Designing 3D User Interfaces

Lecture #12: 3DUI Design

Spring 2021

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Thus far…

- 3DUI hardware
  - input
  - output
- Universal 3DUI tasks
  - navigation
  - selection and manipulation
  - system control
  - symbolic input
- Simple combination of techniques and devices does not guarantee enjoyable experience

Overview

Discuss some general strategies and principles for designing 3D UIs

- High level strategies that can be used in a wide variety of 3D tasks and applications
- Some are designed to match 3D UIs to the basic properties of human psychology and physiology; others are based on common sense, rules of thumb, or cultural metaphors

Introduction

- Simply combining iconic interaction techniques does not necessarily guarantee an intuitive, easy-to-use, and enjoyable user experience: many micro/macro level problems
- Strategies and principles can be roughly divided into two large groups that can affect each other:
  - **Designing for humans**: i.e., strategies to match the design of interaction techniques and applications to human strengths, limitations, and individual differences
  - **Inventing 3D user interfaces**: i.e., designing techniques based on common sense approaches, creative exploration of 3D UI design, or rules of thumb

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Introduction

Designing for Humans

- Most interface design principles from general UI literature can be applied to the design of 3D UIs
  - Many have been studied extensively in the frame of human factors research, and include:
    - Reduction of short-term memory load, consistency of interface syntax and semantics, feedback, error prevention, and aesthetic appeal are as important in 3D interaction as in any other human–machine interface
- Expanding to the third dimension, however, brings new challenges
  - I.e. designing for user comfort, that require different design strategies that are usually not explored in the traditional UI literature

Introduction

Inventing 3D User Interfaces

- Often necessary to invent a new technique
  - General 3D user interface techniques may not be applied in all different kinds of applications
  - While human factors–based principles can offer valuable insight into how 3D UIs should be designed, they are not always prescriptive
- More formal methods inspired by human factors research
- Informal, rule-of-thumb approaches that have often been used in creating new 3D UI

Designing for Humans

Unconventional Interfaces

- While designing for humans, we tend to optimize interfaces for user limitations
  - Perspective has been proven effective in many applications, close analysis of human factors always useful
  - However, looking at human factors issues only as potential bottlenecks may also be limiting
    - Researchers have also been looking at the *potential* of the human body, rather than its limitations, as an approach to design novel interaction techniques
    - Has proven useful in for example gaming systems

Designing for Humans

Feedback in 3D User Interfaces

- Refers to any information conveyed to the user that helps the user understand the state of the system, the results of an operation, or the status of a task
  - Information may come from the system, from the environment, or from the user's own body
  - Often important to provide sufficient levels of feedback to the user and ensure compliance (agreement) between different levels and types of feedback

Designing for Humans

Feedback in 3D User Interfaces

- *Sensory dimensions* of feedback include all human sensory channels: interface designer can affect all but self-produced feedback (kinesthetic and proprioceptive cues)
- From a *systems* point of view, feedback can be split into three categories:
  - Reactive
  - Instrumental
  - Operational

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Designing for Humans

Feedback Compliance

- Key principle in designing effective feedback for interactive systems is the principle of **compliance** between different dimensions of the feedback provided to the user
  - For efficient interaction, the 3D UI should *maintain spatial and temporal correspondence between multiple feedback dimensions* that the user receives
  - Conflicting cues can cause severe side effects, including headaches and cybersickness

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Designing for Humans

Spatial Compliance

- Types of spatial feedback compliance include:
  - Directional compliance
  - Nulling compliance

Designing for Humans

Temporal Compliance and Latency

- Most typical example lack of temporal compliance is latency
  - Latency is the temporal delay between user input and sensory feedback generated by the system in response to it
  - Latency affects user performance due to lack of compliance between internal feedback and external sensory feedback received by the user
  - Not only *absolute* latency but also its *variability* may affect user performance
  - Simplest technique for dealing with latency is to increase the update rate by reducing the environment's complexity, however, simply increasing the update rate does not eliminate all the sources of latency

Designing for Humans

A mockup of an AR application illustrating potential interpretation problems due to tracking accuracy and/or latency (as well as perceptual issues): Where exactly is apartment 6? (Image courtesy of Ernst Kruijff)

Designing for Humans

Feedback substitution

- In designing and developing 3D UIs, it is often difficult to allow for all possible types of feedback
  - In particular, haptic feedback often requires devices that are expensive and difficult to operate
  - In the absence of haptic feedback, feedback substitution principles have often been used
- Many examples of sensory feedback substitution in VR, some of which are surprisingly effective

Kruijff et al. (2016) found that self-motion perception could be increased in the absence of normal vestibular and haptic feedback by playing walking sounds, showing visual head bobbing, and providing vibrotactile cues to the user's feet

Designing for Humans

Passive Haptic Feedback or Props

- Matches the shape and appearance of a virtual object with the shape and appearance of a physical object
  - User can both see and "feel" the virtual object, type of instrumental feedback
- Can provide inexpensive physical and tactile feedback, significantly increasing the sense of presence and ease of interaction
- Establishes a common perceptual frame of reference between the device and the virtual objects, can ease of use and may make it easier to learn the 3D UI
- However, requires multiple trackers, and performance improvement has not been shown yet

Designing for Humans

Two-handed interface with passive haptic feedback provided by the doll's head and cutting plane tool held by the user. (Hinckley et al. 1994, © 1994 IEEE)

Designing for Humans

Constraints

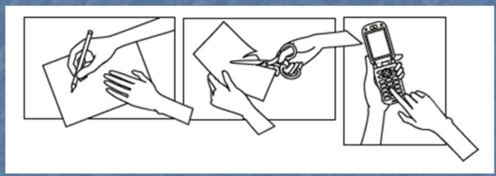
- Relations that define some sort of *geometrical coherence* of the virtual scene during the user's interaction with it
- Can simplify interaction while improving accuracy and user efficiency
- Several types of constraints can be used in 3D UIs
  - Physically realistic constraints
  - Dynamic alignment tools
  - Intelligent constraints
- Can reduce user control over the interaction
- Can be a very effective design tool for 3D UIs

Designing for Humans

Two-handed control

- Allows users to transfer their everyday manipulation experiences and skills to 3DUI
- Can also significantly increase user performance on certain tasks
- Theoretical foundation behind most research on bimanual 3D interaction was proposed by Guiard
- Tasks can be unimanual, bimanual symmetric or bimanual asymmetric

Designing for Humans



- Nondominant hand dynamically adjusts the spatial frame of reference for the actions of the dominant hand
- Dominant hand produces fine-grained precision movements, while the nondominant hand performs gross manipulation
- Manipulation is initiated by the nondominant hand

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Designing for Humans

- Further factors should be considered during human-centric design:
  - Age
  - Prior experience
  - Physical characteristics
  - Perceptual, cognitive and motor abilities

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Inventing 3D User Interfaces

- Introduce informal approaches that have often been used in creating novel 3D UIs and interaction techniques
  - Lie in a continuum between strict imitations of reality (naturalism or isomorphism) and magic (nonisomorphism, or things that can't be found in the real world)
  - Approaches should be taken as illustrative examples to help designers and developers ask the right questions that will lead to the development of compelling 3D UIs

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Inventing 3D User Interfaces

Borrowing from the Real World

- Most basic, tried-and-true approach is to attempt to simulate, or adapt from, the physical world
- Two main approaches
  - Simulating reality
  - Adapting from the real world

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Inventing 3D User Interfaces

Borrowing from the Real World

- Simulating reality is key in all simulation applications
- Advantages:
  - User already knows how to use the interface
  - Can be implemented based either on the designer's intuition and common sense or on the clearly specified technical design requirements
  - Advanced and special-purpose 3D interaction techniques not always necessary
- Designers may, however, need to compromise on how realistic the simulation needs to be
- Needed realism depends per application

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Inventing 3D User Interfaces

Adapting from the Real World

- Instead of attempting to replicate the real world, 3D UIs can also adapt artifacts, ideas, and philosophies from the real world
  - The metaphors are only a starting point
  - Interaction techniques based should be carefully designed to match the requirements of the applications and limitations of the technology
- Because users are already familiar with real-world artifacts, it is easy for them to understand the purpose and method of using 3D interaction techniques based on them

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Inventing 3D User Interfaces

Adapting from 2D User Interfaces

- Adapting interaction techniques from traditional 2D UIs has been another common 3D UI design technique
- Can be attractive approach, based on experience, limited DOF
- Does not always scale well to 3D
- Various approaches exist:
  - Overlaying a 2D GUI on a 3D world
  - 2D GUI as an element of the 3D environment
  - 2D interaction with 3D objects

Inventing 3D User Interfaces

The Eye of Ra hybrid interface, combining 2D and 3D interaction. (Image courtesy of Ernst Kruijff)

Inventing 3D User Interfaces

Magic and Aesthetics

- Real power of 3D UIs may not only lie in simulating or adapting real-world features, but also in creating a "better" reality by utilizing magical interaction techniques
  - Allow users to overcome many human limitations
  - Reduces the effect of technological limitations through enhanced capabilities
  - Many approaches that can help to develop new magical techniques, including overcoming human limitations or specific metaphors
- The discussion of realism and magic in designing 3D UIs also directly relates to the **aesthetics** of the 3D environment
  - Realism often a main goal, but still hard to achieve
  - In many applications, though, realism may not be needed

Design Guidelines

- Move wires and cables out of the way or use wireless solutions when possible; reduce weight of the equipment.
- Provide physical and virtual barriers to keep the user and the equipment safe.
- Limit interaction in free space; provide a device resting place.
- Design public systems to be sanitary.
- Design for relatively short sessions and encourage breaks.

Design Guidelines

- Design for comfortable poses.
- Ensure temporal and spatial compliance between feedback dimensions.
- Use constraints.
- Consider using props and passive feedback, particularly in highly specialized tasks.
- Use Guiard's principles in designing two-handed interfaces.

Design Guidelines

- Consider real-world tools and practices as a source of inspiration for 3D UI design.
- Consider designing 3D techniques using principles from 2D interaction.
- Use and invent magical techniques.
- Consider alternatives to photorealistic aesthetics.

Case Studies

VR Gaming Case Study

- Many of the 3D UI design approaches used
  - Two-handed interaction
  - Flashlight serves as a constraint to limit the selectable items in the world, passive haptic feedback is provided by the handheld controllers
- Primary design issue we faced has to do with the naturalism (or *interaction fidelity*)
  - However, the game does take place in a semirealistic environment
  - Can be coupled with *hypernaturalism*

Case Studies

VR Gaming Case Study

- Key concepts:
  - Consider carefully the level of interaction fidelity for your 3D UI
    - Naturalism is not always the most desirable or most effective approach
  - Especially in games, fun and playful hypernatural interactions can significantly enhance the user experience

Case Studies

Mobile AR Case Study

- Design strategy highly driven by human factors issues
    - Perceptual issues affect the general view management and system control aspects
    - Cognitive issues are prominent in the design of navigation techniques
    - Physical ergonomics provide design constraints to create the overall system setup
  - System was used for *longer durations* and exhibited a higher level of *complexity,* stressing mentioned issues
  - Two-handed interaction and designing for different user groups important

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Case Studies

Mobile AR Case Study

- Key concepts:
  - Human-factors-driven design: designing with perceptual, cognitive and physical ergonomics in mind has great potential when designing AR systems
    - While in simple systems these issues may not be evident, when complexity increases, addressing these issues can be a make-or-break item for user performance and acceptance
  - User groups: always consider the full range of potential end-users and involve them frequently in all cycles of iterative system design

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Conclusion

- 3DUI design space is huge
  - Sometimes difficult to decide how to pursue certain ideas
  - We have shown several prominent approaches and strategies to aid the design process

Next Class

- 3DUI Evaluation
- Readings
  - 3DUI Book – Chapter 10