3D User Interface Design

An introduction to
3D user interface design issues
for virtual environments

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Introduction

- Goal of 3D UI design is
  - Help user perform system tasks effectively
  - Avoid causing discomfort
  - Avoid causing frustration
  - *Performance - Usability - Usefulness*
- Not easy due to several factors
  - 2D/3D input, simulator sickness, human perception, compexity, precision, lack of standards for best practices

Introduction

- Universal interaction tasks (Bowman)
  - Navigation
    - Travel - motor component
    - Wayfinding - cognitive component
  - Selection
  - Manipulation
  - System control

Travel

- Travel is the manner in which a user moves between two locations in a virtual world
  - Most common form of interaction in 3D software systems

Travel

- Why does a user navigate?
  - Explore environment
  - Search for something specific when its location is not known
  - Go to a known location
  - Systematically learn about the environment
  - Position the “view” while performing a task

Travel Metaphors

- Steering-based
  - User continuously steers in the motion direction
    - Follow direction of focus
    - Follow a virtual pointing finger or hand
    - Steer with some sort of steering wheel or joystick
      - even a virtual one, based on gestures
    - Walking, flying, orbiting are different ways of moving, with different constraints imposed
  - Useful when the user wants to become acquainted with an environment

Travel Metaphors

- Target-based
  - User specifies a target and the system takes the user to the location of the target
    - User enters coordinates
    - User selects targets from a list
      - Object names
      - Viewpoints
    - User selects (or points at) an object
  - Quick and efficient when the user knows where he/she wants to go (or thinks he/she knows…)

Travel Metaphors

- Other userful metaphors include
  - Route planner
    - User draws a route on an overview map
      - system takes the user along the route
    - System may automatically identify an optimal route based on some user-defined criteria
  - Hand-held camera
    - Quick and accurate for controlling a camera within a limited space (e.g. motion sensor used to represent a physical camera)
    - But if user needs to use both hands then will need assistance

Wayfinding

- To aid the user acquire an understanding of an environment it is helpful to assist the user in constructing a cognitive map of the space, by providing
  - Maps
  - Landmarks
  - Audio
  - Temporarily widen field of view

Selection and Manipulation

- Selection: Pick one or more objects
- Manipulation: Modify object attributes

Selection

- Why?
  - To prepare to manipulate a specific object
  - To move closer to an object
  - To activate behaviour associated with an object
  - To retrieve information about an object

Selection

- How?
  - Point at an object (ray-casting)
  - “Touch” an object (3D hand)
  - But can also
    - Select from a list
    - Search for specific attributes

Selection

- What needs to be taken into account?
  - Distance from user
  - Size of target
  - Other objects in the way
  - When to select a target (e.g. pick command, on intersection)
- What can we do to make selection easier?
  - Dynamically change the size of the target area depending on its distance from the user and/or disallow selecting distant objects
  - Support “X-ray vision” and clicking *through* other objects
  - Use highlighting or audio feedback to identify potential and active selections

Manipulation

- Why?
  - To position objects
  - To navigate
  - To modify an object's attributes
    - e.g. Change it's form, scale, etc.
  - To press/touch/pull an object to trigger an event

Manipulation

- How?
  - Ray-casting
  - Virtual hand
  - Tangible interface techniques
  - Gestural interfaces
- What should be taken into account?
  - Distance from the viewer
  - Precision required
  - Amount of rotation or translation permitted

Manipulation

- What can be do to make manipulation easier?
  - Virtual hand is natural to use, but limits to interacting with near objects and is difficult to control with a 2D input device
  - Ray-casting is easy to implement for both 2D and 3D input
    - But precise 3D manipulation can be a challenge with a 2D input device
  - Can introduce temporary constraints to aid the user
    - E.g. Only rotate around one axis at a time
  - Tangible interface techniques e.g. using physical props can support complex manipulations
  - Gestural interfaces imprecise but may be more *natural*
  - Can combine different techniques

System Control

- "System control" is all other interaction related to the virtual environment
  - e.g. Selecting system configuration options, loading files, changing modes, etc.
    - i.e. commands to change state or mode
- For a typical desktop 3D system, we can use choose to use standard 2D menus and UI components OR we can implement a more immersive fullscreen 3D experience

System Control

- It is most common to implement graphical menus and UI components of some kind
- Can also be appropriate to incorporate
  - Voice control
  - Gesture recognition
  - Physical props
- It is most important that we do not disrupt the user's workflow (or playflow)

Menus for System Control

- Controls in an overlay ("HUD") can work well
  - But can disrupt the 3D experience in an immersive environment
  - Consider allowing the user to toggle display of menus
- Floating 3D menus may be preferable, but
  - Can obstruct the user's view
  - Can be difficult to read/see depending on the angle
  - Can be difficult to select from using 3D input devices

2D interaction in 3D worlds

- It is often useful to apply 2D interaction techniques to 3D environments
  - For desktop VR, where the user typically has only a keyboard an mouse, it is always a challenge to implement rich 3D interaction using 2D input devices (and the keyboard)
  - Even if you have access to 3D input technologies, applying 2D interaction techniques can be useful in some situations
    - Working in 2D is easier physically and cognitively

2D interaction in 3D worlds

- 2D input is often much more precise than 3D input due to the limitations of typical 3D input devices
  - Resolution/accuracy, latency, jitter…
- It is generally easier to select objects with a 2D mouse than a 3D mouse
  - Generally more difficult to manipulate 3D objects with 2D mouse
- Introducing constraints can make a 3D system easier to use
  - e.g. Restricting travel to terrain following rather than flying
  - When you need to include the additional dimension then you will often need to do so in an “unnatural” manner

2D interaction in 3D worlds

- Tablets computers can be used as input devices with secondary displays (e.g. for system control)
  - Need to be well-integrated with the rest of the (3D) system so that the user experiences it as a natural extension to the main 3D view

Design Methods

- Quite a lot of research has been done on 3D UIs
  - Many different requirements
  - Many different input technologies and techniques
  - No common understanding of a 3D UI paradigm…
- General guidelines resulting from research can only be considered as recommendations and not rules
- Good 3D UI design is challenging
  - Requires knowledge and creativity

Design Method

- Systematically consider the users' requirements for performing tasks in the virtual environment
- Use familiar interaction techniques when they appear to be appropriate (e.g. from games, 3d modelling tools, etc.)
- Use appropriate guidelines and usability research results
- Innovate: be creative!
- Use an iterative process with lots of informal testing
  - e.g. Focussing on task performance and subjective usability

Research

- Guidelines are established as a result of formal experiments, user studies, and usability evaluations, where we look at factors such as
  - Task performance
  - Subjective usability
  - Mental workload
  - Situation awareness
  - Sense of presence

Research

- Typical findings include…
  - Teleport type functions are useful but can result in the user losing a sense of location and/or direction
    - Can counter this by animating the transition
  - Perspective & occlusion are most important depth cues
    - Stereoscopic 3D does not necessarily contribute to improved task performance overall, but can contribute to a user more rapidly attaining a sense of presence
  - Users often underestimate distances
  - Visible grids can help users estimate distances

Summary

- Good 3D UI design is challenging
- Applications are diverse and often have complex user input needs to meet system goals
  - Users will often need some form of training
- Designers often need to be creative in identifying good solutions
- Iterative design methods are recommended
- Guidelines are useful but there are no standard solutions for all 3D applications!

Extra Slides

3D UI Guidelines

- Useful sources of general guidelines:
  - Schneiderman in *"Why Not Make Interfaces Better than 3D Reality"*
    - IEEE Computer Graphics & Applications Nov/Dec 2003
  - Bowman's in *"Interaction Techniques For Common Tasks In Immersive Virtual Environments"* (1999)
    - PhD thesis, and incorporated into book on "3D User interfaces: Theory and Practice" published in 2005

Guidelines

Schneiderman

- Use occlusion, shadows, perspective, and other 3D techniques carefully
- Minimise the number of navigation steps for users to accomplish tasks
- Keep text readable
  - better rendering, good contrast with background, and no more than 30-degree tilt

Guidelines

Schneiderman

- Avoid unecessary visual clutter, distractions, contrast-shifts, and reflections
- Simplify user movement
  - Keep movement planar, avoid surprises such as going through walls
- Prevent errors
  - Surgical tools that cut only where need, …

Guidelines

Schneiderman

- Simplify object movement
  - Facilitate docking, follow predictable paths, limit rotations
- Organise groups of items in aligned structures to allow rapid visual search
- Enable users to construct visual groups to support spatial recall
  - Placing items in corners or tinted areas

More Guidelines

Schneiderman

- Provide overview so users can see the big picture
  - Plan view display, aggregated views
- Allow teleportation
  - Rapid context shifts by selecting destination in an overview
- Offer x-ray vision so users can see into or beyond objects
- Provide history keeping
  - Recording, undoing, replaying, editing

More Guidelines

Schneiderman

- Support semantic zooming and movement
  - Simple action brings object front and centre
- Enable landmarks to show themselves even at a distance
- Develop novel 3D icons to represent concepts that are more recongisable and memorable