Evaluation of a Reconfigurable Tangible Device for Collaborative Manipulation of Objects in Virtual Reality

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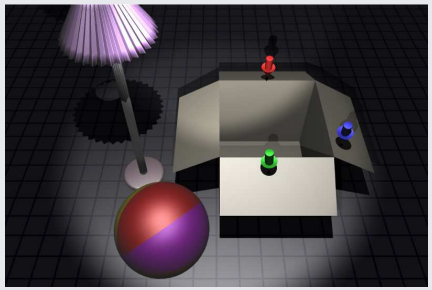
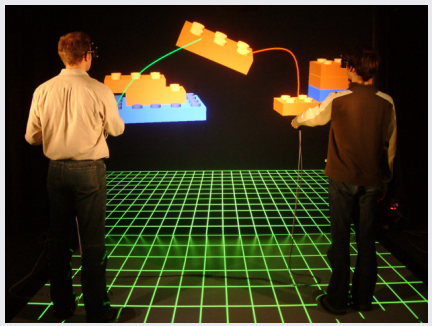
Introduction

Context

- 3D manipulation of virtual objects
  - Is essential
  - Must match various 3D shapes
  - Must be sometimes realistic (for training)
  - Must be sometimes shared between users [Riege et al., 3DUI 2006]

$\Rightarrow$ We need new tools and techniques





Goals

- Improve single-user or multi-user 3D manipulation of virtual objects through new devices and techniques

Known techniques to co-manipulate objects

Tangible User Interface (TUI)

- Manipulation of a windshield
  [Salzmann, Jacobs and Fröhlich, JVRC'2009]

Known techniques to co-manipulate objects

Reconfigurable Tangible User Interfaces

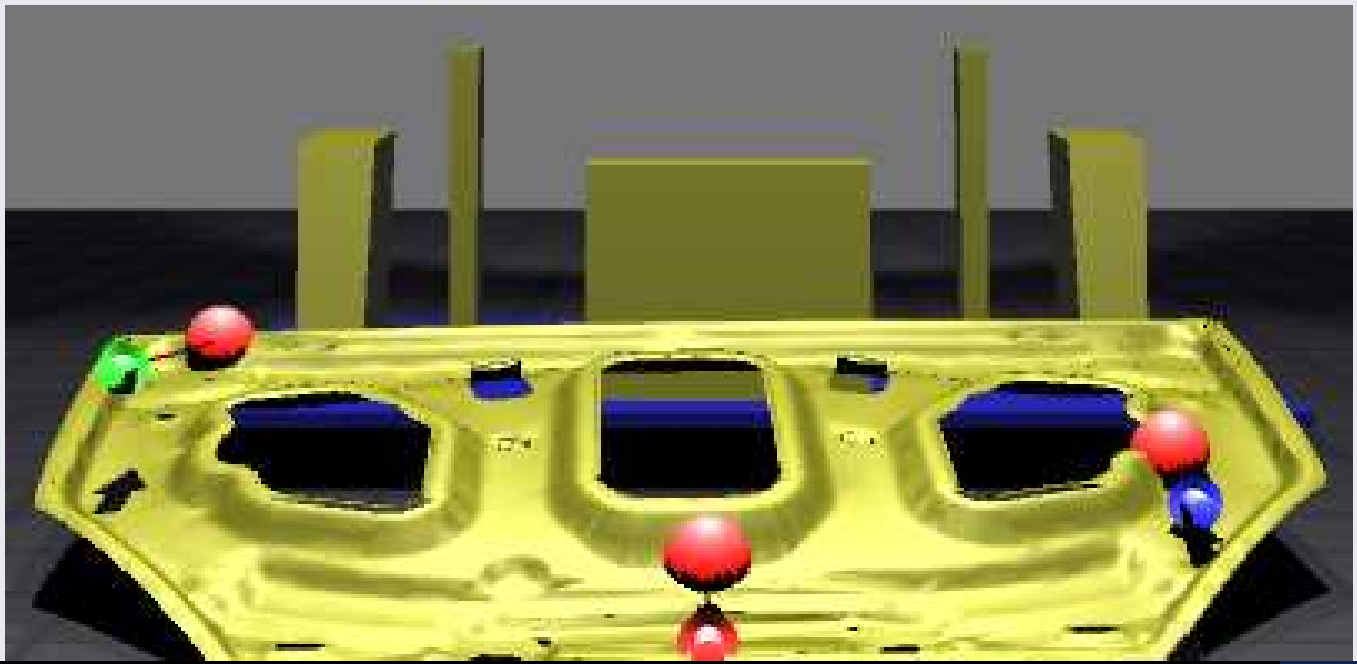
- Activecubes
  [Watanabe et al., Computer in entertainment 2004]

- Senspectra [Leclerc et al., CHI 2007]

Known techniques to co-manipulate objects

The 3-Hand Manipulation Technique

- Use of 3 virtual hands *(pointers on the screen)* [Aguerreche, Duval and Lécuyer, JVRC'2009]
- Only **positions** of hands matter, not their orientations
  - ↪ 3 points define a plane, thus an orientation
- Virtual hands must remain close to their manipulation points

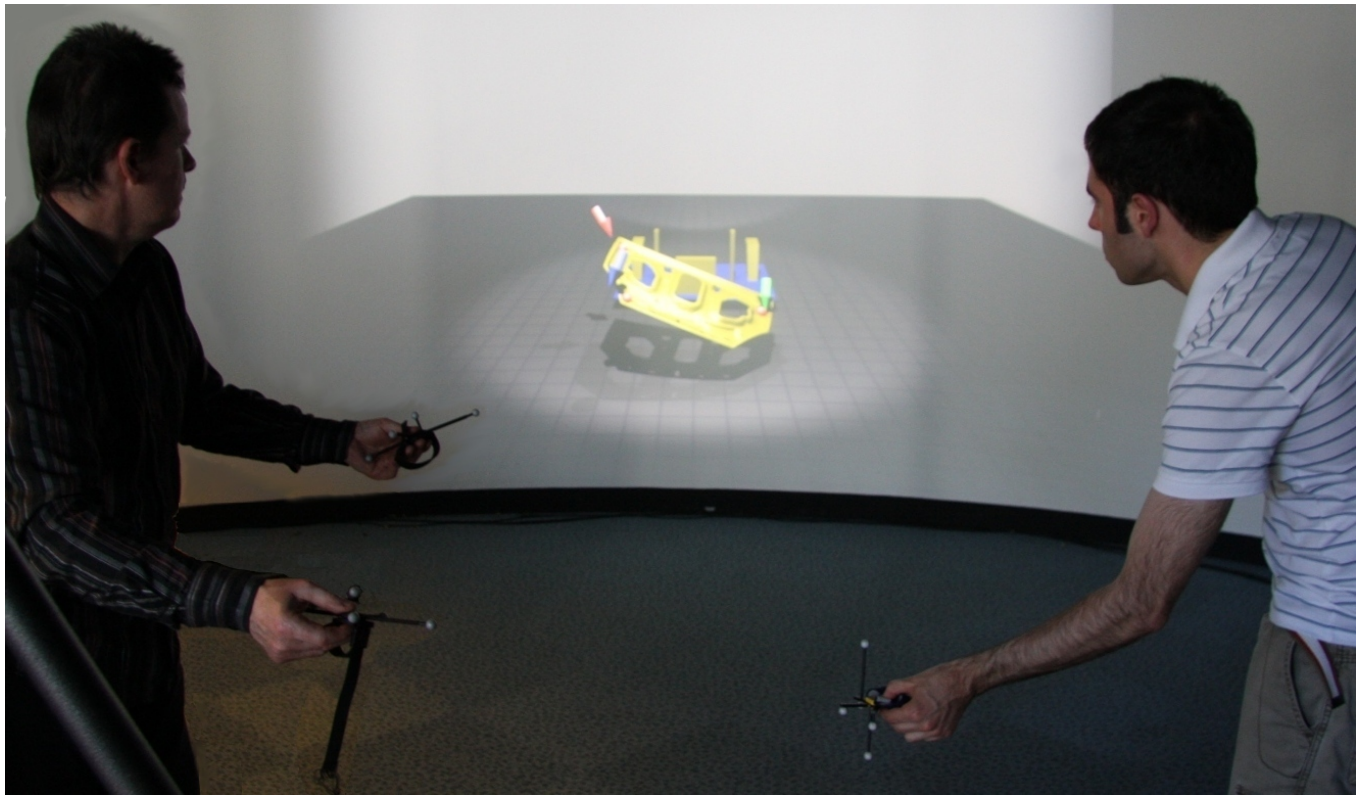


Conclusion about the related work

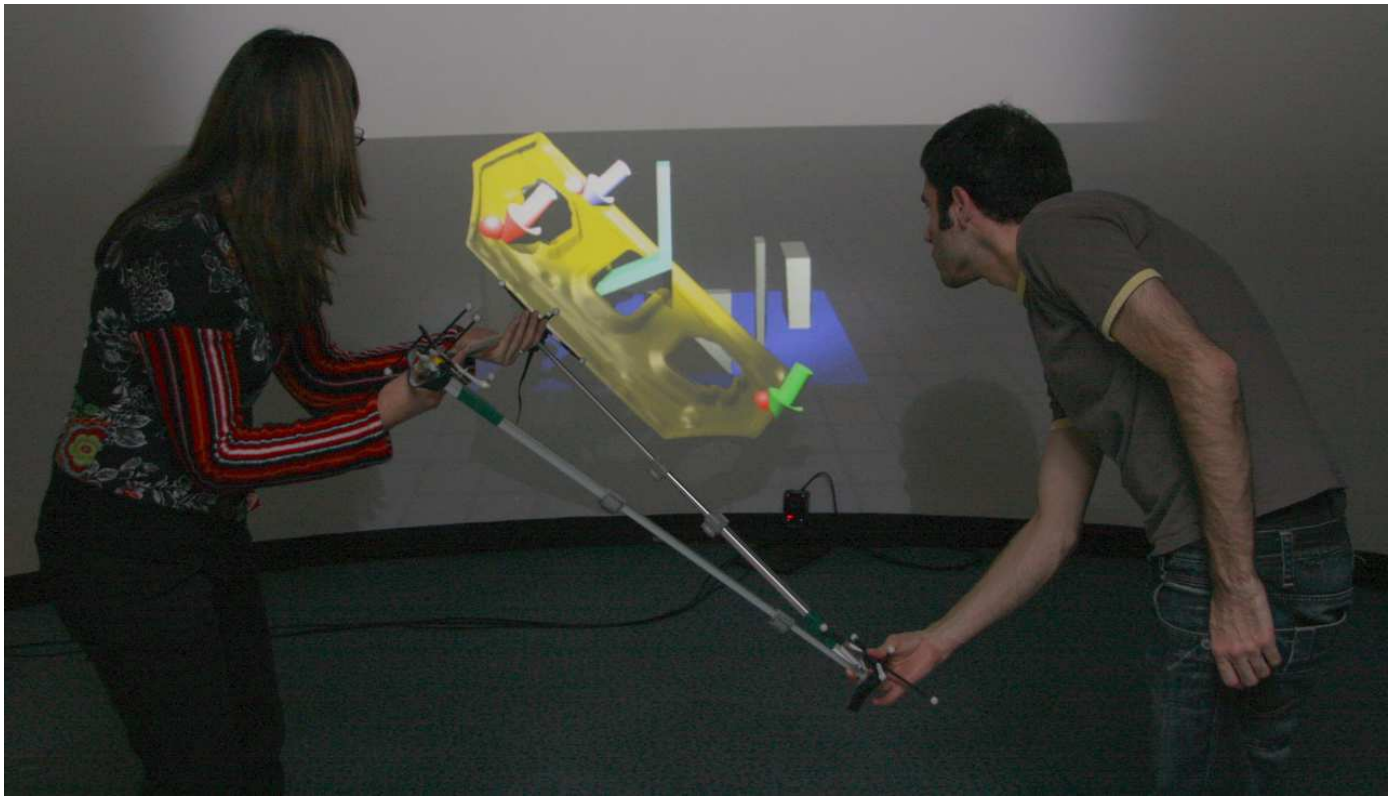
In our opinion...

- 3D manipulation of virtual objects through multi-hand handles is interesting
  - ↪ But how to ensure that the 3-points shape stays the same?
  - ↪ But how to ensure stability with four points which shape would not stay the same?
- Tangible user interfaces often improve 3D interaction...
  - ↪ But quite often they are designed to match only one shape
  - ↪ Or they are not rigid enough to be shared by several users

The Reconfigurable Tangible Device



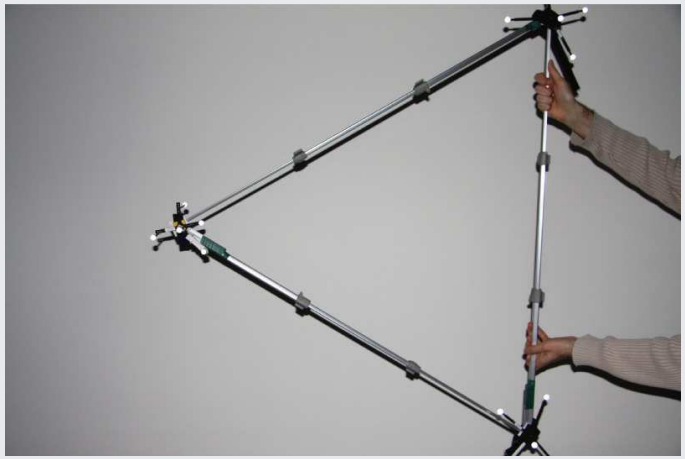
The Reconfigurable Tangible Device

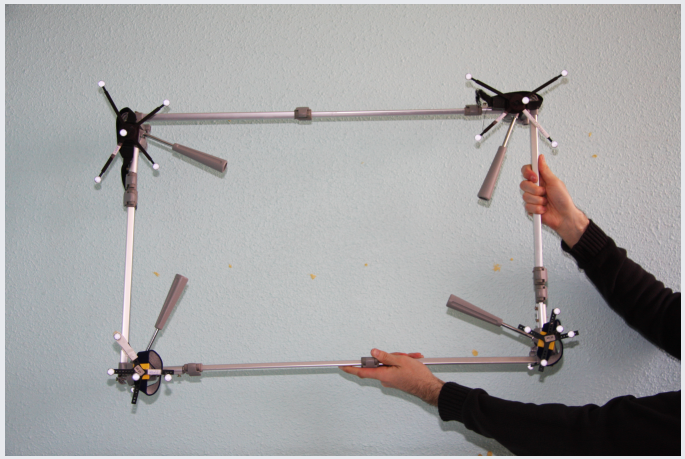


The Reconfigurable Tangible Device (RTD)

Concept

- Ability to match various 3D shapes
- Can be reshaped without breaking immersion
- Rigid, to serve as a passive haptinc link between users
- Two instances : RTD-3 and RTD-4
  [Aguerreche, Duval and Lécuyer, VRST'2010]

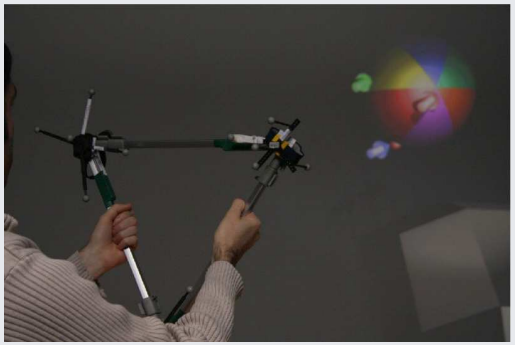
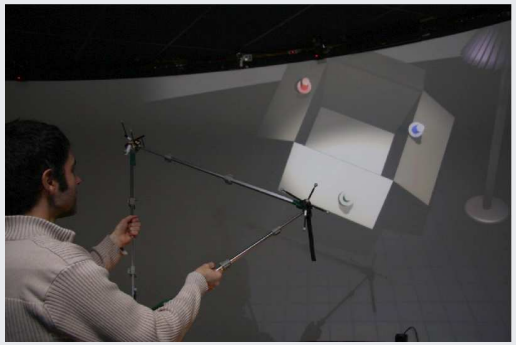
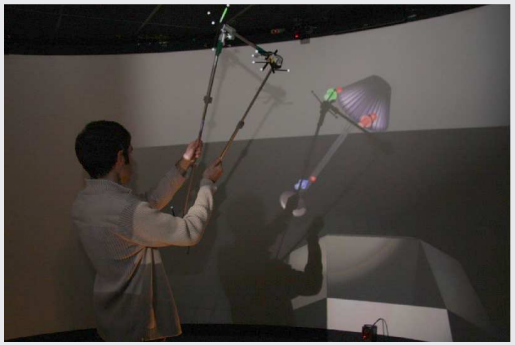




The RTD-3

Triangular RTD

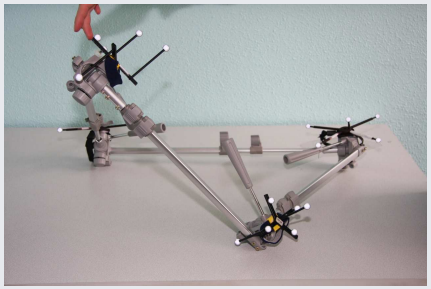
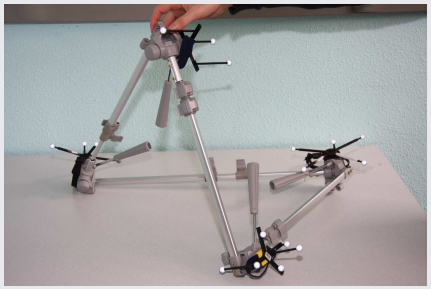
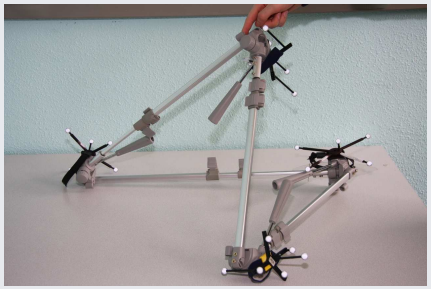
- Three stretchable and rigid arms connected by a pivot
- Three points of manipulations (handles)
- Physical and reconfigurable version of the 3-hand manipulation technique
  - ↪ ensure that the 3 manipulation points keep the good shape

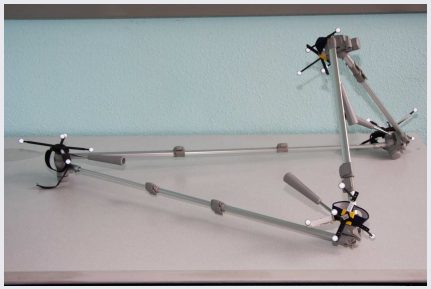




The RTD-4

Quadrilateral or tetrahedral RTD

- Four stretchable and rigid arms connected by linkage balls
- Four points of manipulation
- Extension of the 3-hand manipulation technique to 4 points
  - ↪ stable because the RTD maintains the shape

Evaluation of the RTD-3

Objectives

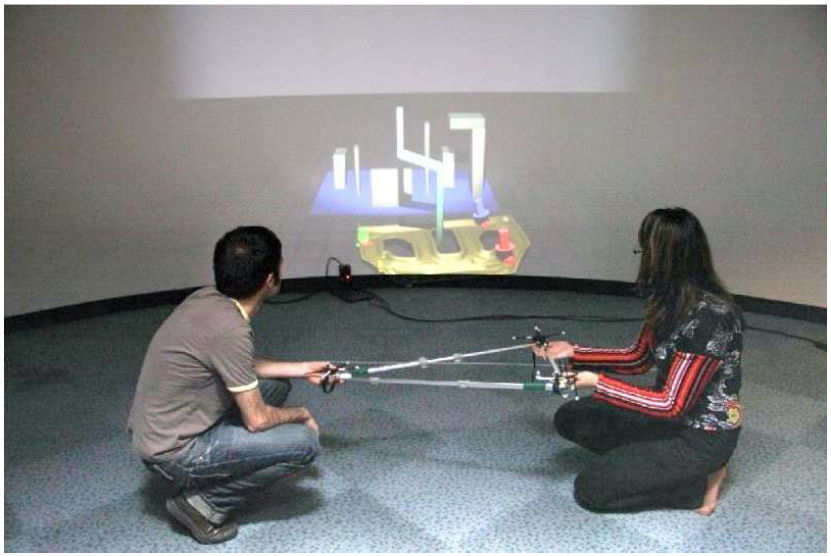
- Determine RTD-3 efficiency and acceptability compared to other techniques

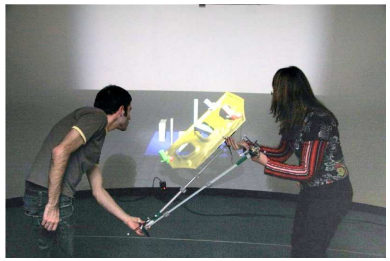
Compared techniques

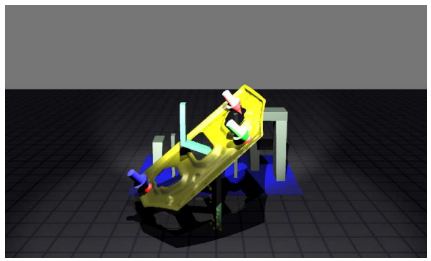
- **RTD-3**
- **Mean**
- **Separation**

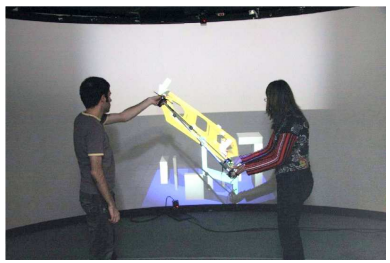
Task

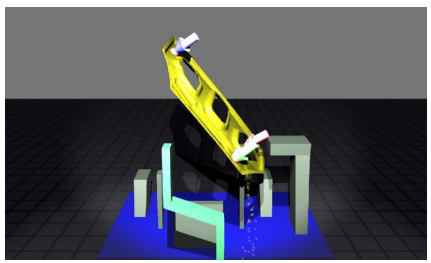
- A ‘pick-and-place’ task











Evaluation of the RTD-3

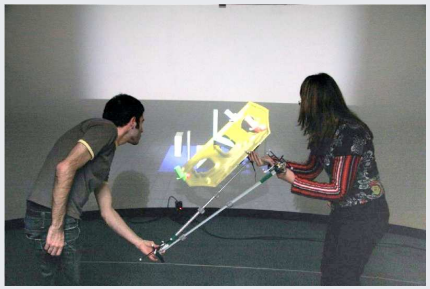
Collected Data

- Objective data
  - Time completion task
  - Number of collisions of the virtual hood with the VE
  - Distance covered by the hood
  - Distance covered by the hands of the users
- Subjective data (using a 7-point Likert scale)
  - **Realism** of the manipulation
  - Feeling of **Presence** in the VE
  - **Training** for the same real task
  - **Fatigue** during the manipulation
  - How much they **Like**d a technique

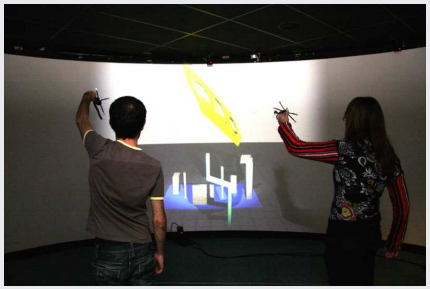
Evaluation of the RTD-3

Three techniques compared

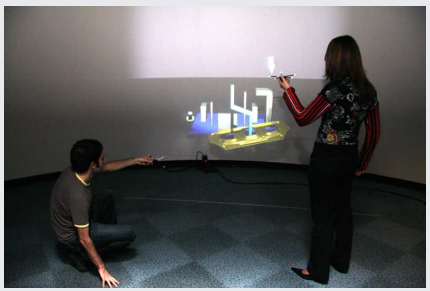
- 1st technique:
  The Reconfigurable Tangible Device (**RTD-3**)
  - Based on the 3-Hand technique



- 2nd technique:
  Averaging movements (**Mean**) of two users
  - Using previous positions and rotations



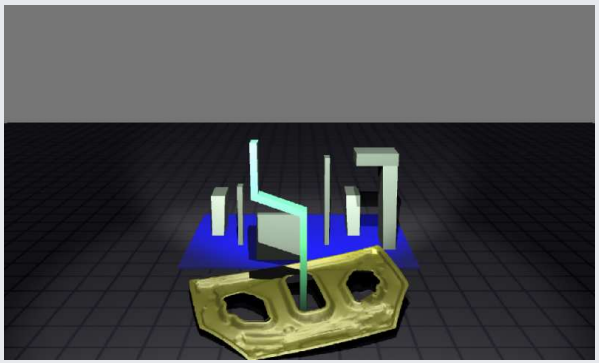
- 3rd technique:
  Splitting degrees of freedom (**Separation**)
  - Translations and rotations

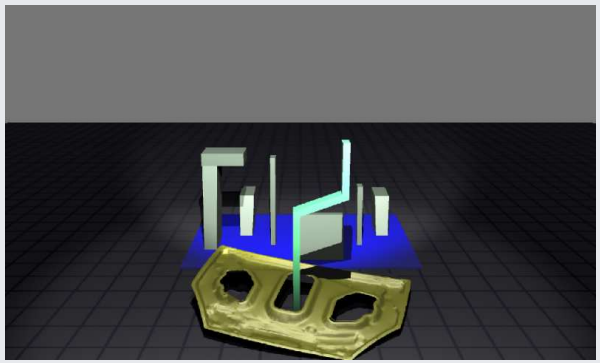


Evaluation of the RTD-3

Experimental plan

- 12 pairs (20 male, 4 female)
- Each pair of participants tested the 3 techniques in various order
- 4 tests for each technique, keeping only the 2 best results
  - Before, ≈ 1 minute to practice and have explanations
- A mirror-version of the scene is randomly proposed
- Global duration $\approx$ 40 minutes





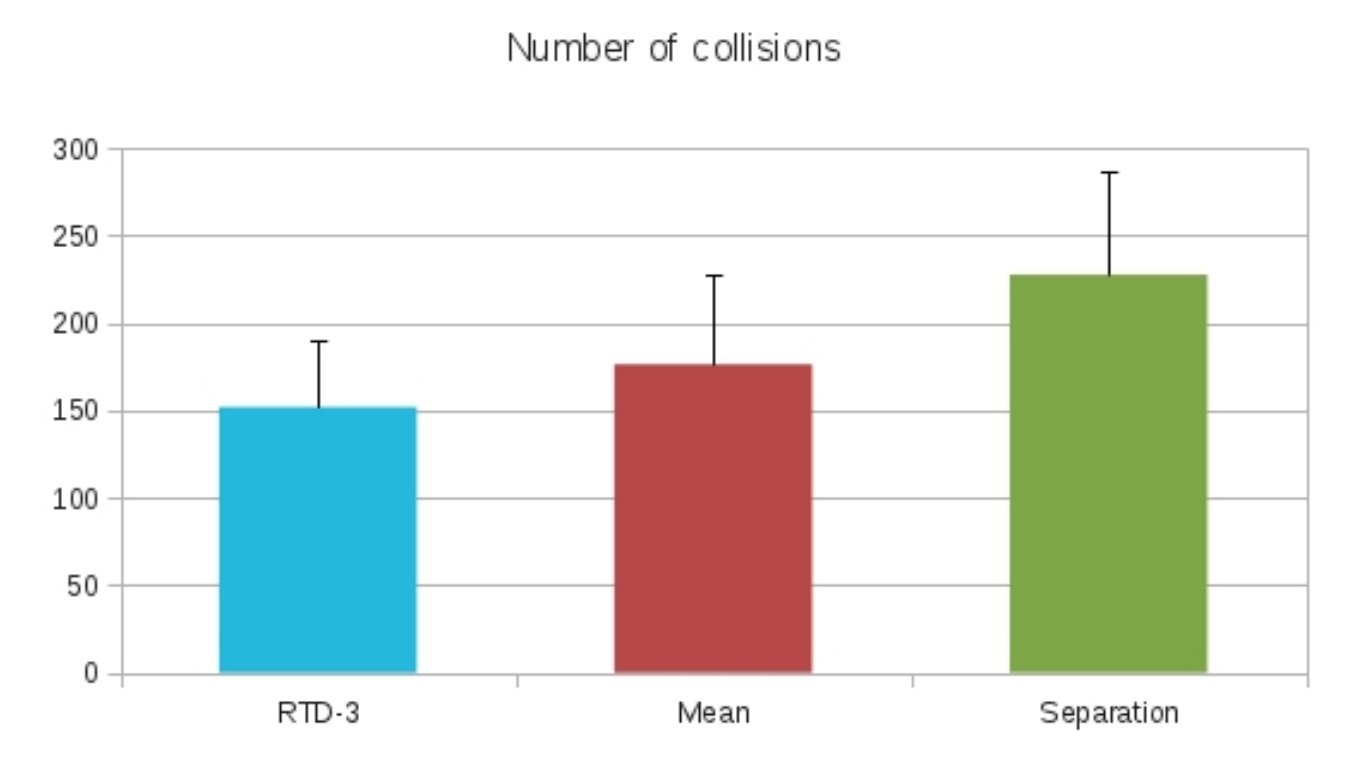
Objective results

Task completion time

- Mean is faster than RTD-3
- Status not so clear for Separation...

Objective results

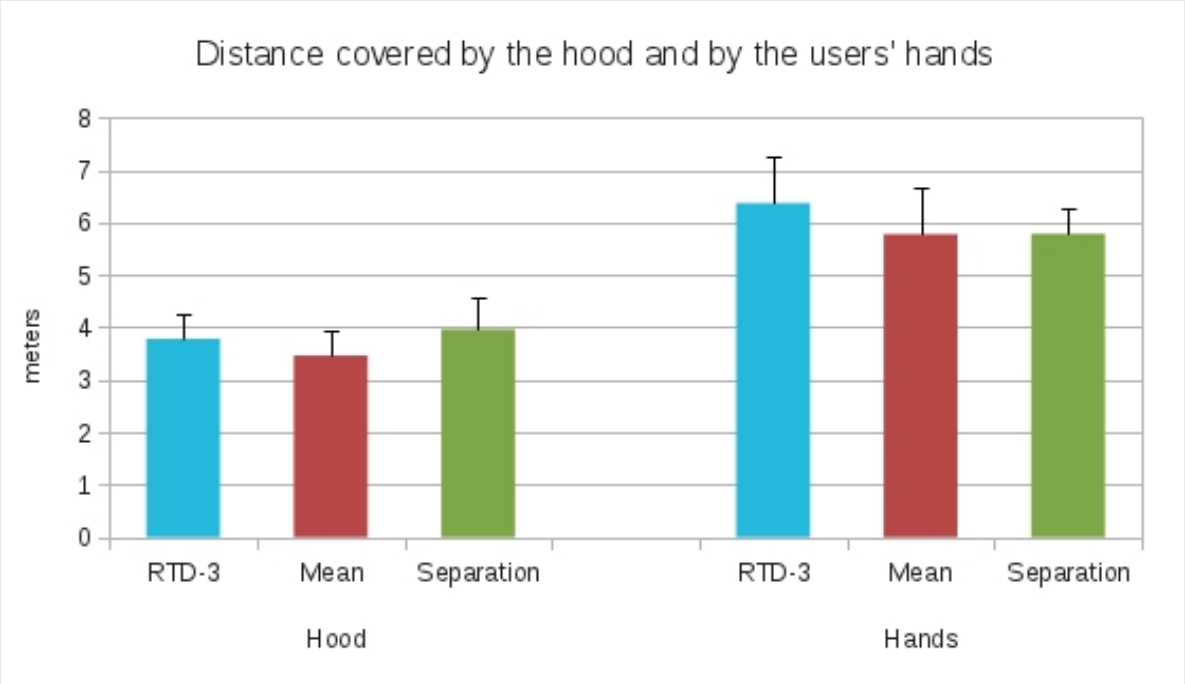
Number of collisions



- Mean and RTD-3 are better than Separation

Objective results

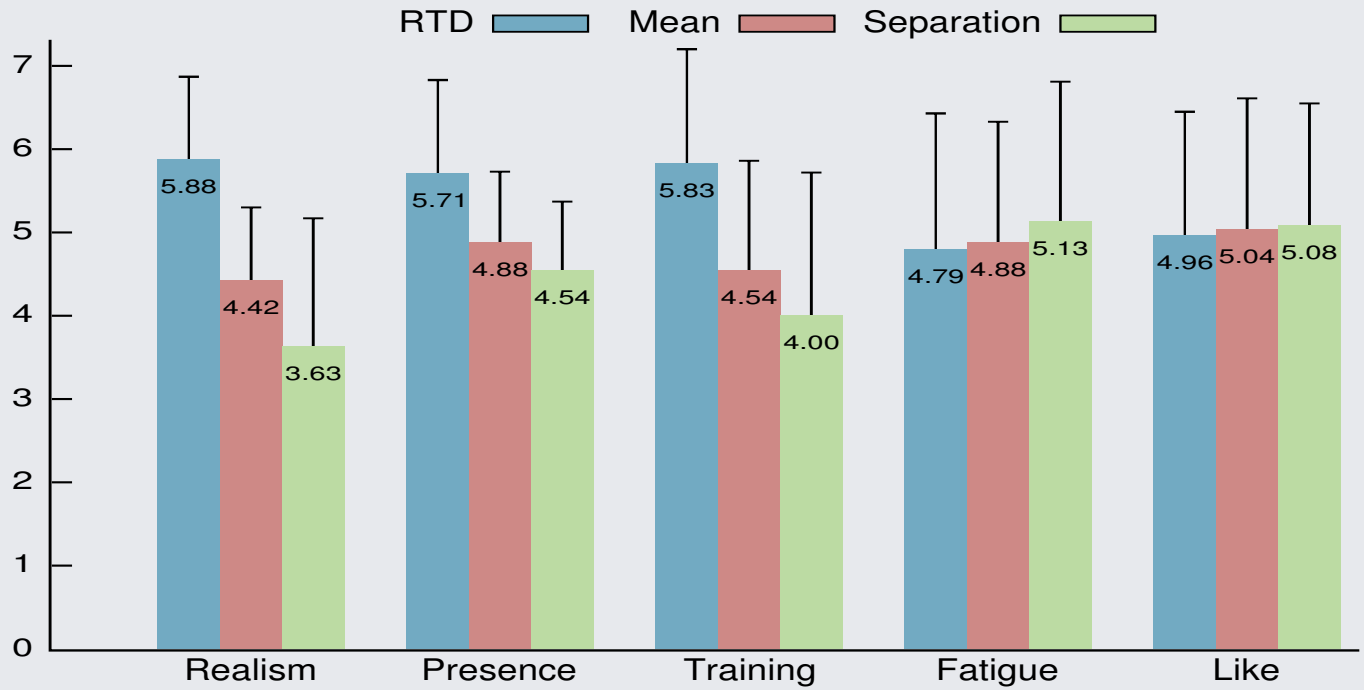
Distance covered by the hood and by the hands



- For the hood:
  - Mean is more efficient than RTD-3 and Separation
- For the hands:
  - Mean and Separation are more efficient than RTD-3

Subjective results

Notations using a 7-point Likert scale



- Realism, Presence and Training are significantly better for RTD-3 than for Mean and Separation
- No significant difference for Fatique and Like

Realism, Presence and Training !

Conclusion

- Reconfigurable Tangible Device (RTD) for 3D object manipulation in virtual environments
  - Provides a physical interface (passive haptic link)
  - Can be reshaped (at any time) to match any virtual shape
  - Is made up of handles rigidly linked together by arms
  - Can be used by single or multiple users
  - Uses only 3D positions to provide 6 DoF manipulation
- Two instances of the RTD: RTD-3 and RTD-4
  - Tested within a virtual reality center
  - Used for collaborative manipulation of 3D objects
- Evaluation of the RTD-3 for collaborative manipulations
  - Is slower than other methods but at least as precise
  - Needs more movements
  - Provides users with a better sense of presence in the VE

Future work

- Make more evaluations of our techniques
  - Compare RTD vs. Mean for other tasks
  - Compare RTD-3 vs. RTD-4
- Make other RTD prototypes
  - With more manipulation points
  - Not necessarily cyclics
  - With different articulations
- Study the use of the RTD in different scenarios and use-cases
  - Object deformation according to RTD deformation
- Add real feedback to the RTD
  - Vibration, sound

Thank you

Questions?

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