E2 Keystroke-Level Modelling

E2.1 Motivation & Introduction

E2.2 Example

E2.3 Mobile Phone Extension

E2.4 Example Scenario
Motivation

- Need early design decisions
- Building working prototypes is expensive
- Need clear metrics for judgements
Success Parameters

- Easy to learn
- Easy to remember
- Quick to complete
- Safe to use
- Keeps your privacy
- etc.

- … a whole bunch of ‘em
User Models

• Predict user behaviour
• Predict system performance

• GOMS \[^{[1]}\]
  (Goals Operators Methods Selection)

• KLM \[^{[2]}\]
  (Keystroke-Level Model)


GOMS
(Goals, Operators, Methods, Selection Rules)

- GOMS techniques produce quantitative and qualitative predictions of how people will use a proposed system
- Different models proposed [3]
- Basics:
  - **Goals**: goal a user wants to accomplish (in real scenarios hierarchical)
  - **Operators**: operation (at a basic level) that are used to achieve a goal
  - **Methods**: sequence of operators to achieve a goal
  - **Selection Rules**: selection of method for solving a goal (if alternatives are given)

Example (Close the window that has the focus, Windows XP))

**GOAL: CLOSE-WINDOW**

- [select GOAL: USE-KEY-SHORTCUT]
  - Hold-ALT-key
  - Press-F4-key

**GOAL: USE-SYSTEM-MENU**

- Move-mouse-win-head
- Open-menu (right click)
- Left-click-close

**GOAL: USE-CLOSE-BUTTON**

- Move-mouse-button
- Left-click-button

**Rule 1:** USE-CLOSE-BUTTON method if no other rule is given

**Rule 2:** USE-KEY-SHORTCUT method if no mouse is present
Example (ATM, Why you need to get your card before the money)

- Design to lose your card…

  GOAL: GET-MONEY
  GOAL: USE-CASH-MACHINE
  INSERT-CARD
  ENTER-PIN
  SELECT-GET-CASH
  ENTER-AMOUNT
  COLLECT-MONEY
  (outer goal satisfied!)
  COLLECT-CARD

- Design to keep your card…

  GOAL: GET-MONEY
  GOAL: USE-CASH-MACHINE
  INSERT-CARD
  ENTER-PIN
  SELECT-GET-CASH
  ENTER-AMOUNT
  COLLECT-CARD
  COLLECT-MONEY
  (outer goal satisfied!)
User Models

- Predict user behaviour
- Predict system performance

- GOMS [1]
  (Goals Operators Methods Selection)

- KLM [2]
  (Keystroke-Level Model)

Keystroke-Level Model (KLM)

- simplified Analysis
- only operators on keystroke-level
- no goals, no methods, no selection rules
- list of basic operators to do a task
  - keystrokes or button presses (K),
  - pointing with the mouse to a target (P),
  - hand movement between mouse an keyboard (H)
  - mental operators (M) – placed by heuristics
  - Drawing (D)
  - System response (R)
Models: Levels of Detail  
(Word Correction Example)

• Abstract: correct-wrong-word

• Concrete: mark-word  
delete-word  
type-word

• Keystroke-Level: hold-shift  
n·cursor-right  
del-key  
recall-word  
n·letter-key

Assuming that old and new word both have n letters
Important

• KLM assumes expert user behaviour

Therefore you need either
  – Users with long experience

or
  – Training sessions for unexperienced users

Be sure to
  – discard and repeat tasks where several errors occurred
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Keystroke-Level Model

• Keystroke-Level: hold-shift
  n·cursor-right
  del-key
  recall-word
  n·letter-key

• Sequence:

  key  n·key  key  recall-word  n·key
  K    n·K    K    M    n·K
Keystroke-Level Model

• Sequence:
  key n·key key recall-word n·key
  K n·K K M n·K

• Operator Time Values
  K = 0.28 sec. and M = 1.35 sec.

• Execution Time
  \[ T_{execute} = \sum_{op \in OP} n_{op} \cdot op \]
  OP: set of operators
  \( n_{op} \): number of occurrences of operator \( op \)
Keystroke-Level Model

- Execution Time
  \[ T_{execute} = \sum_{op \in OP} n_{op} \cdot op \]
  
  \( OP \): set of operators
  \( n_{op} \): number of occurrences of operator \( op \)

- \( K,n \cdot K,K,M,n \cdot K \rightarrow 2n \cdot 0.28 + 1.91 \ \text{sec.} \)
  replace a \( n=7 \) letter word: \( T = 5.83 \ \text{sec.} \)

- Replace using \textit{doubleclick}:
  \( P,2 \cdot B,M,H,n \cdot K \)
  \( n=7 \): \( T = 3.86 \ \text{sec.} \)
Example (Currency Converter)

- Convert 712 GBP into EUR
- In the beginning, the hand is on the mouse

http://www.xe.com/ucc/
# KLM Operator Time Values

<table>
<thead>
<tr>
<th>Operator</th>
<th>Remarks</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Press Key</td>
<td></td>
</tr>
<tr>
<td></td>
<td>good typist (90wpm)</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>poor typist (40wpm)</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>non-typist</td>
<td>1.20</td>
</tr>
<tr>
<td>B</td>
<td>Mouse button press</td>
<td></td>
</tr>
<tr>
<td></td>
<td>down or up</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>click</td>
<td>0.20</td>
</tr>
<tr>
<td>P</td>
<td>Point with mouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fitts's law</td>
<td>0.1 lg(D/S + 0.5)</td>
</tr>
<tr>
<td></td>
<td>Average movement</td>
<td>1.10</td>
</tr>
<tr>
<td>H</td>
<td>Home hands to and from keyboard</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Drawing- domain-dependent</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Mentally prepare</td>
<td>1.35</td>
</tr>
<tr>
<td>R</td>
<td>Response from system - measure</td>
<td></td>
</tr>
</tbody>
</table>
Example (Currency Converter)

- P[to input field]
- B[click]
- H[to keyboard]
- M[consider number]
- 4K[BSP-7-1-2]
- H[to mouse]
- M[consider currency]
- P[to GBP]
- B[click]
- M[consider currency]
- P[to EUR]
- B[click]
- P[to convert]
- B[click]
- R[show page with result]

- 4*P = 4,40s
- 4*B = 0,80s
- 2*H = 0,80s
- 3*M = 4,05s
- 4*K = 1,12s
- 1*R = 1,00s

- Sum = 12,17s
KLM for Desktop Setting

- Keystrokes: $K = 0.28$
- Mouse Button Press or Release: $B = 0.10$
- Mouse pointing: $P = 1.10$
- Homing (keyboard↔mouse): $H = 0.40$
- Drawing lines: $D(n_D, I_D) = 0.9n_D + 0.16I_D$
- Mental preparation: $M = 1.35$
- System response time: $R$ (dependent on application; input to model)

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Mobile Device Interaction

- Different size; mobile
- Different keyboard keys screen
- Different text input methods
- Built-in microphone speaker
- Different storage places
- Attention shifts to real world
- Distractions during tasks more probable
Advanced Mobile Phone Interaction

- Take pictures
- Recognise visual markers
- Touch (RFID) tags
- Gestures
- …
Use of KLM

- Systems and Applications
  
  
  
  
  
  
  
  
Use of KLM

• Mobile Phone Text Input

Use of KLM

• Mobile Phone Interactions


KLM for (Advanced) Mobile Phone Interaction

• **Adopted Operators**
  – Keystroke
  – Mental Act
  – Response Time
  – Pointing (slightly changed meaning)
  – Homing (slightly changed meaning)

• **Added Operators**
  – Initial Act
  – Action (camera focus, tag alignment …)
  – Finger Movement
  – Gesture
  – Attention Shifts
  – Distraction

• **Removed Operators**
  – Drawing (not applicable)
Operators

- Pointing
  move the phone to a target area

- Action
  execute an specific action necessary for a special type of interaction
Operators

• Macro Attention Shift
  look from phone to real world or back
Operators

- Micro Attention Shift
  change concentration between different parts of the mobile phone
Operators

- Micro Attention Shift
Operators

- Gesture
  simple quick movements with the phone
Operators

- Distraction
  influence of real world distractions on execution time

modelled as a multiplicative factor
Model

• Formula for execution time

\[ T_{execute} = \sum_{op \in OP} \left( n_{op} + d_{op} \cdot X_{slight} + D_{op} \cdot X_{strong} \right) \cdot op \]

\( OP = \{A, F, G, H, I, K, M, R, S_{micro}, S_{macro}\} \)

\( n_{op}: \#op \) with no distraction

\( d_{op}: \#op \) with slight distraction

\( D_{op}: \#op \) with strong distraction

If there is no Distraction operator, this is the same as the formula from the standard KLM:

\[ T_{execute} = \sum_{op \in OP} n_{op} \cdot op \]
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Example Model

- Scenario: use public transportation ticket service; poster interaction with NFC tags

<table>
<thead>
<tr>
<th>Description</th>
<th>Operators</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick up the mobile phone from your pocket</td>
<td>I</td>
<td>1.18 sec.</td>
</tr>
<tr>
<td>Select main menu</td>
<td>M, K [Hotkey]</td>
<td>1.35 sec., 0.16 sec.</td>
</tr>
<tr>
<td>Go to folder ‘Programs’</td>
<td>M, K [Hotkey]</td>
<td>1.35 sec., 0.16 sec.</td>
</tr>
<tr>
<td>Choose folder ‘Programs’</td>
<td>K [Hotkey]</td>
<td>0.16 sec.</td>
</tr>
<tr>
<td>Go to folder ‘Collection’</td>
<td>M, K [Hotkey]</td>
<td>1.35 sec., 0.16 sec.</td>
</tr>
<tr>
<td>Choose to folder ‘Collection’</td>
<td>K [Hotkey]</td>
<td>0.16 sec.</td>
</tr>
<tr>
<td>Choose folder ‘choose program’</td>
<td>K [Hotkey]</td>
<td>0.16 sec.</td>
</tr>
<tr>
<td>Choose application ‘PERCI’</td>
<td>K [Hotkey]</td>
<td>0.16 sec.</td>
</tr>
<tr>
<td>Wait for program to open</td>
<td>R [adv]</td>
<td>4.63 sec.</td>
</tr>
<tr>
<td>Read instruction</td>
<td>M</td>
<td>1.35 sec.</td>
</tr>
<tr>
<td>Scroll down</td>
<td>K [Hotkey]</td>
<td>0.16 sec.</td>
</tr>
<tr>
<td>Read instruction</td>
<td>M</td>
<td>1.35 sec.</td>
</tr>
</tbody>
</table>
Example Model

Design Comparisons

- Direct input technique:
  \[ T_{\text{model}} = 123 \text{ seconds} \]
  \[ T_{\text{study}} = 117 \text{ seconds} \]

- NFC interaction technique:
  \[ T_{\text{model}} = 176 \text{ seconds} \]
  \[ T_{\text{study}} = 170 \text{ seconds} \]
### Operators for Advanced Mobile Phone KLM

<table>
<thead>
<tr>
<th>Operator</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$, Action</td>
<td></td>
</tr>
<tr>
<td>marker</td>
<td>1.23</td>
</tr>
<tr>
<td>NFC</td>
<td>0.00</td>
</tr>
<tr>
<td>in general</td>
<td>variable</td>
</tr>
<tr>
<td>$D$, Drawing</td>
<td></td>
</tr>
<tr>
<td>not applicable</td>
<td></td>
</tr>
<tr>
<td>$F$, Finger Movement</td>
<td>0.23</td>
</tr>
<tr>
<td>$G$, Gestures</td>
<td>0.80</td>
</tr>
<tr>
<td>$H$, Homing</td>
<td>0.95</td>
</tr>
<tr>
<td>$I$, Initial Act</td>
<td></td>
</tr>
<tr>
<td>externally</td>
<td>5.32</td>
</tr>
<tr>
<td>internally</td>
<td>3.89</td>
</tr>
<tr>
<td>optimal setting</td>
<td>1.18</td>
</tr>
<tr>
<td>no assumptions</td>
<td>4.61</td>
</tr>
<tr>
<td>$K$, Keystroke</td>
<td></td>
</tr>
<tr>
<td>keypad average</td>
<td>0.39</td>
</tr>
<tr>
<td>keypad quick</td>
<td>0.33</td>
</tr>
<tr>
<td>hot Key</td>
<td>0.16</td>
</tr>
<tr>
<td>$M$, Mental Act</td>
<td>1.35</td>
</tr>
<tr>
<td>$P$, Pointing</td>
<td>1.00</td>
</tr>
<tr>
<td>$R$, Response Time</td>
<td></td>
</tr>
<tr>
<td>NFC</td>
<td>2.58</td>
</tr>
<tr>
<td>Visual Marker</td>
<td>2.22</td>
</tr>
<tr>
<td>general</td>
<td>variable</td>
</tr>
<tr>
<td>$S_{Macro}$, Macro Attention Shift</td>
<td>0.36</td>
</tr>
<tr>
<td>$S_{Micro}$, Micro Attention Shift</td>
<td></td>
</tr>
<tr>
<td>keypad↔display</td>
<td>0.14</td>
</tr>
<tr>
<td>hotkey↔display</td>
<td>0.12</td>
</tr>
<tr>
<td>keypad↔hotkey</td>
<td>0.04</td>
</tr>
<tr>
<td>in general</td>
<td>0.14</td>
</tr>
<tr>
<td>$X$, Distraction</td>
<td></td>
</tr>
<tr>
<td>slight</td>
<td>6 %</td>
</tr>
<tr>
<td>strong</td>
<td>21 %</td>
</tr>
</tbody>
</table>
Questions on the Exercise?

- Members of your own group can be used to validate the model
- Till Tuesday, Nov. 14, only models Siemens S65, Nokia 6630 are available; from Tuesday on, you can also have Nokia 6600
- There will be no exercises on Friday, 10 and Monday, 13; These slots can also be used for groups to meet and write down the models
- If there arise questions feel free to email (mmi1@hcilab.org) or to come to my office in room 206, 2nd floor, Amalienstr. 17