Designing Interactive Systems I

Introduction, Fitts' Law, The CMN Model

Prof. Dr. Jan Borchers
Media Computing Group
RWTH Aachen University

Winter term 20/21

http://hci.rwth-aachen.de/dis
Video Conferencing Etiquette

• We would like to have an interactive class
  • Please **turn on your video** so we can see each other
  • Your video will **not** be in the lecture recording

• Please **ask questions** (only your voice will be in the recording)
  • Use Zoom’s **‘Raise Hand’ function** so we don’t talk over each other
  • Otherwise, please **Mute** yourself to avoid echos (we may do this for you if you forget)
  • In Audio settings, turn on the option to press **Space** to temporarily unmute

• Turn on your **lights** so you don’t look like a zombie :)

Prof. Dr. Jan Borchers: Current Topics in Media Computing and HCI
Who am I?

Studied CS at Karlsruhe (& Imperial)
  • Human-Computer Interaction
PhD CS, TU Darmstadt (& Linz, Ulm)
  • Interaction with multimedia
  • HCI design patterns
Assistant professor at Stanford & ETH Zurich
  • Interactive rooms
  • UbiComp user interfaces
Full professor at RWTH since Oct. 2003
  • Interaction with audio & video
  • Wearable & Tangible UIs, Personal Fabrication, IDEs,…
Our Team

Oliver Nowak, M. Sc.
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Marcel Lahaye, M. Sc.
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They answer all your questions!

Please use the forum on Moodle to ask about the course’s content & organization. Otherwise, please, add this subject line to your mail: “[DIS1]”
Human–Computer Interaction?
"We ran toward the exit and about five other people were in front of us and they're pushing on the door trying to get the door open and it wouldn't open. The emergency exit would not open."
Usability Sells!

- DVD Player (1996): 350,000
- iPhone (1st Q'07): 1,000,000
- iPad (1st 80d '10): 3,000,000

Source: CNBC
What is HCI?

Use and Context

U1 Social Organization and Work
U2 Application Areas
U3 Human-Machine Fit and Adaptation

Human
H1 Human Information Processing
H2 Language, Communication and Interaction
H3 Ergonomics

Computer
C1 Input and Output Devices
C2 Dialogue Techniques
C3 Dialogue Genre
C4 Computer Graphics
C5 Dialogue Architecture

Development Process
D1 Design Approaches
D2 Implementation Techniques and Tools
D3 Evaluation Techniques
D4 Example Systems and Case Studies

ACM SIGCHI Curriculum 1992
## Class Topics

### Human
- Performance
- Models of interaction
  - Affordances
  - Mappings
  - Constraints
  - Types of knowledge
  - Errors
- Design principles

### Case Studies
- History of HCI
- Visions
- Phases of Technology

### Development Process
- Iterative design
- User observation
- Ideation
- Prototyping
- User studies and evaluation
- Interaction design notation

For more details, see [www.hci.rwth-aachen.de/dis#syllabus](http://www.hci.rwth-aachen.de/dis#syllabus).
Textbooks

Required Read

The Design of Everyday Things

Recommended Read

Human–Computer Interaction
Media Computing Group
## Our Classes

<table>
<thead>
<tr>
<th>When?</th>
<th>Type</th>
<th>Credits (ECTS)</th>
<th>Name</th>
</tr>
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<tbody>
<tr>
<td>SS, WS</td>
<td>P</td>
<td>7</td>
<td>The Media Computing Project</td>
</tr>
<tr>
<td>WS, SS</td>
<td>S</td>
<td>4</td>
<td>Post-Desktop User Interfaces</td>
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<tr>
<td>SS</td>
<td>V/Ü</td>
<td>6</td>
<td>Current Topics in HCI</td>
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<tr>
<td>WS</td>
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<td>6</td>
<td>iOS Application Development</td>
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<tr>
<td>SS</td>
<td>V/Ü</td>
<td>6</td>
<td>Designing Interactive Systems II</td>
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<tr>
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<tr>
<td>SS</td>
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<td>Human-Computer Interaction</td>
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<tr>
<td>SS</td>
<td>SW-Pr</td>
<td>7</td>
<td>M3: Multimodal Media Madness</td>
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*Only for B.Sc. students*
Springlets

https://hci.rwth-aachen.de/springlets
Student project “Safe” from M3, SS 2019

https://hci.rwth-aachen.de/m3
Headbang

https://hci.rwth-aachen.de/headbang
Aachen Maker Meetup

• People doing strange things with electricity in Aachen

• 3rd Wednesday every month (currently suspended due to COVID-19)

• Sign up here: https://www.meetup.com/Aachen-Maker-Meetup/
CocoaHeads Aachen

- CocoaHeads: International meet-ups about Apple’s Cocoa Framework for macOS and iOS
- Last Thursday every month
  Next event: Oct. 29, 19:00
- Sign up here: https://www.meetup.com/cocoaheads_ac/
Class Structure
Credits and Grading

• Group-oriented, project-centered

• 6 ECTS Credits

  Normal semester (this holds for now!):
  • 20% assignments
  • 20% project
  • 25% midterm exam
  • 35% final exam

  Planned (not confirmed yet!):
  • 30% assignments
  • 20% project
  • 50% final exam

• Cumulated grades are calculated from the weighted sum of grades (not points!)

• Exam date: Feb. 13, 11:30-12:30 (preliminary date)

• To pass the course, you need to pass the final exam (at least 4.0), and
  • overall, you need an average grade of at least 4.0

• Further details in the lab starting next Monday, Nov. 02 at 14:30
Registering for this Class

• Limited to **120 seats** (already 200+ registrations)

  • Register via RWTHonline **until end of Thursday**

  • We will announce who we have selected on Friday

  • Students for whom DIS 1 is mandatory (e.g., TK students) will be prioritized; others will be selected randomly

• M.Sc. SSE, Erasmus students, and others who cannot register via RWTHonline: Email the supervisors your matriculation number and full name from your official @rwth-aachen.de email-address

  • **Email subject:** [DIS] Registration <your name>
Exam Registration

Deadline to register: **Wednesday, Jan. 15, 23:55** (for both final exams)

- If you fail the first final exam, there will be a short period to register for the second chance
- B.Sc. students: you won’t be registered for the second final exam automatically!
- Do not register just for the second chance final directly (possible, but not recommended)
The Human
Model Human Processor
Model Human Processor

- 3 processors with associated memory
- Slow, middle, fast performers
Experiment 1

- Work in pairs of 2 (we will create breakout rooms)
  - Move near to the camera
  - Open the experiment sheet in a fullscreen window
  - Have your partner observe your eye movements while you’re reading the text for “Experiment 1”
How do your eyes move when you are reading?

Tobii TX300

http://www.youtube.com/watch?v=VBTZNydUh0w
Perception

- Eye saccades: 230 ms
- Explains reading rates
  - Maximum: 13 characters/saccade
  - ⇒ 652 words/minute
Perceptual Processor

- Stores sensor signals in visual & auditory stores
- Perception time: $\tau_P \approx 100 \text{ ms}$
  - Explains Bloch’s Law
    - $R = I \times t$
    - $R$ is response
    - $I$ is intensity,
    - $t$ is exposure time
  - Constant response for $t < 100\text{ms}$
In-Class Experiment: Bloch’s Law
In-Class Experiment: Bloch’s Law
In-Class Experiment: Bloch’s Law
A: 0 ms delay

B: 50 ms delay

C: 100 ms delay
Perceptual Processor

- Perception time: $\tau_P \approx 100$ ms
  - Explains animation rates (10 fps for MiddleMan)
  - Explains max. delay before causality breaks down
  - Shortens with intensity
Model Human Processor
Experiment 2

- We will randomly create groups of two.
  - Choose 5 digits secretly from your sheet, then read them to your partner.
  - Have him count backwards aloud from 50.
  - Have him answer some other question (like what he had for dinner 3 days ago).
  - Does he still remember the entire 5-digit sequence correctly? *Write down how many numbers he could remember.*

- Switch roles, repeat with 9 digits.

- Finally, switching roles again, read the long sequence of numbers to your partner, stopping somewhere suddenly. See how many of the last numbers he can repeat immediately.
Cognitive System

- Chunks depend on user & task

- Working memory:
  - Capacity: $\mu_{WM} = 7 \pm 2$ chunks (Miller ’56)
  - Half life: $\delta_{1,WM} = 73$ s (1 chunk)
    $\delta_{3,WM} = 7$ s (3 chunk)
  - Visual/acoustic encoding

- In 2001, Nelson Cowen showed that this is actually $4\pm1$ chunks.
Cognitive System

• Cognitive processor:
  • Processing time \( \tau_C = 70 \text{ ms} \)

• Long-term memory:
  • Infinite capacity and half life
  • Semantic encoding (associations)
  • Fast read, slow write

\[ \Rightarrow \text{Remembering items maxes out at 7 s/chunk learning speed (1 pass)} \]
Model Human Processor
Experiment 3

- Experiment: draw strokes between lines for 5s. Try to reach both lines.
- Count number of reversals
  - How many milliseconds per reversal?
- Create a contour of stroke bottoms, count number of corrections
  - How many milliseconds per correction?

34 reversals/side = 68 total reversals

10 corrections/side = 20 total corrections
Motor System

- Motor processor (open loop)
  - \( \tau_M = 70 \text{ ms} \)

\[ \text{Average time between each reversal} \]

74 ms/reversal
250 ms/correction
Motor System

74 ms/reversal
250 ms/correction

• Closed loop:
  • \( \tau_P + \tau_C + \tau_M = 240 \text{ ms} \)
  \( \Rightarrow \) Average time between each correction
Fitts’ Law
In-Class Experiment 4: Fitts’ Law

Same for 0.5 cm and 2 cm wide strips
Tap for 10 s, count taps afterwards

1cm

4cm

8cm

16cm
Tapping Task Results

• Doubling the distance adds roughly a constant to execution time
  ⇒ indicates logarithmic nature

• Doubling the target width (W) gives about same results as halving the distance (D)
  ⇒ indicates connection of D/W in formula
Motor System: Fitts’ Law

• Goal: Predict time to press buttons (physical or on-screen) as function of distance and size

• Result (Fitts, 1954):  \( T_{pos} = I_M \times I_D \)
  
  • \( T_{pos} \) time to reach button
  
  • \( I_M = 100 \text{ ms/bit} \) index of movement, constant
  
  • \( I_D = \log_2(2D / W) \) index of difficulty, in bits

• Fitts’ law can be derived from CMN model
Visualizing Fitts’ Law

Experiment: fixed distance D, varying width W

\[ I_D = \log_2(2D/W) \text{ [bits]} \]

\[ T_{pos} \text{ [s]} \]

slope = \( I_M \)

\[ D = 2 \text{ inches} \]
\[ D = 0.5 \text{ inches} \]
Alternative measures are compared by [MacKenzie & Buxton, CHI’92]
Windows 10
Improvements

- Welford’s Formulation, 1968:
  \[ T_{pos} = I_M \cdot \log_2 \left( \frac{D}{W} + \frac{1}{2} \right) \]

- Shannon’s Formulation, ISO, 80’s:
  \[ T_{pos} = a + b \cdot \log_2 \left( \frac{D}{W} + 1 \right) \]
  
  - \( a, b \) depend on device, determine experimentally

Use \( a = 0 \, ms \), \( b = I_M = 100 \, ms \) for quick and dirty estimates

Improved curve fit, no negative times for infinite-size targets
Exercise: Mobile Phone

• How much faster does calling become by moving the “call” button from 35 mm distance to 15 mm distance, measured from the middle of the keypad? The size of the call button is 10 x 10 mm

• Welford’s Law: \[ T_{pos} = I_M \cdot \log_2 \left( \frac{D}{W} + \frac{1}{2} \right) \]

• Use \( I_M = 100 \) ms/bit
Solution

⇒ Moving the call button speeds up each call by an average of about 100ms.

\[
T_{pos1} = I_M \cdot \log_2 \left( \frac{D_1}{W} + \frac{1}{2} \right)
\]

\[
T_{pos2} = I_M \cdot \log_2 \left( \frac{D_2}{W} + \frac{1}{2} \right)
\]

\[
T_{pos1} - T_{pos2} = I_M \cdot \left( \log_2 \left( \frac{D_1}{W} + \frac{1}{2} \right) - \log_2 \left( \frac{D_2}{W} + \frac{1}{2} \right) \right)
\]

\[
= 100 \text{ ms} \cdot (\log_2 \frac{35}{10} + \frac{1}{2}) - \log_2 \left( \frac{15}{10} + \frac{1}{2} \right) \text{ bit}
\]

\[
= 100 \text{ ms} \cdot (\log_2 4 - \log_2 2)
\]

\[
= 100 \text{ ms} \cdot (2 - 1)
\]

\[
= 100 \text{ ms}
\]
Summary

• The Media Computing Group does cool stuff

• HCI is about humans, computers, the design process, and the social context

• The CMN model allows estimating reaction times and memory performance

• Fitts’ Law allows estimating times for typing, pointing, and similar tasks

• Assignment:
  Read “Human-Computer Interaction” (Dix, et al.) chapter “The Human” (pp. 11-59)

• Buy and start reading “The Design of Everyday Things”, by Donald Norman