# 3D User Interfaces

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# Introduction

Example: Google’s Tilt Brush @ Oculus Quest

Some example interfaces

## Some example interfaces


## Some definitions

HCI:

- *Process* of communication between users and computers
- Goal: design, implementation and evaluation of interactive systems

UI:

- *Medium* through which the communication takes place.
- Translates user actions (inputs) into a representation the computer can understand.
- Translates computer's state (output) into a representation the user can understand.

# Some definitions

3D Interaction:

- Interaction where user's tasks are performed directly in a **3D spatial context.**

3D UI:

- A UI that involves 3D interaction.

Usability:

- Characteristics of a device/technique/UI that affect the user's use.
- Aspects: ease of use, performance (time to complete, #errors), user comfort.

# Some definitions

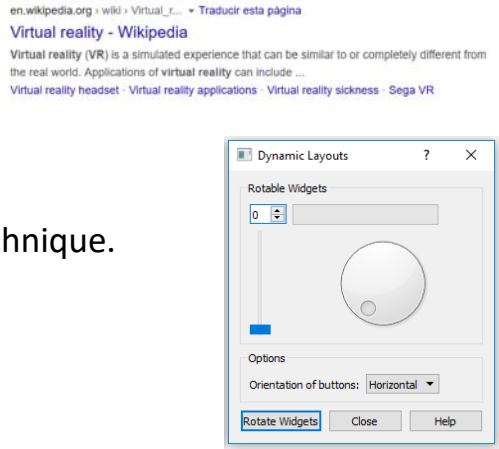
Affordances:

- What users can do using a technique

Constraints:

- What users cannot do using a technique.

# Some definitions




Affordances:

- What users can do using an interaction technique.

Constraints:

- What users cannot do using a technique.

# Components of a UI

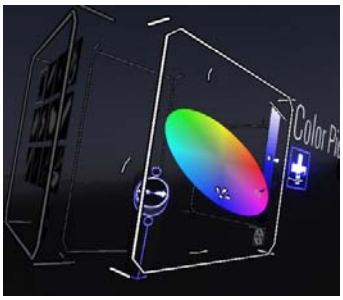
- Input devices
- Output devices
- Interaction techniques (e.g. drag-and-drop)
  - Method allowing the user to accomplish a task.
  - Responsible for mapping: input → state change → output
- Interaction widgets (e.g. pull-down menus)
- Interaction metaphors (e.g. virtual hand)

**Virtual hand manipulation example**

Input:
hand.position

State change:
obj.position = TracktoWorld(hand.position)

Output:
Obj (& hand avatar) drawn at new location



# Why using 3D user interfaces?


Potential benefits:

- More intuitive in some apps (e.g. simulators).
- Users can interact using natural skills.
- More direct → short cognitive distance between user action and feedback.

Technology for 3D UI is becoming mature.

# Application areas

- Gaming and entertainment
- Simulation and training
- Art, Design, Prototyping
- Architecture and construction
- Heritage and tourism
- Visual data analysis
- Medicine and psychiatry
- Education
- Collaboration
- Robotics

## Task classification

User's tasks in a VE can be classified as:

- Selection/Manipulation
- Navigation
- Application control
- Symbolic input

## Contents

# Selection & Manipulation

## Defs

Selection: identifying a particular object from a set.

Manipulation:

- **Positioning**
- **Rotation**
- Scaling
- Deformations are usually accomplished via 3D widgets using the tasks above.

## Key issues:

- How to map the user actions captured by input devices into the desired selection/positioning/rotation in the virtual world.
- Giving appropriate feedback.

## Limitations of input devices

- Input devices restrict which manipulation techniques can be used.
- **Number of control dimensions**: how many DOFs the device can control.
- **Integration of control dimensions**: how many DOFs can be controlled *simultaneously* with a single movement.
- Ideally: 6DOF or more, fully integrated.


# Control types

Following [Zhai and Milgram 03]:

- **Isomorphic** control: the device measures the **position** of the user's hand (e.g. tracking).
  - Preferable for manipulation
- **Isometric** control: the device measures the **force** applied by the user (e.g. joystick).
  - Preferable for controlling rates (e.g. speed).

# Hand-attached vs hand-held

Hand-attached (e.g. virtual glove)

Hand-held (e.g. precision grasp, VR controller)

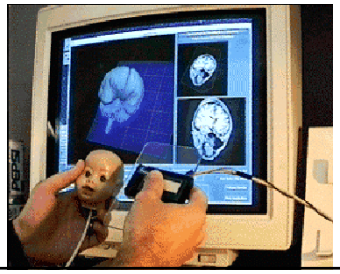
In general:

- Larger muscles (shoulder, elbow, wrist) → slower movements [Zhai 96]
- Smaller and faster muscles (fingers) → faster movements.

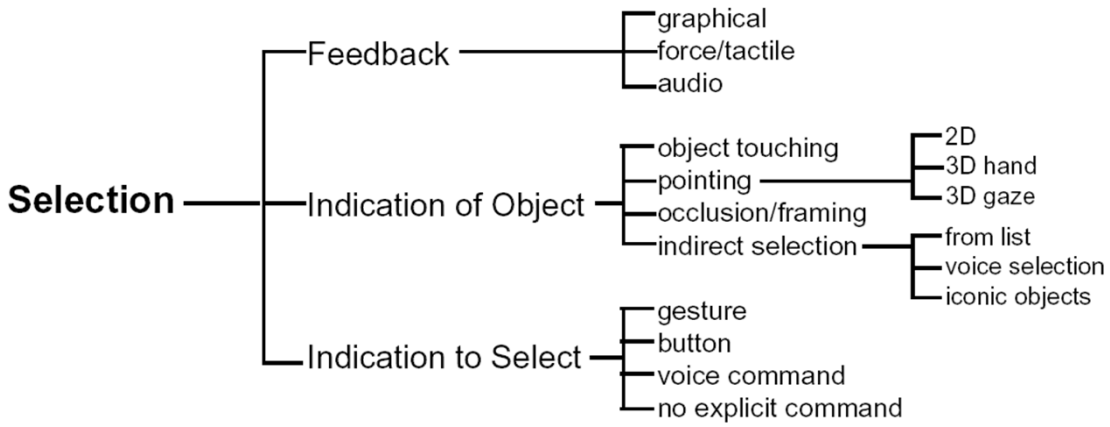
## Limitations of input devices

**Physical props** can be used for selection and manipulation.

- Replicating the shape of the virtual object gives no benefit for manipulation [Ware and Rose 99].
- Devices with generic shapes usually perform better.



## Classification of techniques



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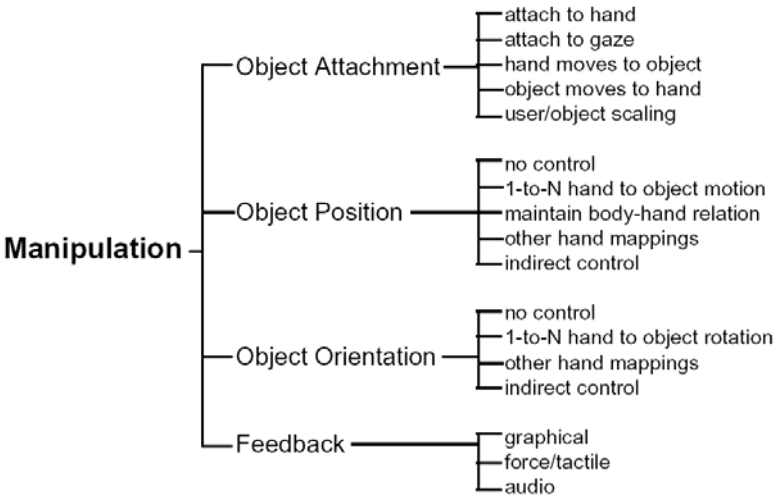

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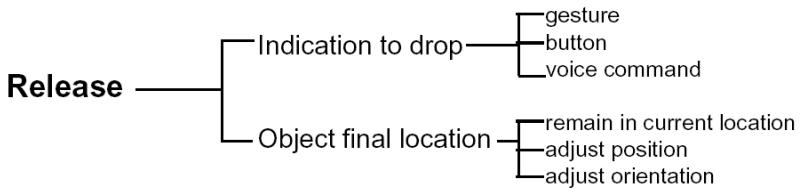



# Classification of techniques

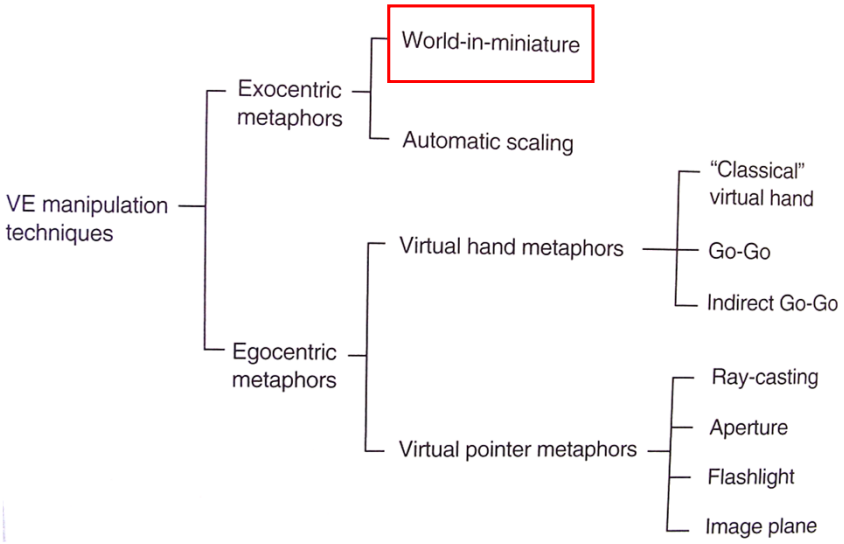
**Isomorphic** manipulation:

- One-to-one correspondence between hand motions in the real and virtual world.
- More natural and intuitive.
- Less cognitive distance.

**Non-isomorphic** manipulation:

- No one-to-one correspondence: *magic* virtual tools (laser beams, rubber arms…).
- Overcomes hardware limitations (e.g. haptics)
- Overcomes human limitations (e.g. arm length)

# Classification of techniques




# Exocentric techniques

World-in-miniature (Stoakley et al. 1995)

The user is provided with a handheld miniature of the scene.

# Exocentric techniques

**World-in-Miniature Interaction for Complex Virtual Environments**

*Ramón Trueba, MOVING Group, Universitat Politècnica de Catalunya, Spain*
*Carlos Andujar, MOVING Group, Universitat Politècnica de Catalunya, Spain*
*Ferran Argelaguet, MOVING Group, Universitat Politècnica de Catalunya, Spain*

World-in-miniature (Stoakley et al. 1995)

Requires careful use of occlusion management

Manual clipping

Automatic

(a) (b) (c)

Transparency

(d) (e) (f)

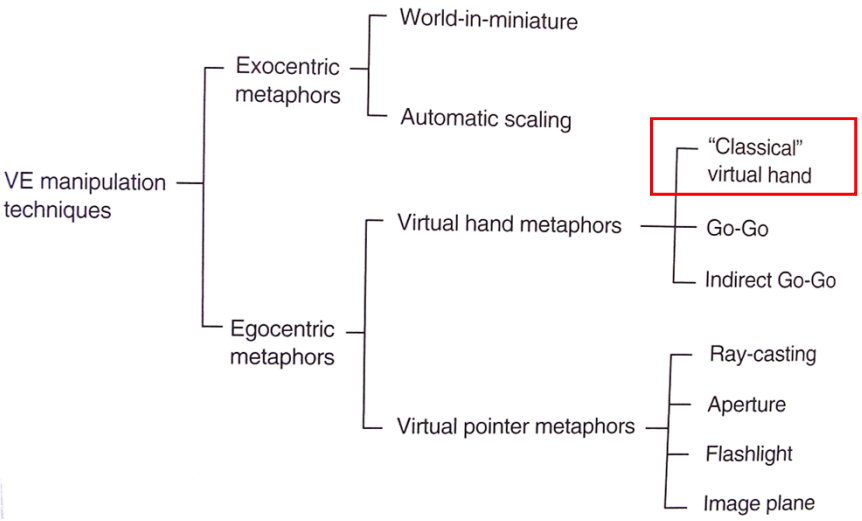
Cut-away

## WIM


## WIM

# WIM

# Classification of techniques



# Virtual hand techniques

- The user selects and manipulates objects directly with his hand.
- Typically a 3D cursor is displayed:
  - Avatar
  - Semitransparent volume
- Selection: user intersects the 3D cursor with the target and uses a trigger technique.
- Manipulation: the object is attached to the virtual hand → natural hand movements.

# Virtual hand techniques

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  - Avatar
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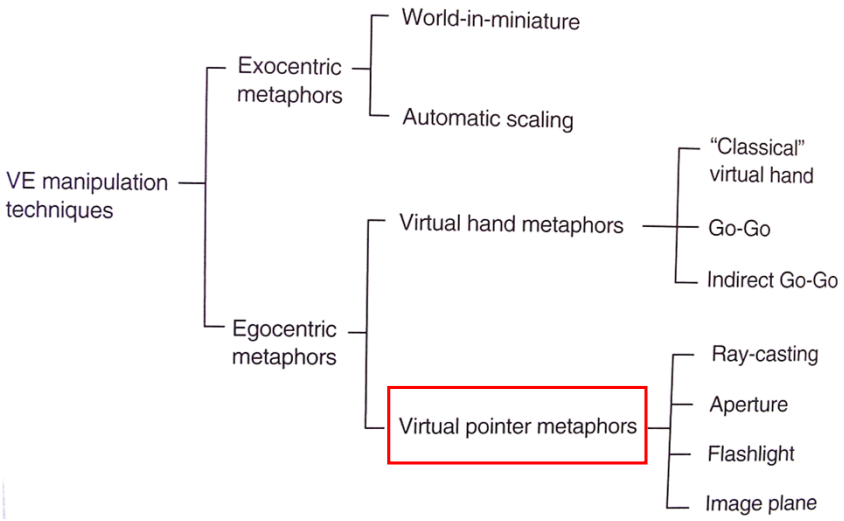
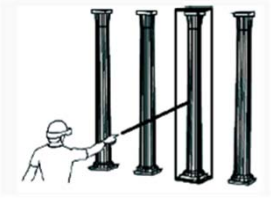
- Selection: user intersects the 3D cursor with the target and uses a trigger technique.
- Manipulation: the object is attached to the virtual hand → natural hand movements.
- Main problem: only objects within user's reach can be selected and manipulated → users are required to travel.

# Classification of techniques



# Virtual pointer techniques

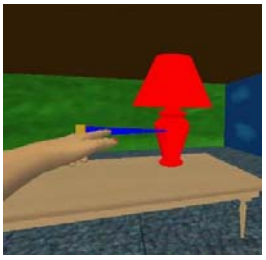


- Select and manipulate objects beyond the area of reach.
- Main concerns:
  - How the pointing direction is defined.
  - Shape of the selection volume.
- Suitability:
  - Selection → Good!
  - Position → Bad: only radial movements, bad for changing distance to the user.
  - Rotation → Bad: effective only for 1 DOF (axis defined by pointing vector).

# Virtual pointer techniques

Metaphors for pointing techniques:

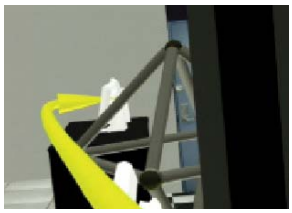
- Ray-casting and variations
- Two-handed pointing
- Flashlight
- Aperture
- Image-plane
- Fishing-reel

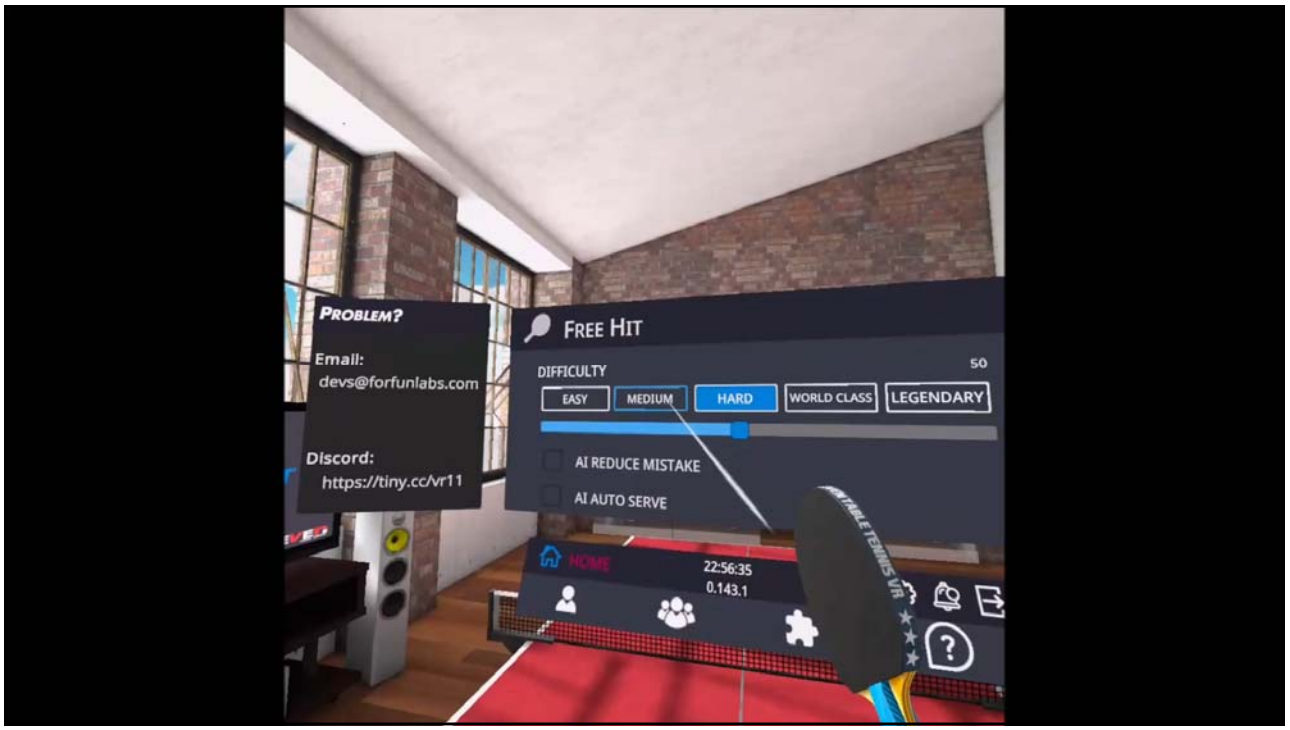


# Virtual pointer techniques

Ray-casting

- A line segment attached to the hand defines the pointing direction.
- Selection volume: a ray
- Problems in selecting faraway objects [Poupyrev, Weghorst et al 98].
- Many variants (bent rays, snap to nearest object…).

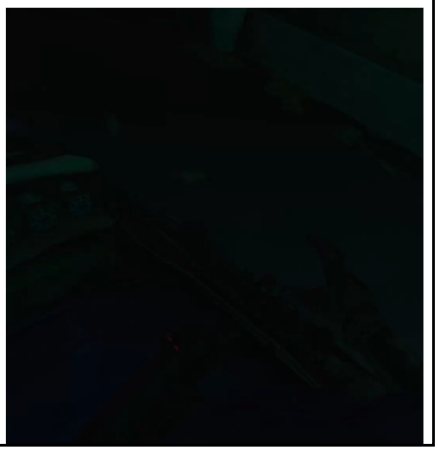




# Virtual pointer techniques

Two-handed pointing [Mine et al 97]

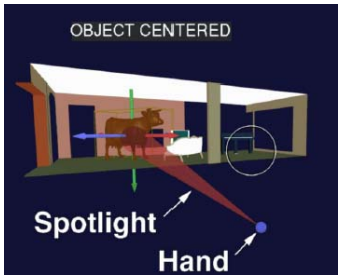
- One hand defines the origin.
- The other specifies where the ray is pointing to.
- Two hands must be tracked.



# Virtual pointer techniques

Flashlight [Liang and Green 94]

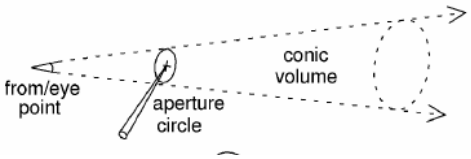
- Selection volume is a cone.
  - Cone apex: user's hand position.
  - Cone axis: user's hand orientation.
  - Cone aperture: constant.
- Disambiguation problem.
- Disambiguation rules:
  - Select object closer to the cone's axis
- Problems in cluttered environments.



# Virtual pointer techniques

Aperture [Forsberg et al 96]

- Selection volume is a cone.
  - Cone apex: user's eye position.
  - Cone axis: pointing to user's hand position.
  - Cone aperture: spread angle is increased by moving the sensor closer
- Device orientation (twist) can be used to disambiguate.




# Virtual pointer techniques

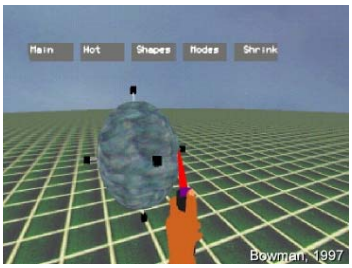
Image-plane [Pierce et al 97]

- Objects are manipulated through their 2D projections on a virtual image plane.
- First, objects are selected (e.g. by drawing a frame).
- Then, the user manipulates a copy projected on an image-plane within user's reach.

# Virtual pointer techniques

Fishing-reel technique

- An additional input device controls the length of the virtual ray.
- Example: analog joystick




# Clutching

Occurs when a manipulation cannot be achieved in a single motion → the object must be released and regrasped.


# Hybrid techniques

Combining interaction techniques:

- Aggregation: explicit mechanism for choosing the interaction technique.
- Integration: the interfaces switches transparently between interaction techniques depending on current *task context* (e.g. one for selection and another for manipulation).

Main techniques:

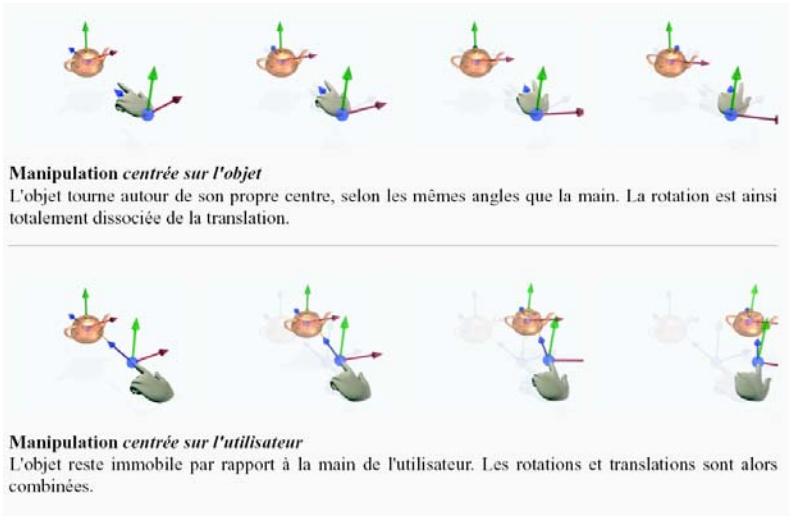
- HOMER
- Voodoo dolls

# Hybrid techniques

HOMER (Bowman and Hodges 97)

- Hand-centered Object Manipulation Extending Ray-casting.
- Selection→ uses classic ray-casting.
- Manipulation → instead of the object being attached to the ray, the user's virtual hand moves to the object and attaches to it.
- Not suitable for moving local objects farther away.

# Hybrid techniques



**Manipulation *centrée sur l'objet***
L'objet tourne autour de son propre centre, selon les mêmes angles que la main. La rotation est ainsi totalement dissociée de la translation.

**Manipulation *centrée sur l'utilisateur***
L'objet reste immobile par rapport à la main de l'utilisateur. Les rotations et translations sont alors combinées.

## Hybrid techniques

Voodoo dolls (Pierce et al 1999)

- Combines image-plane and WIM.
- Uses a pair of pinch gloves.
- Manipulation: using temporary, miniature, handheld copies (dolls).
- Unlike WIM, the user is able to choose which objects will be scaled.

## Main factors

Each manipulation task has several variables that affect the suitability of a particular technique.

- General variables:
  - Application goals.
  - Physical conditions of the users.
  - Psychological conditions of the users.

## Main factors

Variables of positioning tasks:

- Distance and direction to initial position.
- Distance and direction to target position.
- Translation distance.
- Required precision.

## Main factors

Variables of rotation tasks:

- Distance to target.
- Initial orientation.
- Final orientation.
- Amount of rotation.
- Required precision.

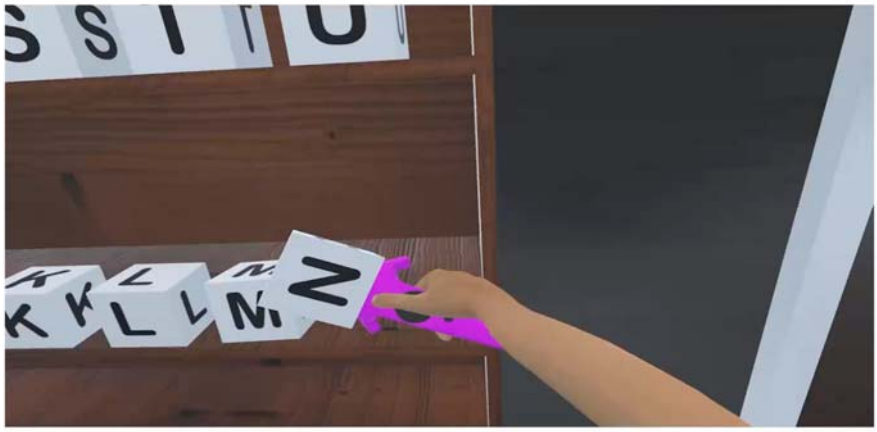
# Design guidelines

- Analyze task variables when choosing a 3D manipulation technique (e.g. how precise is the manipulation required? How large are the objects?...)
- Match the interaction technique with the device.
- Non-isomorphic techniques are useful and intuitive.
- Use pointing for selection and virtual hand for manipulation.
- Reduce degrees of freedom when possible.

# Hand tracking interaction


https://www.youtube.com/watch?v=G_HKJ1qxOwI

**Stretch your reach: Studying Self-Avatar and Controller Misalignment in Virtual Reality Interaction**



**Paper 5579**