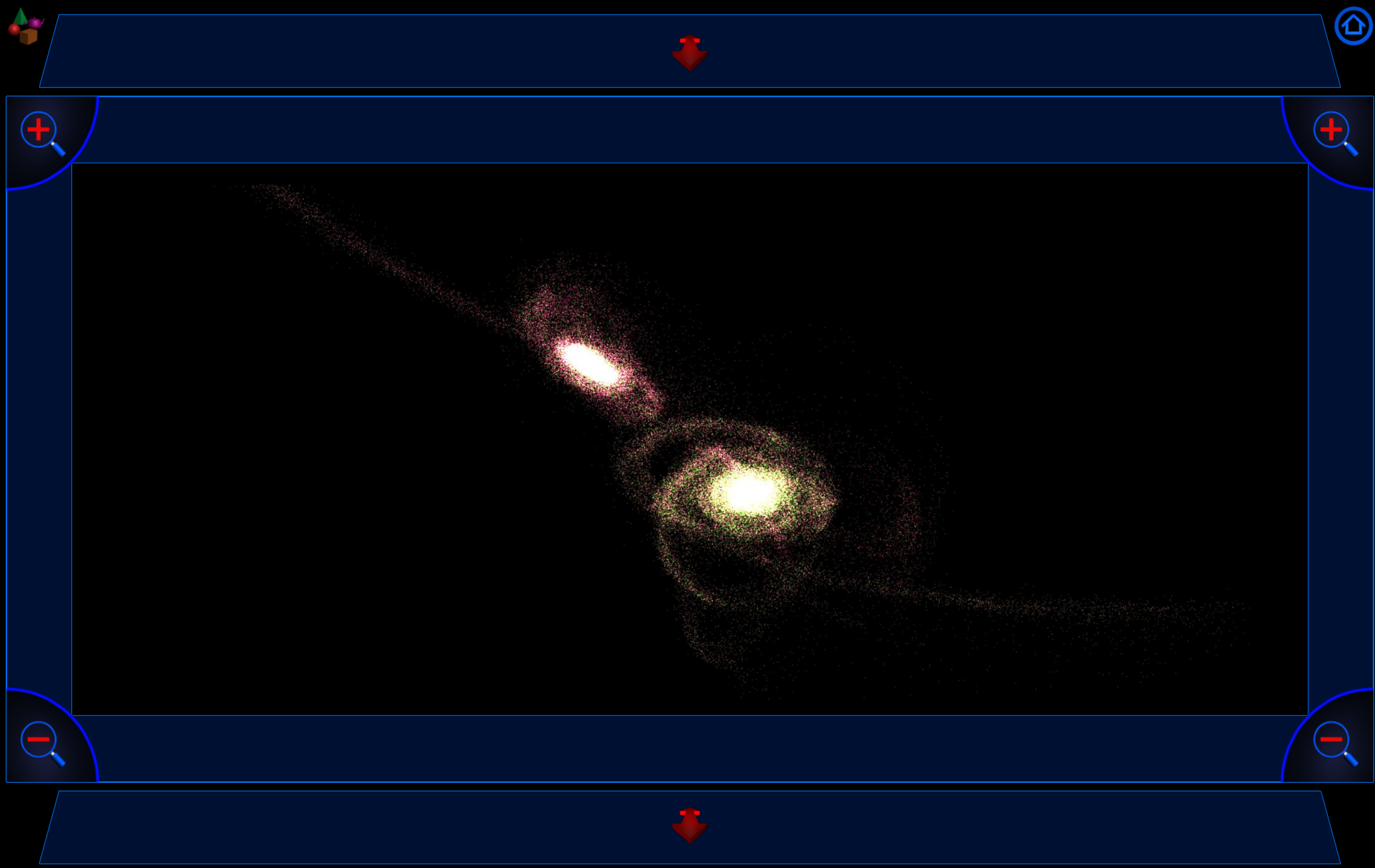
[Hancock et al., 2009]

Challenges of 2D to 3D Mapping

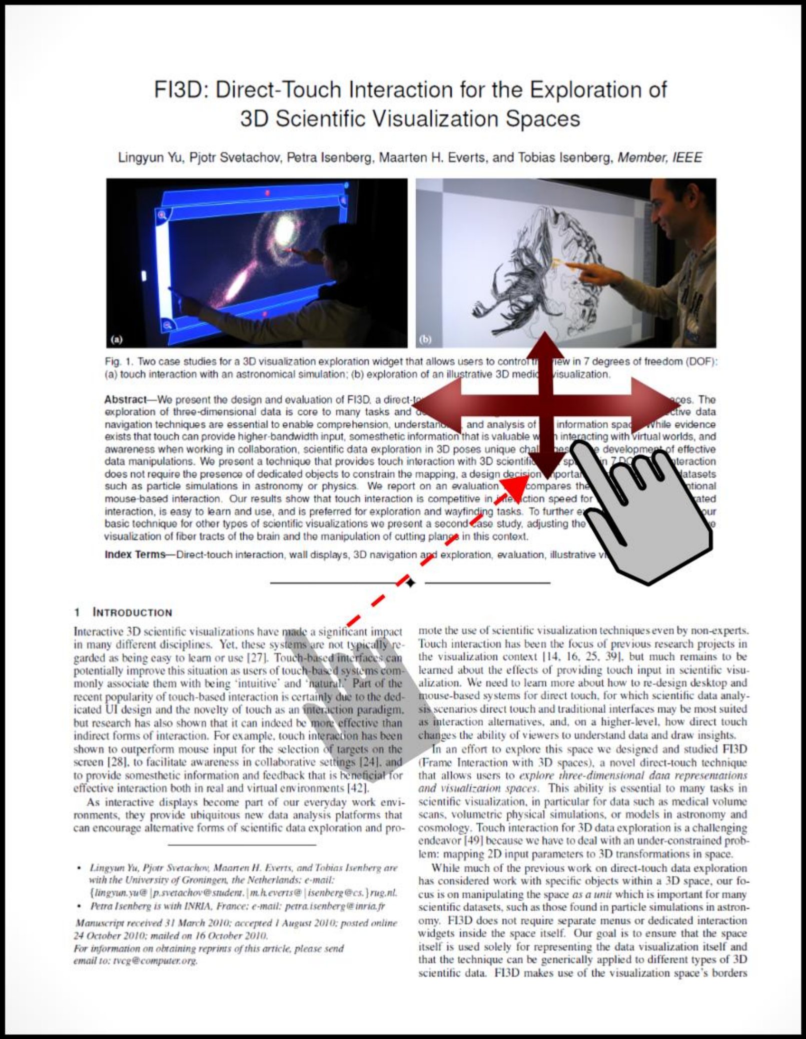
[Reisman et al., 2009]

[Fu et al., 2010]

Design: Frame Interaction



Design: Translation



FI3D: Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces

Lingyun Yu, Pjotr Svetachov, Petra Isenberg, Maarten H. Everts, and Tobias Isenberg, *Member, IEEE*

Fig. 1. Two case studies for a 3D visualization exploration widget that allows users to control [illegible] view in 7 degrees of freedom (DOF): (a) touch interaction with an astronomical simulation; (b) exploration of an illustrative 3D medi[illegible] visualization.

Abstract—We present the design and evaluation of FI3D, a direct-to[illegible]ces. The exploration of three-dimensional data is core to many tasks and d[illegible]ctive data navigation techniques are essential to enable comprehension, understand[illegible], and analysis of [illegible] information spa[illegible]. While evidence exists that touch can provide higher-bandwidth input, somesthetic information that is valuable w[illegible]n interacting with virtual worlds, and awareness when working in collaboration, scientific data exploration in 3D poses unique chal[illegible]es [illegible]e development of effective data manipulations. We present a technique that provides touch interaction with 3D scientifi[illegible] sp[illegible] in 7 DO[illegible]teraction does not require the presence of dedicated objects to constrain the mapping, a design decision importa[illegible] datasets such as particle simulations in astronomy or physics. We report on an evaluation [illegible] compares the [illegible]ntional mouse-based interaction. Our results show that touch interaction is competitive in [illegible]ction speed for [illegible]rated interaction, is easy to learn and use, and is preferred for exploration and wayfinding tasks. To further e[illegible] our basic technique for other types of scientific visualizations we present a second case study, adjusting the [illegible]e visualization of fiber tracts of the brain and the manipulation of cutting planes in this context.

Index Terms—Direct-touch interaction, wall displays, 3D navigation and exploration, evaluation, illustrative vi[illegible]

1 INTRODUCTION

Interactive 3D scientific visualizations have made a significant impact in many different disciplines. Yet, these systems are not typically regarded as being easy to learn or use [27]. Touch-based interfaces can potentially improve this situation as users of touch-based systems commonly associate them with being 'intuitive' and 'natural.' Part of the recent popularity of touch-based interaction is certainly due to the dedicated UI design and the novelty of touch as an interaction paradigm, but research has also shown that it can indeed be more effective than indirect forms of interaction. For example, touch interaction has been shown to outperform mouse input for the selection of targets on the screen [28], to facilitate awareness in collaborative settings [24], and to provide somesthetic information and feedback that is beneficial for effective interaction both in real and virtual environments [42].

As interactive displays become part of our everyday work environments, they provide ubiquitous new data analysis platforms that can encourage alternative forms of scientific data exploration and promote the use of scientific visualization techniques even by non-experts. Touch interaction has been the focus of previous research projects in the visualization context [14, 16, 25, 39], but much remains to be learned about the effects of providing touch input in scientific visualization. We need to learn more about how to re-design desktop and mouse-based systems for direct touch, for which scientific data analysis scenarios direct touch and traditional interfaces may be most suited as interaction alternatives, and, on a higher-level, how direct touch changes the ability of viewers to understand data and draw insights.

In an effort to explore this space we designed and studied FI3D (Frame Interaction with 3D spaces), a novel direct-touch technique that allows users to *explore three-dimensional data representations and visualization spaces*. This ability is essential to many tasks in scientific visualization, in particular for data such as medical volume scans, volumetric physical simulations, or models in astronomy and cosmology. Touch interaction for 3D data exploration is a challenging endeavor [49] because we have to deal with an under-constrained problem: mapping 2D input parameters to 3D transformations in space.

While much of the previous work on direct-touch data exploration has considered work with specific objects within a 3D space, our focus is on manipulating the space *as a unit* which is important for many scientific datasets, such as those found in particle simulations in astronomy. FI3D does not require separate menus or dedicated interaction widgets inside the space itself. Our goal is to ensure that the space itself is used solely for representing the data visualization itself and that the technique can be generically applied to different types of 3D scientific data. FI3D makes use of the visualization space's borders

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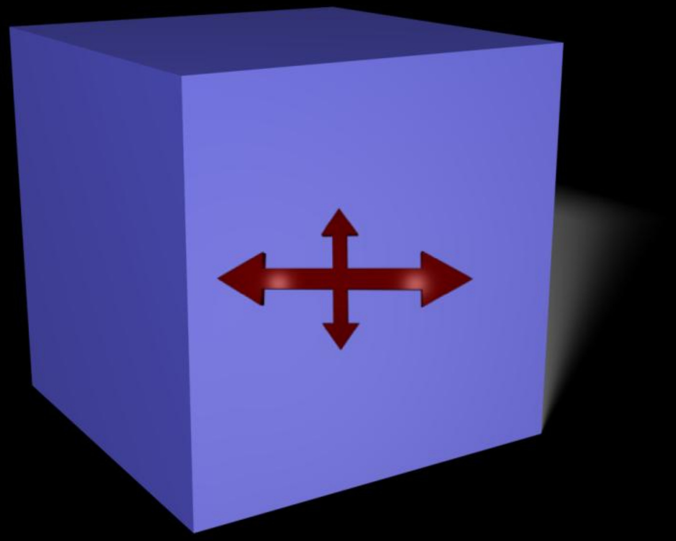
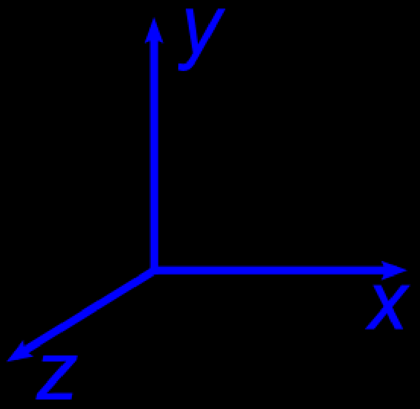
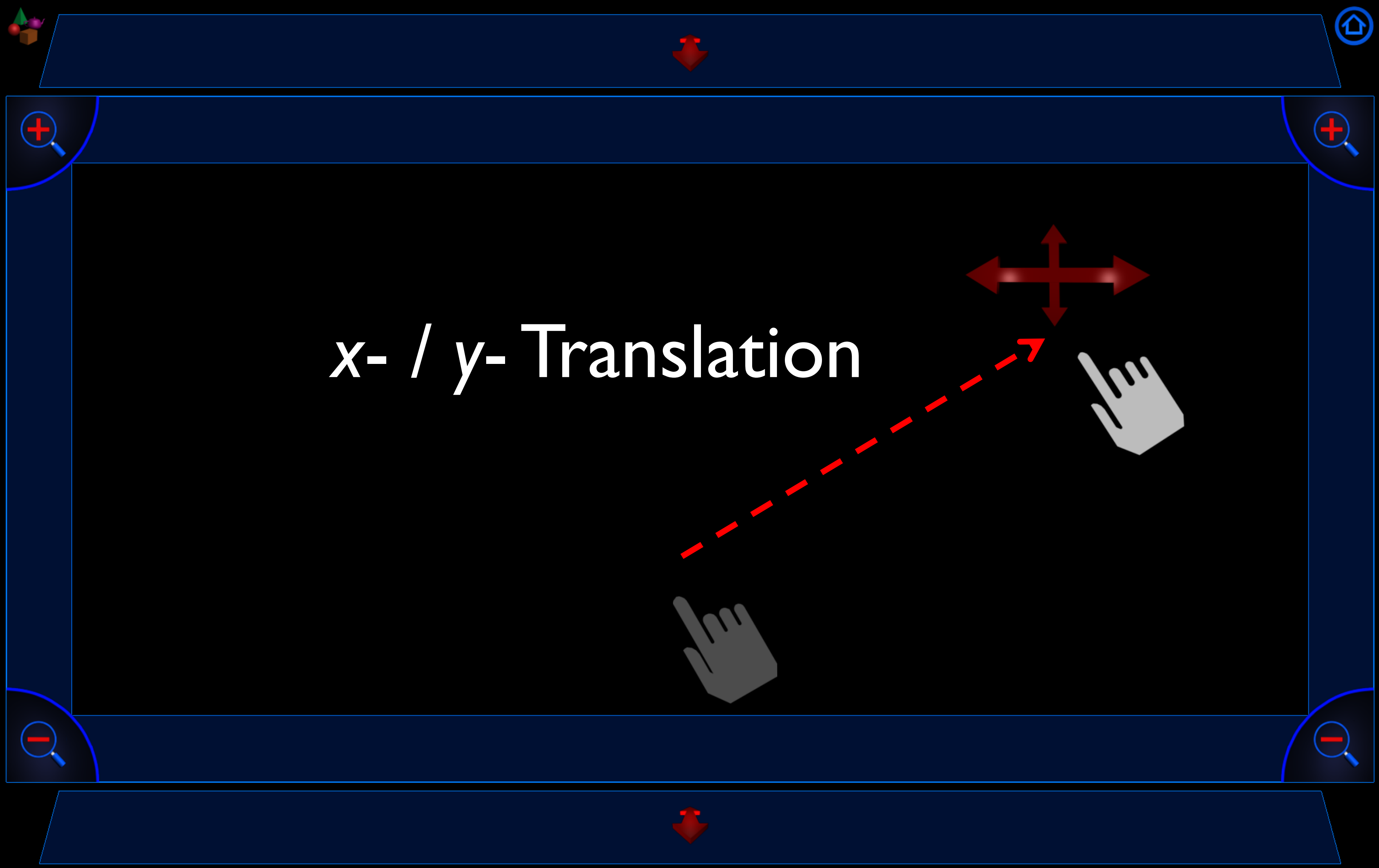




Design: Translation



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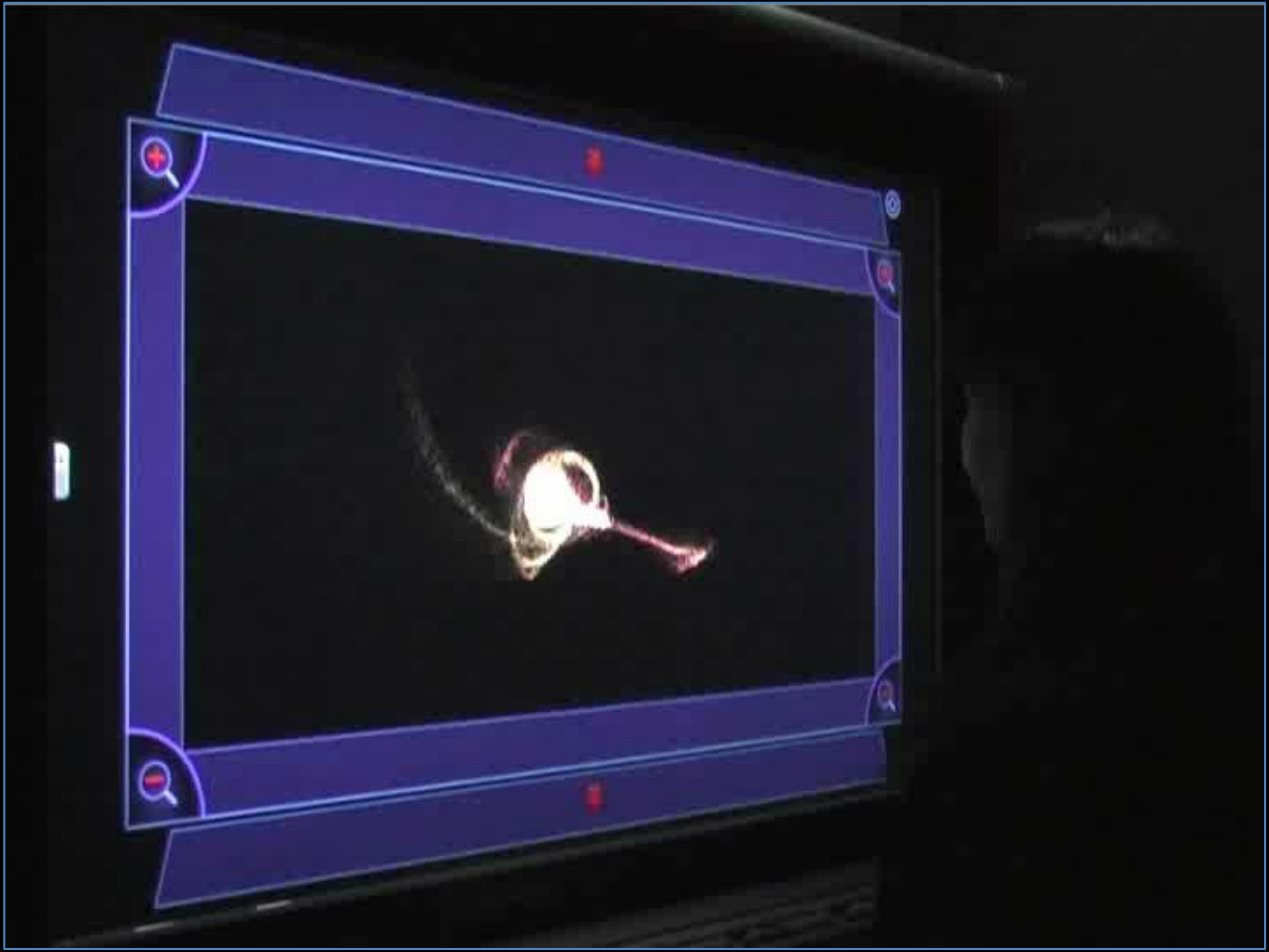
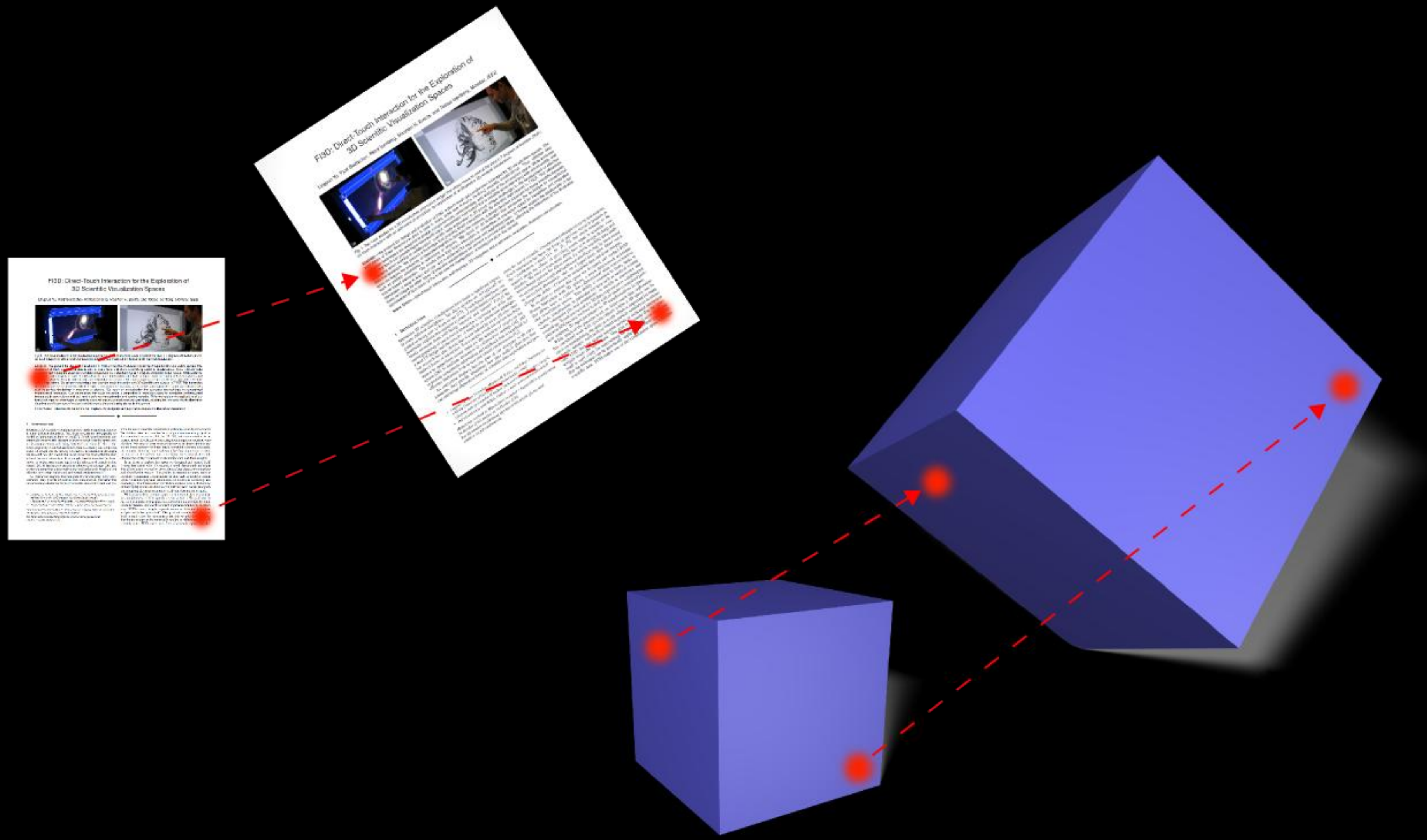
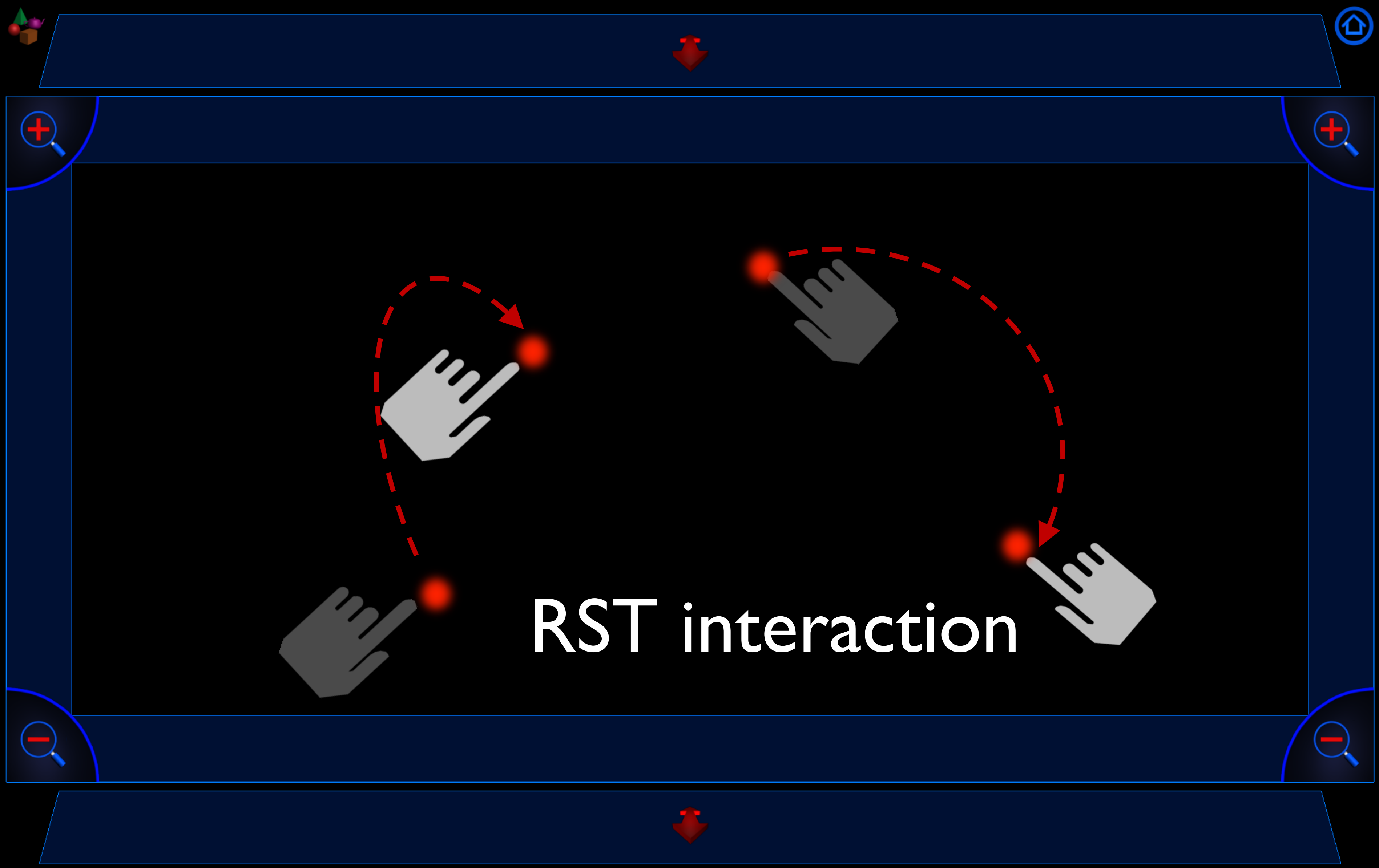


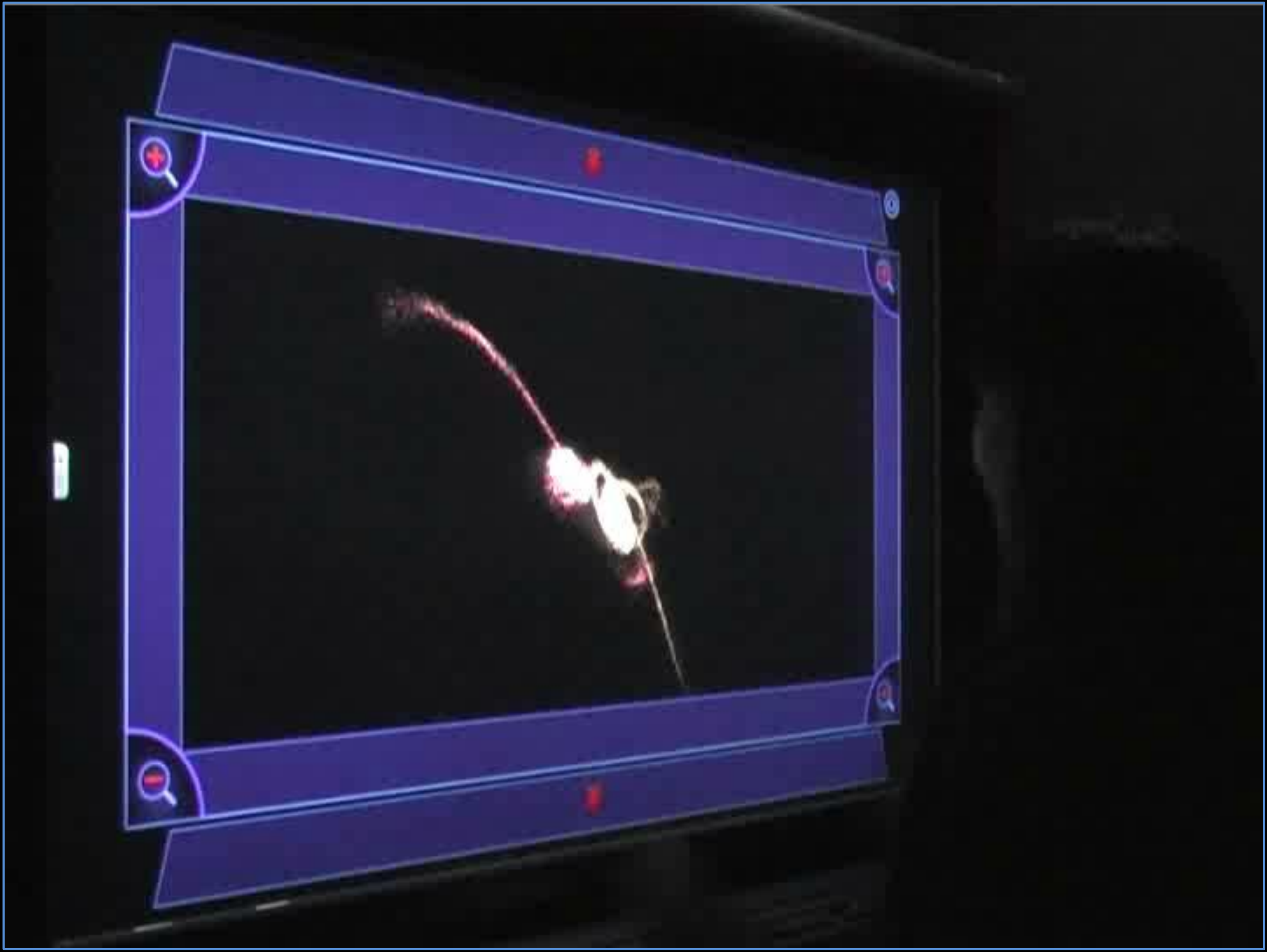
Design: Rotate-Scale-Translate (RST)



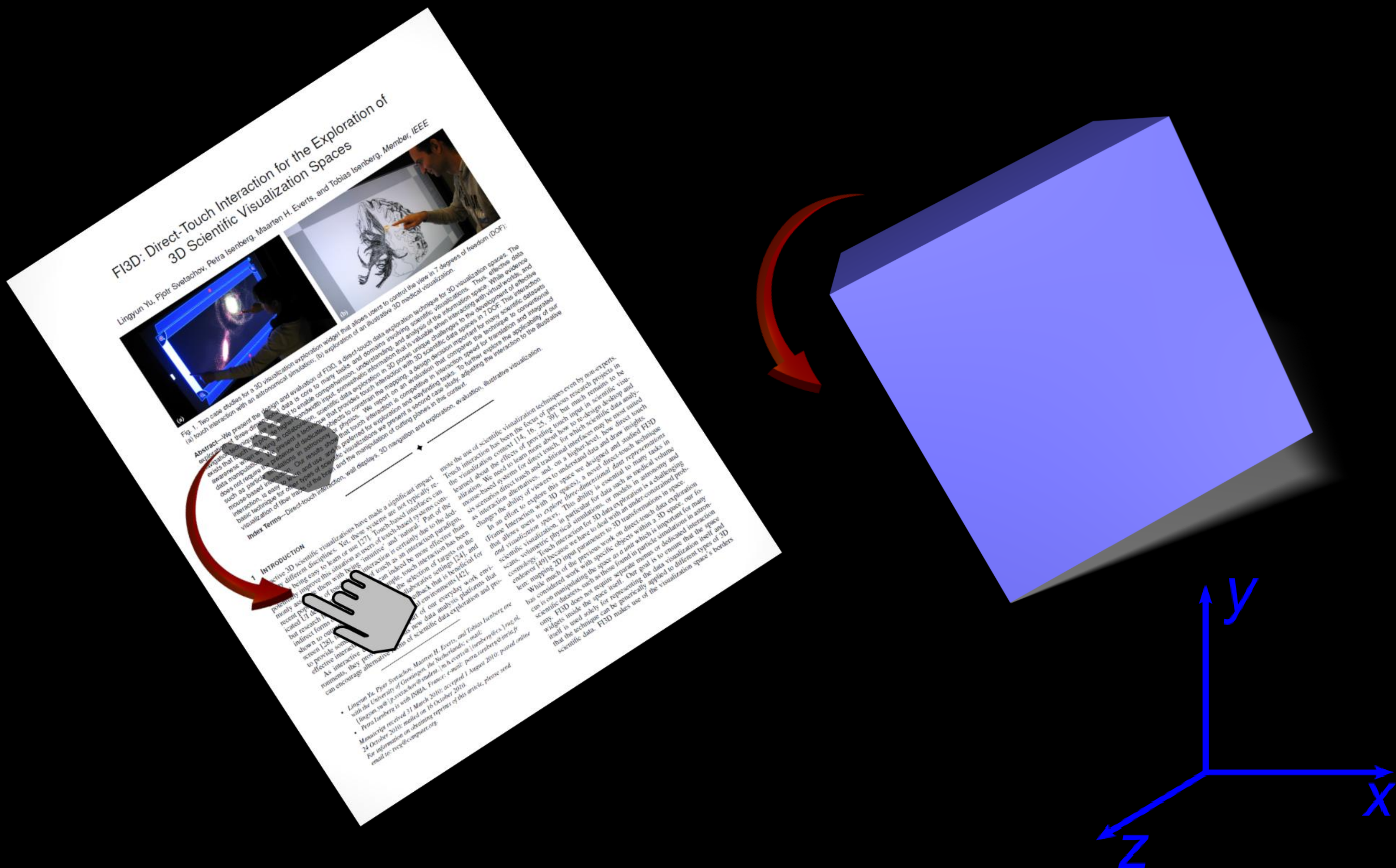
Design: Rotate-Scale-Translate (RST)



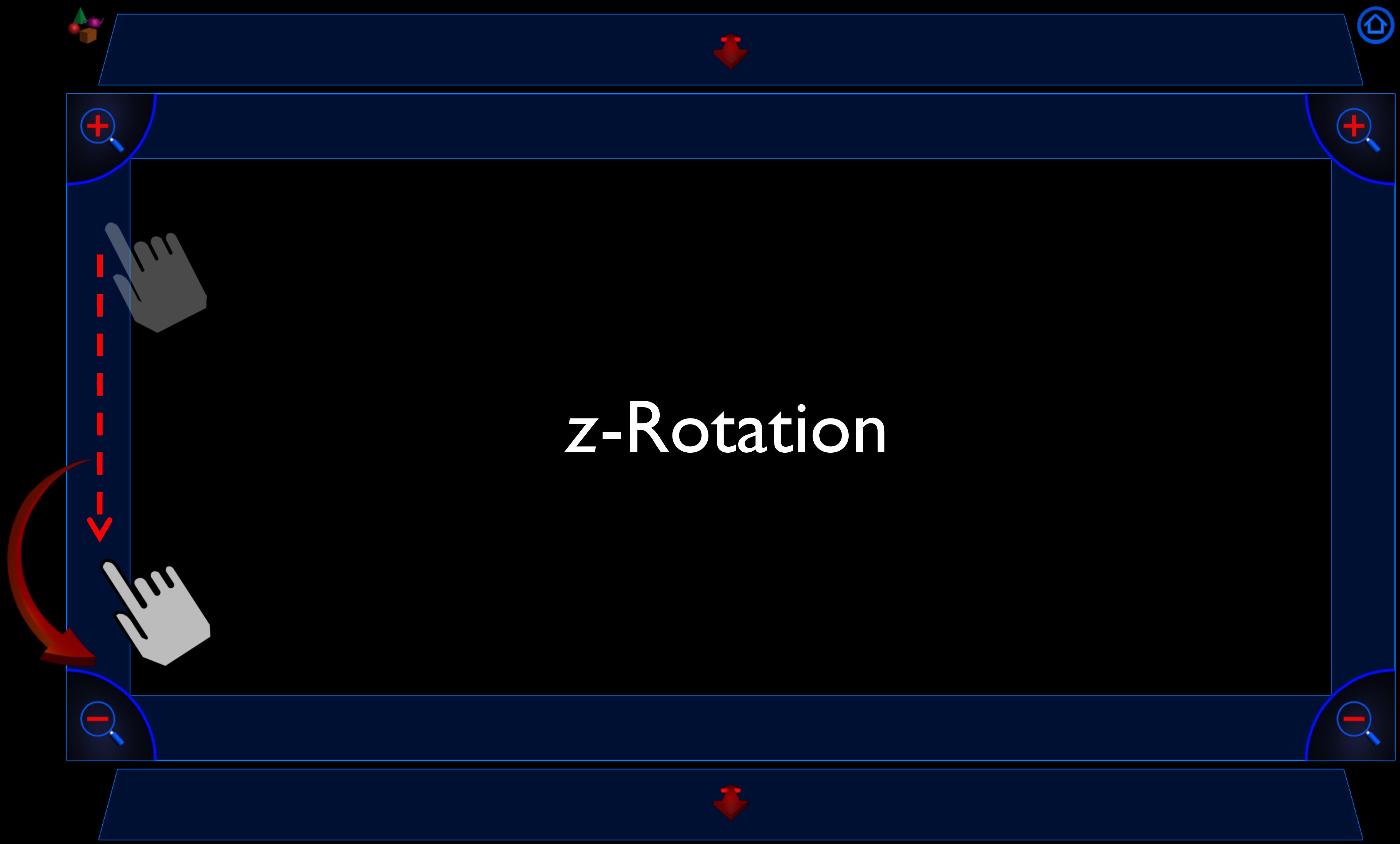
Design: Rotate-Scale-Translate (RST)



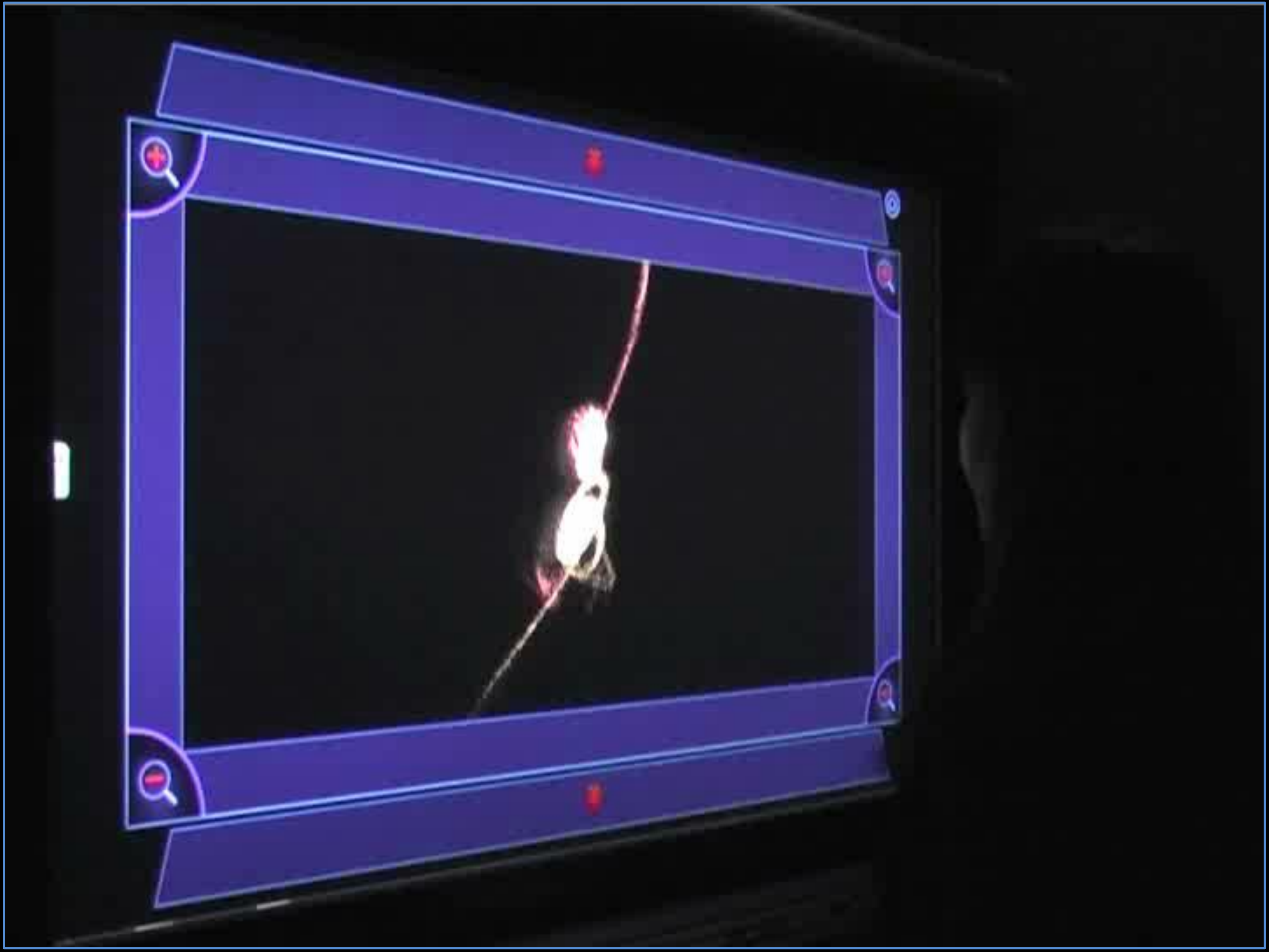
Design: z-Rotation



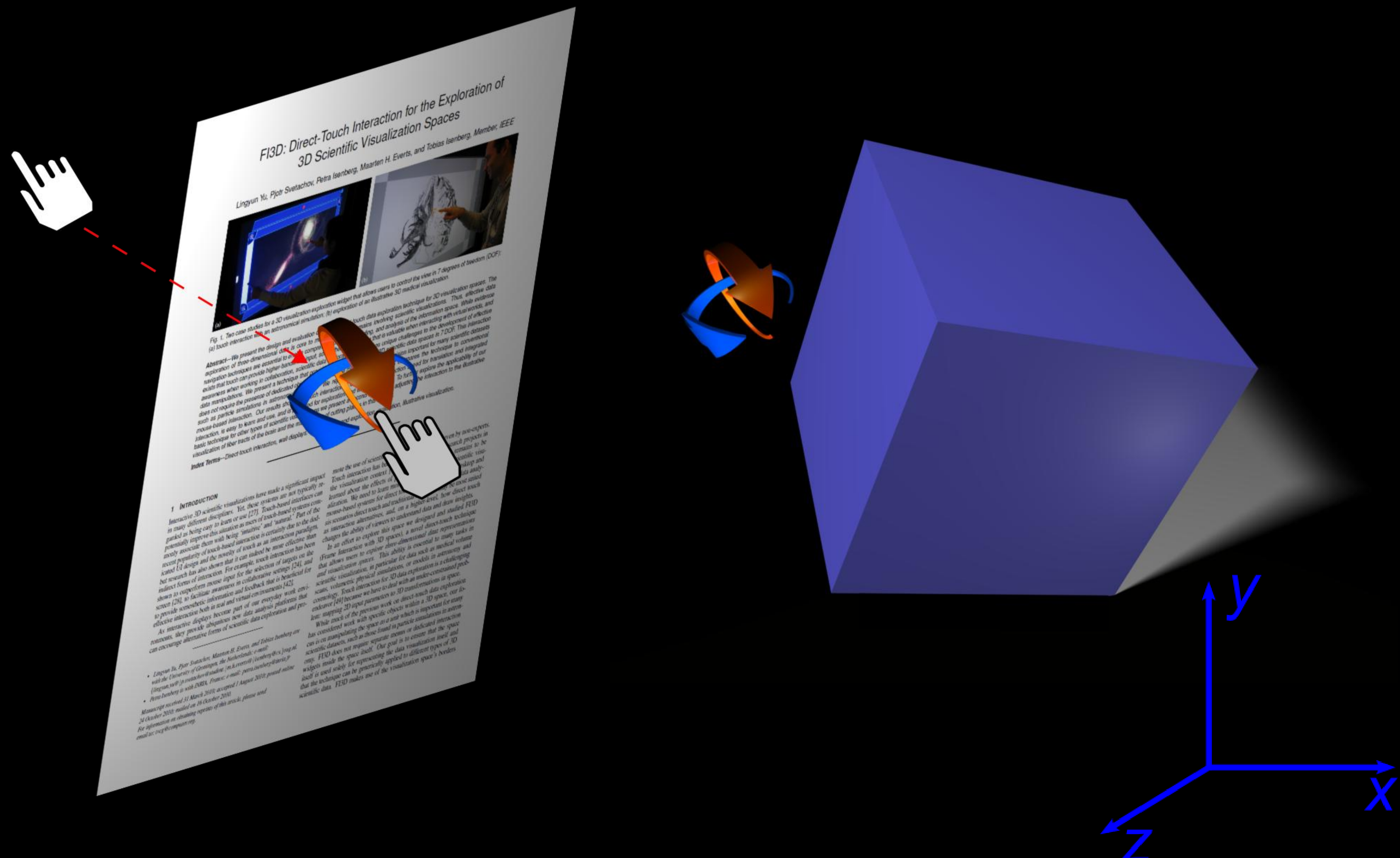
Design: z-Rotation



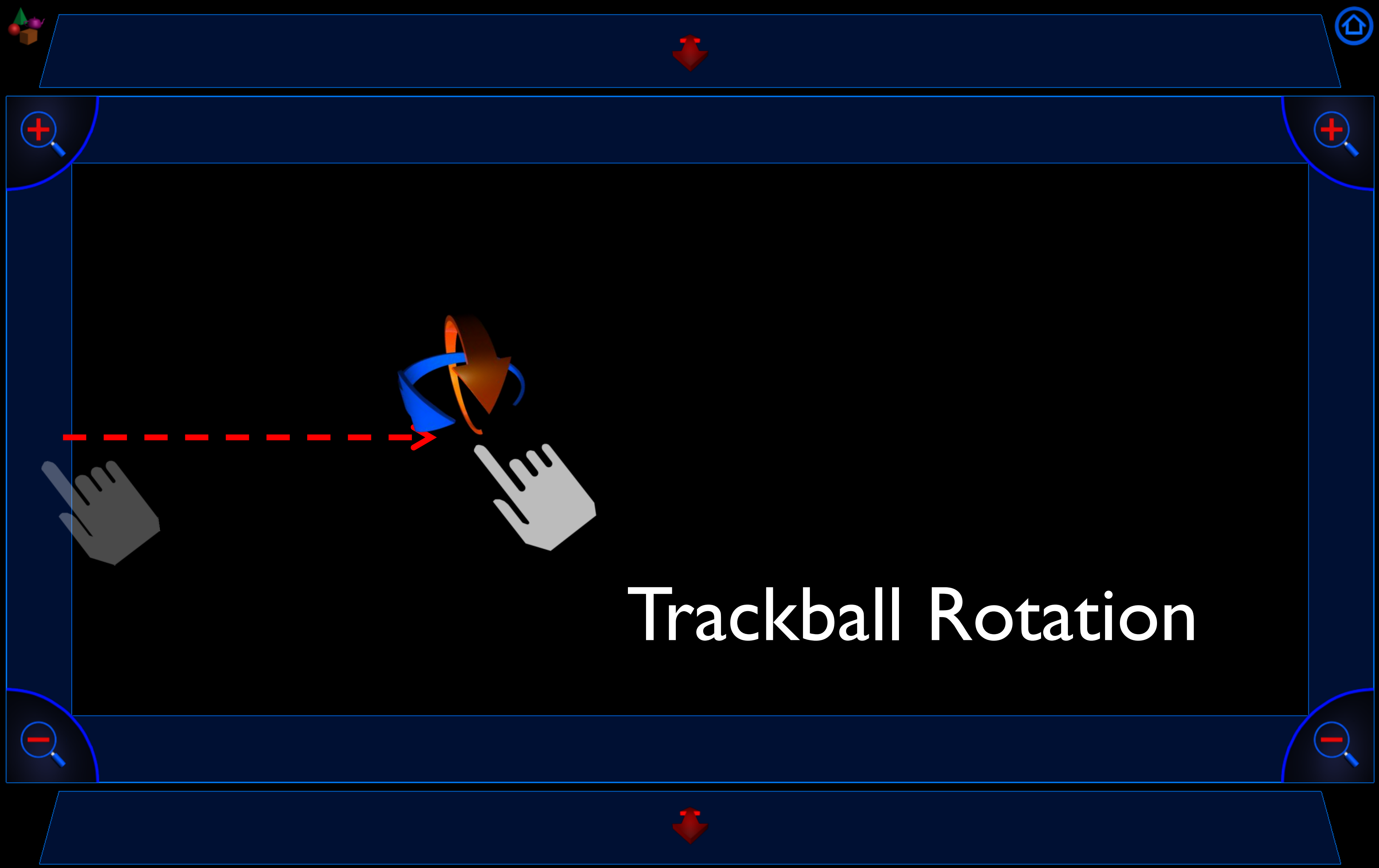
Design: z-Rotation



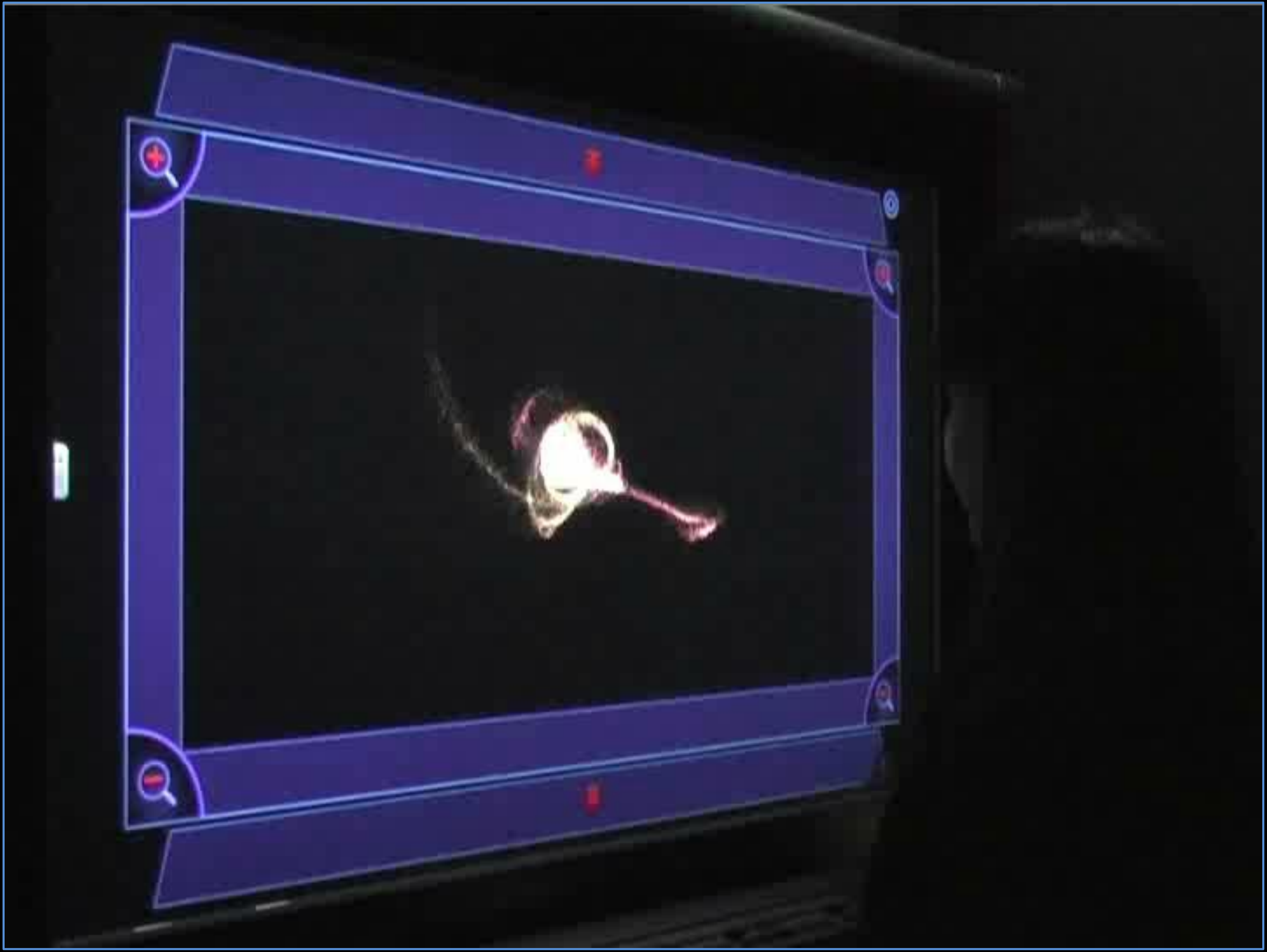
Design: Trackball Rotation



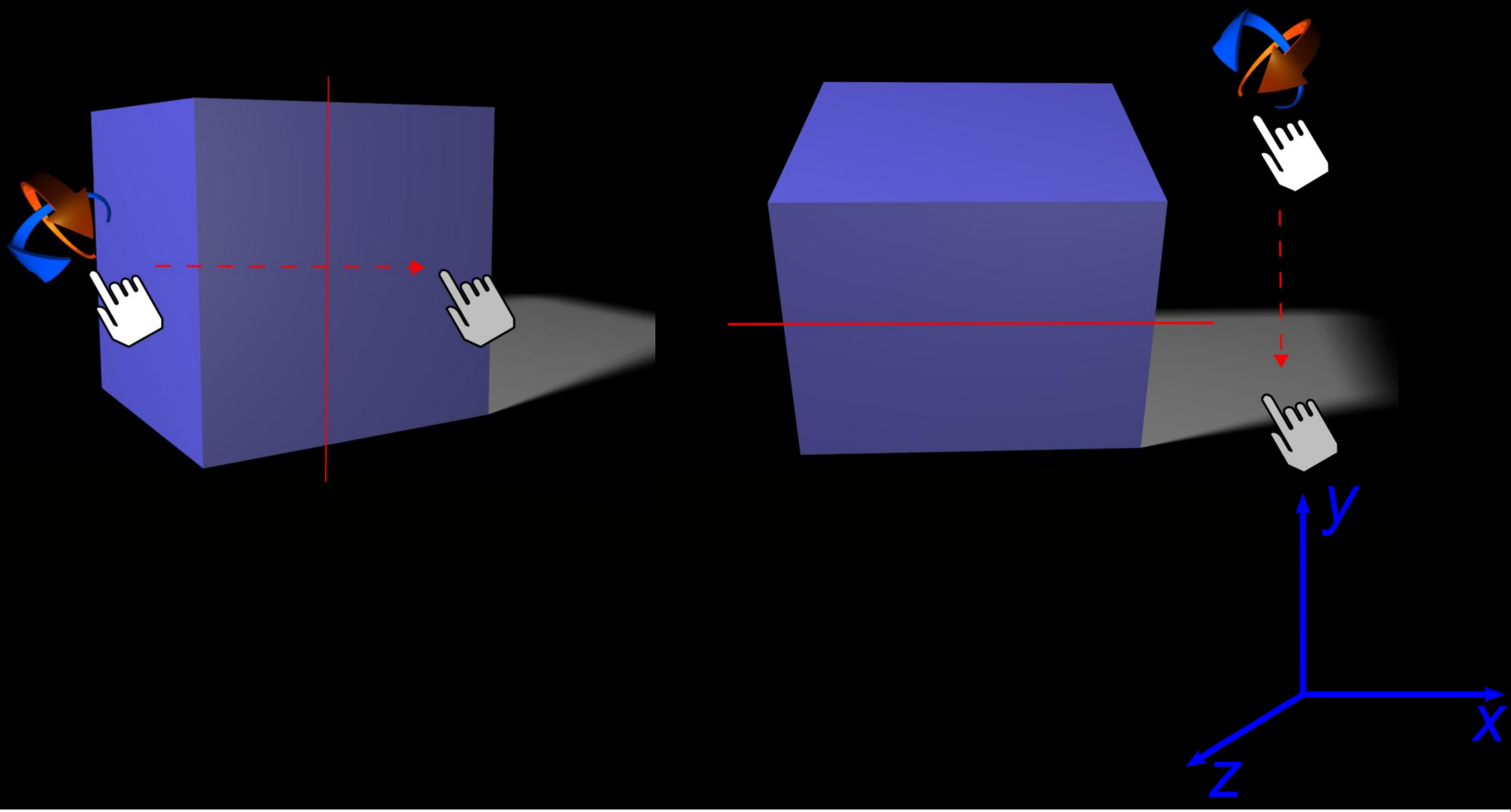
Design: Trackball Rotation



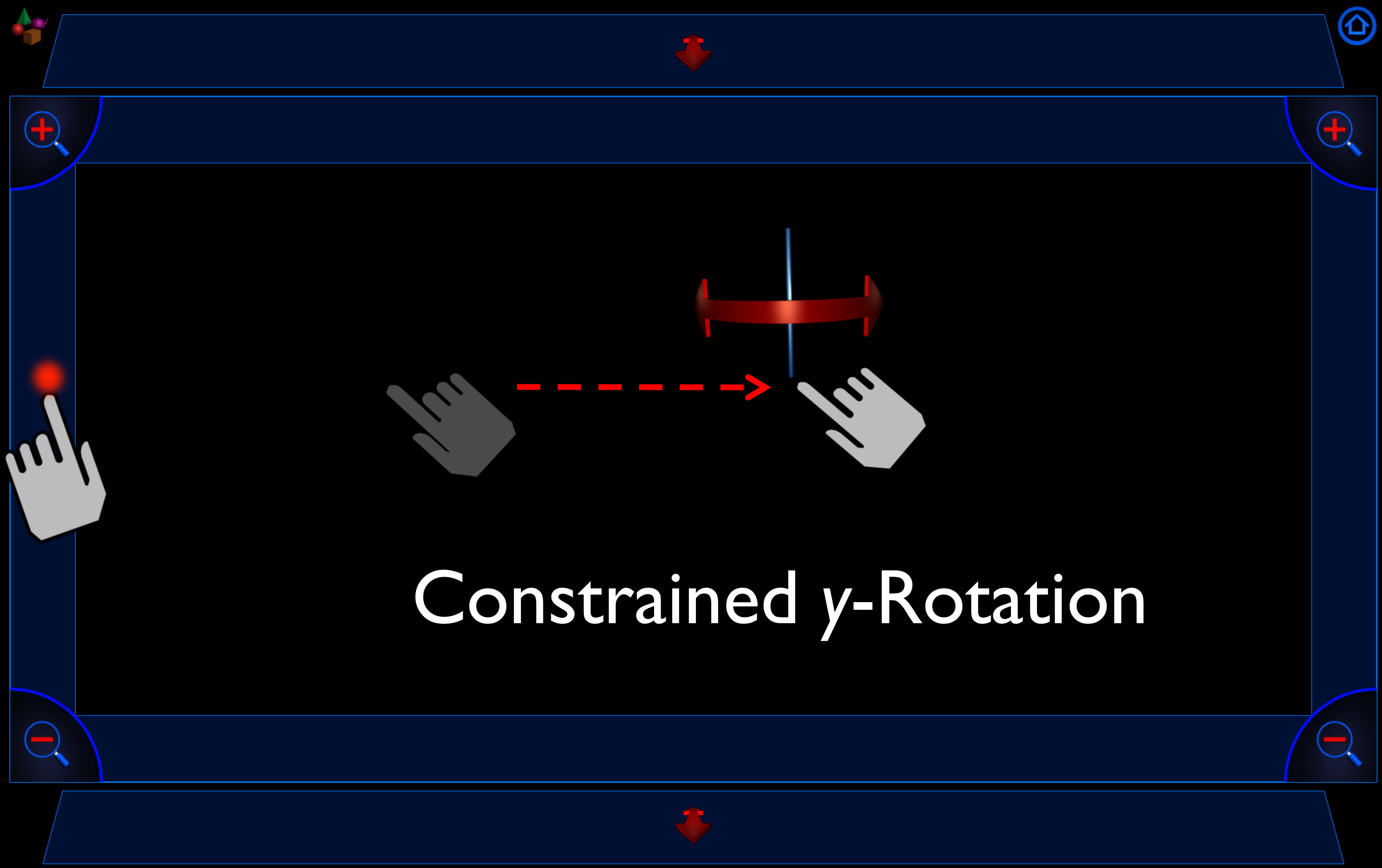
Design: Trackball Rotation



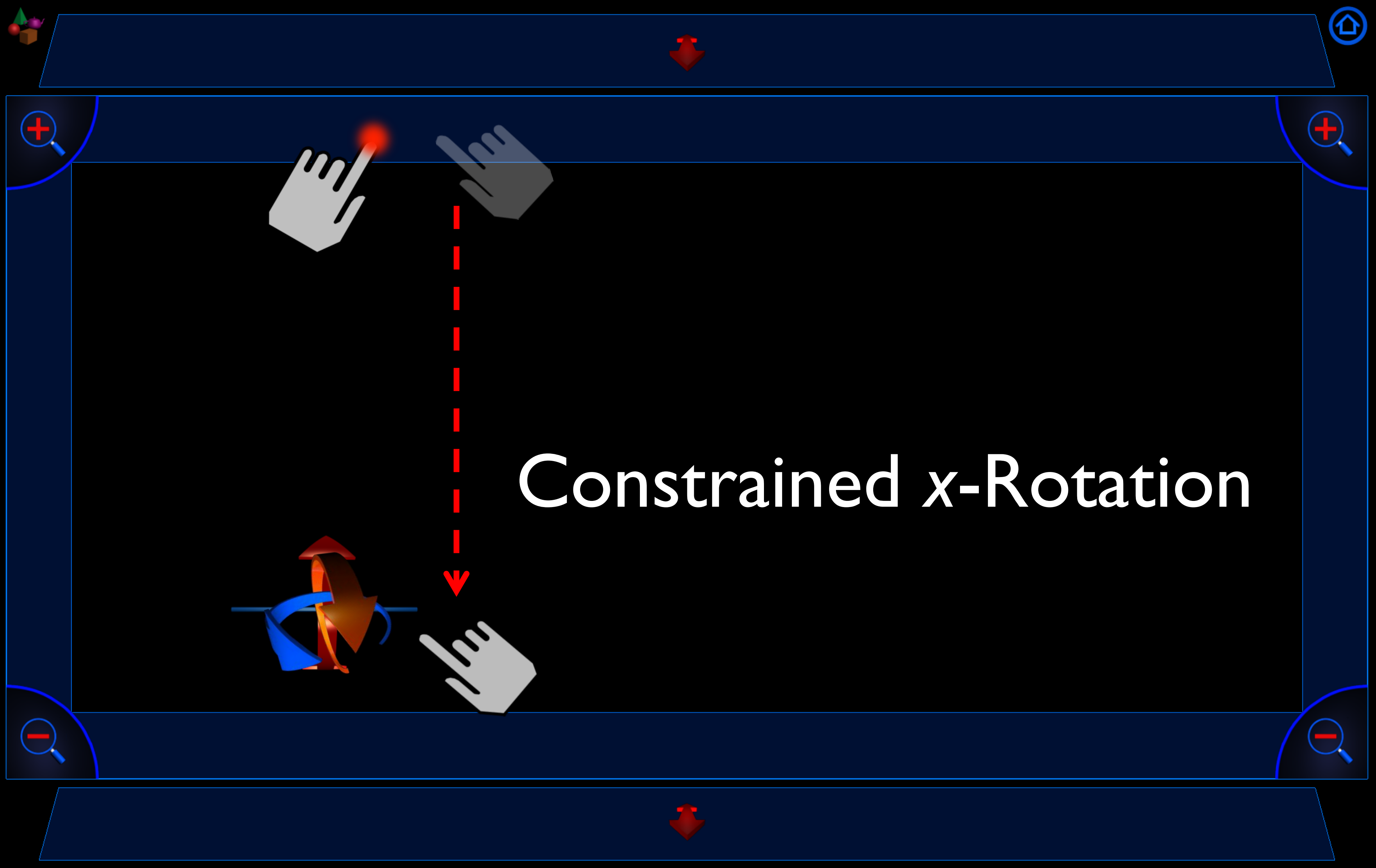
Design: Constrained Rotation



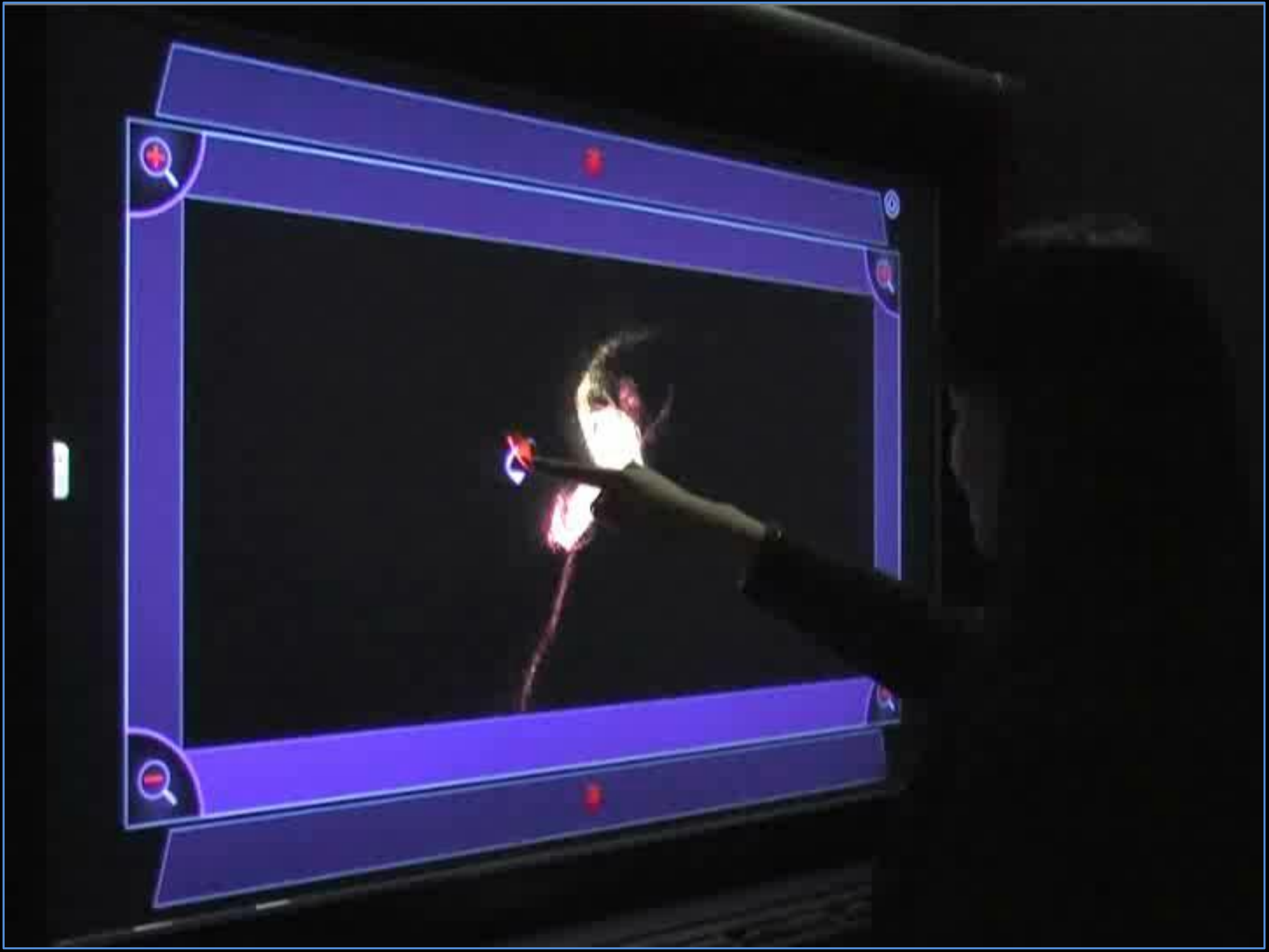
Design: Constrained y-Rotation



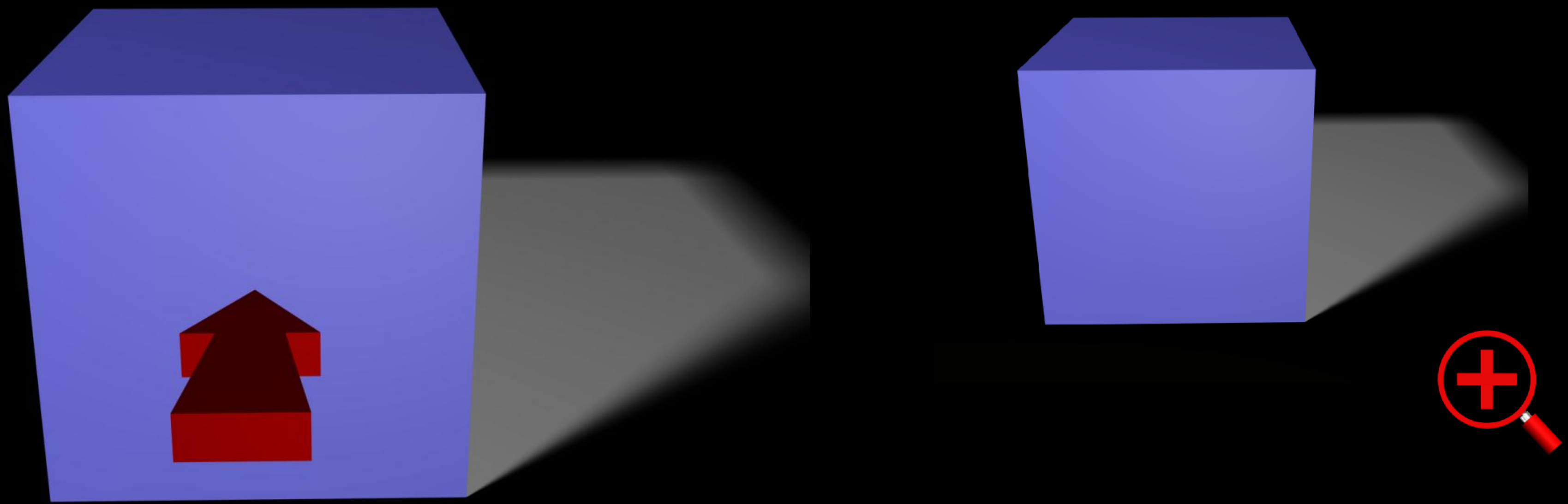
Design: Constrained *x*-Rotation



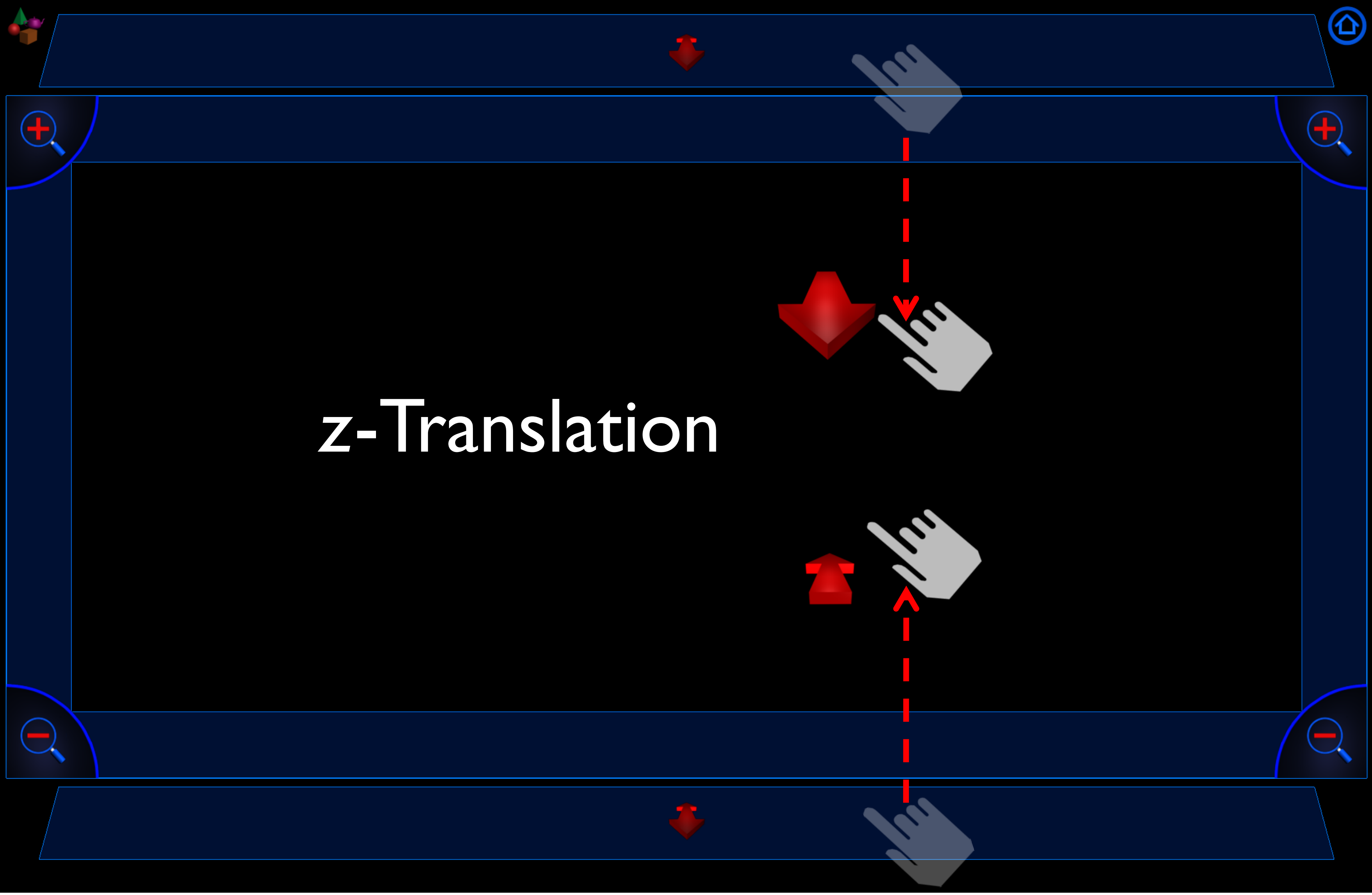
Design: Constrained Rotation



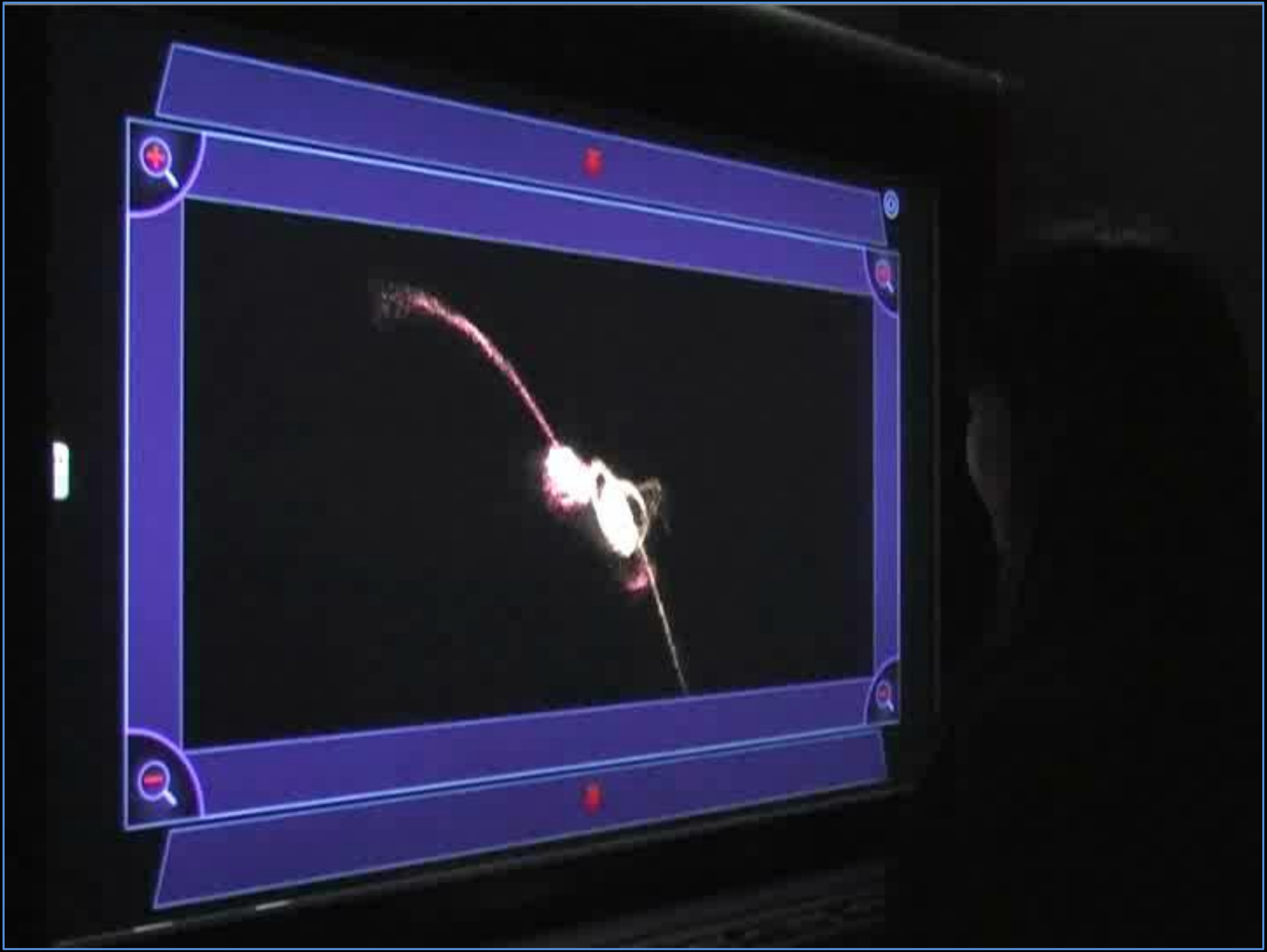
Design: z-Translation, Zoom



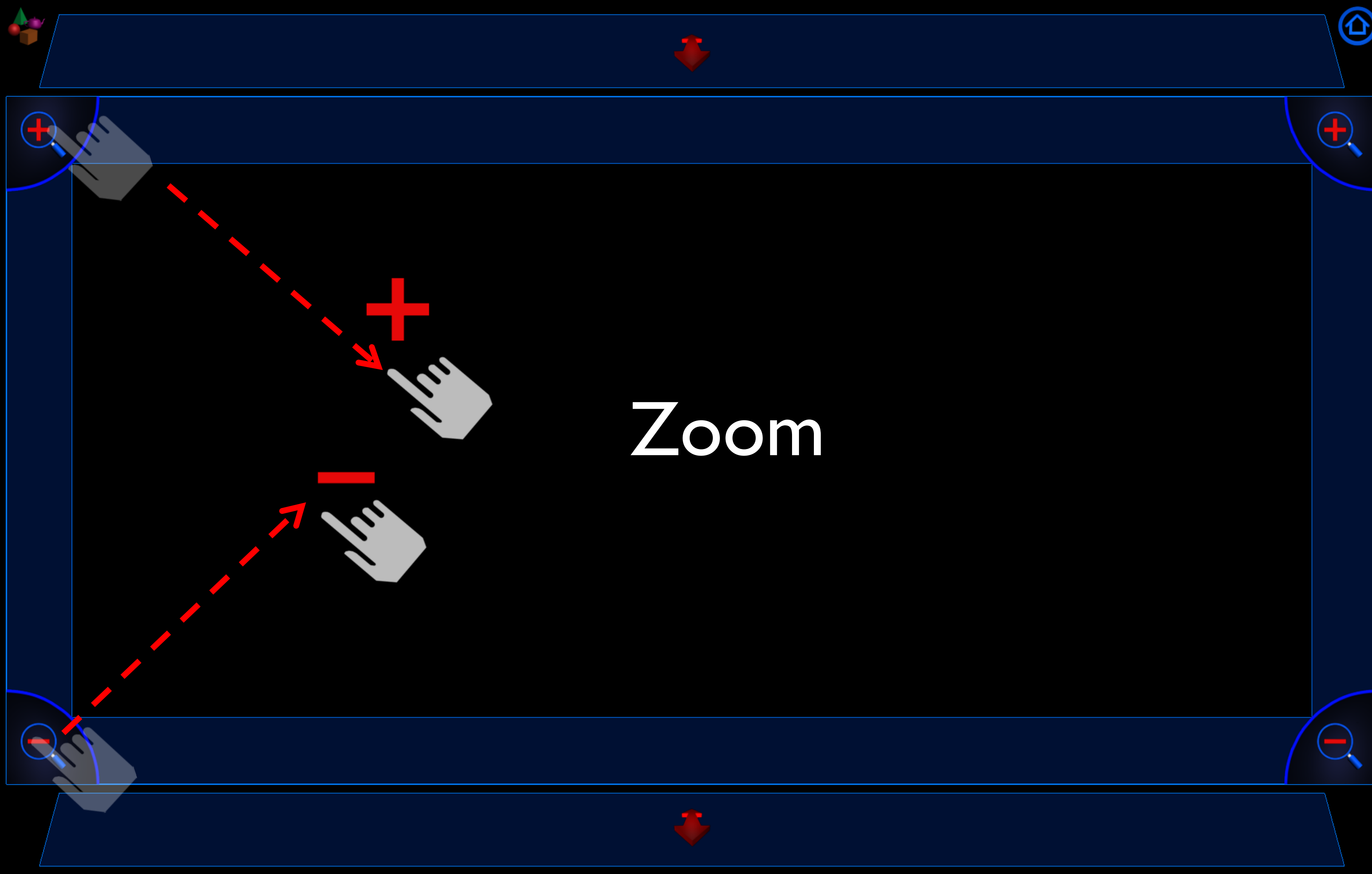
Design: z-Translation



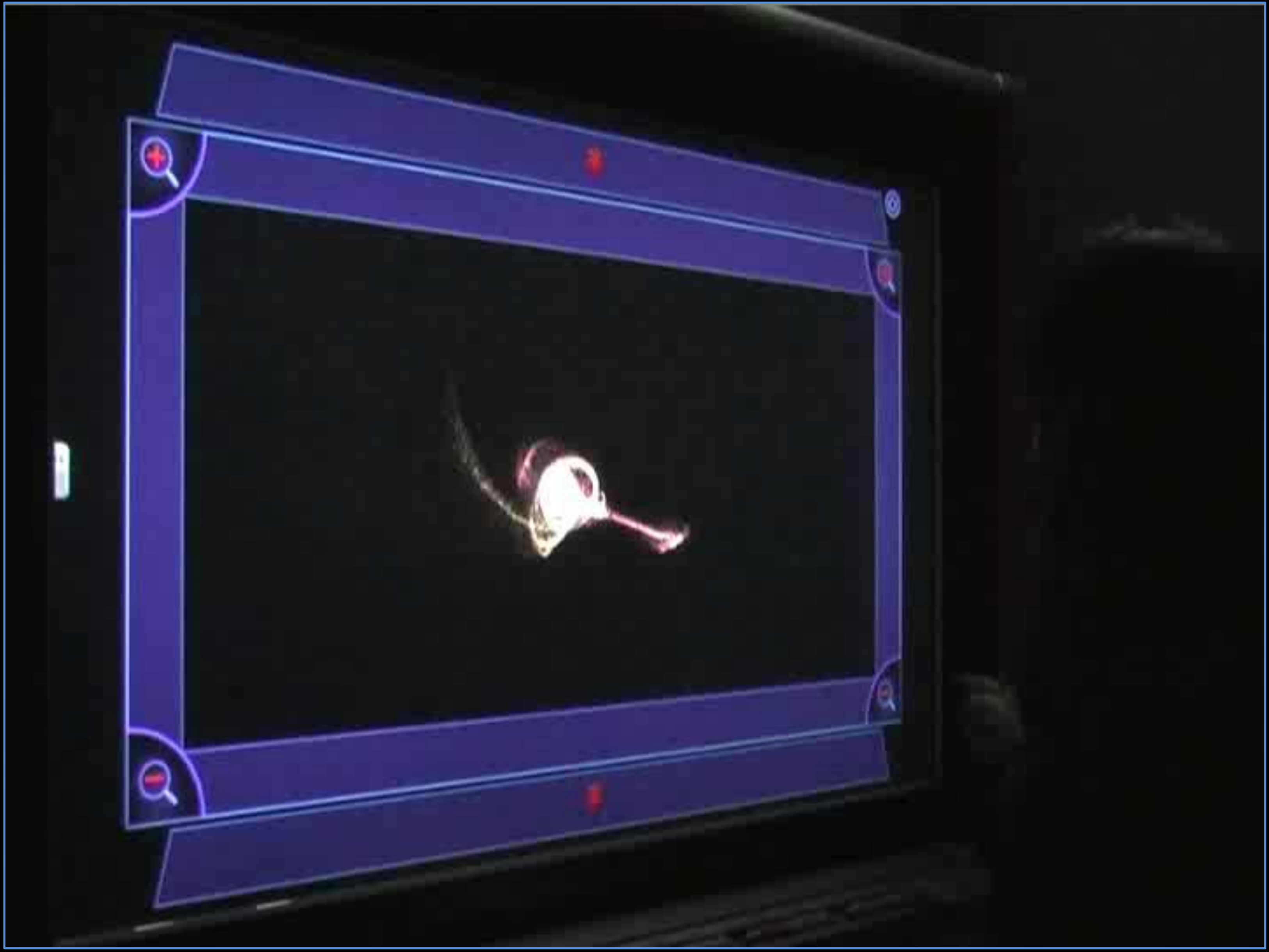
Design: z-Translation



Design: Zoom



Design: Zoom



Frame Interaction – Recap

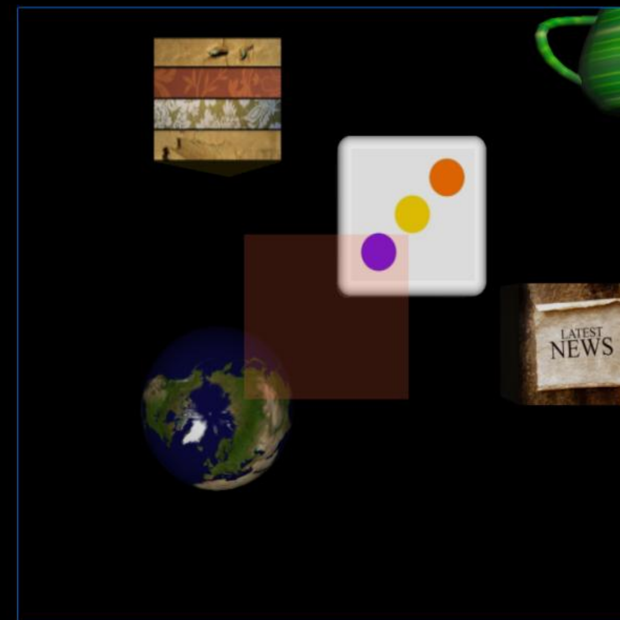
- Use frame to control the interactions
- Navigation in 3D space
- 7 DOF: three translations, three rotations, and zoom
- Integrated interaction

User study

- Participants:
  - Twelve members (6 male, 6 female).
  - Ages from 19 to 39, all right-handed

- Apparatus:
  - 52” LCD screen with full HD resolution (1920 × 1080 pixels)
  - SMART DViT overlay, supports two independent inputs

Study: Design



Study: Design

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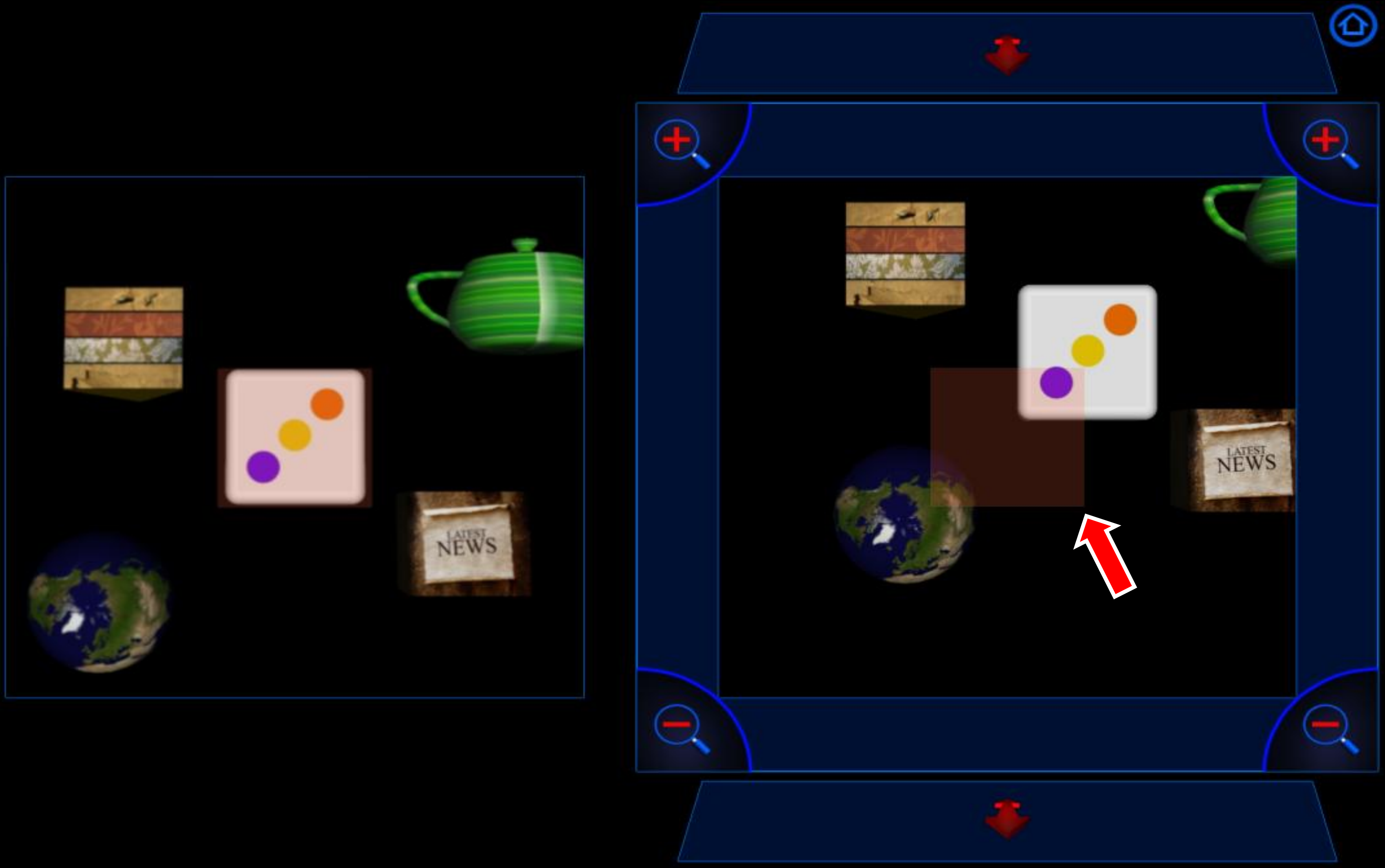
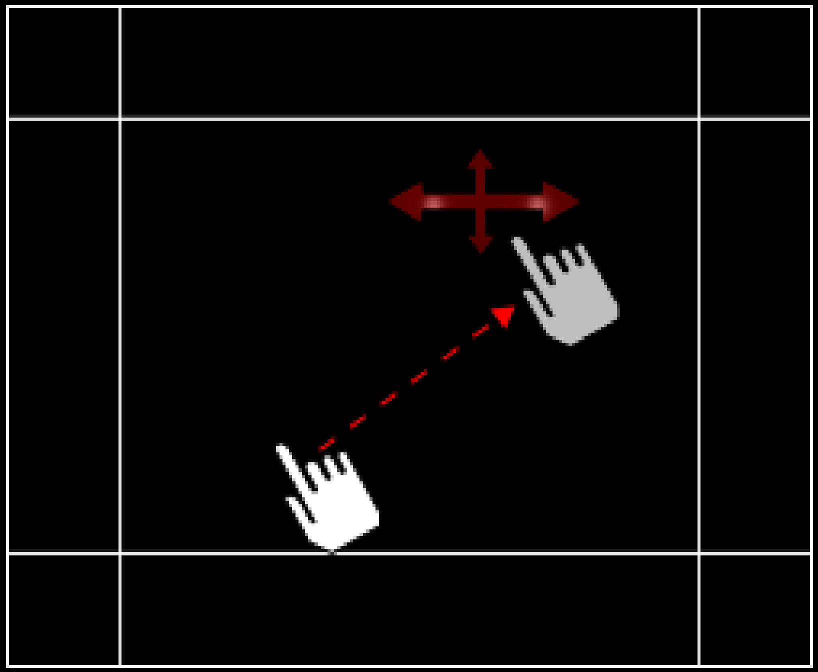
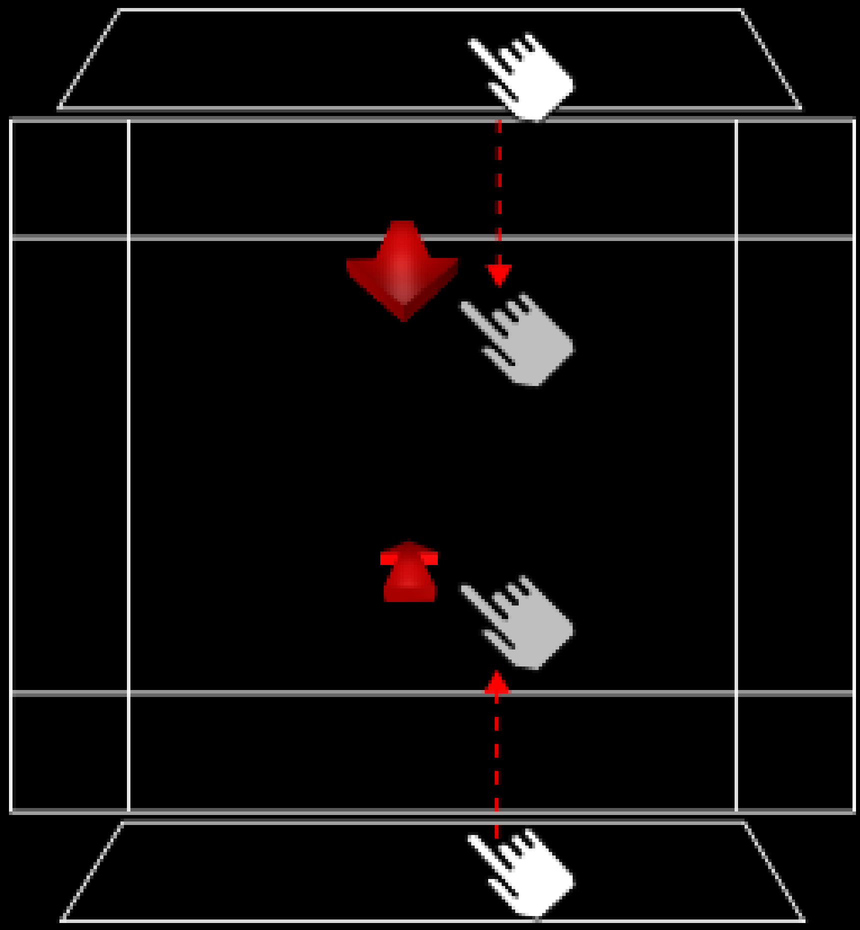
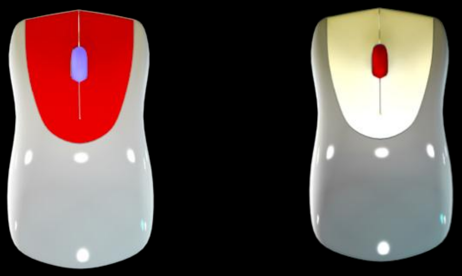


Study: x/y-Translation

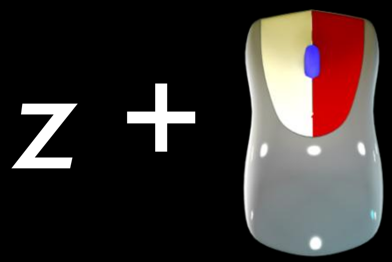


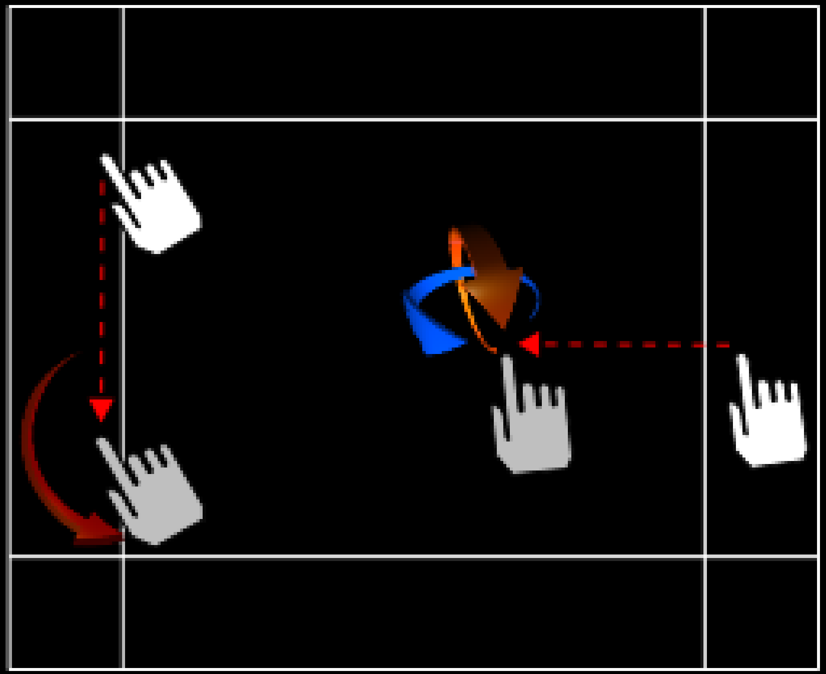
Study: z-Translation



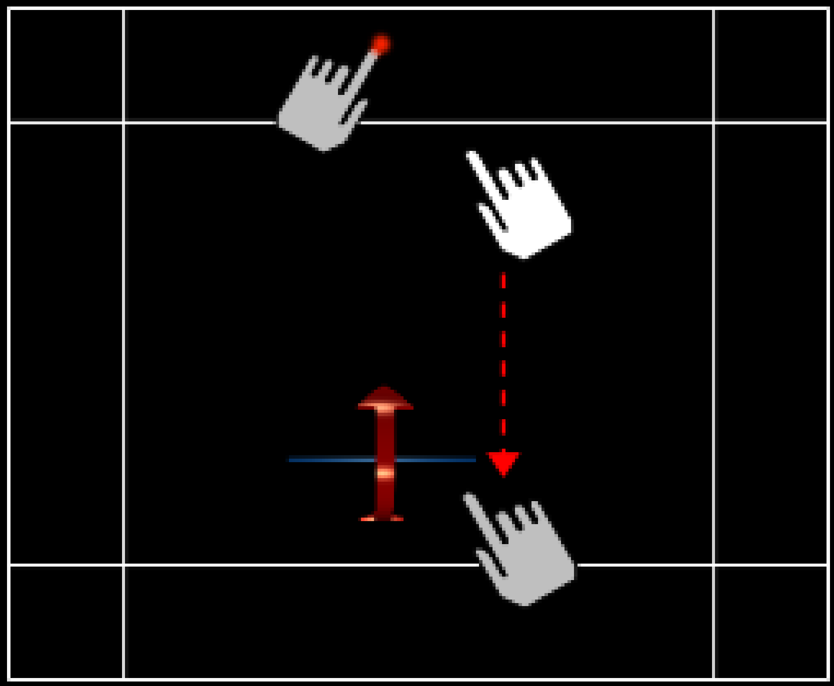


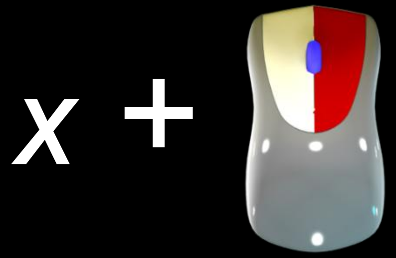
Study: Rotation

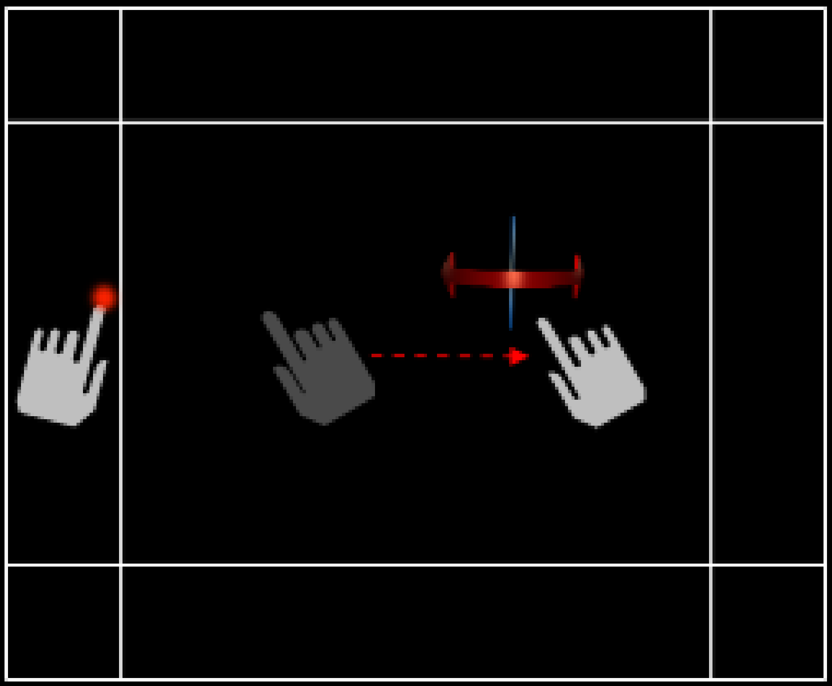


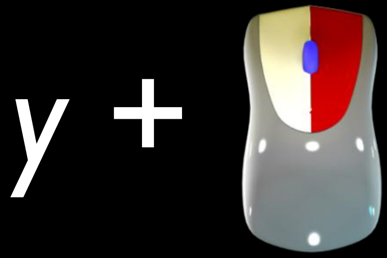


Study: Rotation

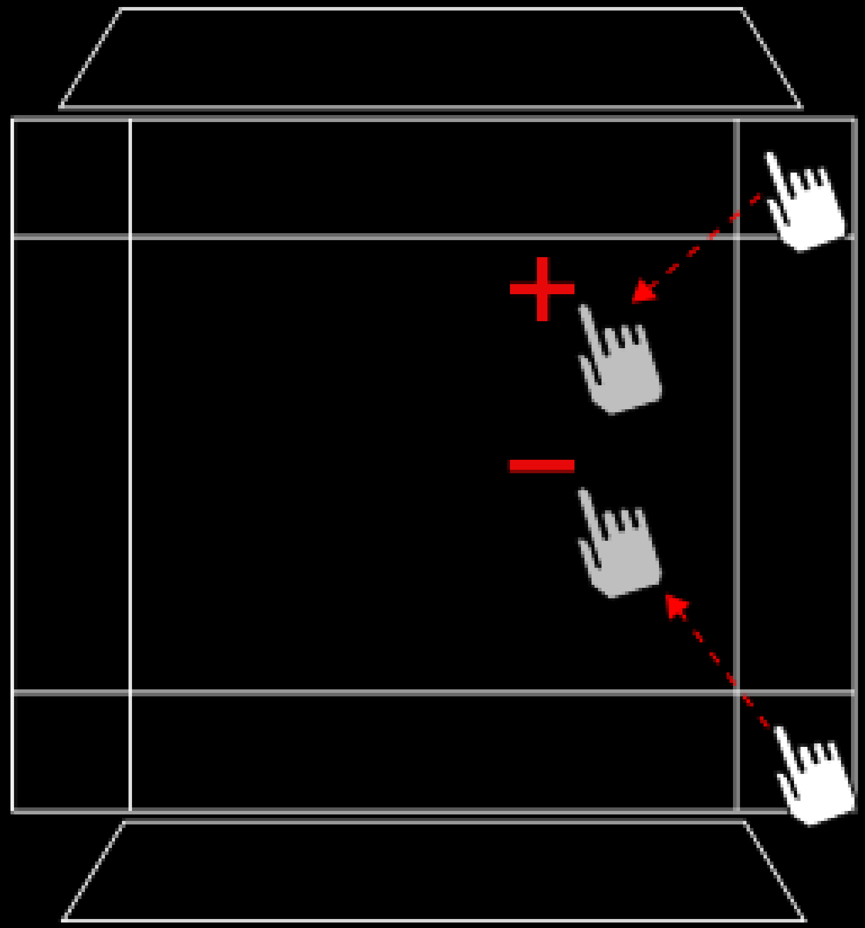




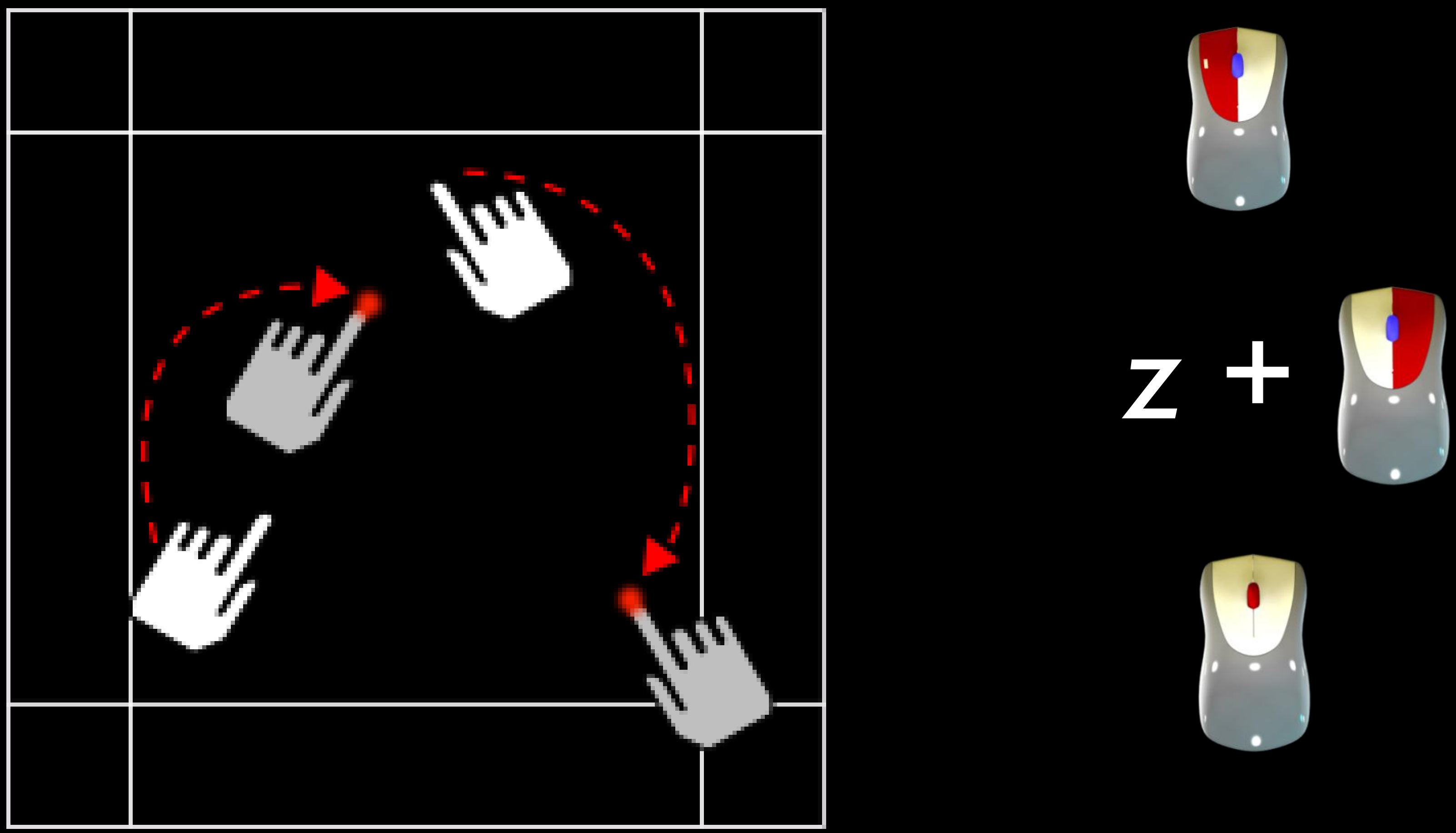




Study: Zoom

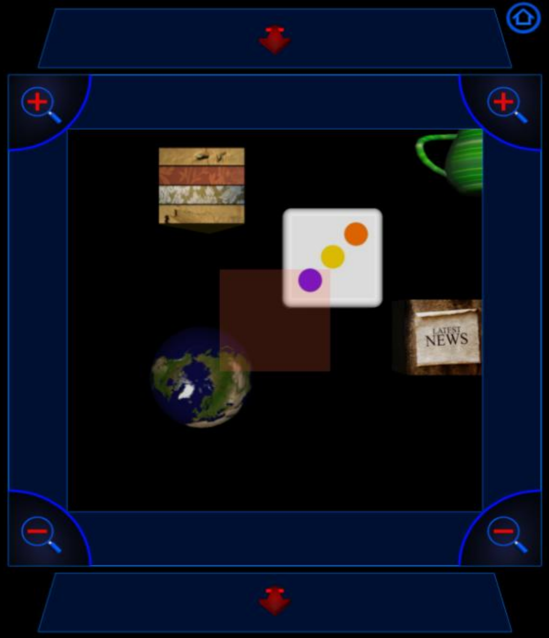


Study: RST



User Study: 1st Part – Travel Tasks

- eight travel tasks: *x*/*y*-translation, *x*/*y*/*z*-translation, *x*-rotation, *y*- rotation, *z*-rotation, trackball rotation, zoom, RST
- trails
- real testing
- complete part of questionnaire



User Study: 2nd Part – Wayfinding

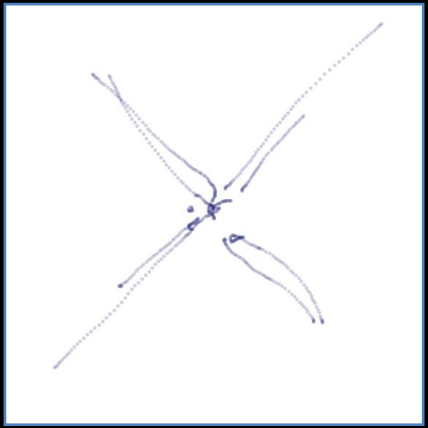
Study: Results

- Touch:
  - Interactions found to be easy to remember and perform
  - Additional interaction capabilities valued
  - Preferred for data exploration
  - No time improvement over mouse but also no large difference
- Mouse
  - Years of expertise valuable
  - Preferred for time-critical tasks
  - Faster for rotation and zoom

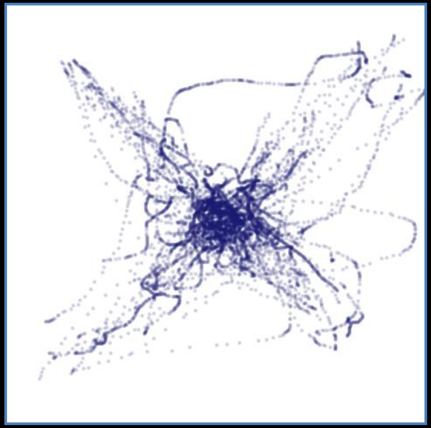
Lessons Learned

- familiar devices: time-pressured tasks
- touch: open-ended exploration

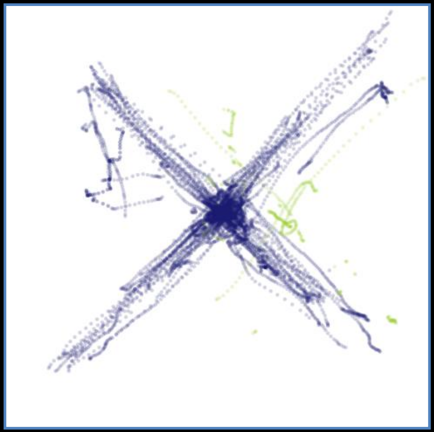
Participant 1 Mouse



Participant 1 Touch



Participants all Mouse



Participants all Touch

Lessons Learned

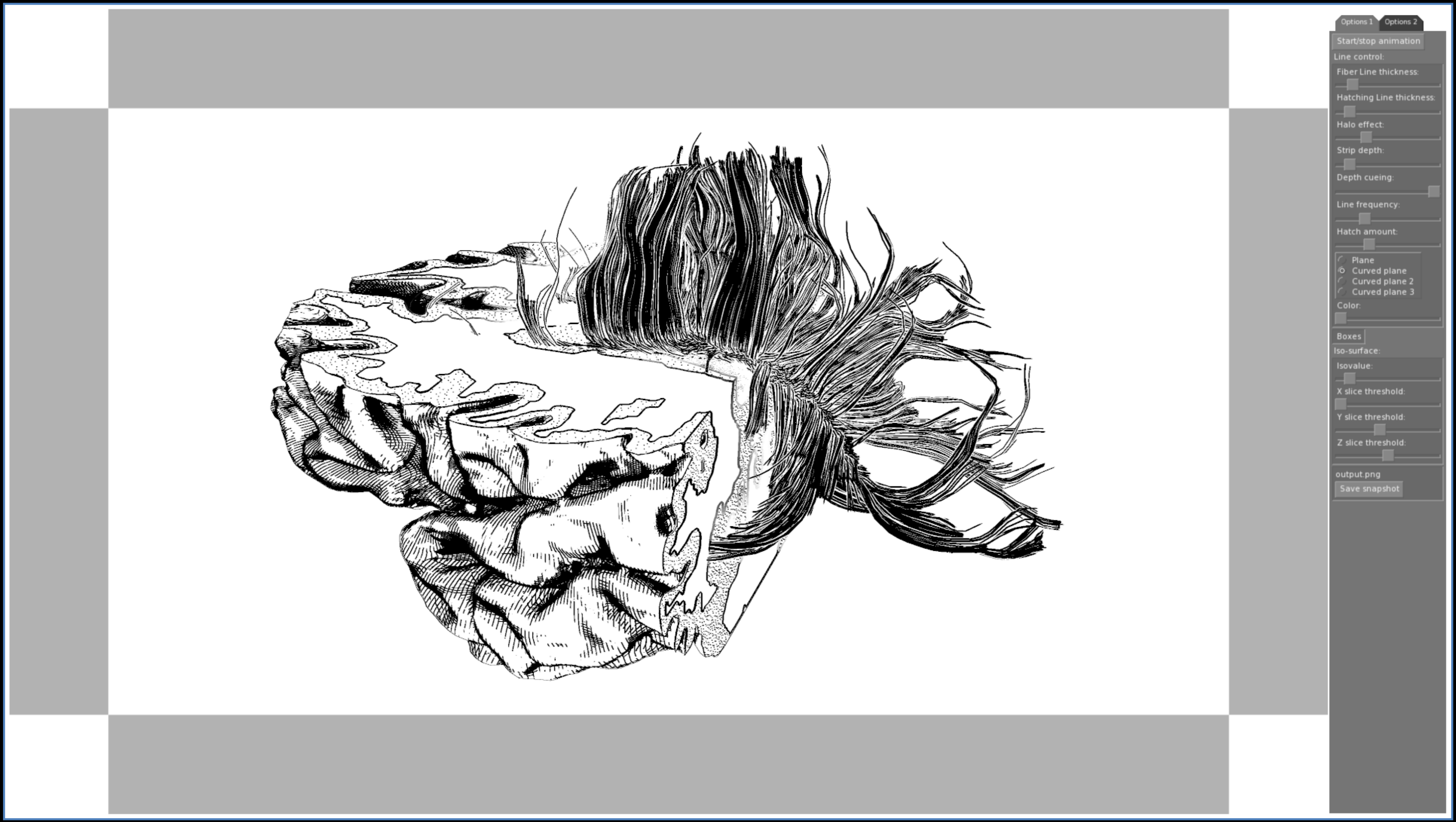
- rotation task:
  - hardware issues

- zoom task:
  - wheel is faster
  - touch has advantage of continuous zoom

Improvement from Study

Improvement from Study

Exploration of Brain Anatomy



Exploration of Brain Anatomy

Conclusion

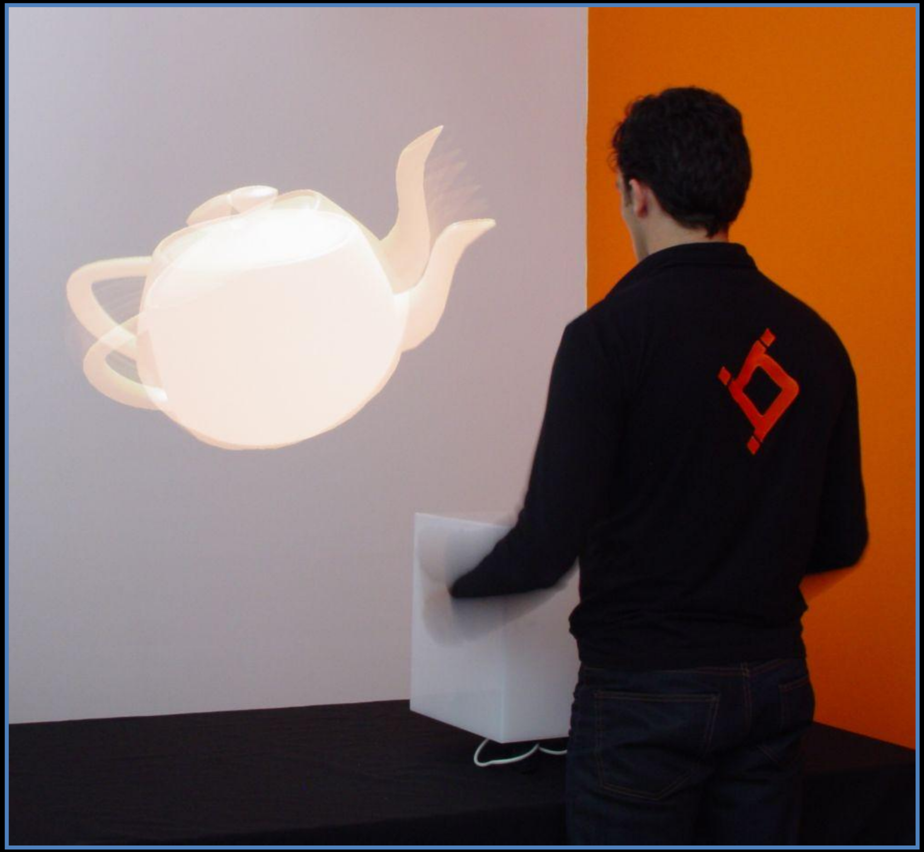
- design study for enabling direct-touch interaction with three-dimensional scientific visualization spaces
- 7DOF frame interaction with the whole space
- both large-scale and precise interactions
- different scientific visualization domains
- user study:
  touch competitive with mouse as familiar device

FI3D: Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces

http://www.cs.rug.nl/svcg/to/FI3D

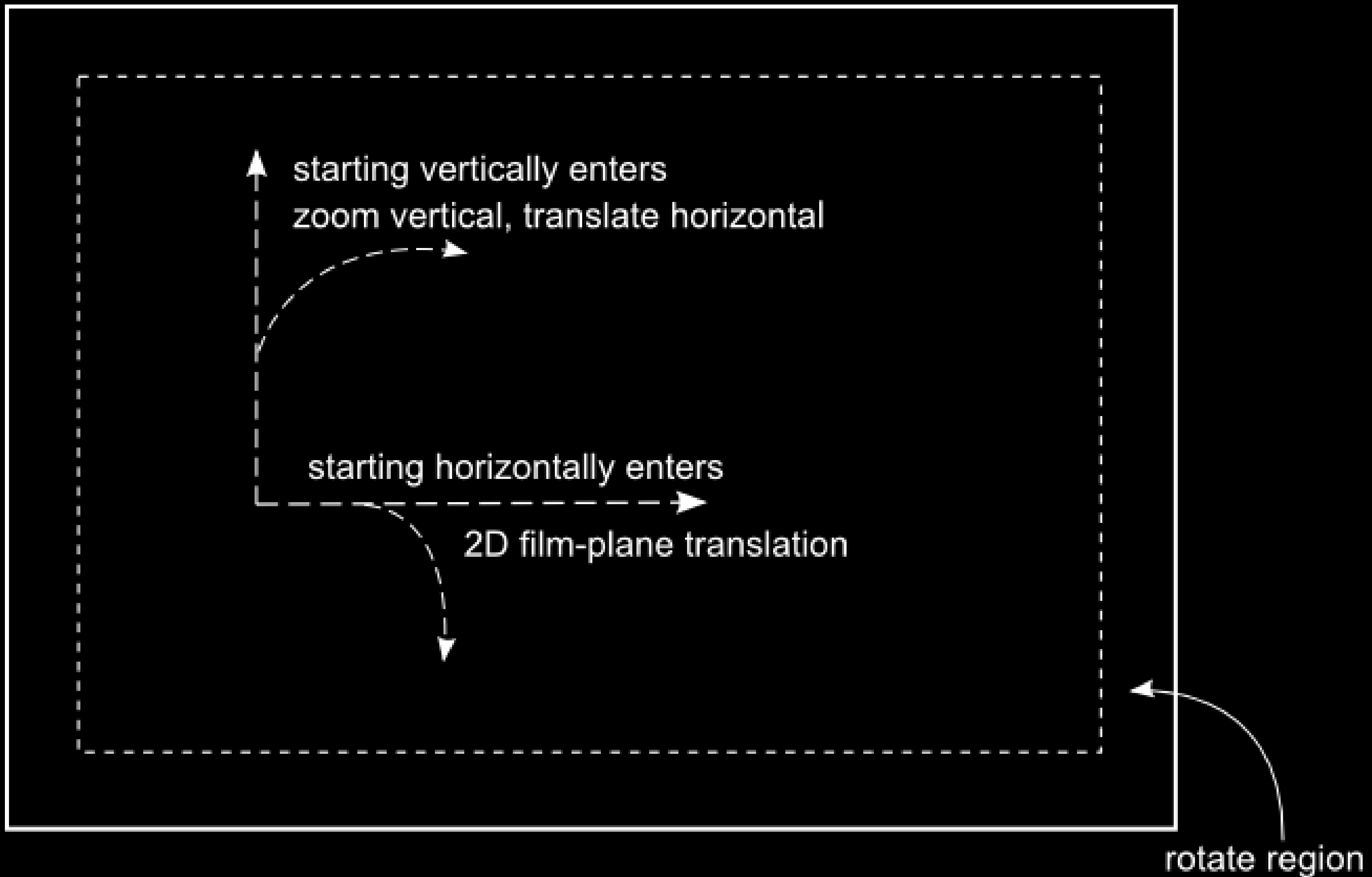
Additional Slides

From real tube to virtual object



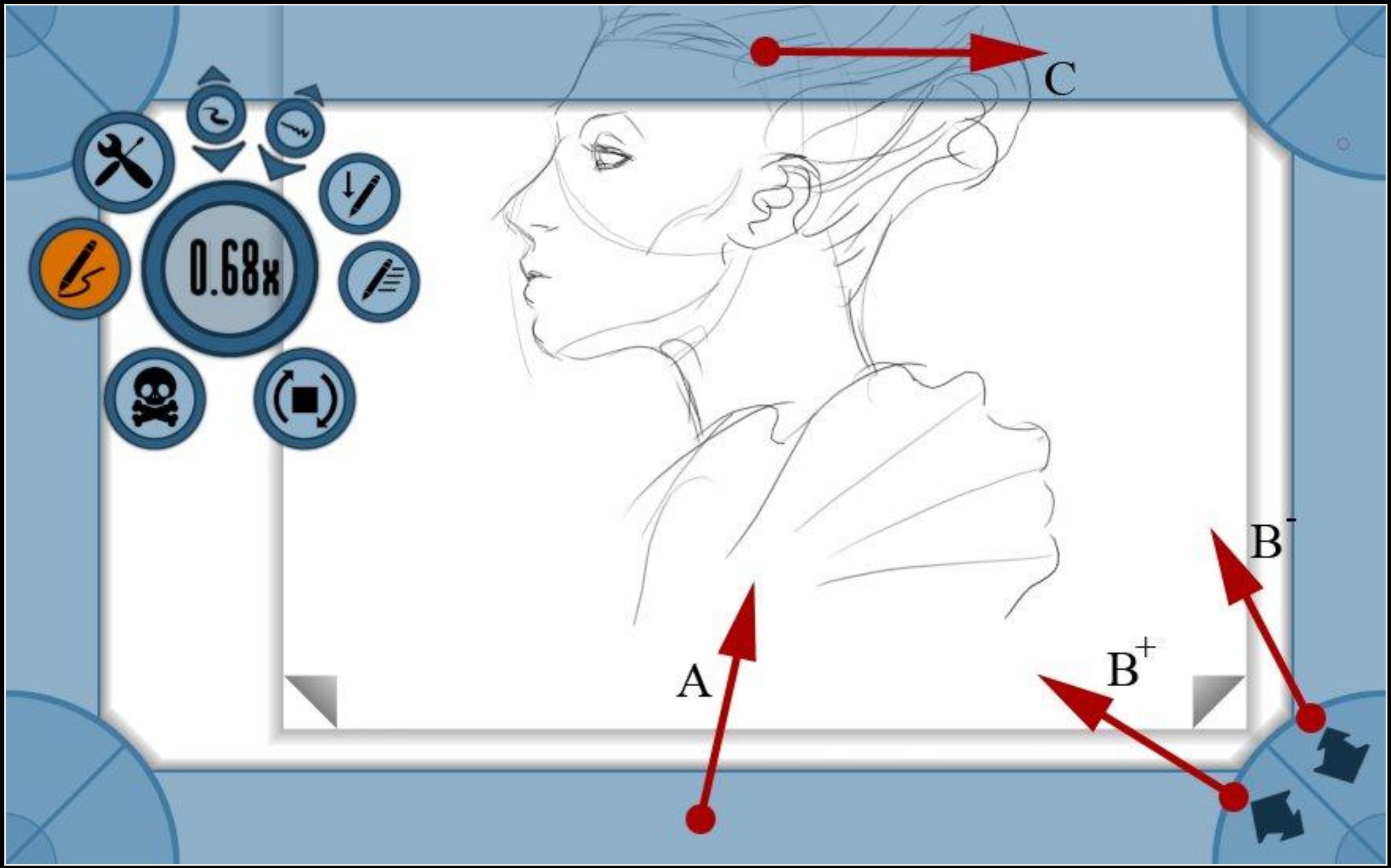
[de la Riviere et al, 2008]

Frame Interaction



[R. Zeleznik and A. Forsberg, 1999]

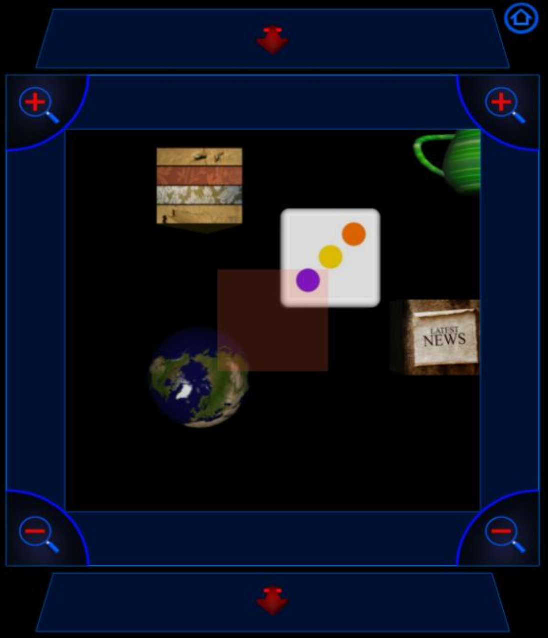
Frame Interaction



[Nijboer et al., 2010]

User Study: 1st Part – Travel Tasks

- 12 participants × 2 input devices × 8 tasks × 4 runs of trials × 4 trials = 3072 interactions
- eight travel tasks: *x*/*y*-translation, *x*/*y*/*z*-translation, *x*-rotation, *y*- rotation, *z*-rotation, trackball rotation, zoom, RST



Study: Results

- log files:
  - translation, RST : touch is slightly faster (not significant)
  - all rotations, zoom: mouse is significantly faster
  - wayfinding: 75% chose touch, 25% chose both
- questionnaire: overall preference
  - after all travel tasks, 66% of participants prefer mouse
  - after wayfinding task, 75% of participants chose touch over mouse

Overall preferences

- after all travel tasks, 66% of participants prefer mouse
  - Mouse: familiarity(2×), speed(2×), less physical involvement(4×)
  - Touch: intuitiveness, natural, closer feel
- after wayfinding task, 75% of participants chose touch over mouse
  - Touch: perceived immersion(2×), intuitiveness and ease of learning(2×), “things under control”(1×)
  - Mouse: easy because of familiarity

Significance scores for the four rotation tasks

Task:	**trackball**	***x*-rotation**	***y*-rotation**	***z*-rotation**
$F(1,11) =$	8.040	18.967	41.837	7.439
$P <$	.016	.001	.001	.020

Significance scores for the four other tasks

Task:	*x/y*-translation	*x/y/z*-translation	zoom	RST
$F(1,11) =$	.075	3.57	64.70	.982
$P <$	.79	.08	.001	.343

Scores about ease of use

Task:	translation	rotation	zoom
touch	6.5	6	7
mouse	6	6	7

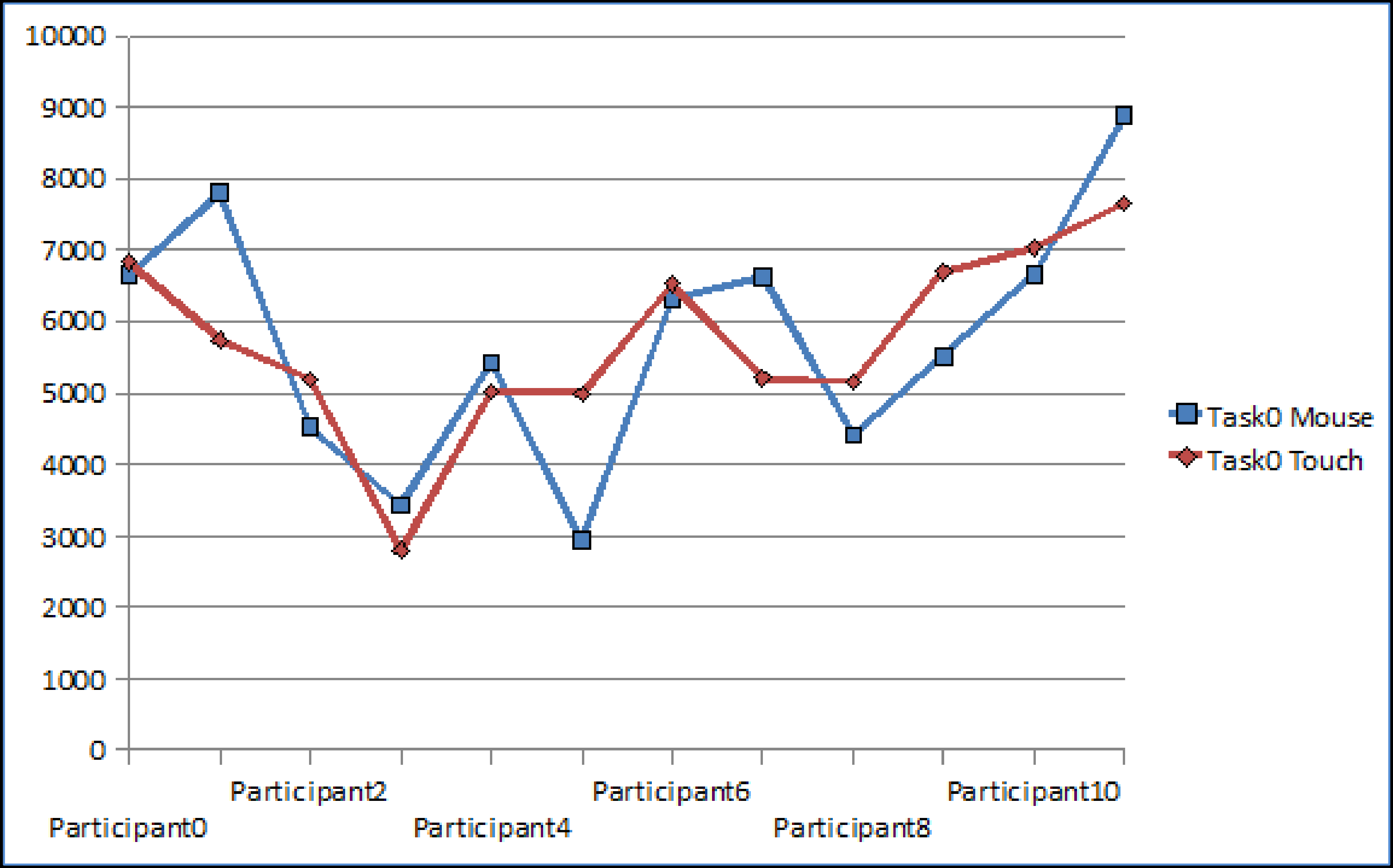
- 7-point Likert scale

Disagree Strongly	Disagree	Disagree Somewhat	No opinion	Agree somewhat	Agree	Agree Somewhat
1	2	3	4	5	6	7

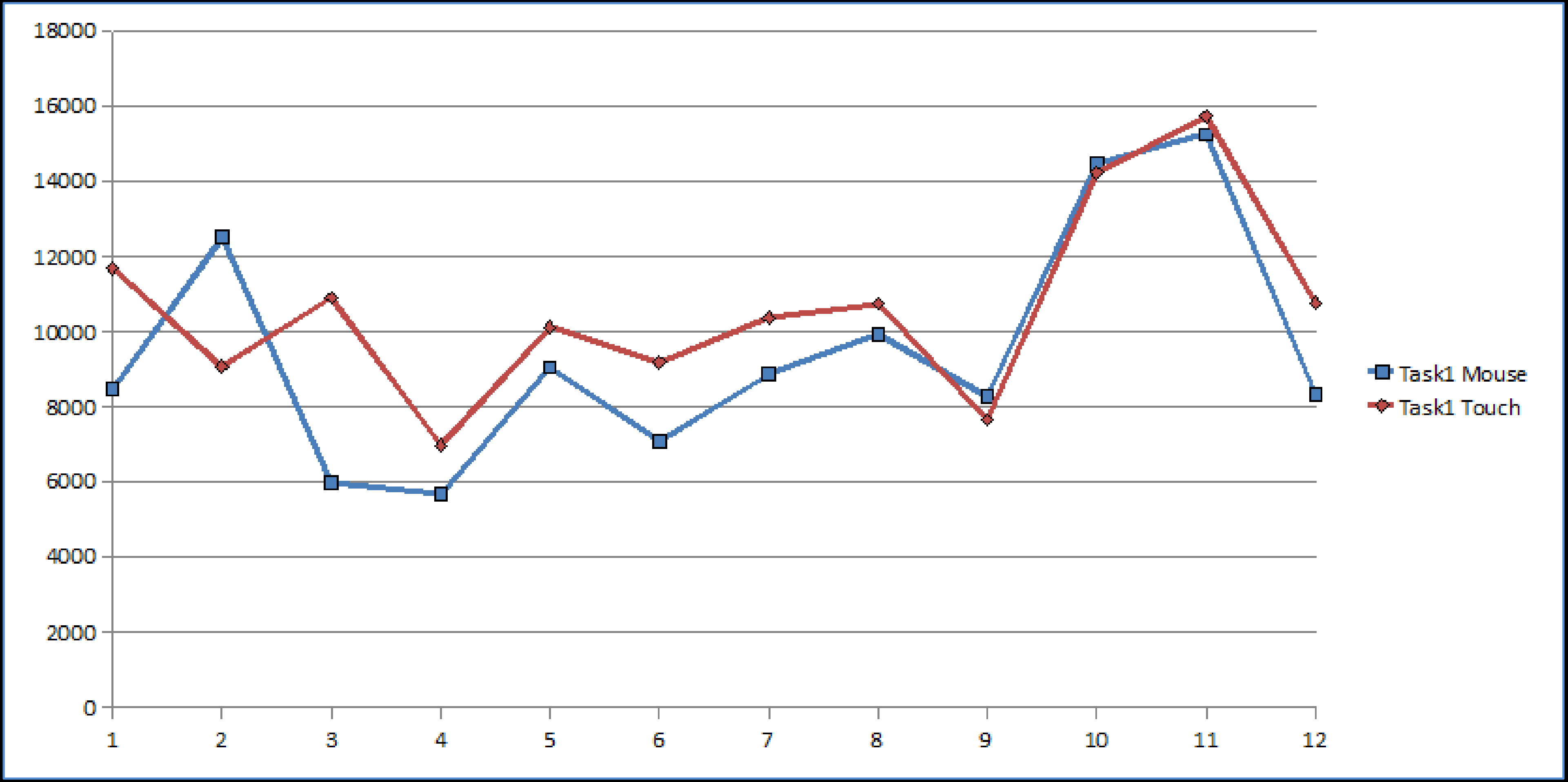
Overall rating

Usability	Easy of use	Remember time	Precise	Effective	Difficult
Touch	6	2	5.6	5.8	2.25
Mouse	5.9	3	5.7	5.4	2.75

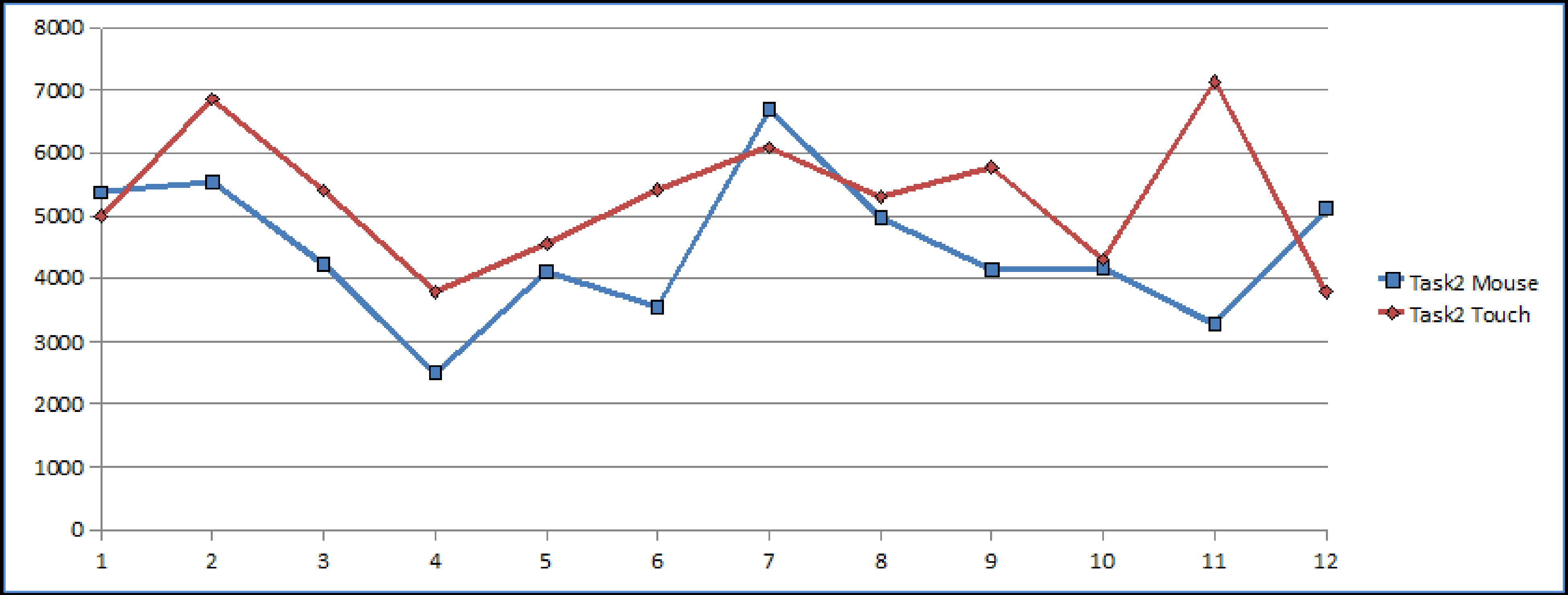
Study: timing result – *x/y*-translation



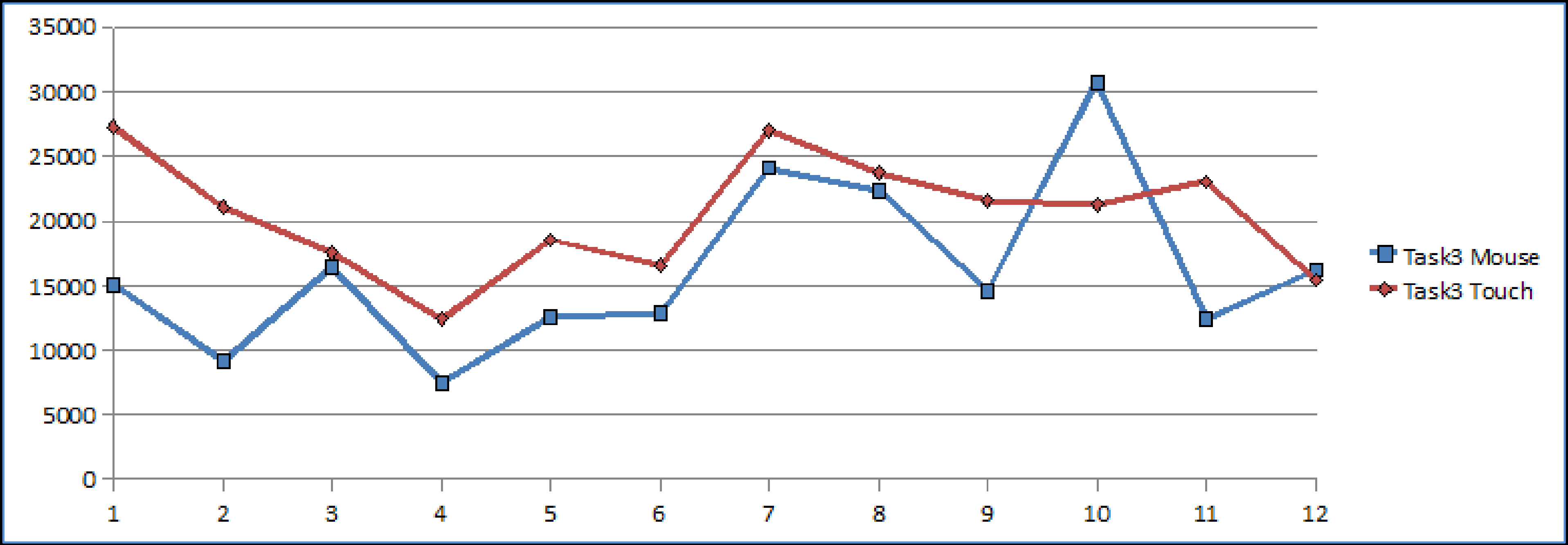
Study: timing result – *x/y/z-translation*



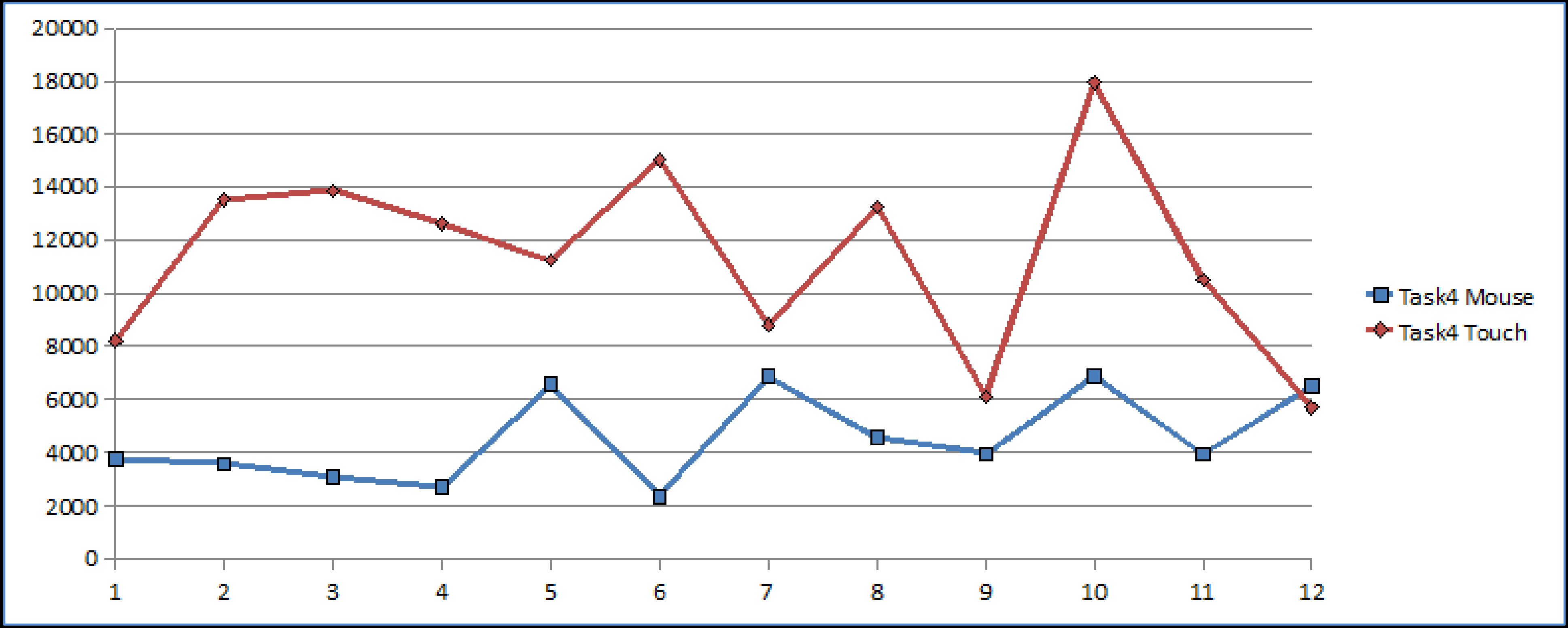
Study: timing result – z-rotation



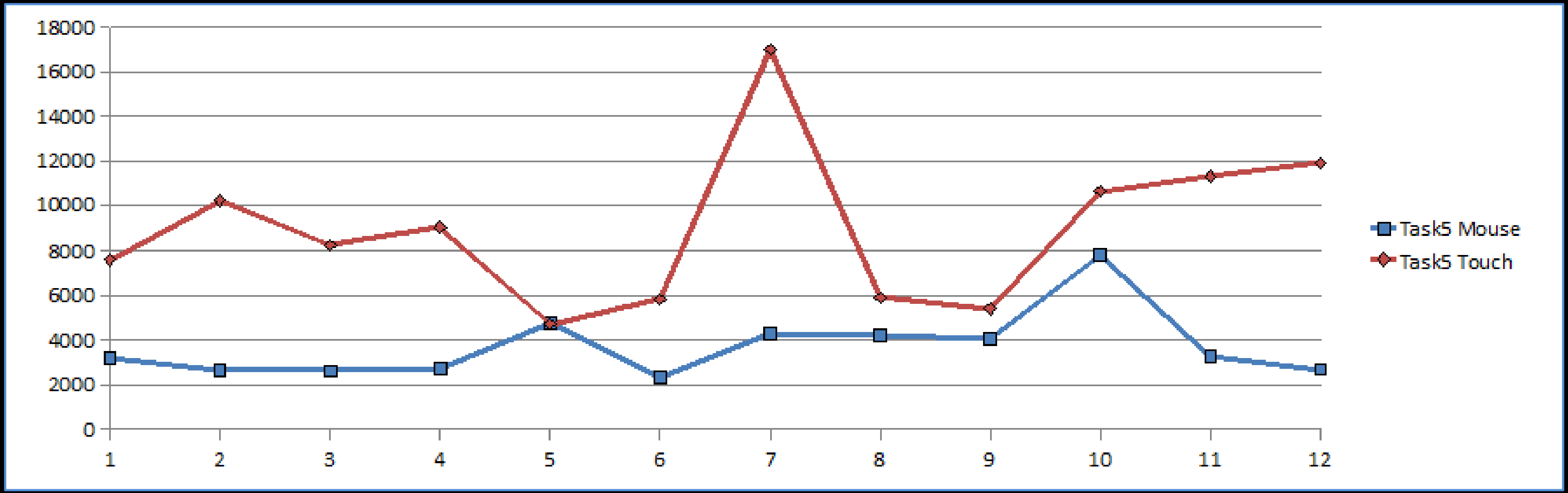
Study: timing result – trackball rotation



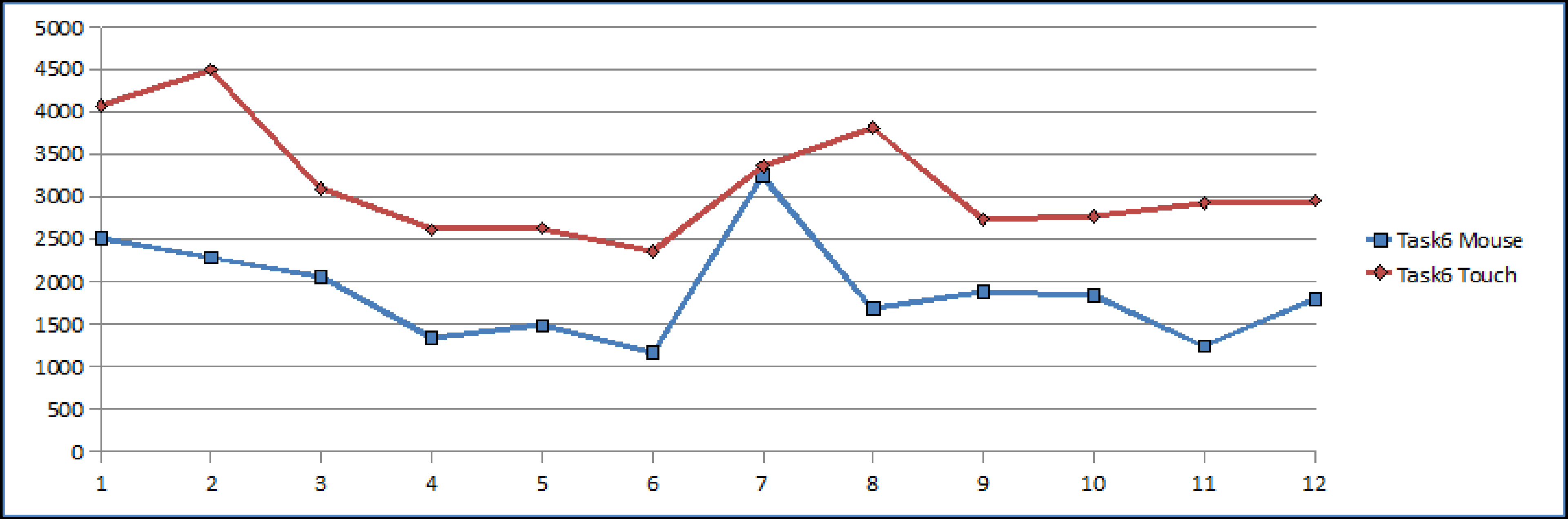
Study: timing result – x-rotation



Study: timing result – y-rotation



Study: timing result – zoom



Study: timing result – RST