

# Augmented Reality II

## User Interfaces: Theories, Principles, Guidelines

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# Outline

- Motivation: Examples of AR as a novel User Interface (Reminder)
- Introduction to “traditional UI design”
  - Human factors (last week)
  - Theories
  - Principles
  - Guidelines

# Literature

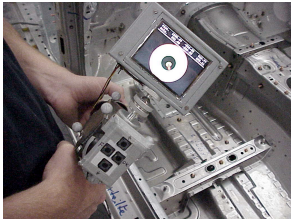
- Ben Shneiderman, “Designing the User Interface, Strategies for Effective Human-Computer Interaction”, Addison Wesley.  
(Chapter 2)

# Motivation

- Augmented Reality as a new, three-dimensional user interface supporting direct manipulation.
- How can it be integrated / used in real applications?
- What are the theories, principles and guidelines of creating good user interfaces?

# Motivation

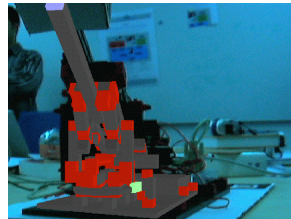
## - Examples -



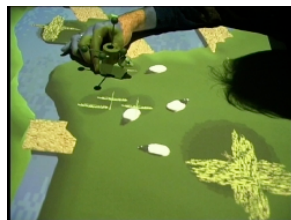
- PAARTI (stud welding)
  - heARts (Minimally invasive surgery)



- Fatamorgana (car design)



- FixIT (diagnosis of machine malfunctions)
  - STARS (plant maintenancs)



- SHEEP (collaborative process control)
  - CAR (rapid prototyping of UI functionality)

1. Human Factors  
(last week)

## 2. Theories

## 2. Theories

- High-Level Theories
- Object-Action Interface Model



## 2.1 High-Level Theories

- Predictive
  - Perceptual/Cognitive Tasks
  - Motor Tasks
- Explanatory
  - Taxonomies

# 2.1 High-Level Theories

## - Taxonomies -

- Input Devices
  - direct vs. indirect
  - linear vs. rotary
- Tasks
  - structured vs. unstructured
  - controllable vs. immutable
- Personality Styles
  - convergent vs. divergent
  - field dependent vs. independent
- Technical Aptitudes
  - spatial visualization
  - reasoning
- User Experience Levels
  - novice vs. knowledgeable vs. expert
- User Interface Styles
  - menus vs. form-fillins vs. commands

# 2.1 High-Level Theories

## - Overview -

- Top-Down Model
- GOMS and keystrokes model
- Stages of Action Model
- Consistency through grammars
- Widget-level theories

# 2.1 High-Level Theories

## - Top-Down Model -

Separation of concerns

# 2.1 High-Level Theories

## - Top-Down Model -

- Conceptual Level
  - user's mental model
- Semantic Level
  - meanings conveyed by the user's command input and by the computer's output display
- Syntactic Level
  - assembly of units (words) into complete sentences
- Lexical Level
  - device dependencies, precise mechanisms of specifying syntax

## 2.1 High-Level Theories

### - GOMS and Keystroke-Model -

“How to do it” knowledge is described in a formal form that can be executed, performance can be predicted

## 2.1 High-Level Theories

### - GOMS and Keystroke-Model -

- GOMS
  - Goals  
and subgoals of users
  - Methods  
and procedures are used by the users (coarse grain)
  - Operators  
on elementary perceptual motor/cognitive acts (fine grain)
  - Selection rules  
control structure to choose among several methods
- Keystroke-Level Model
  - Production rules  
to describe conditions and actions

## 2.1 High-Level Theories - Stages of Action Models -

Describe user exploration of an interface



## 2.1 High-Level Theories

### - Stages of Action Models -

- Users go through 7 stages of action in trying to use a system
  - Form the goal
  - Form the intention
  - Specify the action
  - Execute the action
  - Perceive the system state
  - Interpret the system state
  - Evaluate the outcome
- Key ideas:
  - Cycle of action
  - Evaluation
  - Gulf of execution mismatch: user's intention vs. allowable action
  - Gulf of evaluation mismatch: system's representations vs. user's expectations

## 2.1 High-Level Theories - Stages of Action Models -

- 4 principles of good design
  - State and action alternatives should be visible
  - Good conceptual model with consistent system image
  - Interface must include good mappings that reveal the relationships between stages
  - User should receive continuous feedback
- Emphasis on studying errors, occurring when moving from <goals> to <intentions> to <actions> to <executions>

## 2.1 High-Level Theories

### - Stages of Action Models -

- Helps describe user exploration of an interface
- Critical points for a user interface
  - Users can form an inadequate goal
  - Users might not find the correct interface object due to incomprehensible icon or label
  - Users may not know how to specify or execute a desired action
  - Users may receive inappropriate or misleading feedback

## 2.1 High-Level Theories

### - Consistency Through Grammars-

Enforce consistency and completeness of an  
interface

## 2.1 High-Level Theories

### - Consistency Through Grammars-

- In order to be easy to learn and to retain, a command language / set of actions should be
  - orderly
  - predictable
  - describable by a few rules
- Concepts of consistency and completeness

## 2.1 High-Level Theories - Widget-Level Theories -

Build upon simplifications provided by well-established sets of widgets

## 2.1 High-Level Theories

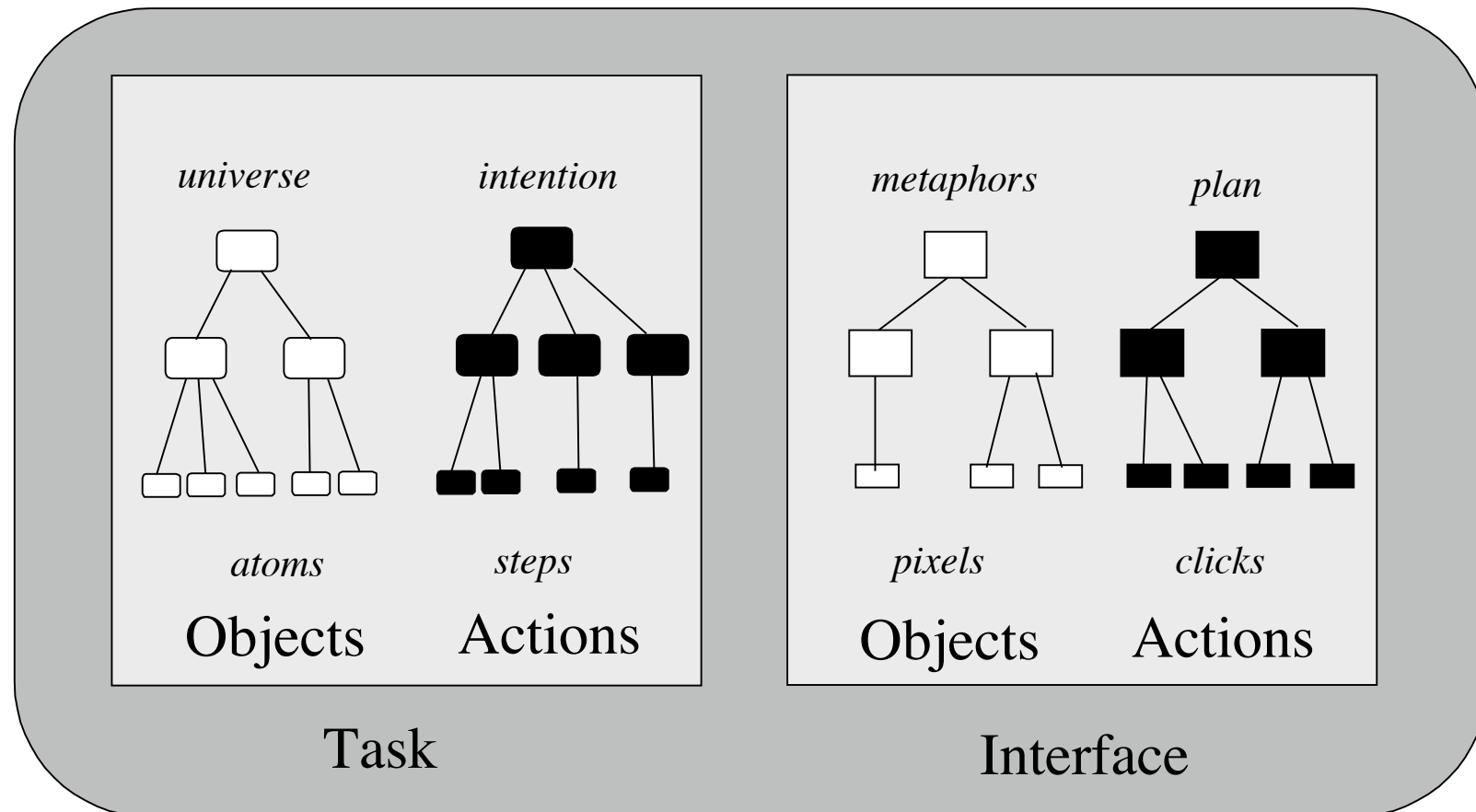
### - Widget-Level Theories -

- Hierarchical decomposition ok, but often too many details.
- Follow simplifications on the higher level of UI building tools
- Measure of layout appropriateness
  - associated widgets should be next to one another
  - left-to-right sequence according to task sequence

## 2.2 Object-Action Interface Model



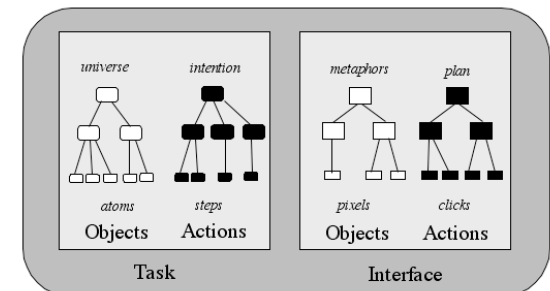
## 2.2 Object-Action Interface Model - General Concept: OAI -



## 2.2 Object-Action Interface Model

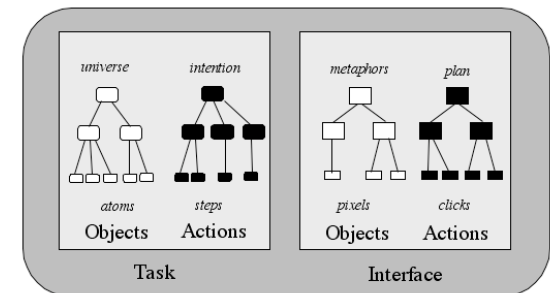
### - Task Hierarchies of Objects and Actions -

- Decomposition of real-world objects
- Decomposition of intentions into smaller steps
- System support for professionals:
  - Designers must learn about the application domain before building interfaces
  - Users must know the domain before using interfaces



## 2.2 Object-Action Interface Model

- Interface Hierarchies of Objects and Actions -
  - Interface object deals with storage in a computer (directories, files)
  - Interface action (high-level plan, mid-level plan, low-level plan)
- Metaphoric representation (abstract vs. concrete vs. analogical)
- Users learn by watching a demo, hearing explanations, or conducting trial-&-error sessions



## 2.2 Object-Action Interface Model

### - Disappearance of Syntax -

- Command interface: many special keys
  - position, meaning varies across systems and languages
  - rote memorization
  - formal notations (BNF) confusing to non-computer scientists
- OK for experts, but not for novices and knowledgeable users
- Better: menus

# 3. Principles

# 3. Principles

- Principle 1: Recognize Diversity
- Principle 2: Eight Golden Rules of Interface Design
- Principle 3: Prevent Errors

# 3.1 Principle 1: Recognize Diversity

- Usage profiles
- Task profiles
- Interaction styles

# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -



# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -

### “Know Thy User”

- Population profiles
  - e.g., age, gender, physical abilities, education, cultural/ethnic background, training, motivation, goals, personality
- User communities
  - e.g., teachers, nurses, doctors, programmers, museum patrons, librarians, ...
- Different countries
- Location
  - urban vs. rural
- Economic profile
- Disabilities
- Attitude towards using technology
- Specific knowledge
  - e.g., boolean expressions, set theory, foreign languages, map icons, ...

# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -

Generic separation (different design goals)

- Novice / first-time user
- Knowledgeable / intermittent user
- Expert / frequent user

# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -

### Novice / first-time user

- no/some knowledge of task
- no knowledge of interface
  
- interface with instruction, dialog boxes, online help
- restricted vocabulary
- small number of actions
- informative feedback
- constructive, specific error messages
- carefully designed paper manuals
- step-by-step online tutorials

# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -

### Knowledgeable / intermittent user

- works with many systems, has broad interface concepts
- stable task concepts
- difficulty retaining structure of particular interface
  
- orderly menu structure
- consistent terminology
- high interface awareness
- consistent action sequences
- meaningful messages
- guides to frequent patterns of usage
- protection from danger to support a relaxed exploration of features and attempts to invoke a partially forgotten action sequence
- online help screens to fill in missing pieces
- well-organized reference manuals

# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -

### Expert / frequent user

- thoroughly familiar with task and interface
- seeks to get work done
  
- rapid response times
- brief non-distracting feedback
- carries out actions with a few keystrokes / selections (creation of macros)
- accelerators
  - command strings
  - shortcuts through menus
  - abbreviations

# 3.1 Principle 1: Recognize Diversity

## - Usage Profiles -

Designing for several classes of users

- level-structured (layered, spiral) approach
- permit users to control the density of information feedback

# 3.1 Principle 1: Recognize Diversity

## - Task Profiles -

# 3.1 Principle 1: Recognize Diversity

## - Task Profiles -

- Task analysis should be done before UI design
- but often, new commands/features are added incrementally
- Design / implementation convenience should not dictate system functionality
  - High-level actions decomposed into mid-level, atomic actions
  - What is the right set of atomic actions? (RISC, CISC)
  - Shape menu tree according to relative task frequencies



# 3.1 Principle 1: Recognize Diversity

## - Interaction Styles -

# 3.1 Principle 1: Recognize Diversity

## - Interaction Styles -

- Direct manipulation
  - appealing to novices
  - easy to remember for intermittent users
  - rapid for frequent users
- Menu selection
  - appropriate for novice, intermittent users
  - can be appealing to experts, if display is rapid
- Form fillin
  - best for knowledgeable, expert users
- Command language
  - for frequent users
- Natural language
  - great goal, limited success so far

## 3.2 Principle 2: Eight Golden Rules of Interface Design

## 3.2 Principle 2: Eight Golden Rules of Interface Design

1. Strive for consistency
2. Enable frequent users to use shortcuts
3. Offer informative feedback
4. Design dialogs to yield closure
5. Offer error prevention and simple error handling
6. Permit easy reversal of actions
7. Support internal locus of control
8. Reduce short-term memory load

## 3.2 Principle 2: Eight Golden Rules of Interface Design

### 1. Strive for consistency

- consistent action sequence for similar situations
- identical terminology in prompts, menus, help screens
- consistent color, layout, capitalizations, fonts

some exceptions

## 3.2 Principle 2: Eight Golden Rules of Interface Design

2. Enable frequent users to use shortcuts

- abbreviations
- special keys
- hidden commands
- macro facilities

short response time

fast display rates

## 3.2 Principle 2: Eight Golden Rules of Interface Design

### 3. Offer informative feedback

- system feedback for every user action
  - modest feedback for frequent/minor actions
  - substantial feedback for infrequent/major actions
- visual presentation of objects of interest often convenient

## 3.2 Principle 2: Eight Golden Rules of Interface Design

### 4. Design dialogs to yield closure

- define action sequences (groups of actions)
  - <beginning> <middle> <end>
- feedback at completion of a group of actions
  - satisfaction of accomplishment for user
  - sense of relief
  - signal to drop contingency plans
  - indication that the way is clear for next group of actions



## 3.2 Principle 2: Eight Golden Rules of Interface Design

5. Offer error prevention and simple error handling
  - design systems s.t. users cannot make serious errors
    - prefer menu selection over form fillin
    - do not allow alphabetic characters in numeric entry fields
  - detect errors, give simple constructive specific instructions for recovery
    - users should not have to retype an entire command
  - erroneous actions should leave system state unchanged or system should bive instructions how to restore the previous state

## 3.2 Principle 2: Eight Golden Rules of Interface Design

### 6. Permit easy reversal of actions

- relieve user anxiety
- units of reversability
  - single action
  - data entry task
  - complete group of actions

## 3.2 Principle 2: Eight Golden Rules of Interface Design

7. Support internal locus of control (experts)
  - avoid “acausality”:
    - surprising system actions
    - tedious sequences of data entries
    - inability or difficulty in obtaining necessary information
    - inability to produce the action desired
  - users should be the initiators of actions rather than the responders to actions

## 3.2 Principle 2: Eight Golden Rules of Interface Design

### 8. Reduce short-term memory load

- “Humans can remember seven  $\pm$  two chunks”
  - displays must be kept simple
  - multiple page displays must be consolidated
  - frequency of window motion must be reduced
  - sufficient training time for codes, mnemonics, sequences of actions
  - online access to command-syntax form, abbreviations, codes.

## 3.3 Principle 3: Prevent Errors

- Avoid “slips”
  - organize screens, menus functionally
  - design commands / menu choices to be distinctive
  - make it difficult for users to take irreversible actions
  
  - no modes!
  - feedback about system state
  - design command consistence

## 3.3 Principle 3: Prevent Errors

- Correct matching pairs
- Complete sequences
- Correct commands

## 4. Guidelines

## 4. Guidelines

- Guidelines for Data Display
- Guidelines for Data Entry
- Balance of Automation and Human Control



## 4.1 Guidelines for Data Display

- Organizing the display
- Getting the user's attention

# 4.1 Guidelines for Data Display

## - Organizing the Display -

- Consistency of data display
- Efficient information assimilation by the user
- Minimal memory load on user
- Compatibility of data display with data entry
- Flexibility for user control of data display

# 4.1 Guidelines for Data Display

## - Organizing the Display -

### Consistency of data display

- standardized
    - terminology
    - abbreviations
    - formats
    - colors
    - capitalization
- provide a written (or computer-managed) dictionary

# 4.1 Guidelines for Data Display

## - Organizing the Display -

Efficient information assimilation by the user

- familiar format, related to tasks performed on the data
  - neat columns of data
  - left justification for alphanumeric data
  - right justification for integers
  - lining up of decimal points
  - proper spacing
  - comprehensible labels
  - appropriate measurement units and numbers of decimal digits

# 4.1 Guidelines for Data Display

## - Organizing the Display -

Mimimal memory load on user

- don't require users to remember information from one screen to another
- task completion with few actions, minimizing chance to forget a step
- labels and common should be provided for novices and intermittent users

# 4.1 Guidelines for Data Display

## - Organizing the Display -

Compatibility of data display with data entry

- data display similar to data entry
- if possible: editable output fields

# 4.1 Guidelines for Data Display

## - Organizing the Display -

Flexibility for user control of data display

- user-definable order of columns
- user-definable sorting of rows

# 4.1 Guidelines for Data Display

## - Getting the User's Attention -

- Critical situations
  - exceptional conditions
  - time-dependent information
- Level of intensity ( $\leq 2$ )
- Marking styles
- Size ( $\leq 4$ )
- Fonts ( $\leq 3$ )
- Inverse video
- Blinking
- Colors ( $\leq 4$ )
- Color blinking
- Audio



# 4.1 Guidelines for Data Display

## - Getting the User's Attention -

- Beware of cluttered displays by overusing techniques
- For novices:
  - simple
  - logically organized
  - well-labelled displays
- For experts:
  - extensive labels on fields
  - subtle highlighting
  - positional presentation

## 4.2 Guidelines for Data Entry

- Consistency of data-entry transitions
  - similar sequences of actions
  - similar delimiters
  - similar abbreviations
- Minimal input actions by users
  - making a clear choice by a single keystroke, mouseclick,...
  - select from a list of choices (to reduce short term memory load)
  - but: hand-motion is worse than typing some characters
  - avoid redundant data entry
- Minimal memory load on users
- Compatibility of data entry with data display
- Flexibility for user control of data entry

## 4.3 Balance of Automation and Human Control

- Simplify the user's task by eliminating human actions when no judgement is required
- Computers:
  - keep track of and retrieve large volumes of data
  - follow preset patterns
  - carry out complex mathematical or logical operations
- Critical human role:
  - world is an open system
  - computer is a closed system

Fred Brooks: IA > AI

## 4.3 Balance of Automation and Human Control

- Human judgement for unpredictable events
  - incomplete/errorneous data
  - respond to unanticipated situations
  - equipment failure
  - unproper human performance
- Humans must be continually involved s.t. they are well informed and can take over in emergencies

## 4.3 Balance of Automation and Human Control

- Autonomous agents with personalities
- User model to guide system adaptation
- If an adaptive system makes surprising changes, users must pause to see what has happened



# 2.2 Object-Action Interface Model

## - General Concept: OAI -

