

3D User Interface System Control Techniques

Lecture #11: System Control
Spring 2024

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Overview

Goal

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

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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

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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

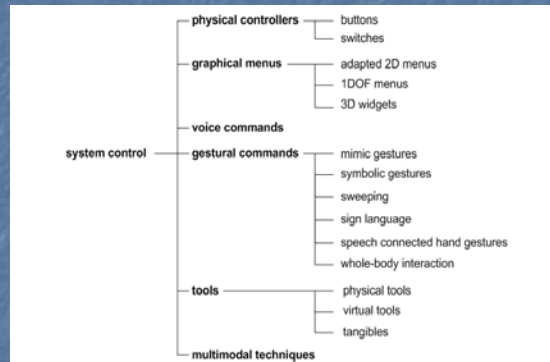
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Classification

- System control techniques can be classified as follows



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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.)

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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

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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

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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

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Graphical Menus



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

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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

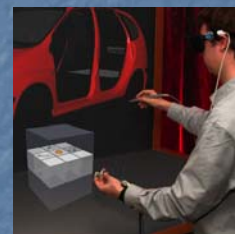
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Graphical Menus

- 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)

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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

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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

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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.
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Gestural Commands



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

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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

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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)

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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

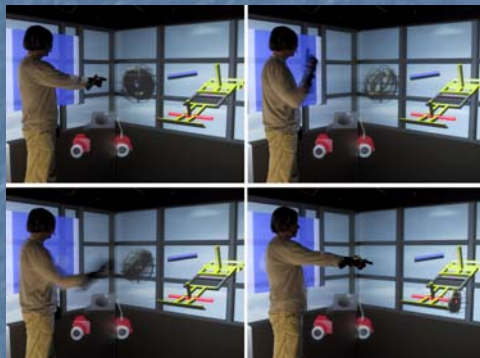
- Decoupling
- Error reduction and correction
- Flexibility and complementary behavior
- Control of mental resources

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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)

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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

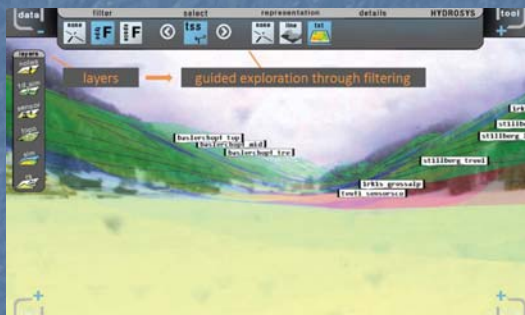
- HYDROSYS application provided access to a wider range of functions
 - System control was highly dependent on the display type and input method, a smaller screen and finger or pen input
 - To access functions in a screen-effective manner, we provided access to four different task categories
 - Function 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

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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).

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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