Freehand gesture-based 3D manipulation methods for interaction with large displays

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Outline

- Motivation
- Proposed manipulation methods
  - One Hand
  - Handle Bar
  - Improved Handle Bar
- User Studies
  - Results and Discussion
- Conclusions and Future Work

Motivation

Advent of low cost sensors (eg. Wii Remote, Microsoft Kinect, Leap Motion)

Advances in gesture recognition algorithms

Increasing popularity of gesture-based interfaces

\+ Relevance in a growing number of scenarios (Virtual and Augmented Reality)

\- Usability and technical issues:

- Lack of consensus in gesture-function associations
- Variety of environments

Motivation

- 3D user interfaces as a natural choice for large displays contexts
  - multiple users
  - freedom of movement
  - no wearable devices

- Unconstrained interaction through user own body

Our interactive system

- Public display interactive system at the entrance hall of our department
- Large screen + Kinect sensor
- Besides 2D contents, should allow virtual walkthroughs and manipulation of 3D prototype models

Fig. 1. Public display interactive system installed at the entrance hall of our Department

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Fig. 1. Public display interactive system installed at the entrance hall of our Department

Related Work

<u>Manipulation</u> – one of the three universal interaction tasks

↓

The ability to perform rotation, translation and scaling operations over an object

- Desirable feature in many VR applications
- Commonly achieved through a real-world metaphor

Virtual Reality as a particularly interesting application of freehand gestures

Attractive alternative for ubiquitous computing and interaction with large public displays

Metaphors for manipulation gestures

- Metaphors commonly used to achieve desired properties
- Physical familiarity and natural mental mapping between operations
- Allow effective control between the user's hands and the virtual object manipulation

Iterative process, based on analysis of qualitative and quantitative data collected while observing users interacting with the system

Preliminary results used as formative evaluation

We deem summative evaluation is key to guarantee methods usability

User study to compare alternatives and select the most suitable method for 3D object manipulation

Proposed manipulation methods

- Basic operations
  - **Rotation:** changing object's orientation
  - **Scaling:** changing object's size

- One Hand

- HandleBar

One Hand

- Single hand manipulation
- Inspired by the cursor metaphor for grabbing and manipulating with one hand

Rotation

offset between the grabbing point and the position of the moving hand

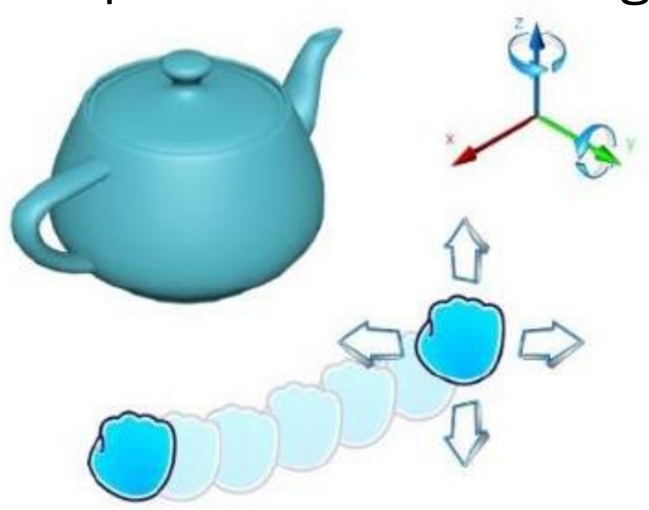

Fig. 2. *One Hand* method: Rotation around the Y and Z axes

Scaling

two GUI buttons

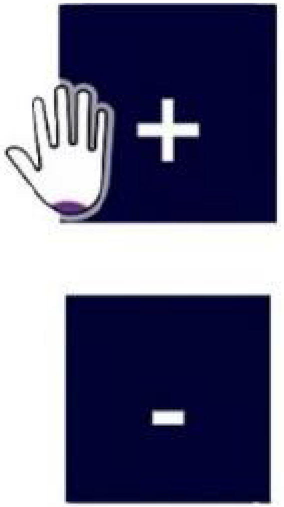

Fig. 3. *One Hand* method: Scaling

One Hand

- Limitations:
  - cursor-based movement: mapping of a 2D coordinate of the cursor into the 3D space of the object
  - only captures 2 rotation DOF: Kinect not able to detect wrist orientation

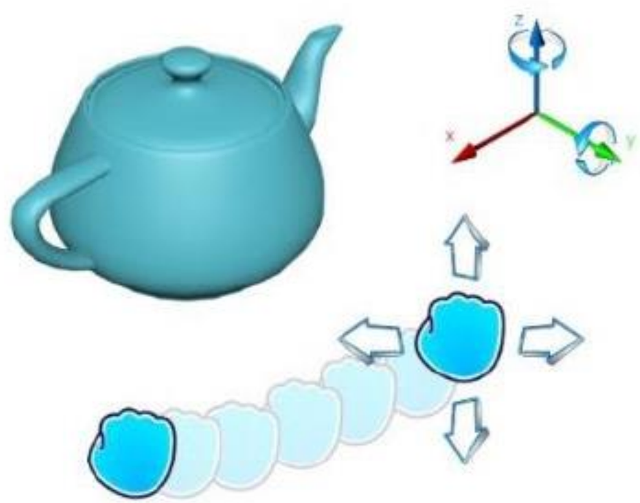

Fig. 2. *One Hand* method: Rotation around the Y and Z axes

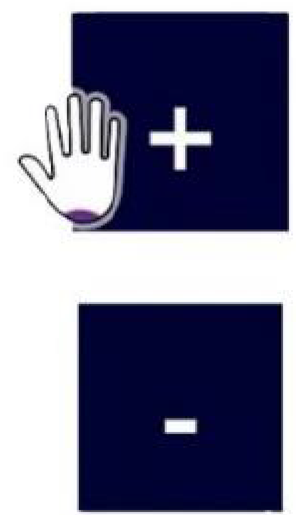

Fig. 3. *One Hand* method: Scaling

HandleBar

- Manipulation in 3D space
- Handle bar metaphor
- Direct map between coordinates of user's hands and coordinates of the object
- Bi-manual interaction using grab and release events – allows cumulative transformations from successive operations

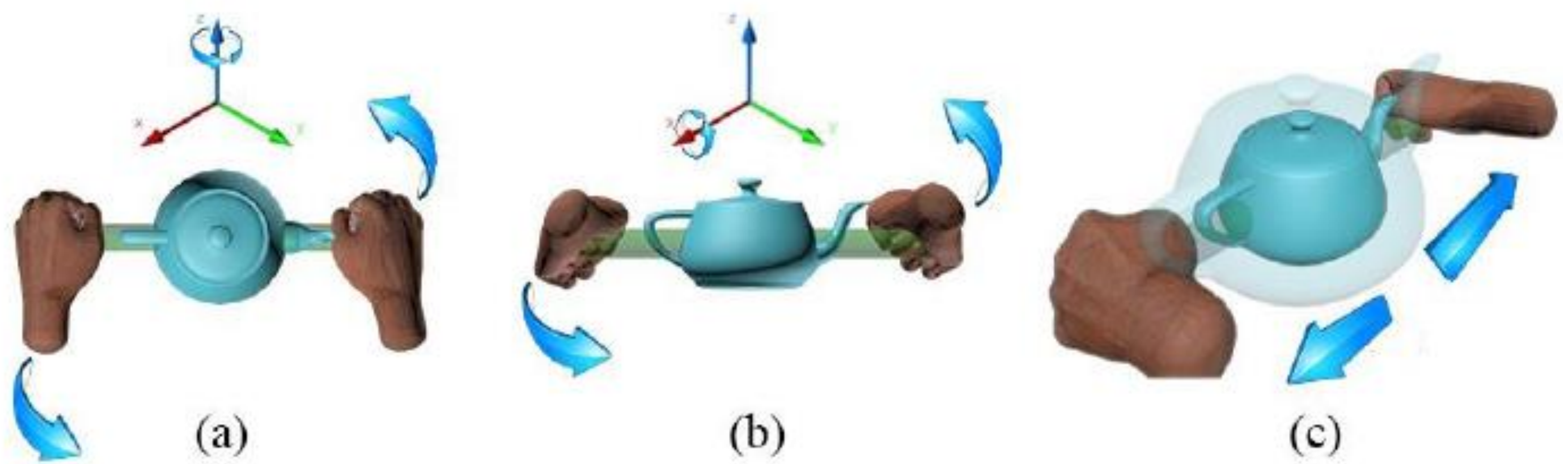

Fig. 4. *HandleBar* method: a) Top view, rotation around the Z axis. b) Front view, rotation around the X axis. c) Scaling

HandleBar

Rotations

relative offset of the handlebar rotation (hand position)

a) Around Z axis: move one hand forward and the other backwards
b) Around X axis move one hand up and the other down

Scaling

proportional to the distance between the left hand and the right hand

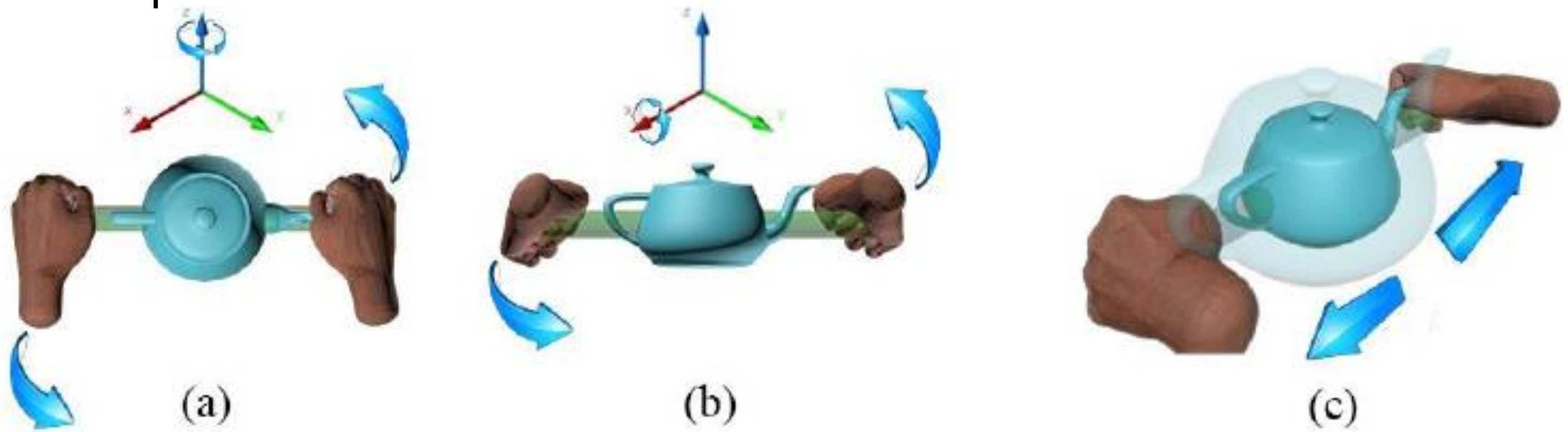

Fig. 4. *HandleBar* method: a) Top view, rotation around the Z axis. b) Front view, rotation around the X axis. c) Scaling

HandleBar

- Limitations:
  - only implements 2 DOF, like One Hand

- During preliminary evaluation tests, users proposed an improvement :
  - Suggested movement to introduce missing DOF

Improved HandleBar

- Adds both hands movement (up or down) for third DOF (rotation around Y axis)

Rotation around Y axis

if in grab state and both hands are parallel: rotation is the angle between Y axis and line from the hip center joint and middle point between hands

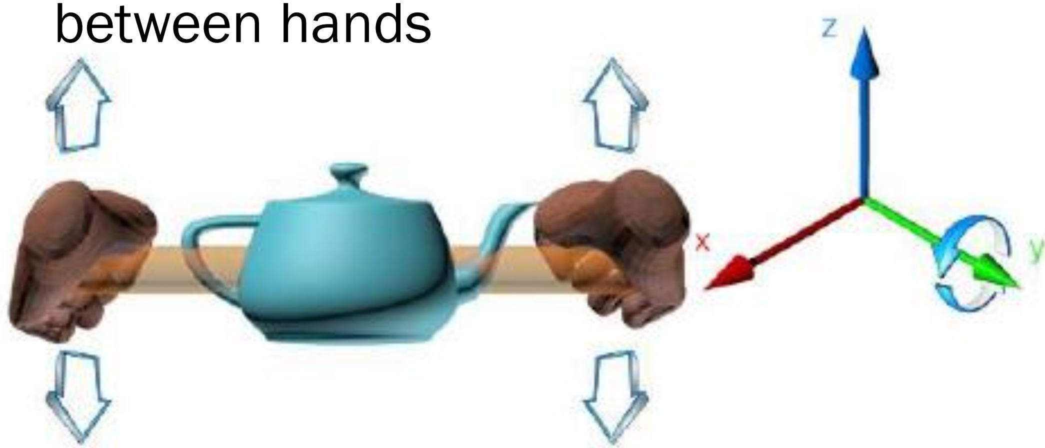

Fig. 5. Improved *HandleBar* method: rotation around the Y axis

Improved HandleBar

- Allows full rotation DOF (roll, pitch and yaw)
- Provides visual feedback about the different rotations through a color scheme

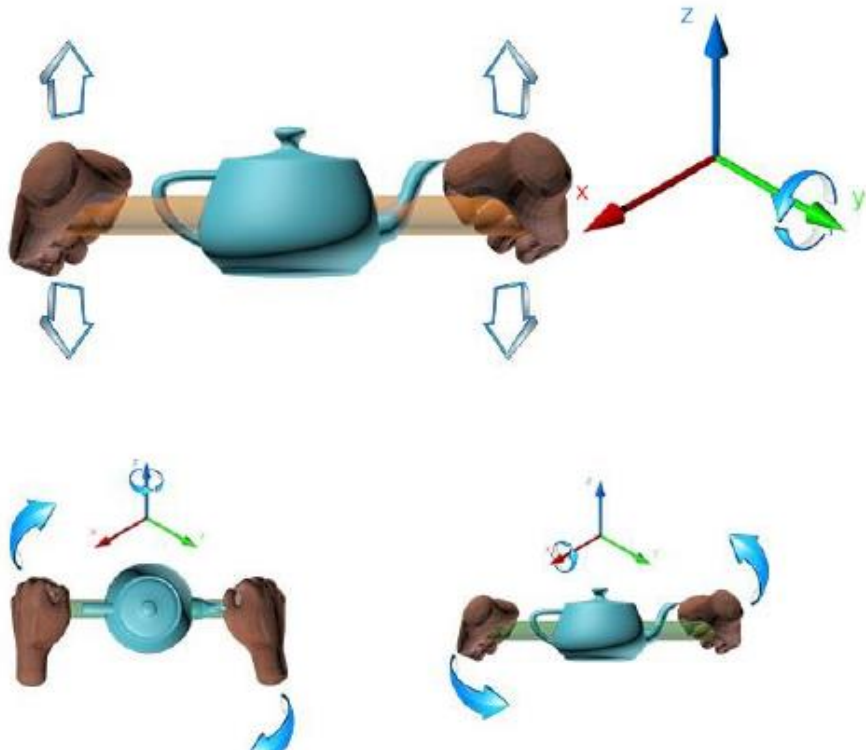

Fig. 6. Improved *HandleBar* method

User Studies

- Goal: compare usability of proposed manipulation methods
- **Preliminary test** with 8 students to establish experimental protocol
  - which performance measures should be used?
  - Improved HandleBar method appears
- **Second user study** with 40 participants

Preliminary test

- Two tasks to compare *OneHand* and *HandleBar* methods in terms of:
  - usability
  - accuracy attained by users manipulating an object

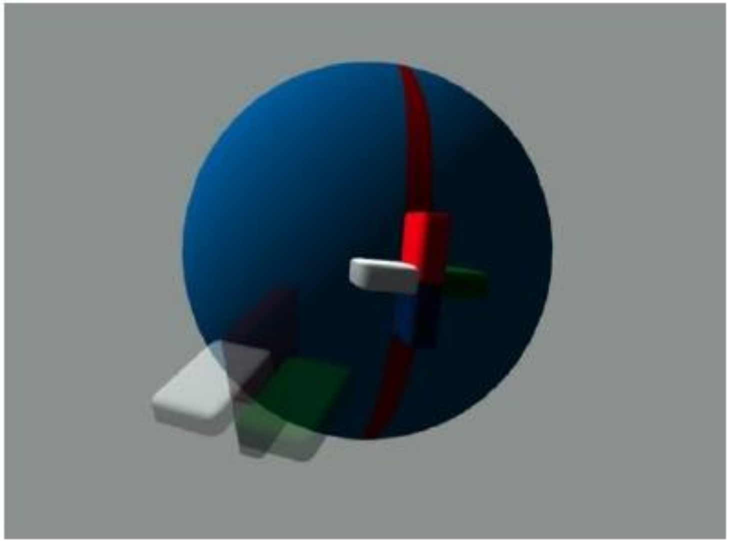

Fig. 7. 3D Manipulation: model used in the rotation test

First task (rotation only):
Manipulate a sphere using only rotation to align marker with target position

End of task:
Users considered marker to be best overlapped with target
and
No interaction for 15 seconds

Variables logged: angular difference between models and elapsed time

Preliminary test

- Two tasks to compare *OneHand* and *HandleBar* methods in terms of:
  - usability
  - accuracy attained by users manipulating an object

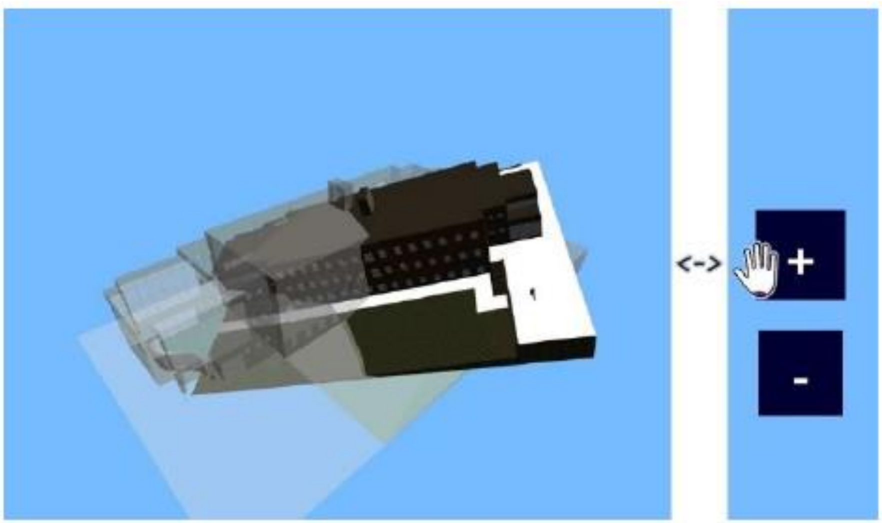

Fig. 8. 3D Manipulation with *OneHand*: model and GUI used in the rotation and scaling test

Second task (with scaling):
Manipulate a 3D model to match it with a target model

End of task:
Users considered marker to be best overlapped with target
and
No interaction for 15 seconds

Variables logged: angular and scaling difference between models, elapsed time

Controlled experiment

- Test the **equality hypothesis**: both methods provide the same level of usability

- Independent (input) variable: manipulation method with two levels:
  - *OneHand*
  - *Improved HandleBar*

- Dependent (output) variables: participant's performance and satisfaction:
  - Angular distance
  - Scaling factor
  - Time to achieve angular difference < 5 degrees
  - Answers to post-task questionnaire (10 questions in a 5 level Likert-type scale)

Controlled experiment

- Within-subject experimental design

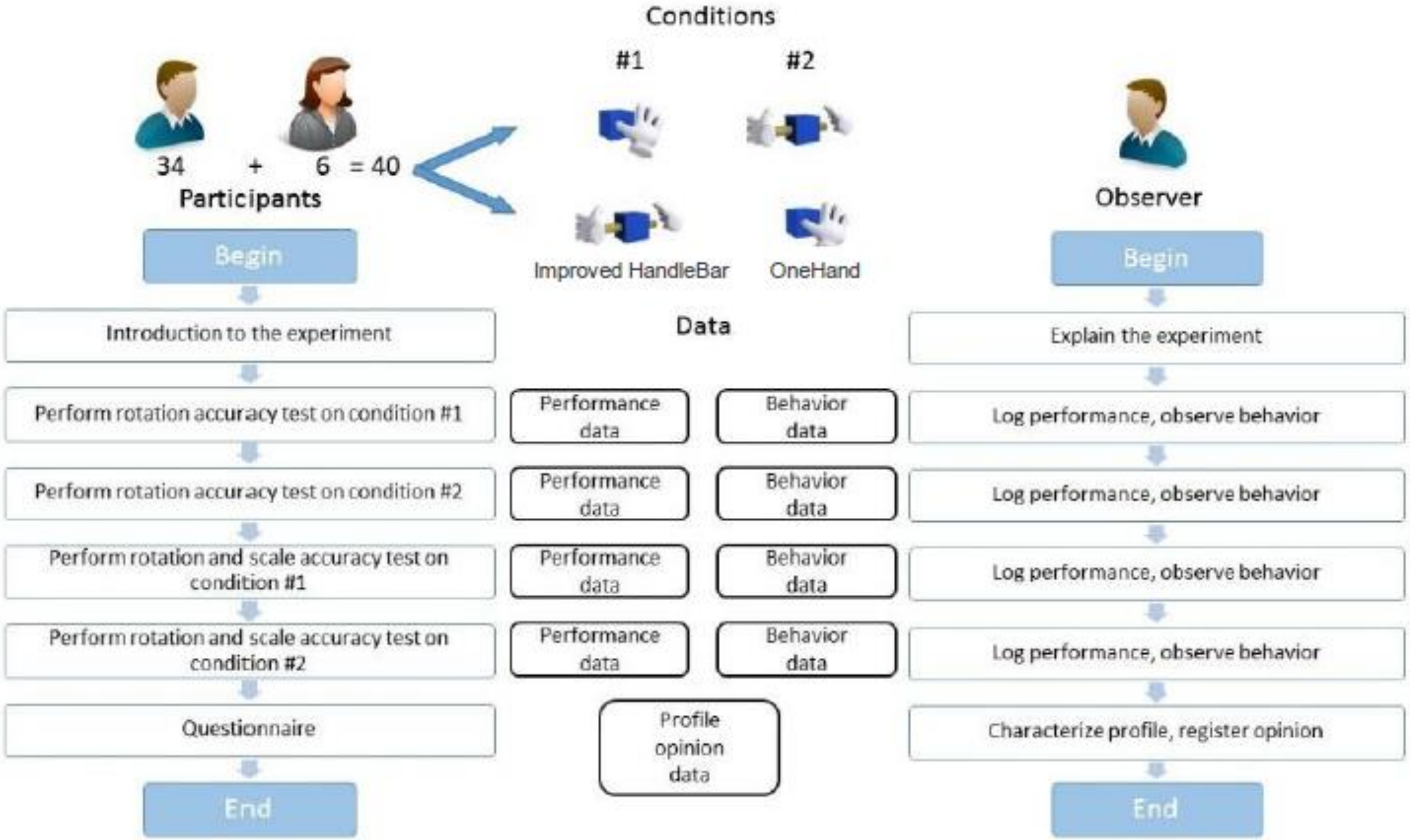

Fig. 9. Experimental protocol

Results

	Rotation		Rotation and scaling	
	OneHand	HandleBar	OneHand	HandleBar
Angular Distance (degrees)	5.24	2.79	4.52	3.07
Total Time (min:sec)	02:31	01:57	02:44	02:12
Time below 5° (min:sec)	02:00	01:05	02:10	00:58
Scaling Factor	--	--	0.995	0.997

Table 1. Average performance values obtained with *OneHand* and *Improved HandleBar* methods

- Better performance with *Improved HandleBar*
- For all variables, Wilcoxon tests rejected the equality hypothesis (with $p<0.05$ for all cases)
- Difference between methods is **statistically significant** in both tests

Results – rotation only

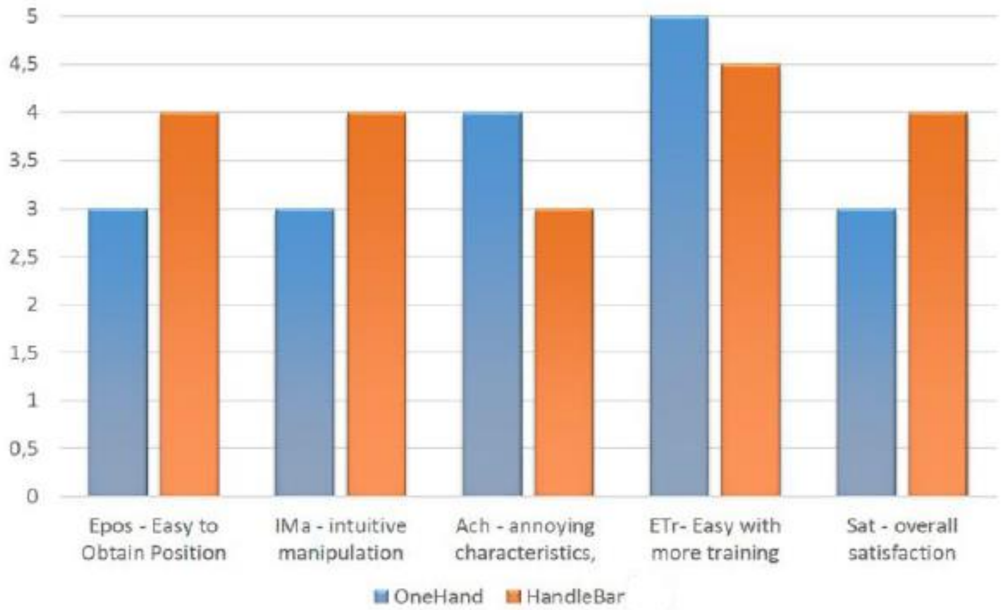

Fig. 10. Questionnaire results for the rotation only test with *OneHand* and *Improved HandleBar* (median values in a 5 level Likert-type scale: 1- completely disagree, 5- completely agree)

- *Improved HandleBar* attained much better acceptance among users during rotation only test
- Overall satisfaction evaluated **more positively for *Improved HandleBar***
- **Significant differences** validated by a Wilcoxon matched pairs ($p<0.05$) for "Easy to obtain position", "Intuitive Manipulation", "Annoying characteristics" and "Overall Satisfaction"

Results – rotation and scaling

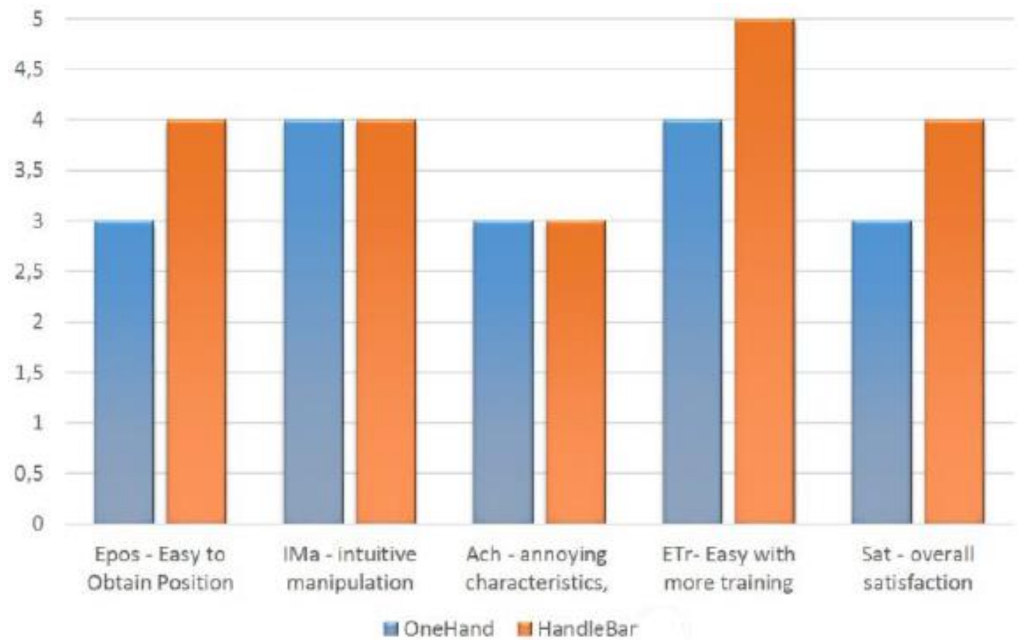

Fig. 11. Questionnaire results for the rotation and scaling test with *OneHand* and *Improved HandleBar* (median values in a 5 level Likert-type scale: 1- completely disagree, 5- completely agree)

- Despite smaller differences between methods, slight **user preference for *Improved HandleBar*** prevails
- **Significant differences** validated by a Wilcoxon matched pairs ($p<0.05$) for “Easy to obtain position”, “Easy with more training” and “Overall Satisfaction”
- Introduction of missing DOF improved usability

Conclusions

Goal

- Integrate interaction methods in a large public display
- Proposed and implemented two gesture based manipulation methods

Methods

- *OneHand* (cursor based-method)
- *HandleBar* (bi-manual interaction method)
- *Improved HandleBar* (introduced missing DOF, after preliminary tests)

Results

- Experiment with 40 participants to evaluate methods' usability
- Significant differences in several usability dimensions
- *Improved HandleBar* clearly outperformed *OneHand* method

Future Work

- Test methods with KinectOne
- Expand methods to afford object translation
- Explore user representation in the virtual world

Towards a more **natural** way of manipulating objects in virtual worlds by grabbing, moving, rotating and scaling using the **hands as manipulation device**