3D User Interface Evaluation I

Lecture #13: Evaluating 3DUIs – Part I

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User Evaluation in 3DUIs

- Was missing component for many years
  - novelty
  - limitless possibilities
  - exploration of design space
- Field has matured
  - Need to compare
    - devices
    - interaction techniques
    - applications
    - etc...

Introduction

- Look at 3D UI designs in terms of *user experience* (including usability, usefulness, and emotional impact)
- Must critically analyze, assess, and compare devices, interaction techniques, UIs, and applications
- If 3D UIs are to be used in the real world

Introduction

Purposes of Evaluation

- Evaluation: analysis, assessment, and testing of an artifact
- Usability-problem identification and UI redesign are the main goals of evaluation
- General understanding gained from evaluation can lead to design guidelines
- A more-ambitious goal of UI evaluation is the development of models that predict user performance

Introduction

Terminology

- Evaluator: a person who designs, implements, administers, or analyzes an evaluation
- User (or participant): a person who takes part in an evaluation by using the interface, performing tasks, or answering questions
- Evaluation method: particular steps used in an evaluation
- Evaluation approach: a combination of methods, used in a particular sequence, to form a complete usability evaluation

Introduction

Chapter Roadmap

- Evaluation methods for 3D UIs
- Evaluation metrics for 3D UIs
- Characteristics of 3D UI evaluations
- Classification of evaluation methods
- Three Multimethod Approaches
- Guidelines for 3D UI Evaluation
- Case Studies

Evaluation Methods for 3D UIs

- Cognitive walkthrough: stepping through common tasks that a user would perform and evaluating the interface's ability to support each step
- Heuristic evaluation: several usability experts separately evaluate a UI design by applying a set of design guidelines
- Formative evaluation: an observational, empirical evaluation that identifies usability problems by iteratively placing representative users in task-based scenarios

Evaluation Methods for 3D UIs

- Summative evaluation:
  - Comparing the usability of a UI to target usability values, or
  - Comparing two or more UI designs, components, and/or techniques
- Formal summative evaluations use:
  - Research questions
  - Independent variables (manipulated among multiple levels)
  - Dependent variables
  - Factorial designs and conditions

Evaluation Methods for 3D UIs

- Questionnaire: a set of questions used to obtain information from users before or after they have participated in an evaluation
- Interview: gathering information from users by talking directly to them

Evaluation Metrics for 3D UIs

System Performance Metrics

- Frame rate
- Latency
- Network delay
- Optical distortion
- Etc.

Evaluation Metrics for 3D UIs

Task Performance Metrics

- Speed
- Accuracy
- Errors

Evaluation Metrics for 3D UIs

Subjective Response Metrics

- Presence: the “feeling of being there”
- Cybersickness: symptomatically similar to motion sickness and may result from mismatches in sensory information
- User comfort: strains on arms/hands/eyes

Characteristics of 3D UI Evaluations

Physical Environment Issues

- Evaluator must ensure that the user does not bump into physical objects, trip over cables, or move outside the tracking space
- Hardware or software must be set up so that the evaluator can see the same image as the user
- Think-aloud protocols are difficult to use with speech recognition as an interact technique
- Recording video of both the user and the interface is often difficult
- Collaborative 3D applications present several complications

Characteristics of 3D UI Evaluations

Evaluator Issues

- Evaluators can cause breaks in presence if the user senses them
- Experimental applications should be robust enough that the evaluator does not have to interrupt the session to fix a problem
- Multiple evaluators may be needed due to the complexity of 3D UI hardware and software
- It is very difficult for an evaluator to observe multiple input streams, which are common to many 3D UIs, simultaneously and record an accurate log of the user's actions
- Automated data collection is very important

Characteristics of 3D UI Evaluations

User Issues

- The target user population for a 3D application or interaction technique may not be known or well understood
- It may be difficult to differentiate between novice and expert users because there are few potential participants who would be experts
- The number of participants needed to obtain a good picture of performance may be larger than for traditional usability evaluations
- Users must be able to adapt to a wide variety of situations for within-subject evaluations that compare two or more 3D UIs
- 3D UI evaluations must consider the effects of cybersickness and fatigue
- Presence is often required in VE evaluations

Characteristics of 3D UI Evaluations

Evaluation Type Issues

- Automated data collection of system and task performance metrics is nearly a necessity
- Heuristic evaluations are very difficult due to a lack of verified guidelines for 3D UI design
- Usability inspections are difficult to perform on early prototypes, because 3D UIs must be experienced firsthand
- Few performance models have been developed for or adapted to 3D UIs
- Statistical 3D UI experimental evaluations may be either overly complex or overly simplistic

Characteristics of 3D UI Evaluations

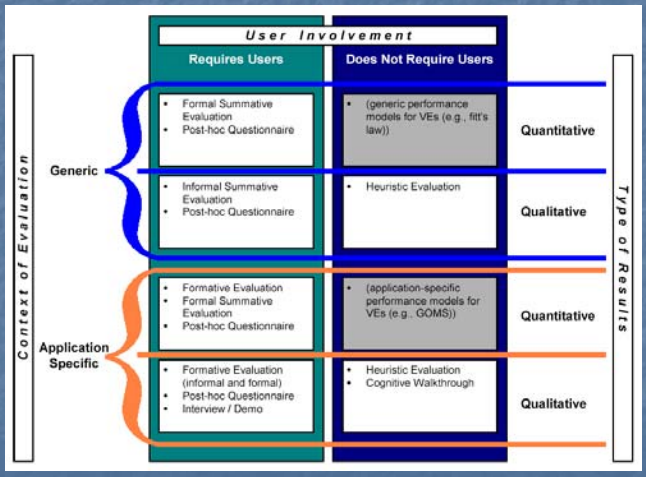
General Issues

- 3D UI evaluations most often evaluate lower-level components, such as interaction techniques or input devices because there are no interface standards
- It is important to report information about the apparatus with which the evaluation was performed and to evaluate with a range of setups if possible
- It is the responsibility of 3D UI evaluators to ensure that the proper steps are taken to protect their human subjects

Classification of Evaluation Methods

- Three key characteristics
  - Involvement of representative users: participants required or not
  - Context of evaluation: generic or application-specific context
  - Types of results produced: qualitative or quantitative

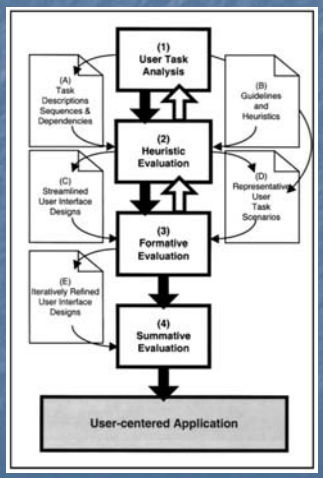
Classification of Evaluation Methods



Three Multimethod Approaches

Sequential Evaluation Approach

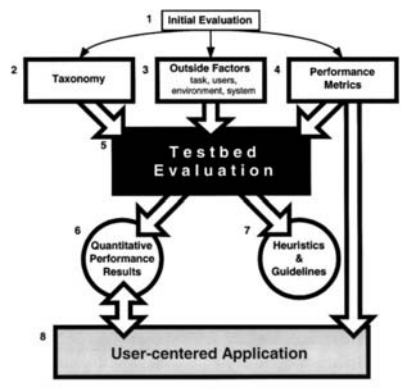
- Produces a usable and useful interface for a particular application
- Employs application-specific guidelines
- For domain-specific representative users
- Relies on application-specific user tasks



Three Multimethod Approaches

Testbed Evaluation Approach

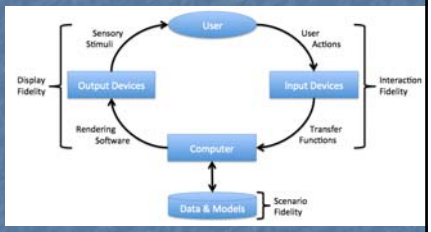
- Empirically evaluates interaction techniques in a generic context
- Supported by a framework for design and evaluation
- Primarily aimed at researchers who are attempting to gain an in-depth understanding of interaction techniques and input devices



Three Multimethod Approaches

Component Evaluation Approach

- Focuses on the stages of action and the components that affect those stages
- The User-System Loop serves as the basis of the approach
- At each stage, there are components that affect the overall usability of the system



Three Multimethod Approaches

Component Evaluation Approach

- Interaction Fidelity Components
  - Interaction fidelity: objective degree of exactness with which real-world actions are reproduced in a 3D UI system
  - Biomechanical symmetry includes anthropometric symmetry, kinematic symmetry, and kinetic symmetry
  - Input veracity includes accuracy, precision, and latency
  - Control symmetry focuses on transfer function symmetry

Three Multimethod Approaches

Component Evaluation Approach

- Scenario Fidelity Components
  - Scenario fidelity: objective degree of exactness with which behaviors, rules, and object properties are reproduced
  - Behaviors refer to artificial intelligence properties
  - Rules refer to physics and other models that determine what happen within the simulation
  - Object properties refer to dimensional and physics-related qualities of objects

Three Multimethod Approaches

Component Evaluation Approach

- Display Fidelity Components
  - Display fidelity: objective degree of exactness with which real-world sensory stimuli are reproduced by a system
  - Also referred to as immersion
  - Components of visual display fidelity include stereoscopy, field of view, field of regard, display resolution, display size, refresh rate, and frame rate

Three Multimethod Approaches

Comparison of Approaches

- What are the goals of the approach?
  - Sequential evaluation: iterate toward a better 3D UI
  - Testbed evaluation: finding generic performance characteristics of interaction techniques
  - Component evaluation: determining the main and interaction effects of specific system components for either an application-specific or generic context

Three Multimethod Approaches

Comparison of Approaches

- When should the approach be used?
  - Sequential evaluation: early and continually throughout the design cycle of a 3D application
  - Testbed evaluation: before the design cycle begins
  - Component evaluation: before the design cycle for knowledge of the general effects of one or more components or during the development of a 3D application to decide upon unclear design choices

Three Multimethod Approaches

Comparison of Approaches

- In what situations is the approach useful?
  - Sequential evaluation: throughout the design cycle of a 3D UI, but especially during the early stages
  - Testbed evaluation: when choosing common interaction techniques and interface elements for a suite of applications
  - Component evaluation: when making design choices that directly involve one or more system components

Three Multimethod Approaches

Comparison of Approaches

- What are the costs of using the approach?
  - Sequential evaluation: development of useful task scenarios and incorporating suggested design changes
  - Testbed evaluation: very costly due to difficult experimental design and experiments requiring large numbers of trials
  - Component evaluation: depends on whether employed for an application-specific or generic context

Three Multimethod Approaches

Comparison of Approaches

- What are the benefits of using the approach?
  - Sequential evaluation: likely to produce a more-refined and usable 3D UI
  - Testbed evaluation: generality of the results
  - Component evaluation: vary based on when and how the approach is used

Three Multimethod Approaches

Comparison of Approaches

- How are the approach's results applied?
  - Sequential evaluation: results are tied directly to changes in the interface of the 3D application
  - Testbed evaluation: results are applicable to any 3D UI that uses the tasks studied with a testbed
  - Component evaluation: results are applicable to any 3D UI system that includes the system components evalauted

3D Usability Evaluation

Things To Consider

Formality of Evaluation

- Formal: independent & dependent variables, statistical analysis, strict adherence to procedure, hold constant all other variables, usually done to compare multiple techniques or at the end of the design process
- Informal: looser procedure, often more qualitative, subject comments very important, looking for broad usability issues, usually done during the design process to inform redesign

What is Being Evaluated?

- Application:
  - Prototype - consider fidelity, scope, form
  - Complete working system
  - Controlled experiments are rare
- Interaction techniques / UI metaphors
  - Can still evaluate a prototype
  - More generic context of use
  - Formal experiments more often used
- Consider "Wizard of Oz" evaluation

Subjects / Participants

- How many?
- What backgrounds?
  - technical vs. non-technical
  - expert vs. novice VE users
  - domain experts vs. general population
- What age range?
- Recruiting
  - flyers
  - email/listservs/newsgroups
  - psychology dept.
  - CS classes

Number of Evaluators

- Multiple evaluators often needed for 3DUI evaluations
- Roles
  - cable wrangler
  - software controller
  - note taker
  - timer
  - behavior observer
  - ...

Procedure

- Welcome
- Informed consent
- Demographic/background questionnaire
- Pre-testing
- Familiarize with equipment
- Exploration time with interface
- Tasks
- Questionnaires / post-testing
- Interviews

- Subject "packets" are often useful for organizing information and data
- Pilot testing should be used in most cases to:
  - "debug" your procedure
  - identify variables that can be dropped from the experiment

Instructions

- How much to tell the subject about purposes of experiment?
- How much to tell the subject about how to use the interface?
- Always tell the subject what they should try to optimize in their behavior.
- If using think-aloud protocol, you will have to remind them many times.
- If using trackers, you will have to help users "learn" to move their heads, feet, and bodies – it doesn't come naturally to many people.
- Remind subjects you are NOT testing them, but the interface.

Formal Experiment Issues

- Choosing independent variables
- Choosing dependent variables
- Controlling (holding constant) other variables
- Within- vs. between-subjects design
- Counterbalancing order of conditions
- Full factorial or partial designs

Independent Variables

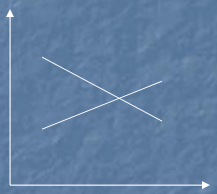
- Main variable of interest (e.g. interaction technique)
- Secondary variables
  - task characteristics
  - environment characteristics
  - system characteristics
  - user characteristics

Metrics (dependent variables)

- Task performance time
- Task errors
- User comfort (subjective ratings)
- Observations of behavior (e.g. strategies)
- Spoken subject comments (e.g. preferences)
- Surveys/questionnaires
- Interviews

Data Analysis

- Averages (means) of quantitative metrics
- Counts of errors, behaviors
- Correlate data to demographics
- Analysis of variance (ANOVA)
- Post Hoc analysis (t-tests)
- Visual analysis of trends (esp. learning)



- *Interactions between variables* are often important
- Expect high variance in 3DUI interaction studies

Analysis Tools

- SPSS, SAS, etc.
  - full statistical analysis packages
  - parametric and non-parametric tests
  - test correction mechanisms (e.g., Bonferroni)
- Excel
  - basic aggregation of data
  - Correlations
  - confidence intervals
  - graphs
- Matlab, Mathematica

Guidelines for 3D UI Evaluation

General Guidelines

- Begin with informal evaluation.
- Acknowledge and plan for the differences between traditional UI and 3D UI evaluation.
- Choose an evaluation approach that meets your requirements.
- Use a wide range of metrics.

Guidelines for 3D UI Evaluation

Guidelines for Formal Experimentation

- Design experiments with general applicability.
- Use pilot studies to determine which variables should be texted in the main experiment.
- Use automated data collection for system performance and task performance metrics.
- Look for interactions between variables—rarely will a single technique be the best in all situations.

Case Studies

VR Gaming Case Study

- Working prototypes and iteration of individual interaction concepts and several rounds of iteration
- Prototype of the complete UI using just a couple of rooms representative of the entire game
- Key concepts:
  - Working prototypes are critical to understand the potential of 3D UI designs.
  - Be sure to evaluate the complete UI, not just the individual interaction techniques.
  - Start with usability evaluation, but for real 3D UI applications, go beyond usability to understand the broader user experience

Case Studies

Mobile AR Case Study

- Informal study with simple paper-based prototype
- Outdoor AR experiments were affected by lighting conditions
- Users experienced cognitive load and ergonomic issues
- Key concepts:
  - Be sure to evaluate AR systems in the environment in which the system is deployed.
  - Assess subjective mental load of more complex systems, as it may greatly affect performance.
  - Study ergonomics of systems that are used for lengthy time periods.

Conclusion

- Evaluation is almost always necessary
- Initial 3D UI design require assessment of usability and user experience so that the design can be iterated and improved
- Formal experimentation deepens our understanding of 3D interaction and provides new knowledge, guidelines, and models

Next Class

- 3DUI evaluation examples
- Readings
  - 3DUI Book – Chapter 11