E2 Keystroke-Level Modelling

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)

[1] Card S. K. Newell A. and Moran T. P. The Psychology of Human-Computer Interaction. Lawrence Erlbaum Associates Inc. 1983

[2] Card S. K. Moran T. P. and Newell A. The Keystroke-level Model for User Performance Time with Interactive Systems. Comm. ACM 23 7.396-410. 1980

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)

[3] John, B. & Kieras, D. (1996). Using GOMS for user interface design and evaluation: which technique? *ACM Transactions on Computer-Human Interaction, 3,* 287-319.

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

ALT-F4 Key-shortcut

System-menu

Close-button

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

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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

E2 Keystroke-Level Modelling

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

  OP: set of operators

  n_{op}: number of occurrences of operator op

$$T_{execute} = \sum_{op \in OP} n_{op} \cdot op$$

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·K,K,M,n·K ➔ 2n·0.28 + 1.91 sec.

  replace a n=7 letter word: **T = 5.83 sec.**

- Replace using *doubleclick*:

  P,2·B,M,H,n·K n=7: **T = 3.86 sec.**

Example (Currency Converter)

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

KLM Operator Time Values

Operator	Remarks	Time(sec)
K	Press Key	
	good typist(90wpm)	0.12
	poor typist(40wpm)	0.28
	non-typist	1.20
B	Mouse button press	
	down or up	0.10
	click	0.20
P	Point with mouse	
	Fitts's law	0.1lg(D/S +0.5)
	Average movement	1.10
H	Home hands to and from keyboard	0.40
D	Drawing- domain-dependent	__
M	Mentally prepare	1.35
R	Response from sytem - measure	__

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 [2]

- 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: $\mathbf{D(n_D,l_D) = 0.9n_D+0.16l_D}$
- Mental preparation: **M = 1.35**
- System response time: **R** (dependent on application; input to model)

[2] Card S. K. Moran T. P. and Newell A. The Keystroke-level Model for User Performance Time with Interactive Systems. Comm. ACM 23 7.396-410. 1980

E2 Keystroke-Level Modelling

E2.1 Motivation & Introduction

E2.2 Example

E2.3 Mobile Phone Extension

E2.4 Example Scenario

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

  - Gong, R., Elkerton, J., Designing Minimal **Documentation** Using a GOMS Model: a Usability Evaluation of an Engineering Approach. In Proc. CHI 1990. ACM Press. 99-107. 1990
  - John, B. E., Extensions of GOMS Analyses to Expert Performance Requiring **Perception of Dynamic Visual and Auditory Information**. In Proc. CHI 1990. ACM Press. 107-115. 1990
  - John, B. E., Vera, A. H., A GOMS Analysis of a **Graphic Machine-paced, Highly Interactive Task**. In Proc. CHI 1992. ACM Press. 251-258. 1992
  - Gong, R., Kieras, D., A Validation of the GOMS Model Methodology in the Development of a **Specialized, Commercial Software Application**. In Proc. CHI 1994. ACM Press. 351-357, 1994
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  - Manes, D., Green, P., and Hunter, D., Prediction of **Destination Entry and Retrieval Times** Using Keystroke-Level Models (Technical Report UMTRI-96-37). The University of Michigan Transportation Research Institute.
  - Hinckley, K., Guimbretiere, F., Baudisch, P., Sarin, R., Agrawala, M., and Cutrell, E., The Springboard: Multiple Modes in one **Spring-loaded Control**. In Proc. CHI 2006. ACM Press. 181-190. 2006

Use of KLM

- Mobile Phone Text Input

  - Dunlop, M.D., Crossan, A., **Predictive Text Entry Methods** for Mobile Phones. Personal Technologies, 4(2-3), 2000
  - Silfverberg M., MacKenzie, I. S., and Korhonen, P. **Predicting Text Entry Speed** on Mobile Phones, in Proc. CHI 2000, 9-16. 2000
  - James, C.L., Reischel, K.M., Text Input for Mobile Devices: Comparing Model Prediction to **Actual Performance**. In Proc. CHI 2001, 365-371
  - Myung R., Keystroke-level Analysis of **Korean Text Entry** Methods on Mobile Phones, International Journal of Human-Computer Studies 60, 5-6, HCI Issues in Mobile Computing. 545-563. 2004
  - Pavlovych, A., Stuerzlinger, W., Model for **Non-expert Text Entry Speed** on 12-button Phone Keypads. In Proc. CHI 2004. ACM Press. 351-358. 2004
  - How Y., Kan M.Y., **Optimizing Predictive Text Entry** for Short Message Service on Mobile Phones. In Proc. HCII 2005. 2005

Use of KLM

- Mobile Phone Interactions

  – Mori, R., Matsunobe, T., Yamaoka, T., A Task Operation Prediction Time Computation based on GOMS-KLM Improved for the Cellular Phone and the Verification of that Validity, 2003.10, Journal of the Asian Design International Conference Vol.1. 2003

  – Luo, L., John, B. E., Predicting Task Execution Time on Handheld Devices Using the Keystroke-level Model. In Extended Abstracts CHI 2005. ACM Press. 1605-1608, 2005 (**stylus input**)

  – Teo, L., John, B. E., Comparisons of Keystroke-level Model Predictions to **Observed Data**. In Extended Abstracts CHI 2006. ACM Press. 1421-1426, 2006

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

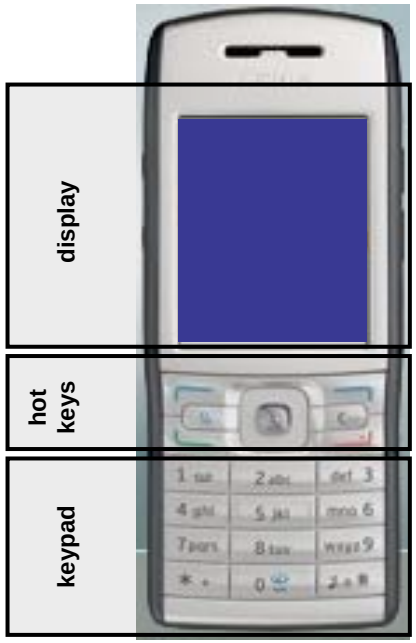
- Action
  execute an specific action necessary for a special type of interaction

Operators

- Macro Attention Shift
  look from phone to real world or back

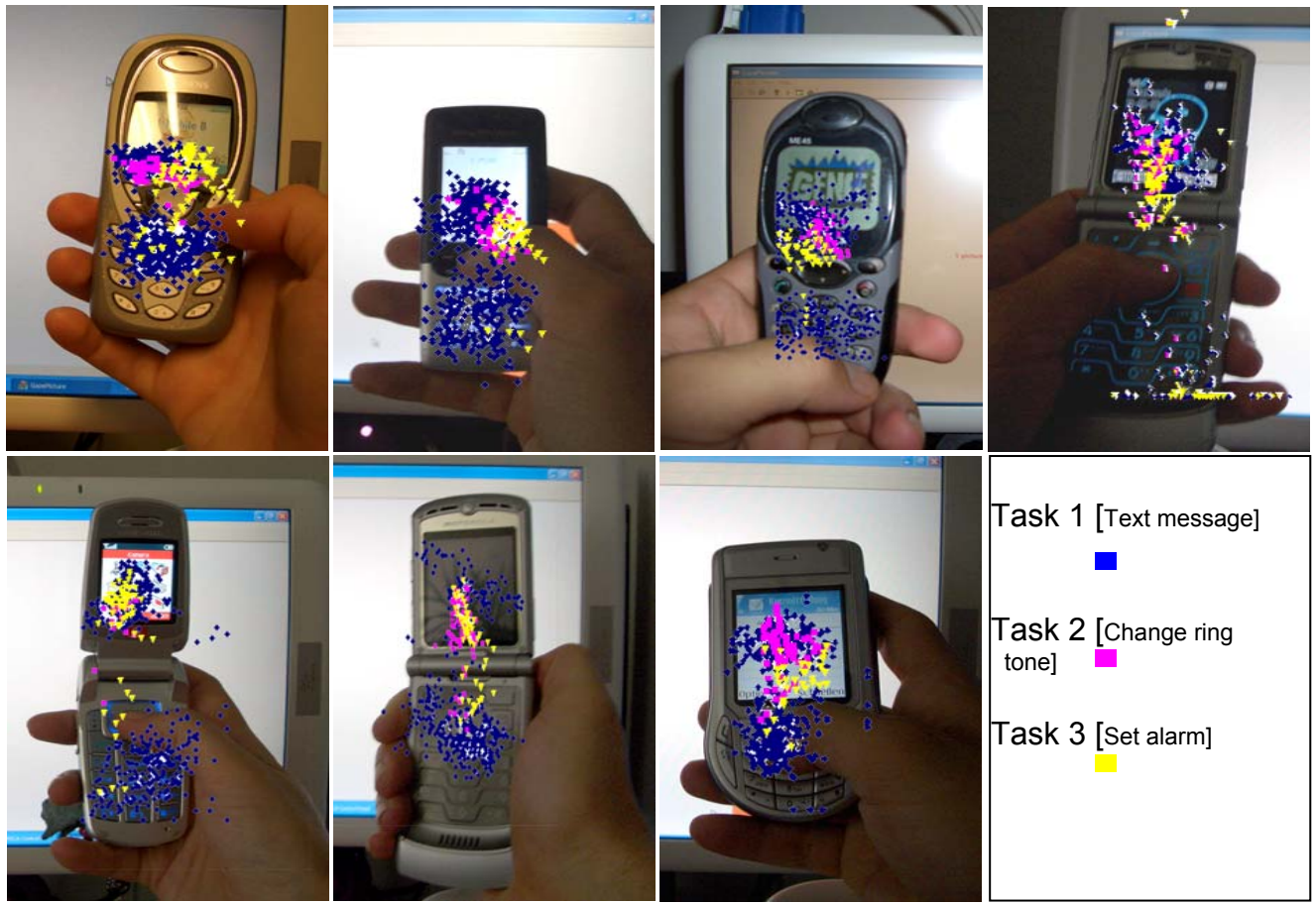
Operators

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



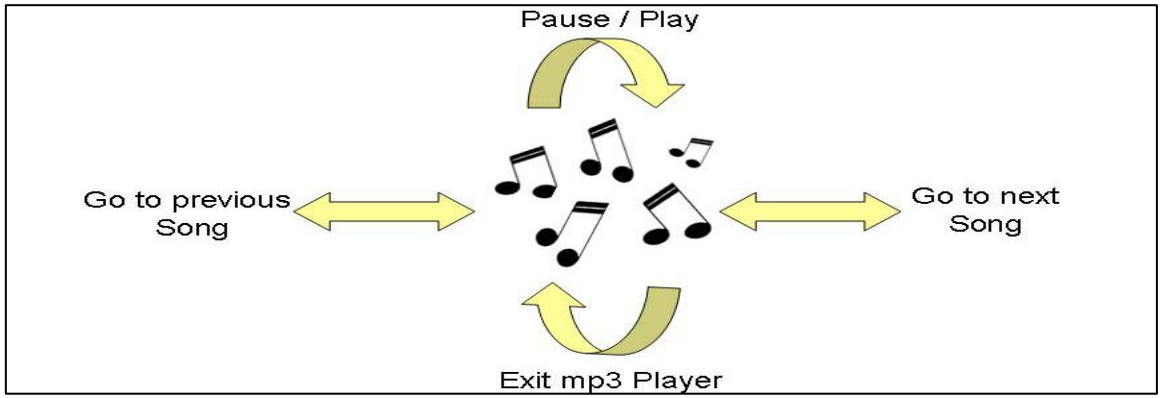
Operators

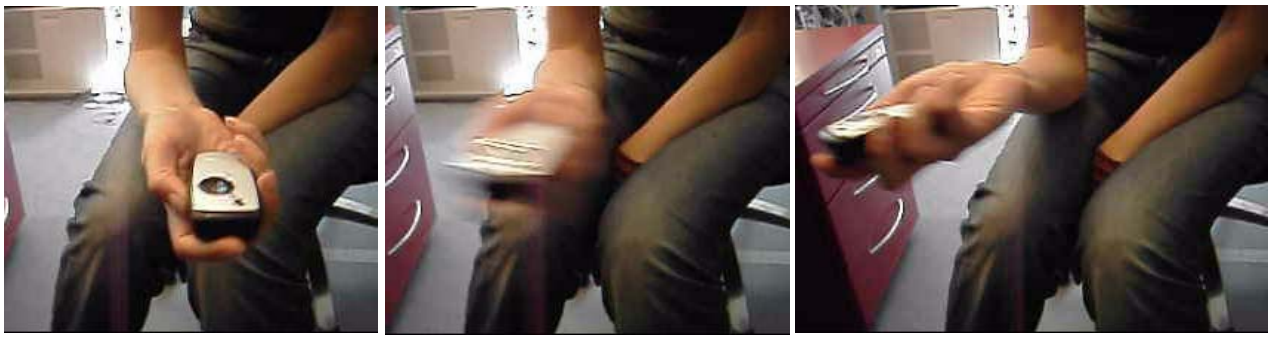
- Micro Attention Shift



Operators

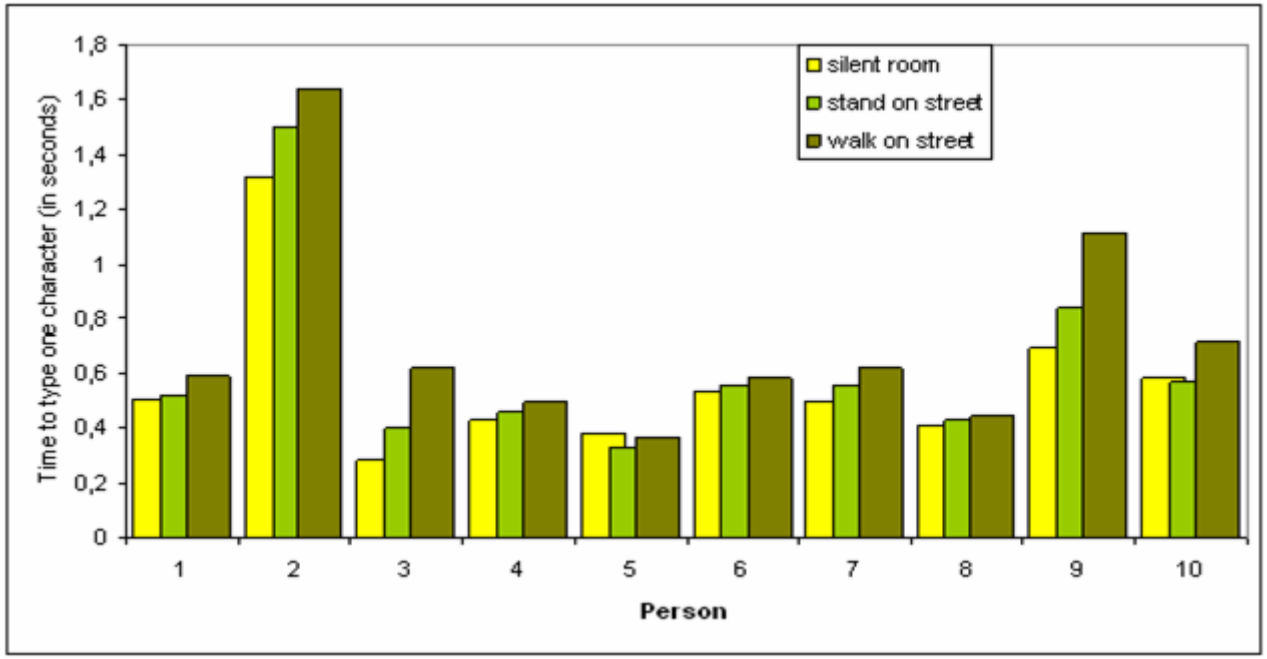
- Gesture
  simple quick movements with the phone





Operators

- Distraction
  influence of real world distractions on execution time



modelled as a multiplicative factor

Model

- Formula for execution time

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

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:

$$T_{execute} = \sum_{op \in OP} n_{op} \cdot op$$

E2 Keystroke-Level Modelling

Example Model

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

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

Example Model

I M K M K K M K K K K R[adv] **M K M M K K M** 2**K K M K M K M K M K M K R**[adv] **M K K M K K M K K M K K M K M K R**[adv] **M K M M K M K R**[adv] **M K MM K M K M** 4**K**[Keypad] **A**[micro] 4**K A**[micro] 4**K A**[micro] 4**K A**[micro] **M K M K M** 3**K K M K M K R**[adv] **M K M K M M K K R**[adv]

Design Comparisons

- Direct input technique:

  T_{model} = 123 seconds
  T_{study} = 117 seconds

- NFC interaction technique:

  T_{model} = 176 seconds
  T_{study} = 170 seconds

Operators for Advanced Mobile Phone KLM

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

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