CS3483 Notes

Introduction

Core Concepts in HCI

1. **Human-Computer Interaction (HCI)**:
    - Study of how people design, implement, and use interactive computer systems.
    - Examines the impact of computers on individuals, organizations, and society.
2. **Requirements of HCI**:
    - Ease of use (e.g., GUI vs. command language).
    - Online help, documentation, and training.
    - Universal access to information (minimal technical sophistication).
    - Support for diverse data types (e.g., multimedia) and new interaction techniques.
3. **Importance of HCI**:
    - Critical for product success, safety, and user satisfaction.
    - Reduces costs/errors, improves productivity, and decreases training time.

Technological Trends

1. **Wearable Devices & Ubiquitous Computing**:
    - Embedding computers in everyday objects (e.g., Apple Watch).
2. **Recognition-Based Interfaces**:
    - Input via speech, gestures, or body movements.
    - Requires feedback mechanisms to handle recognition errors.
3. **Conversational Interfaces**:
    - **Formal Notation for Response Generation**:

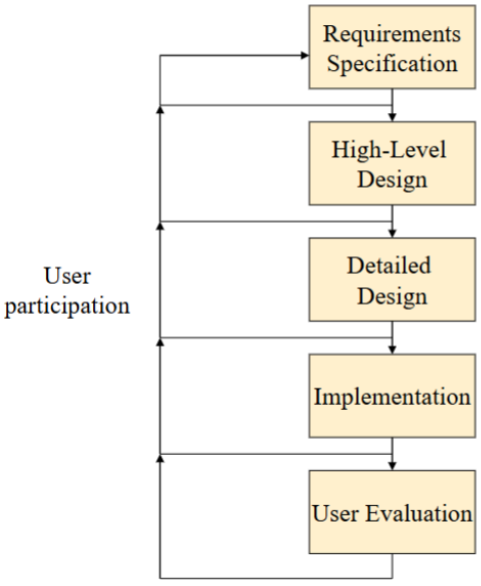
    - Pattern: `"(1) you (3) me"` → Response: `"What makes you think I (3) you"`.
  - Components:
    - Speech recognition → Natural language understanding → Response generation → Speech synthesis.
4. **3-D Technologies**:
  - Challenges: Object selection, navigation, and "near-real-time" interactivity.
  - Applications: Training, simulation, data exploration (e.g., CAVE, data gloves).

Goals of User Interface Design

- **Time to learn**: Duration to master commands.
- **Speed of performance**: Task completion time.
- **Rate of errors**: Frequency/type of user mistakes.
- **Retention over time**: Knowledge recall (linked to learning time/usage frequency).
- **Subjective satisfaction**: User enjoyment.

Human Factors in Interface Design

UI Design Process



Prototyping (For Design)

- **Methods**: Pen/paper, tools (Figma, Sketch), development frameworks (SwiftUI).
- **Advantages**: Low cost, early problem detection, user feedback on alternatives.

Human Diversity in Design

- **Perceptual/Cognitive/Physical Abilities**:
  - Vision, hearing, touch, memory (sensory/short-term/long-term).
  - **Recognition > Recall**: GUIs/icons outperform command-based interfaces.
- **Cultural/International Diversity**: Localized interfaces for global markets.
- **Users with Disabilities**:
  - Visual: Text-to-speech, Braille.
  - Hearing: Visual signals.
  - Mobility: Eye-gaze control, speech recognition.
- **Elderly Users**: Larger fonts, high contrast, simplified devices.

Human Perception Principles

Vision

- **Stages**: Physical reception (eyes → retina) → interpretation (brightness, color).
- **Color Perception**: Hue/intensity/saturation; color blindness (8% males, 0.5% females).

Gestalt Principles of Perception

1. **Prägnanz**: Simplicity/stability in interpretation.
2. **Proximity**: Close objects = grouped.
3. **Similarity**: Shared visual traits = related.
4. **Closure**: Fill gaps to perceive complete shapes.
5. **Continuity**: Prefer smooth over abrupt changes.

6. **Common Fate**: Shared movement = grouped.
7. **Symmetry**: Symmetrical = whole figures.
8. **Area**: Smaller area = foreground.
9. **Surroundedness**: Surrounded area = foreground.

Other Visual Characteristics

- **Stimulus Intensity**: Prioritized over meaning.
- **Size**: Indicates hierarchy.
- **Context Dependence**: Interpretation varies by context.
- **Eye Movement**: Linear reading (centered text disrupts flow).

Hearing

- **Sound Attributes**: Pitch (frequency), loudness (amplitude), timbre (quality).
- **Range**: 20Hz–20kHz; declines with age.
- **Cocktail Party Effect**: Focus on sounds amid noise.

Touch

- Critical for visually impaired; key for mobile gestures.

Memory

- **Sensory**: Immediate input.
- **Short-term**: Rapid access/decay; limited capacity.
- **Long-term**: Slow decay; large capacity.

Accessibility Features

- **Visual Impairments**: Screen readers, high contrast.
- **Hearing Impairments**: Visual alerts.
- **Mobility**: Sticky keys, on-screen keyboards.

Theories and Principles of UI Design

Object-Action Interface Model (OAI)

- **Core Idea**:

    - Icons represent real-world objects; actions on icons mirror real-world actions.
    - **Mapping**:
        - Task object → Interface object
        - Task action → Interface action

Task Hierarchies

- **Objects**:
    - High-level (abstract) → Low-level (concrete components).
- **Actions**:
    - High-level goals → Intermediate sub-goals → Atomic steps.

Task Analysis

- **Decomposition**: Break tasks into sub-tasks; choose atomic actions.
    - **Atomic Action Sizing**:
        - Too small → Excessive steps.
        - Too large → Reduced flexibility.
- **Action Frequency Design**:
    - Frequent: Single-key shortcuts.
    - Intermediate: Few keys/menus.
    - Rare: Multi-step sequences.

GOMS Model

- **Components**:
    - **G**oals: Desired end states.
    - **O**perators: Basic cognitive/motor actions (e.g., keystrokes, clicks).
    - **M**ethods: Learned procedures to achieve goals.
    - **S**election Rules: Choose between methods (e.g., "If large text, use Method A").

Keystroke Level Model (KLM)

- **Predicts expert performance** by summing operator times:
  - **Operators**:
    - **K** (Keystroke): 0.12s (expert) to 1.20s (novice).
    - **P** (Pointing): 1.10s.
    - **B** (Button press/release): 0.10s.
    - **H** (Homing): 0.40s.
    - **M** (Mental preparation): 1.35s.
  - **Formula**:
    - Total time = Sum of operator times (e.g., 2M+2H+P+2B+4K = 5.60s).

Stages of Action Models

1. **Forming the goal**
2. **Forming the intention**
3. **Specifying the action**
4. **Executing the action**
5. **Perceiving system state**
6. **Interpreting system state**
7. **Evaluating the outcome**

- **Key Contributions**:
  - **Gulf of Execution**: Mismatch between user intentions and allowable actions.
  - **Gulf of Evaluation**: Mismatch between user expectations and system feedback.

Eight Principles of Interface Design

1. **Consistency**: Uniform commands, terminology, and layouts.
2. **Universal Usability**: Cater to:
   - **Novices**: Limited actions, clear feedback, tutorials.
   - **Intermittent Users**: Recognition over recall, consistent flows.

- **Experts**: Shortcuts, macros, minimal feedback.

3. **Informative Feedback**: Proportional to action significance.
4. **Dialog Closure**: Group actions with clear beginnings/middles/ends.
5. **Error Prevention & Handling**:
   - Prevent errors (e.g., auto-pairing symbols).
   - Provide specific recovery instructions.
6. **Reversible Actions**: Undo functionality encourages exploration.
7. **User Control**: Avoid surprises; let users initiate actions.
8. **Reduce Memory Load**: Simple displays, contextual help.

Guidelines of User Interface Design

Menus

- **Purpose**: Emphasize recognition over recall; ideal for novices/infrequent users.
- **Types**:
  - **Single Menus**: Binary (yes/no), multiple-item, or multi-selection.
  - **Linear Sequence**: Guides users step-by-step (e.g., wizards).
  - **Tree-Structured**: Hierarchical (categories → subcategories).

    - **Depth vs. Breadth**:
        - Optimal: 4–8 items per menu, ≤3 levels.
        - **Hick's Law**: $t = k\ log_2(N + 1)$ (time for selection).
        - **Total Traversal Time**: $T = D[k_1\ log_2(N + 1) + k_2]$, where $D = log_N P$.
        - i.e. P is the total number of items, N is the number of equally probable
          choices
    - **Networks**:
        - *Acyclic*: Multiple paths to menus.
        - *Cyclic*: Allows revisiting menus.
- **Design Guidelines**:
    - **Item Order**: Group related items; avoid random/mixed sequences.
    - **Layout**: Clear titles, brief labels, separators, keyboard shortcuts.

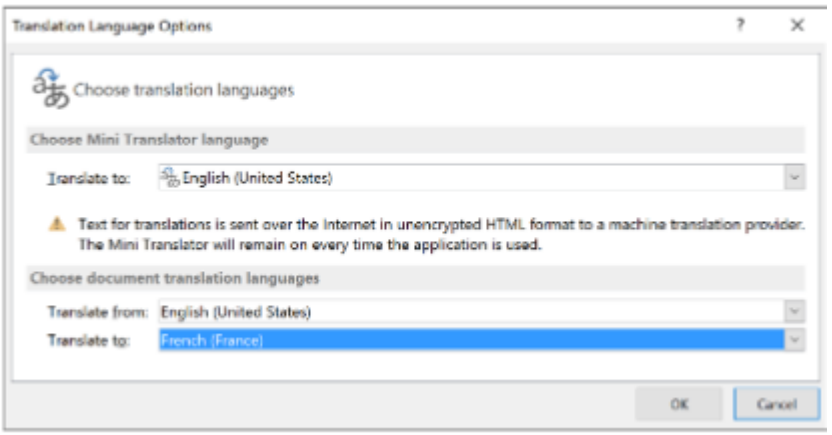
Form Fill-in

- **Use Case**: Data entry (e.g., name/address forms).
- **Design Guidelines**:

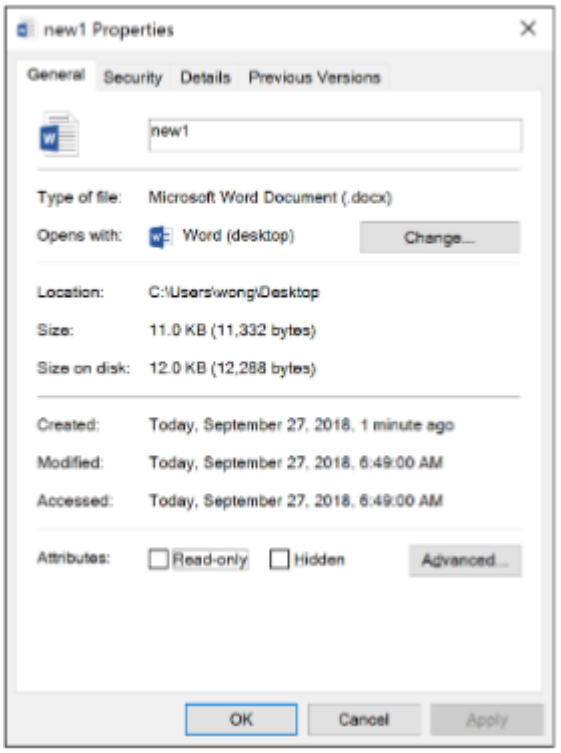
- **Structure**: Logical grouping, familiar labels, consistent terms.
- **Visuals**: Uniform spacing, visible field boundaries.
- **Interaction**: TAB navigation, error prevention/correction.
- **Feedback**: Mark optional fields, provide completion signals.

Secondary Windows

- **Types**:
  - **Modal**: Requires completion before proceeding (critical tasks).
  - **Modeless**: Allows switching between primary/secondary windows (ongoing tasks).
- **Examples**:
  - **Dialog Boxes**: Mirror menu item titles; include OK/Cancel.



  - **Property Windows**: Tabbed attributes with OK/Apply/Cancel.



- **Message Boxes**: Specific error descriptions + solutions.

Tabbed Document Interface (TDI)

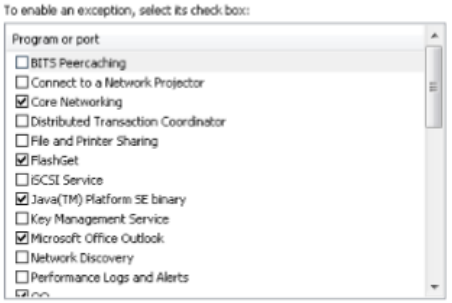
- **Features**:
  - Multiple documents in one window with tabs.
  - Pros: Space-efficient, quick access.
  - Cons: Hard to compare documents side-by-side.
- **General Guidelines**:
  - **Fitts' Law**: Predicts target acquisition time:

    $$t = a + b\ log_2(\frac{D}{S} + 1)$$

    where $S = min\{W, H\}$.
  - Labels, hot zones, access keys.
- **Types**:
  - **Command Buttons**: Trigger actions (short labels).
  - **Radio Buttons**: Mutually exclusive choices (small sets).
  - **Checkboxes**: Independent choices.

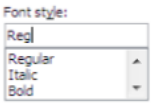
- **List Boxes**:
  - *Single/Multi-selection*: For item lists.

Single-selection list box

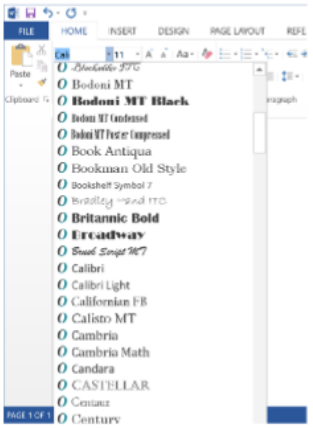


Multiple-selection list box

  - *Drop-down/Combo*: Space-saving; editable (combo).

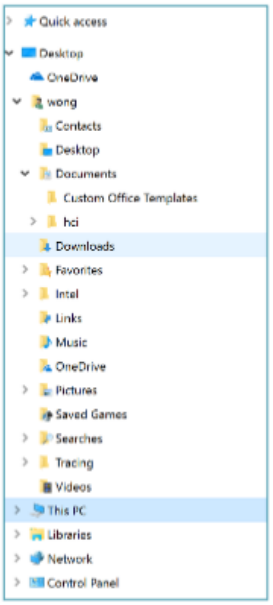


Combo box

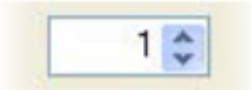


Drop-down combo box

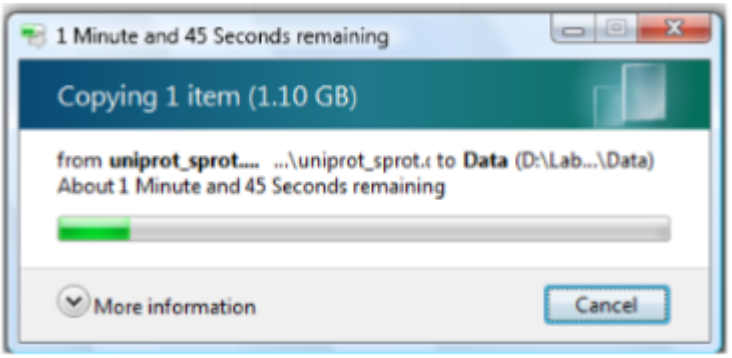
- **Other Controls**:
  - *Scroll Bars*: Incremental/destination actions.
  - *Tree View*: Hierarchical data.



- *Spin Box*: Adjust numeric values.



- *Progress Indicator*: Shows task completion.



- *Slider*: Continuous value adjustment (e.g., volume).

Natural User Interface: Input and Output Devices

- **Objective**: Minimize the *Gulf of Execution* (gap between user intentions and actions).

- **Core Idea**: Leverage innate human skills to reduce training needs.

Input Device Classification

1. **Absolute vs. Relative Measurement**:
   - *Absolute*: Measures actual pointer position (e.g., touchscreen).
   - *Relative*: Measures position change (e.g., mouse).
2. **Direct vs. Indirect Control**:
   - *Direct*: Control surface = display surface (e.g., touchscreen).
   - *Indirect*: Control surface ≠ display surface (e.g., mouse).
3. **Control-Display Ratio (CD Ratio)**:
   - Ratio of input device movement to on-screen movement (e.g., 1:2 for mouse).
   - **Trade-offs**:
     - High CD ratio → Precision.
     - Low CD ratio → Speed/compactness.

3D Tracking Technologies

1. **Magnetic Tracking**:
   - Uses magnetic fields to determine sensor position/orientation.
   - **Accuracy**: ±1.5mm, ±0.5°.
   - **Limitation**: Distorted by ferromagnetic/conductive objects.
2. **Acoustic Tracking**:
   - Measures *time-of-flight* of ultrasonic pulses to calculate distance.
   - **Calculation**: Distance = Speed of sound × Time-of-flight.
   - **Pros**: Low cost.
   - **Cons**: Short range; affected by reflective surfaces.
3. **Camera-Based Tracking**:
   - Uses computer vision to track user movements (no sensors required).

3D Display Systems

1. **Head-Mounted Display (HMD)**:
    - Stereo screens + head motion tracking for dynamic scene adjustment.
2. **CAVE (Cave Automatic Virtual Environment)**:
    - Room-sized stereo projections; head tracking for leading viewer.

Gesture Input Devices

1. **Data Glove**:
    - Tracks finger joints via optical fibers/mechanical sensors.
    - Includes 3D tracker for hand position/orientation.
    - **Challenges**: Discomfort, sizing issues, high cost.
2. **Pinch Glove**:
    - Detects finger touches via conductive materials.
    - **Use Case**: Object selection via pinching gestures.
    - **Limitation**: Rough joint angle estimates.

Gesture Recognition

- **Glove-Based**:
    - Relies on hardware sensors for precise gesture data.
- **Camera-Based**:
    - Uses computer vision to interpret hand/finger positions from video.