Chapter 4: Analyzing the Requirements and Understanding the Design Space

- 3.1 Factors that Influence the User Interface
- 3.2 Analyzing work processes and interaction
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- 3.6 Understanding the Solution Space
- 3.7 Design Space for Input/Output
Basic Input Operations

- Text Input
  - Continuous
  - Keyboard and alike
  - Handwriting
  - Spoken
  - Block
  - Scandoptic camera and OCR
- Pointing & Selection
  - Degree of Freedom
    - 1, 2, 3, 6, <more> DOF
  - Isotonic vs. Isometric
  - Translation function
  - Precision
  - Technology
  - Feedback
- Direct Mapped Controls
  - Hard wired buttons/controls
  - On/off switch
  - Volume slider
  - Physical controls that can be mapped
  - PalmPilot buttons
  - "Internet-keyboard" buttons
  - Industrial applications
- Media capture
  - Media type
    - Audio
    - Images
    - Video
  - Quality/Resolution
  - Technology

Basic Output Operations / Option

- Visual Output
  - Show static
    - Text
    - Images
    - Graphics
  - Animation
    - Text
    - Graphics
    - Video
- Audio
  - Earcons / auditory icons
  - Synthetic sounds
  - Spoken text (natural / synthetic)
  - Music
- Tactile
  - Shapes
  - Forces
- Further senses
  - Smell
  - Temperature
    - ...
- Technologies
  - Visual
    - Paper
    - Objects
    - Displays
  - Audio
    - Speakers
    - 1D/2D/3D
  - Tactile
    - Objects
    - Active force feedback

Complex Input Operations

- Examples of tasks
  - Filling a form = pointing, selection, and text input
  - Annotation in photos = image capture, pointing, and text input
  - Moving a group of files = pointing and selection
- Examples of operations
  - Selection of objects
  - Grouping of objects
  - Moving of objects
  - Navigation in space

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Design Space and Technologies

Why do we need to know about technologies?

- For standard applications
  - Understanding the differences in systems potential
  - Users may have to access / use once software product
- For specific custom made applications
  - Understanding options that are available
  - Creating a different experience (e.g. for exhibition, trade fare, museum, …)
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Pointing Devices with 2DOF

- Pointing devices such as
  • Mouse
  • Track ball
  • Touch screen
  • Eye gaze
  • …
- Off the desktop other technologies and methods are required
  • Virtual touch screen
  • Converting surfaces into input devices
  • Smart Board
  • Human view
  • …

Classification of Pointing devices

- Dimensions
  • 1D / 2D / 3D
- Direct vs. indirect
  → integration with the visual representation
  • Touch screen is direct
  • Mouse is indirect
- Discrete vs. continuous
  → resolution of the sensing
  • Touch screen is discreet
  • Mouse is continuous
- Absolute vs. Relative
  → movement/position used as input
  • Touch screen is absolute
  • Mouse is relative

Examples of Pointing Devices (most with additional functionality)

Virtual Touch Screen

- Surfaces are converted into touch screens
- Image/video is projected onto the surface
- Using a camera (or other tracking technology) gestures are recognized
- Interpretation by software
  • simple – where is someone pointing to
  • complex – gestures, sign language
- Application
  • Kiosk application where vandalism is an issue
  • Research prototypes …

Smart-Board

- Large touch sensitive surface
- Front or back projection
- Interactive screen

Examples of Pointing Devices (most with additional functionality)
Smart-Board
DViT (digital vision touch)

- Vision based, 4 cameras, 100FPS
- Nearly on any surface
- More than one pointers

Example: Window Tap Interface

- locates the position of knocks and taps atop a large sheet of glass.
- piezoelectric pickups
  - located near the sheet's corners
  - record the structural-acoustic waveform
  - relevant characteristics from these signals,
    - amplitudes,
    - frequency components,
    - differential timings
  - to estimate the location of the hit
- simple hardware
- no special adaptation of the glass pane
- knock position resolution of about s=2 cm across 1.5 meters of glass
http://www.media.mit.edu/resenv/Tapper/

What is the drawback of 2D interaction using a single Pointing device?

- With 2DOF most often time multiplexing is implied!
- One operation at the time (e.g. slider can be only be moved sequentially with the mouse)
Game Controllers
Force feedback
more degrees of freedom
time-multiplex is an issue

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3D Input
6 DOF Interfaces
- 3D input is common and required in many different domains
  - Creation and manipulation of 3D models (creating animations)
  - Navigation in 3D information (e.g. medical images)
- Can be simulated with standard input devices
  - Keyboard and text input (6 values)
  - 2DOF pointing device and modes
  - Gestures
- Devices that offer 6 degrees of freedom
  - Criteria
    - Speed
    - Accuracy
    - Ease of learning
    - Fatigue
    - Coordination
    - Device persistence and acquisition
  - Little common understanding

Basic Terms: different rotations
Translation
rotation

6DOF
Controller resistance
- Isotonic = device is moving, resistance stays the same
  - Displacement of device is mapped to displacement of the cursor
- Elastic
- Isometric = device is not moved
  - Force is mapped to rate control

Transfer function
- Position control
  - Free moving (isotonic) devices – device displacement is mapped/scaled to position
- Rate control
  - Force or displacement is mapped onto cursor velocity
  - Integration of input over time -> first order control

Analysis of Position versus Rate Control

http://liftoff.msfc.nasa.gov/academy/rocket_sci/shuttle/attitude/pyr.html
http://vered.rose.utoronto.ca/people/shumin_dir/papers/PhD_Thesis/Chapter2/Chapter23.html
Performance depends on transfer function and resistance

Controller resistance
- Isometric
  - pressure devices / force devices
  - infinite resistance
  - device that senses force but does not perceptibly move
- Isotonic
  - displacement devices, free moving devices or unloaded devices
  - zero or constant resistance
- Elastic: Device’s resistive force increases with displacement, also called spring-loaded
- Viscous: resistance increases with velocity of movement,
- Inertial: resistance increases with acceleration

Flying Mice (I)
- a mouse that can be moved and rotated in the air for 3D object manipulation.
- Many different types...
- flying mouse is a free-moving, i.e. isotonic device.
- displacement of the device is typically mapped to a cursor displacement.
- Such type of mapping (transfer function) is also called position control.

Flying Mice (II)
- The advantages of these "flying mice" devices are:
  - Easy to learn, because of the natural, direct mapping.
  - Relatively fast speed
- disadvantages to this class of devices:
  - Limited movement range. Since it is position control, hand movement can be mapped to only a limited range of the display space.
  - Lack of control feel. Since an isotonic device feels completely rigid

Stationary devices (I)
- devices that are mounted on stationary surface.
- Have a self-centering mechanism
- They are either isometric devices that do not move by a significantly perceptible magnitude or elastic devices that are spring-loaded.
- Typically these devices work in rate control mode, i.e. the input variable, either force or displacement, is mapped onto the velocity of the cursor.
- The cursor position is the integration of input variable over time.

Stationary devices (II)
- isometric device (used with rate control) offers the following advantages:
  - Reduced fatigue, since the user’s arm can be rested on the desktop.
  - Increased coordination. The integral transformation in rate control makes the actual cursor movement a step removed from the hand anatomy.
  - Smoother and more steady cursor movement. The rate control mechanism (integration) is a low pass filter, reducing high frequency noises.
- Device persistence and faster acquisition. Since these devices stay stationary on the desktop, they can be acquired more easily.
- isometric rate control devices may have the following disadvantages:
  - Rate control is an acquired skill. A user typically takes tens of minutes, to gain controllability of isometric rate control devices.
  - Lack of control feel. Since an isometric device feels completely rigid
Multi DOF Armatures

- multi DOF input devices are mechanical armatures.
- the armature is actually a hybrid between a flying-mouse type of device and a stationary device.
- Can be seen as a are near isotonic - with exceptional singularity positions - position control device (like a flying mouse)
- has the following particular advantages:
  - Not susceptible to interference.
  - Less delay: response is usually better than most flying mouse technology
- Can be configured to "stay put", when friction on joints is adjusted and therefore better for device acquisition.
- drawbacks:
  - Fatigue: as with flying mouse.
  - Constrained operation. The user has to carry the mechanical arm to operate. At certain singular points, position/orientation is awkward.
- This class of devices can also be equipped with force feedback, see later Phantom Device

Technology Examples

Data Glove

- Data glove to input information about
  - Orientation, (roll, pitch)
  - Angle of joints
  - Sometimes position (external tracking).
- Time resolution about. 150...200 Hz
- Precision (price dependent):
  - Up to 0.5 ° for expensive devices (> 10.000 €)
  - Cheap devices (€100) much less

3D-Mouse

- Spacemouse und Spaceball:
  - Object (e.g. Ball) is elastically mounted
  - Pressure, pull, torsion are measured
  - Dynamic positioning
- 6DOF

http://www.alsos.com/Products.Devices.SpaceBall.html

3D-Graphic Tablet

- Graphic tablets with 3 dimensions
- Tracking to acquire spatial position (e.g. using Ultrasound)

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- Force Feedback Mouse

- Pointing devices with force feedback:
  - Feeling a resistance that is controllable
  - Active force of the device
  - Common in game controllers (often very simple vibration motors)
- Examples in desktop use
  - Menu slots that snap in
  - feel icons
  - Feel different surfaces
  - Can be used to increase accessibility for visually impaired
- Logitech iFeel Mouse
  - http://www.dansdata.com/ifeel.htm
Phantom – Haptic Device

- high-fidelity 3D force-feedback input device with 6DOF
- GHOST SDK to program it

www.sensable.com

Specification: PHANTOM® Omni™ Haptic Device

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footprint (Physical area</td>
<td>6 5/8 W x 8 D in. ~168 W x 203 D mm.</td>
</tr>
<tr>
<td>device base occupies on desk</td>
<td></td>
</tr>
<tr>
<td>Range of motion</td>
<td>Hand movement pivoting at wrist</td>
</tr>
<tr>
<td>Nominal position resolution</td>
<td>&gt; 450 dpi. ~ 0.055 mm.</td>
</tr>
<tr>
<td>Maximum exertable force</td>
<td>0.75 lbf. (3.3 N)</td>
</tr>
<tr>
<td>at nominal (orthogonal arms)</td>
<td></td>
</tr>
<tr>
<td>position</td>
<td></td>
</tr>
<tr>
<td>Force feedback</td>
<td>x, y, z</td>
</tr>
<tr>
<td>Position sensing</td>
<td>x, y, z (digital encoders)</td>
</tr>
<tr>
<td>(Stylus gimbal)</td>
<td>(Pitch, roll, yaw ± 0.5%</td>
</tr>
<tr>
<td></td>
<td>linearity potentiometers)</td>
</tr>
<tr>
<td>Applications</td>
<td>Selected Types of Haptic Research and</td>
</tr>
<tr>
<td></td>
<td>The FreeForm® Concept™ system</td>
</tr>
</tbody>
</table>

Examples: Programming Abstractions for haptic devices

- GHOST SDK
  

- OpenHaptics™ Toolkit
  

  - toolkit is patterned after the OpenGL® API
  - Using existing OpenGL code for specifying geometry, and supplement it with OpenHaptics commands to simulate haptic material properties such as friction and stiffness

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Taxonomy for Input Devices (Buxton)

- continuous vs discrete?
- agent of control (hand, foot, voice, eyes ...)?
- what is being sensed (position, motion or pressure), and the number of dimensions being sensed (1, 2 or 3)
- devices that are operated using similar motor skills
- devices that are operated by touch vs. those that require a mechanical intermediary between the hand and the sensing mechanism
“...basically, an input device is a transducer from the physical properties of the world into the logical parameters of an application.” (Bill Buxton)

Physical Properties used by Input devices (Card91)

<table>
<thead>
<tr>
<th>Linear</th>
<th>Rotary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Position</td>
</tr>
<tr>
<td>Absolute</td>
<td>P (Position)</td>
</tr>
<tr>
<td>Relative</td>
<td>dP</td>
</tr>
<tr>
<td>Force</td>
<td>Force</td>
</tr>
<tr>
<td>Absolute</td>
<td>F (Force)</td>
</tr>
<tr>
<td>Relative</td>
<td>dF</td>
</tr>
</tbody>
</table>


Example: Touch Screen

Example: Wheel mouse
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Exertion Interfaces

Exertion Interfaces
http://www.exertioninterfaces.com/technical_details/index.htm

Example: Vision-Based Face Tracking System for Large Displays

- stereo-based face tracking system
- can track the 3D position and orientation of a user in real-time
- application for interaction with a large display

Example: Vision-Based Face Tracking System for Large Displays


Input beyond the screen
- Capture (photo, tracking)
- Interactive modeling

Capture Interaction
- Mimio
  - Tracking of flip chart makers
  - Capture writing and drawing on a large scale
- PC Notes Taker
  - Capture drawing and handwriting on small scale

Photo Capture
- Write on traditional surfaces, e.g. blackboard, white board, napkin
- Capture with digital camera
New applications due the availability of capture tools
- Paper becomes an input medium again (people just take a picture of it)
- Public displays can be copied (e.g. taking a picture of an online time table on a ticket machine)

Interactive Modelling (Merl)

Interactive Modelling Cont. (Merl)

References
- Computer Rope Interface
  http://web.merl.com/cgi-bin/Copy%20Rope/Interface/index.htm
- Vision Systems for Interactive Surfaces, E. Petriella, K. Plakias, J. Steck, J. Lifton, and A. Adler,
- Window: Tap Interface
- Vision-Based Face Tracking System for Large Displays
- Logitech iFeel Mouse
  http://www.dansdata.com/ifeel.htm
- Exertion Interfaces
  http://www.exertioninterfaces.com/technical_details/index.htm