3D User Interface System Control Techniques

Lecture #11: System Control

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Overview

Goal

- Provide an overview of system control and symbolic input
- Describe the main techniques with their advantages and disadvantages

Introduction

- "System control" refers to the user task in which commands are issued to
  - Request the system to perform a particular function,
  - Change the mode of interaction, or
  - Change the system state
- Often the "glue" that allows the user to control the interaction flow between the other key tasks

Background

- Issuing of commands is a critical way to access any computer system's functionality
- To perform such tasks, we use system control techniques like menus or function keys on a keyboard
  - In classical GUIs, a plethora of methods is available
  - Designing a 3D UI to perform system control can be challenging, 2D interaction styles not always useful
- In many tasks system control is intertwined with *symbolic input*, the input of characters and numbers

Human Factors

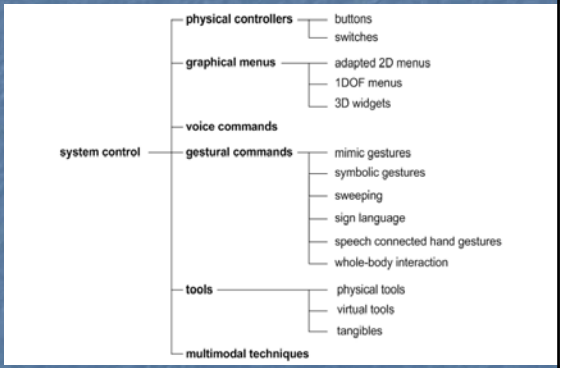
- **Perceptual issues:**
  - Visibility, like occlusion and legibility
  - Focus switching
  - Choice of a feedback modalities
- **Cognitive issues:**
  - Functional breadth and depth of the system, structuring of tasks to lower cognitive hurdles
- **Ergonomic issues:**
  - Control placement, and the pose, grip and motion types a particular device is used with
  - Shape, size, and location of controls can highly affect system control performance

System Factors

- High-level characteristics of the system are important to consider when designing system control interfaces
  - System characteristics can even dictate specific choices for system control
- Main issues:
  - *Visual display devices* will impose specific perceptual boundaries, such as resolution, size, and luminance
  - *Input devices* define the possibilities for control mappings
  - *Ambient factors* such as noise, device constraints, or the motion range may limit the choice of a technique

Classification

- System control techniques can be classified as follows



Physical Controllers

Techniques

- Physical controllers such as buttons and switches offer a lightweight solution for performing system control
  - Analogous to function keys in desktops
  - Direct way of changing a mode in an application
  - In contrast to using a pointing device to select, for example, an item from a menu, the physical controller allows the user to directly switch the mode between different state

A flight joystick deploying numerous switches and buttons (© Guillemot Corporation S.A. All rights reserved. Thrustmaster ® is a registered trademark of Guillemot Corporation S.A.)

Physical Controllers

Design and Implementation Issues

- Placement and control
  - When built-in controllers are used, you should carefully validate their placement and the potential need for regrasping a device to access the button
  - Critically reflect physical form and quality, as some buttons and switches are difficult to control

Physical Controllers

Design and Implementation Issues

- Representation and structure
  - Buttons and switches are not necessarily connected to any menu-like structure
    - Structure is based on the placement of buttons and their interrelationship
  - Button locations are often defined by accessibility (ergonomic placement) rather than by functional structure
    - Feedback changes should be clearly communicated to the user
  - Placing a small label or pictogram on the button can indicate its usage

Physical Controllers

Practical Application

- Buttons and switches are particularly useful
  - When users need to switch frequently between functions: can be lightweight, quick, and straightforward
  - In applications that are used for short durations by inexperienced users, function keys may be very useful, but only with a small functional space
  - If users have the time and motivation to learn more complicated sets of functions, this may come with a great increase in performance

Graphical Menus

Techniques

- Graphical menus for 3D UIs are the 3D equivalent of the 2D menus that have proven to be a successful system control technique in desktop UIs
- Graphical menus used in 3D UIs can be subdivided into three categories:
  - Adapted 2D menus
  - 1-DOF menus
  - 3D widgets

Graphical Menus

- Adapted 2D menus
  - Simple adaptations of their 2D counterparts
    - Have been the most popular group system control techniques
    - Basically function in the same way as on desktop
    - Common choice for more complex sets of functions
  - Menus can occlude the environment, and users may have trouble finding the menu or selecting items using a 3D selection technique

Graphical Menus

Pie menu in immersive virtual environment. (Photograph courtesy of Thorsten Kuhlen, Virtual Reality & Immersive Visualization Group, RWTH Aachen)

Graphical Menus

- 1DOF menus
  - Often attached to the user's hand, with the menu items arranged in a circular pattern around it
  - Examples include the ring menu and handheld widgets
- In general, 1-DOF menus are quite easy to use
  - Menu items can be selected quickly, as long as the number of items is relatively small and ergonomic constraints are considered
  - Because of the strong placement cue, 1-DOF menus also afford rapid access and use
  - 1-DOF menus can also be used eyes-off by coupling the rotational motion of the wrist to an audio-based menu

Graphical Menus

- 3D widgets
  - Extra DOF can enable more complex menu structures or better visual affordances for menu entries
  - Two kinds of 3D widgets:
    - Collocated (context-sensitive): the functionality of a menu is moved onto an object in the 3D environment, and geometry and functionality are strongly coupled
    - Non-context-sensitive widgets: general purpose widgets

The command and control cube. (i3D-INRIA. Data © Renault. Photograph courtesy of Jerome Grosjean)

Graphical Menus

Design and Implementation Issues

- Placement
  - The placement of the menu influences the user's ability to access the menu and the amount of occlusion of the environment
  - Hybrid systems combining 2D and 3D interaction can be good choice
  - Non-collocated menus can cause focus switching
  - Occlusion of menu over graphical content can be big issue

Graphical Menus

Design and Implementation Issues

- Selection
  - Using a 3D selection method with 2D (or even 1D) menus can be problematic
- Representation and structure
  - Size of and space between items is very important
  - Structure is crucial, especially in complex applications
  - In outdoor AR, color and size should be carefully chosen, due to visibility issues

Graphical Menus

Practical Application

- Graphical menu techniques can be very powerful in 3D UIs when their limitations can be overcome
- Especially with applications that have a large number of functions, a menu is probably the best choice
- Approach of putting graphical menus on a remote device works only when users can see the physical world

Voice Commands

Techniques

- Issuing of voice commands can be performed via simple speech recognition or by means of spoken dialogue techniques
  - Speech recognition techniques are typically used for issuing single commands to the system
  - A spoken dialogue technique is focused on promoting discourse between the user and the system
- Most critical component is the *speech recognition engine*
  - today's recognition systems are advanced and widespread

Voice Commands

Design and Implementation

- Define which tasks need to be performed via voice interfaces
  - Highly complex applications may need conversational UIs
- In spoken dialogue system, it should also be considered what vocal information is needed to determine the user's intentions
- Be aware that voice interfaces are *invisible* to the user
- Speech-based techniques initialize, select, and issue a command at once
  - Button to initialize the speech system may be needed
- Error rates will increase when the application involves direct communication between multiple participants

Voice Commands

Practical Application

- Speech input as a system control technique in a 3D UI can be very powerful as it is hands-free and natural
- Users may first need to learn the voice commands
- For hybrid interfaces or handheld AR, voice recognition may be a good option due to built in voice recognition support of smartphones
- Voice can be used hands-off

Gestural Commands

- Gesture interfaces are often thought of as an integral part of *perceptual user interfaces* (Turk and Robertson 2000) or *natural user interfaces* (Wigdor and Wixon 2011)
- Designing a truly well performing and easy-to-learn system is a challenging task
- Gestural commands can be classified as either **postures** or **gestures**
  - Posture: a static configuration of the hand
  - Gesture: a movement of the hand, perhaps while it is in a certain posture

Gestural Commands

Techniques

- In everyday life, we use many different types of gestures that may be combined
- We identify the following gesture categories:
  - Mimic gestures
  - Symbolic gestures
  - Sweeping
  - Sign language
  - Speech-connected hand gestures
  - Surface-based gestures
  - Whole-body interaction

Gestural Commands

Mimic gesture.
(Schkolne et al. 2001; © 2001 ACM.
Reprinted with permission from ACM)

Gestural Commands

TOUCHEO—combining 2D and 3D interfaces.
(© Inria / Photo H. Raguet).

Gestural Commands

Design and Implementation Issues

- Gestural interaction depends heavily on input device
- Gesture recognition is still not always reliable
- When a menu is accessed via a gestural interface, the lower accuracy of gestures may lead to the need for larger menu items
- Gesture-based system control shares many of the characteristics of speech input discussed in the previous section
  - Combines initialization, selection, and issuing of the command
  - Gestures should be designed to have clear *delimiters* that indicate the initialization and termination of the gesture
- Users may need to discover the actual gesture or posture language

Gestural Commands

Practical Application

- Entertainment and video games are just one example of an application domain where 3D gestural interfaces are becoming more common
- Medical applications used in operating rooms are another area where 3D gestures have been explored, to maintain a sterile environment
- Gesture interfaces have also been used for symbolic input

Gestural Commands

A user controlling an unmanned aerial vehicle (UAV) with 3D gestures. (Image courtesy of Joseph LaViola).

Tools

- In many 3D applications, the use of real-world devices for 3D interaction can lead to increased usability
  - These devices, or their virtual representations, called **tools**, provide directness of interaction because of their real-world correspondence
  - Tools in 3D UIs provide a simple and intuitive technique for changing the mode of interaction: simply select an appropriate tool
- We distinguish between three kinds of tools:
  - Physical tools
  - Tangibles
  - Virtual tools

Tools

Techniques

- Virtual tool belts
- Tangible user interfaces (TUIs), based on the idea of props
  - Physical representations are computationally coupled to underlying digital information
  - Physical representations embody mechanisms for interactive control
  - Physical representations are perceptually coupled to actively mediated digital representations

Tools

Tool belt menu. Note that the tool belt appears larger than normal because the photograph was not taken from the user's perspective. (Photograph reprinted from Forsberg et al.[2000], © 2000 IEEE)

Tools

Visualization artifacts—physical tools for mediating interaction with 3D UIs. (Image courtesy of Brygg Ullmer and Stefan Zachow, Zuse Institute Berlin)

Tools

Design and Implementation

- Form of the tool communicates the function the user can perform with the tool, so carefully consider the form when developing props
  - General approach is to imitate a traditional control design
- Compliance between the real and virtual worlds is also important
  - Correspondence between real and virtual positions, shapes, motions, and cause-effect relationships
- Use of props naturally affords eyes-off operation
  - Prop must be designed to allow tactile interaction

Tools

Practical Application

- Physical tools are very specific devices
  - In many cases, they perform only one function
  - In applications with a great deal of functionality, tools can still be useful, but they may not apply to all the user tasks
- Tradeoff between the specificity of the tool (a good affordance for its function) and the amount of tool switching the user will have to do
- Public installations can greatly benefit from the use of tools

Multimodal Techniques

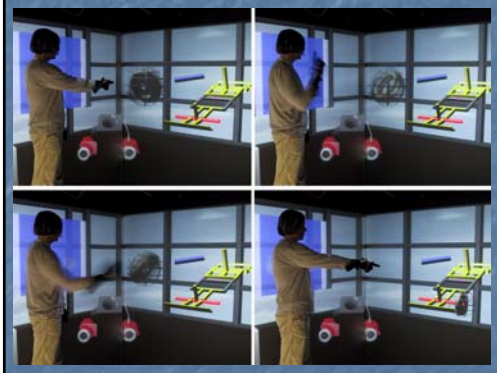
- Multimodal techniques connect multiple input streams
  - Users switch between different techniques while interacting with the system
- In certain situations, the use of multimodal system control techniques can significantly increase the effectiveness of system control tasks
  - However, it may also have adverse effects when basic principles are not considered

Multimodal Techniques

Potential Advantages

- Decoupling
- Error reduction and correction
- Flexibility and complementary behavior
- Control of mental resources

Multimodal Techniques



A car wheel is selected, rotated, and moved to its correct position using voice and gestures. (Photographs courtesy of Marc Eric Latoschik, AI & VR Lab, University of Bielefeld; Latoschik 2001)

Multimodal Techniques

Design Principles

- Combination of modalities will depend on the task structure
  - Switching may affect the flow of action in an application
  - While multimodal techniques may free cognitive resources, this is not necessarily the case for all implementations

Multimodal Techniques

Practical Application

- Complex applications can benefit from the complementary nature of multimodal techniques
  - Allowing for more flexible input and potentially reducing errors
  - Reduction of errors is especially important for applications with limited or no time for user learning
- Some modalities may be easier to perform by certain classes of users
- Multimodal techniques are applicable to scenarios that mimic natural behavior

Design Guidelines

- Avoid disturbing the flow of action of an interaction task.
- Prevent unnecessary focus switching and context switching.
- Design for discoverability.
- Avoid mode errors.

Design Guidelines

- Use an appropriate spatial reference frame.
- Structure the functions in an application and guide the user.
- Consider using multimodal input.
- 3D is not always the best solution—consider hybrid interfaces.

Case Studies

VR Gaming Case Study

- Not just about direct interaction with the world
  - Variety of small commands and settings that the player needs to be able to control
- Two more prominent system control tasks that will occur often
  - Opening the inventory: move the dominant hand close to the bag's handle, representing the inventory (essentially a "virtual tool" approach)
  - Choosing a tool to be used with the tool handle on the player's dominant hand

Case Studies

VR Gaming Case Study

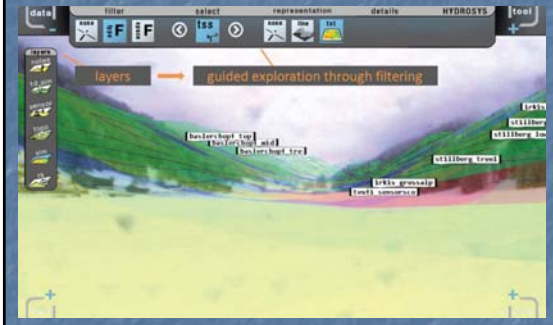
- Key concepts:
  - Think differently about the design of system control that's part of gameplay and system control that's peripheral to gameplay
  - When there are few options to choose from, a toggle that simply rotates through the choices is acceptable (and maybe even faster), rather than a direct selection
  - System control doesn't have to be boring, but be careful not to make it too heavyweight

Case Studies

Mobile AR Case Study

- HYDROSYS application provided access to a wider range of functions
  - System control was highly dependent on the display type and input method, a smaller screen and finger or pen input
  - To access functions in a screen-effective manner, we provided access to four different task categories
  - Function groups could be accessed by menu buttons in corner of screen: once a menu was selected, a menu bar would appear
  - To streamline menu item selection, guided exploration was used

Case Studies



Example of a menu bar, in this case the data search menu, using the guided exploration approach. (Image courtesy by Ernst Kruijff and Eduardo Veas).

Case Studies

Mobile AR Case Study

- Key concepts:
  - Perceptual issues: visibility and legibility affect the design methods of AR system control in a way similar to those of general 2D menu design. However, their effects are often stronger, since AR interfaces are highly affected by display quality and outdoor conditions
  - Screen space: as screen space is often limited, careful design is needed to optimize the layout of system control methods to avoid occlusion of the augmentations

Conclusion

- We have provided an overview of the various system control techniques that can be used for 3D
  - Though system control methods for 3D UIs have been developed and used extensively, many issues are still open for further research
  - There is also a lack of good empirical evidence for the user experience of various system control techniques at the present time

Next Class

- 3D UI Design
- Readings
  - 3DUI Book – Chapter 9