The Need for an Interaction Cost Model in Adaptive Interfaces

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Advances in Visual Interfaces (AVI’08)
Need for Software Customization

• Increasing complexity
  – Lost in interface/functionality
  – Repeated customization effort

• Most affected users
  – People with cognitive, sensory, motor impairments
  – Elderly people
  – Children
  – Novices
Intelligent Interfaces

• Design objectives
  – Minimize user effort
  – Maximize ease of interaction

• Existing implementations:
  – Auto-completion
  – Toolbar suggestions
  – Adaptive menus (add/hide/move)
  – Etc.
Research Objectives

• Account for existing interaction factors

• Predict costs/benefits of interaction

• Explain individual differences
Decision-Theoretic Framework

• Actions lead to outcomes probabilistically

• Impact of intelligent actions

• Tradeoffs between costs and benefits

• Maximizing (long-term) \textit{expected utility}
## Utility of Customization Actions

- **Impact of actions:**

<table>
<thead>
<tr>
<th>Action</th>
<th>Savings</th>
<th>Processing</th>
<th>Occlusion</th>
<th>Bloat</th>
<th>Disruption</th>
<th>Interruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTO</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>TOOLBAR</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ADD</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HIDE</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>MOVE</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HINT</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ASK</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Utility of Customization Actions

• Compute utility of each interaction factor

• Overall Utility = $w_1 \text{utility}_{\text{factor}_1} + w_2 \text{utility}_{\text{factor}_2} + \ldots$

• Each component models:
  • Objective value
  • Subjective utility
Utility of Customization Actions

• Compute utility of each interaction factor

• Overall Utility = \( w_1 \text{utility}_{\text{factor1}} + w_2 \text{utility}_{\text{factor2}} + \ldots \)

• Each component models:
  - **Objective value**
  - **Subjective utility**

Models existing interaction factors
Predicts costs/benefits of interaction
Models individual differences
Interaction Cost Model

• Predictive model of interaction factors
  • Savings
  • Information processing
  • Occlusion
  • Bloat
  • Disruption
  • Interruption
Model of Savings

- Quality = GOMS(Steps, Mode)
Model of Processing

- ProcessTime = Hick-Hymann(Length) if expert
- = Visual_Search(Length) if naive
Model of Occlusion

Overlap

Cost of Occlusion

Frustration

Distractibility
Model of Bloat

Excess

Cost of Bloat

Feature Tolerance

Distractibility
Occlusion Experiment

- Direction, Size, Opacity, Proximity, Intersection
- Task completion time
- 12 participants
Analysis Techniques

• Factor analysis
  – Identifies most relevant variables

• ANOVA
  – Finds significance among means of different users

• F-test
  – Determines minimal model complexity required
Model of Occlusion

Opacity → Overlap → Cost of Occlusion

Blocked → Overlap → Cost of Occlusion

Overlap → Frustration

Cost of Occlusion
Objective Occlusion Function

• Overlap = f(Blocked, Opacity)
  • Blocked=0:
    • overlap = constant
  • Blocked=1:
    • Cubic in Opacity, for half of the users
    • Linear in Opacity, for remaining users
Bloat Experiment

• Shown, Used
• Task completion time
• 12 participants
Model of Bloat

- Used
- Shown
- Excess
- Feature Tolerance
- Distractibility

Cost of Bloat
Objective Bloat Function

• Unused = Shown - Used

• Excess = f(Unused)
  • Linear, for most users
  • Quadratic, for 1 user
  • Cubic, for 1 user
Simulations

• Markov decision process (MDP)
• Adaptive menu
• Actions: add/delete menu item or do nothing
• Utility = \( w_1 \text{Bloat} + w_2 \text{Savings} \)
• Bloat = \( f(\text{Excess}, \text{Feature Tolerance}, \text{Distractibility}) \)
• Savings = \( f(\text{Quality}, \text{Frustration}, \text{Neediness}, \text{Distractibility}, \text{Independence}) \)
MDP for Adaptive Menu

- Feature Tolerance
- Distractibility
- Frustration
- Independence
- Neediness
- Used
- Shown
- Quality
- Savings
- Bloat
MDP for Adaptive Menu

- Feature Tolerance
- Distractibility
- Frustration
- Independence
- Neediness
- Quality
- Used
- Shown
- Bloat
- Savings
MDP for Adaptive Menu

- Distractibility
- Feature Tolerance
- Quality
- Shown
- Used
- Savings
- Bloat
- Frustration
- Independence
- Neediness
<table>
<thead>
<tr>
<th>Distractibility</th>
<th>Tolerance</th>
<th>Shown</th>
<th>Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low/medium</td>
<td>Feature-keen</td>
<td>Any</td>
<td>Add</td>
</tr>
<tr>
<td>High</td>
<td>Feature-keen</td>
<td>Few</td>
<td>Add</td>
</tr>
<tr>
<td>Low</td>
<td>Feature-shy</td>
<td>Many</td>
<td>Delete</td>
</tr>
<tr>
<td>other</td>
<td>other</td>
<td>other</td>
<td>No action</td>
</tr>
</tbody>
</table>
Results: Individual Adaptation

• Most receptive user:

<table>
<thead>
<tr>
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<th>Tolerance</th>
<th>Shown</th>
<th>Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Keen/shy</td>
<td>Any</td>
<td>Add</td>
</tr>
<tr>
<td>Medium/high</td>
<td>Feature-keen</td>
<td>Any</td>
<td>Add</td>
</tr>
</tbody>
</table>

• Least receptive user:

<table>
<thead>
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<th>Tolerance</th>
<th>Shown</th>
<th>Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Feature-shy</td>
<td>Many</td>
<td>Delete</td>
</tr>
<tr>
<td>Medium</td>
<td>Feature-shy</td>
<td>Many</td>
<td>Delete</td>
</tr>
</tbody>
</table>

• Do nothing for all other cases
Summary and Future work

• Decision-theoretic framework for adaptive interfaces
• Formal model for interaction costs
• Systematic analysis
• Models individual differences
• Simulation as proof of concept

• Usability evaluation (next)