Interaction Concepts for Adaptive Automotive User Interfaces

Master Seminar

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Outline

• Introduction
• Objective
• Related Work
• Methodology
• Summary
Interactive In-Car Systems

• Power Window Control System

• Driver Assistance System
  – Parking Assistance
  – Adaptive Cruise Control
  – ...

• In-Vehicle Information System
  – Navigation System
  – Internet Services
  – ...

• Entertainment System
Interactive In-Car Systems

- Interactions in the car
  - Primary Task – maneuvering
  - Secondary Task – maintaining safety
  - Tertiary Task – all other comfort
Interactive In-Car Systems

• Advantages:
  – Enhance Safety
  – Stay Connected with Outside World
  – Accessibility
  – Entertaining
Interactive In-Car System

• Effects:
  – Changes Driver Behavior and Performance
  – Leads to Driver Distraction
  – Threat to safe driving
Driver Distraction

- Driver distraction and inattention has become a leading cause of motor-vehicle crashes
  - Nearly 80% of crashes and 65% of near-crashes (the 100-car study)
  - Increasing use of In-Vehicle Information Systems (IVISs), such as, navigation systems, MP3 players, and internet services
Interactive In-Car System

• Other Issues
  – Usability
  – Work Load
  – Hardware Support
Goal – To strike balance
Solution

• Every cat has a Mouse

• Most Problems have a solution
Why this problem exists?

• It’s not because of

• But, it rely on
How we can Optimize?

Interaction/Interface Concepts

Choice of the optimal concept in the right situation, i.e.
* For a certain task(function)
* For a certain context/device
* For a certain user
Interaction Techniques

An interaction technique is the fusion of input and output, consisting of all software and hardware elements, that provides a way for the user to accomplish a task.
Touch Screen

- Can be used for both Input and Output Modalities

- Advantages:
  - Low Error
  - More Interactive

- Disadvantages:
  - Not hands free Interaction
  - Requires more attention (Visual in Particular)
Speech Interaction

• Advantages:
  – Hands-free
  – Eyes-free

• Disadvantages:
  – Requires Patience
  – Speech Recognition Errors
Integrated Operations

- Buttons, Knobs, Joystick

Examples:
1. BMW iDrive
2. Lexus Remote Touch
Gestures

• Alternative to existing input modalities
• Offers Hand and Head Gesture Interactions

Advantages:
• Less Distracting
• More Intuitive

Disadvantages:
• Remembering Gestures
• Gesture Recognition Errors
Discrete Hand Gestures

1. next menu point
   move object right

2. last menu point
   move object left

3. increase volume
   move object up

4. reduce volume
   move object down

5. downsize object

6. enlarge object

7. choose actual menu point

8. mute volume
   abort function
and more..

- Eye Tracking
- Face Recognition
- Haptic Interaction

1-6 Haptic feedback
steering wheel vibration
accentuate real world feedback
Futuristic Approach

• Brain Computer Interfaces
• “Cyborg” from Mercedes Benz
How Interface Design Can Influence Driver Performance

Results: Average Number of Lane Exceedences per Trial by Device

- Nav System - Joystick Entry
- Nav System - Knob Entry
- Nav System - Voice Entry
- Nav System - Key Entry
- Cell Phone - Dialing
- Radio - Tune

Device

Average Number of Lane Exceedences
Adaptive User Interface

- Adaptation
  - System Adapts itself to the User/Context

- Context Adaptation
  - Adaptation of services to the changes in environment

- User Adaptation
  - Achieving Personalization
  - Example: Making the Interaction adaptive according to user profile (Age, Gender, Bad Sight etc.,)
Context Adaptation

• Car Vs. Motorbike

• Situations
Achieving Personalization

1. Acquire User Data
2. Represent and Store Information
3. Analyze User Behavior and Draw Inference
4. Adapt System parameters to Individual Users
5. Realize Adaptations
How to Acquire Data?

- Sensors
- Usage Log
- External User Profiles

- User profile / context data
  (comes from a knowledge management component)
“Best Practices” to do it?

→ Useware Design Principles

• Design Processes → Four Iterative Phases (Analysis, Structuring, Design and Realization)
  – to understand human abilities and limitations and
  – to focus the technology on these abilities and limitations.

• Provides Robustness and Safety
  – Used in Industry Grade Applications (→ Automotive Industry too)

• Usage Concepts
  – Splitting a Function into smaller Atomic Task
  – Refinement of Task at each stage of the function development.

• Atomic Task Examples
  – Enter a Numeric Value (In range)
  – Yes/No Answer
  – Zoom an Image
  – ...
Objective

1. Which Interaction Methods are applicable for different types of Vehicles and by different Users?

2. What are the Usage Concepts in car context that should be supported by in-car Functions?

3. How can UIML support these concepts?

4. How can adaptation be achieved?
Related Work

Useware Engineering Process:
- Incorporates users and clients into all project phases (Iterative)
- Different (overlapping) main phases:
  - **Analysis**: Understanding the users, their tasks and the context-of-use
  - **Structuring**: Deduction of a single, harmonized task structure
  - **Design**: Deduction of abstract & concrete UIs
  - **Evaluation**: Iterative testing of mock-ups/prototypes with users

→ Approved in many different research- and industrial projects since 1991
Related Work

Useware Engineering Example

Task & concepts (useML)

Abstract UI (DISL)

Concrete UI (UIML)

Final UI (Java/Swing)
Related Work

- SmartWeb provides a context-aware user interface, so that it can support the user in different roles. e.g. as a car driver, a motor biker

- Interface designed in a circular shape, just as the wheel control on the handle
Related Work – BMW iDrive

• Integrated Operations – Push Turn Dial Buttons
• Division of Tasks – Minimizes Driver Distraction
Methodology: Selection and Evaluation of Interaction Concepts

1. Deciding on Interaction Techniques for different context
   - Theoretical

2. Deciding on Usage Concepts
   - Experimental

3. Evaluating the Interaction concept for the usage concepts

4. Demonstrating the outcome on Actual hardware
Methodology

RQ-1: Which modalities / interaction methods are applicable for different types of vehicles and by different users?
Methodology

• Research on Existing Interaction Concepts

• Filtering the best ones for Cars and Motorbikes, based on
  – Driver Distraction
  – Usability
  – User Performance
  – Hardware Support
  – Other metrics..
<table>
<thead>
<tr>
<th>Input</th>
<th>References</th>
<th>Modalities</th>
<th>Distraction</th>
<th>Application</th>
<th>Measured Metrics</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>1. Multi-Touch Enable Steering Wheel – Max Pfeiffer et al.</td>
<td>Multi Touch Gesture Input</td>
<td>Distraction were recorded</td>
<td>General</td>
<td>Usability - High (using Gestures)</td>
<td>Remembering gestures is difficult</td>
</tr>
<tr>
<td></td>
<td>2. The New BMW iDrive – Bernhard Niedermaier et al.</td>
<td>Buttons and Knobs</td>
<td>Division of tasks to minimize Distraction Level</td>
<td>General</td>
<td>Performance – Increases (Division of tasks)</td>
<td>Increase difficult with more controls</td>
</tr>
<tr>
<td>Motorbike</td>
<td>1. Context-sensitive, P2P-based detection and representation risks in a motorcycle environment – Frank Reolon</td>
<td>Buttons and Rotating Knobs in Handle Bar</td>
<td></td>
<td>General</td>
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<tr>
<td></td>
<td>Robust Speech Interaction in Motorcycle Interaction – Iosif Mporas et al.</td>
<td>Speech Input Through Helmut Setting</td>
<td>Aims to achieve Zero-Distraction</td>
<td>Police Vehicles</td>
<td>Usability – Increases with Multimodal Interaction</td>
<td>Multimodal Interaction makes more efficient</td>
</tr>
<tr>
<td>Output</td>
<td>1. Multi-Touch Enable Steering Wheel – Max Pfeiffer et al.</td>
<td>Visual Output on Steering Wheel/HUD</td>
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<td>2. The New BMW iDrive – Bernhard Niedermaier et al.</td>
<td>Highly Mounted Displays</td>
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</tbody>
</table>
## Preliminary Results: Car vs. Motorbike

<table>
<thead>
<tr>
<th>Car</th>
<th>Motorbike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safer than Motorbike</td>
<td>Cognitive Load is Higher</td>
</tr>
<tr>
<td>Time to Relax</td>
<td>Not Hands Free</td>
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<tr>
<td>High Comfort Level</td>
<td>Prone to Outside Environment</td>
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<tr>
<td></td>
<td>Difficult to Interact</td>
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<td></td>
<td>Example: Wearing Gloves, Helmut</td>
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<td></td>
<td>More Ergonomics Concern on HMI Design</td>
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<tr>
<td></td>
<td>Instrumentation Issues. Example: Camera for Face Recognition</td>
</tr>
<tr>
<td></td>
<td>Car</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td><strong>Output</strong></td>
</tr>
<tr>
<td>Touch</td>
<td>Visual Displays</td>
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<tr>
<td>Speech</td>
<td>Heads-up Displays</td>
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<td>Eye Tracking</td>
<td>Speech</td>
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<td>Gestures</td>
<td>Haptic Feedback</td>
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<td>Integrated</td>
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<tr>
<td>Operations</td>
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<tr>
<td>Face Recognition</td>
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</tr>
</tbody>
</table>
Methodology

RQ-2: What are typical usage concepts in the car context that should be supported for in-car functions?

Step 1: Finding out the usage concepts that should be supported by in-car functions

Step 2: Filtering the most likely suitable “Interaction Concept” for the respective “Atomic Task”
Usage Concepts Examples

1. Enter a Numeric Value (In Range)

2. Yes/No Answer
## Preliminary Results: Usage Concepts

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Interface Concepts</th>
<th>Interaction Concepts</th>
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<tbody>
<tr>
<td>Enter a Numeric Value</td>
<td>1. Text Box</td>
<td>1. Touch</td>
</tr>
<tr>
<td></td>
<td>2. Input Buttons</td>
<td>2. Speech</td>
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<tr>
<td></td>
<td></td>
<td>3. Eye Tracker</td>
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<td>4. Integrated Operations</td>
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<td></td>
<td>5. Gestures</td>
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<tr>
<td>Yes/No Answer</td>
<td>1. Radio Button</td>
<td>1. Touch</td>
</tr>
<tr>
<td></td>
<td>2. Button</td>
<td>2. Speech</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Eye Tracker</td>
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<td>4. Integrated Operations</td>
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</tbody>
</table>

More Tasks...
- Entering a String
- Menu Item Selection
- Zoom an Image
- Toggle Between Views
- ......
Preliminary Results: Usage Concepts

Tasks

Interface Concepts

Interaction Concepts

Enter a Numeric Value
1. Text Box
2. Input Buttons
1. Touch
2. Speech
3. Eye Tracker
4. Integrated Operations

Yes/No Answer
1. Radio Button
2. Button
1. Touch
2. Speech
3. Eye Tracker
4. Integrated Operations

Select an item from Menu
1. Menu Control (Tree)
1. Touch
2. Speech
3. Eye Tracker
4. Integrated Operations

Selecting a Named Location (e.g., Pushpin in maps)
1. Push pin
2. Button (Icon) Control
1. Touch
2. Speech
3. Eye Tracker
4. Integrated Operations
Methodology

**RQ-3:** How can elements in a concrete language (UIML) be designed to support these concepts for certain interaction methods?
UIML

- UIML – User Interface Markup Language
- UIML is an XML language for defining user interfaces
- Independent of the Device being used
- Provides adaptation for the form factor
- Translated into HTML, Flash, Java etc., using the corresponding renderers
Proposed Method

• Developing widgets using UIML to support the usage concepts
Evaluation

• Human Subject Evaluation
  – Evaluating selected combinations of tasks/concepts

Example Combinations:

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<td>5. Gestures</td>
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</tbody>
</table>

– Driving Simulator
– Conditions
  • Car vs. Motorcycle
  • With/without adaptation
Evaluation

• Evaluation Metrics
  – Cognitive Load → Distraction
  – Timing
  – Error Rates
  – Usability / User satisfaction
Demonstration

- Demonstration on actual hardware from BMW
- Interacting through Knob and two buttons
Summary

- Research on Interaction Concepts
- Usage Concepts Identification
- Development of widgets using UIML
- Human Subject Evaluation
- DEMO
Thank You!!
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