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Pforzheim University, Germany

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Web : www.displaylabor.de
Examples of Different Scenarios for GUIs

Focus:

MES: Embedded Systems + calculations
MIS: Various GUI applications and data mining + calculations
Everybody is a GUI Expert

… as most people use very different devices with individual GUIs. Therefore, everybody has its own experience, preferences etc.

We can learn from “failures”:
Everybody is a GUI Expert

Examples of GUIs @ Pforzheim University:

• Good / great / adequate:

• To be improved:

- Take pictures and argue why good or not
- Email to kh@blankenbach.org
- All inputs will be summarized and presented
Proposal for Exam

• Group work on selected case studies during lectures
• Several presentations (10 min) of group results and discussion
• Programming of one application acc. GUI design rules and evaluation during lecture
• Final presentation of GUI two weeks before exams
• Requirements see “exam specification file” (location same as for hand-outs)
• Documentation due to mid of Feb. (winter term) or mid of Aug. (summer term)

• Advantages:
  - Reduces workload during exams
  - You will experience team work and issues.
Prof. Dr. Karlheinz Blankenbach

- Chairman of 
  
- Chairman DFF e.V.  
  (German Flat Panel Forum)

- Speaker of display group of VDE/ITG

- Chairman of 
  (EU founded)
Activities at Display Lab Pforzheim

- Applied R&D ‘around’ displays
- Funded by BMBF, BW, industry, …
- Many references
- Workshops, …

Displays, driving & systems incl. evaluation

Measurements
Other Topics

• Functions at Pforzheim University:
  - Dean of Engineering Department (1999 – 2005)
  - Member of Senate (1995 – 2005)
  - Member of Board (2009 – 2015)
  - Head International Affairs IT Department (since 2012)

• R&D: BMBF, BMWi and industry

• Education: Physics, PhD @ Univ. Ulm

• Private: married, two kids (graduated 2015)

• Hobbies: Skiing, photography, travel, …
  best: combination ➔
“Work & Travel”

K. Blankenbach, A. Marsal, A. Sycev: Comparison of Key Optical Measurements of Curved to Flat LCD TVs and Their Impact on Image Quality, Society for Information Display, International Symposium 2015, San José, 6/2015


A. Sycev, K. Blankenbach, S. Kurbatfinski, M. Zobl: Comparison of e-Paper Displays, Transflective and Transmissive LCDs under Bright Ambient Light and Image Enhancement Algorithms for Optimized Grey Level and Color Perception (invited), IDW '13, 20th International Display Workshops, Sapporo, Japan, 12/2013

Peter Bitterlich, Karlheinz Blankenbach et al.: Rising the Motivation for Learning Programming by Using Android Apps International Conference on Advanced Education Technology and Management Science (AETMS2013), 12/2013, Hong Kong

K. Blankenbach: E-Signage Display Technologies - from LEDs to Electrowetting, BIT Annual World Congress of Emerging Info-Tech-2012 (WCEIT-2012), Dalian (China), 8/2012
Exhibitions

• ELECTRONICA 2006 – 2010
• SID Display Week 2007 – 2012
• CeBIT 2001 (R&D BW)
• Hannover Fair 2006 (R&D BW)
Sicherer Mausklick auch im Alter
Studenten der Hochschule Pforzheim entwickeln Computerzubehör für
Senioren und Behinderte

Mit ihrem Professor Karlheinz Blankenbach (Zweiter von links) setzten Stefan Schulz, Michael Fischer und Steffen Rapp die Idee einer Senioren-Maus für den Computer in die Praxis um.

From Students Project to Mass Production

HMI
Recommended Textbooks


- D. Redmond-Pyle, A. Moore: Graphical User Interface Design and Evaluation, PRENTICE HALL

- M. Silver: Exploring Interface Design, THOMSON DELMAR

- M. Pearrow: Web Site Usability Handbook, CHARLES RIVER MEDIA

- M. Dahm: Grundlagen der Mensch-Computer-Interaktion, PEARSON
Overview of Lecture

1. Introduction

2. Fundamentals of GUls


4. Evaluating GUI Performance
Overview “§1 Introduction”

- Some Definitions
- Overview with Examples
- Some Fundamentals
- Ergonomics & Displays
**Definition of Human Machine Interface (newer: Interaction)**

HMI = Input + Output + User

**Topics:**
- **User:** Experience, age, environment, ...
- **Input:** Keyboard, touch, mouse, ...
- **Output:** Display, sound, processing speed of inputs, ...

Each topic (input, output and user) influences the two others

⇒ System (HMI) must be optimized not only subassemblies
Definition of Graphical User Interface

GUI = Output (Main task) + User + Input

Topics:

- **User**: Visual parameters like font size
- **Input**: Influence of input devices on screen design, e.g. touch needs larger buttons than mouse
- **Output**: Mainly screen content and display, software orientated

➡ Screen design is main GUI task
Definition of Graphical User Interface

Definition

The Graphical User Interface is defined as software design on a graphics display of a data processing system including I/O objects.

Similar definitions for
- Human Machine Interface (HMI)
- Ma/en Machine Interface (MMI)

What is relevant and/or determines system design?

• Hardware including output (e.g. display) and user input devices (e.g. mouse)
• Operating System which provides basic functions for the GUI
• Data to be displayed and to be processed including user inputs
• GUI design

Not in focus here: web pages
• Users (age, un/experienced, stress, …)
Applications of GUIs

Different application areas:
- GUI for consumer devices like smartphone, PC software
- GUI for kiosk applications like vending machines
- GUI for dedicated devices like in cars, measurement devices
- GUI for data mining (IT applications)
- GUI for automation, medical, industrial, …
- (web pages)
- …

Differences in tasks, users, display size, input devices, user experience, …
User Interfaces – Users - Environment
Graphical User Interface Approaches

- Easy to design but difficult to use
- Time consuming to design but easy to use

This should be the preference for GUIs
Usability & User Experience (UX)

USABILITY AND USER EXPERIENCE
"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."


Usability and user experience (UX) is a major criterion for GUIs
Usability

From a few to 100 functions!
Objective of Lecture

- Understanding of Graphical User Interface merits and shortcomings
- Know how of traditional and advanced approaches to GUI
- Knowledge of interaction of computer (input and output) ↔ user
- Capability to design and to evaluate GUIs for various demands

Not in focus here: Internet / web GUIs

but all recommendations introduced in this lecture are also valuable.
Overview “§1 Introduction”

- Some Definitions
- Overview with Examples
- Some Fundamentals
- Ergonomics & Displays
Software  GUI  Design

Attractive GUIs have to be dynamic, flexible, up-to-date, usable, …

⇒ High demands for software development

Typical requirements

• Project and budget plan (time-to-market, price for end-user)

• Cost pressure in case of products for the mass market

• Often restricted power consumption

• Minimize computing power, memory requirements in order to lag-free user experience
Solutions for SW for GUI Design

• Providing class libraries with ready-made GUI components (widgets, …) (e.g. all major operating systems)

• Should be suitable for design prototypes with limited functionality or use dedicated tools like “PROTOTYPER”

• If possible framework for development teams

• …

Use GUI design software (available from various vendors)
Software for GUI Design

- Tools for CE devices like WINDOWS, APPLE, ANDROID
- Freeware Justinmind “Prototyper”, see next page
- JCONTROL (www.domologic.de), JAVA
- EMWIN (www.segger.com) for 8 - 32-Bit µC, ANSI-C
- HTML 5.0 ATVISE (http://www.videc.info/de/produkte/atvise)
- EMWIZZARD (www.tara-systems.de) for 8 - 32-Bit µC, ANSI-C
- GUI Library (www.simplify-technologies.de) for low res LCD controllers
- SAP
- Automotive: www.qnx.com, www.altia.com, ...
- Trialversions e.g. http://designervista.com/products.php
  http://www.carettasoftware.com/gdsdownloads-v4.html
- ...
Free Software for GUI Prototyping and Evaluation

PROTOTYPER (free): http://www.justinmind.com

Tutorial by M. Mueller available
Examples for Non–WINDOWS Mid Res GUI Design
High End Professional GUI Examples
Examples for High-End Embedded Systems GUI Design

Experience @ Pforzheim University cafeteria

- 36 men month for user GUI development (~ 50 screens)
- 12 men month for service GUI development (150 screens)
- Men years of development for whole system

YOUTUBE “Franke FM800 Bean to Cup Coffee Machine”
https://www.youtube.com/watch?v=iwHVnjDFRHc#t=50
Further Examples of GUIs

VW

BARCO

ZIMMERMANN

BOATTOON

FOTOCOMMUNITY

NW-NEWS

HITOUCHE
Requirements for GUIs

- Easy to understand (icons, text, help, menu, …)
- Intuitive and logical
- Use of standard elements (GUI style guides, often > 500 pages)
- Professional GUI follow CE trends like touch
- Adequate input and output devices
- Input failure tolerant
- Reasonable processing of inputs and updating output
- …
GUI / HMI System Design

User ("in the loop")

Input*

"repeated"

Output*

Input- and output processing*

System with GUI

*: Examples, more devices see next pages

All devices must be optimized for GUI tasks incl. training of users
Application Examples

Smartphone  PC  Kiosk  Car

Typical tasks:

Automation  Positioning  Maintenance

………….  ………..……  …………….  ……………..  ……………..  ……………..  ……………..
HMI Input Devices

- Many devices
- Best one depends on GUI tasks and user environment
HMI Input Devices vs. Application

Smartphone  PC  Kiosk  Car

Challenges:

自动化  定位  维护
## HMI Input Devices vs. Application

<table>
<thead>
<tr>
<th>Input Devices</th>
<th>Smartphone</th>
<th>PC</th>
<th>Kiosk</th>
<th>Car</th>
<th>Automation</th>
<th>Positioning</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyboard</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Mouse</td>
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<td>Joystick</td>
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<tr>
<td>Touch</td>
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<td>Speech</td>
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<td>Buttons</td>
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<tr>
<td>Camera</td>
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</tr>
</tbody>
</table>
HMI Output Devices

- Many devices
- Best size etc. depends on GUI tasks, input devices and user environment
- Examples: stationary, handheld, warning, …
HMI Output Devices vs. Application

Smartphone | PC | Kiosk | Car

Challenges:

Automation | Positioning | Maintenance

........... | ............. | ............. | .............
HMI Output Devices vs. Application

<table>
<thead>
<tr>
<th>Display with touch</th>
<th>Smartphone</th>
<th>PC</th>
<th>Kiosk</th>
<th>Car</th>
<th>Automation</th>
<th>Positioning</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large display</td>
<td></td>
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<tr>
<td>Small display</td>
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<td>HUD, HMD</td>
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<tr>
<td>Sound</td>
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</tr>
</tbody>
</table>
Combinations of Input and Output Devices

- Input and output must be optimized for task and user environment
- This has often consequences for GUI

Input (l, r, scroll, press, …) defines GUI of automotive GUls
HMI Users

- Many different users:
  - Experience
  - IQ
  - Age
  - Disabled
  - Other tasks (driving, …)
  - Stress, …
  - Environment (e.g. ladder)
<table>
<thead>
<tr>
<th></th>
<th>PC SW</th>
<th>Internet</th>
<th>Kiosk</th>
<th>Driver</th>
<th>Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inexperienced</td>
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<tr>
<td>Experienced</td>
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<tr>
<td>Distraction</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Aged, disabled</td>
<td></td>
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</tr>
</tbody>
</table>

HMI Users vs. Application

Professional: Pilot, automation, maintenance, …
Classic Use Case for GUI: Car Rental

Tasks:
- Input of customer data
- Quick interaction with database

Environment:
- Time is money
- Customers in a hurry
Classic Use Case for GUI: Car Rental

Questions:
- Input devices?
- Space for input devices?
- Size and resolution of screen?
Group Work: Case Study I (MES)

- GUI for next generation automotive infotainment
- GUI for high end vending machines like coffee machine
- GUI for measurement devices (e.g. osci)
- GUI for smart home terminal
- GUI for automation
- Other Embedded Systems

Form groups now and select GUI for case studies

x groups
Group Work: Case Study I (MIS)

- GUI for consumer devices like smartphone, PC software
- GUI for kiosk applications like vending machines
- GUI for dedicated devices like in cars
- GUI for data mining (IT applications)
- GUI for other professional applications

Form groups now and select GUI for case studies
Group Work: Case Study I

Topics for presentation, GUI prototyping and final documentation:

• Typical examples (“now”) {~ 1 slide for 1st presentation}

• Typical requirements for input and output devices (“now”)
  {~ 2 slide for 1st presentation}

• Selection of an example and “programming” of this example
  {in parallel during term}

• “First draft on paper” or use PPT
  {~ 3 slides for 1st presentation – main screen shots, 1 slide PAP}

• Presentation of case studies I – III in a single presentation
  (1 week after CS III)
Overview “§1 Introduction”

- Some Definitions
- Overview with Examples
- Some Fundamentals
- Ergonomics & Displays
Benefits of “Great” Graphical User Interfaces

• Intuitiveness

• Images are more intuitive than text

• Touch panel control

• Individual Look & Feel

• Corporate Design (or Branding) generates unique selling points (USP)

• Usability

• Increasing Degrees of Freedom for Product Design

• Universality / Dynamic Contents

• Various Fonts for Multi-Language-Support
Further Fundamentals and Requirements for GUls

• **Actions steps** (“Does the user know what to do?”)

• **User Parameters**
  - Vision (resolution, character size, use of color, …)
  - Displays (resolution, size, requirements, …)

• **Knowledge about users**
  (see §Fundamentals of GUI)

• **Hard- and software for GUI**
  (see §Fundamentals of GUI and §Screen design)
Action Steps: Simple (?) User Interfaces: Phones @ Home

“Does the user know what to do?”

Dial was about 80 years present with only slight changes (mainly design)!

Modern phones differ in their user interfaces and are available only a few years.
**Action Steps: Simple (?) User Interfaces:**

Low cost devices:
- simple symbolism
- only a few functions

High end devices:
- complex symbolism
- (too?) many functions

"Does the user know what to do?"
**Action Steps:** Input and Output should be Logical

**User interface for doors:**
- Push or pull – which design needs no experience?
- Which side opens?

Is the sense of turning of steering device the same as the directional reaction of the vehicle?

(Example from M. Dahm: Basics of Man - Computer – Interaction, PEARSON)
Numeric Keypads

Caused by historic reasons, but also differences within one category
7 Action Steps acc. Donald Norman

Forming a goal

Translate goal to task(s)

Planning the action (sequence)

Executing the action (sequence)

What happened ↔ what was intended

Interpreting the outcome

Perceiving what happened

7 Action Steps: Gulf of Execution

Human Action Cycle

Forming a goal

Translate goal to task(s)

Planning the action (sequence)

Executing the action (sequence)

- Insufficient idea of concept
- To little idea of action
- Insufficient way to function(s)
7 Action Steps: Gulf of Evaluation

Human Action Cycle

- No relationship to goal
- Visualisation unclear
  - Change not shown or not readable

GUI

What happened ↔ what was intended

Interpreting the outcome

Perceiving what happened

Executing the action (sequence)
GUI Overkill

(Example from M. Dahm: Basics of Man - Computer – Interaction, PEARSON)
User Interface Evolution on PCs …

Command Line Interface (CLI)

Graphical User Interface (GUI)

Time

Natural User Interface (NUI)
### User Interface Evolution on PCs …

<table>
<thead>
<tr>
<th></th>
<th>CLI</th>
<th>GUI</th>
<th>NUI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary input media</strong></td>
<td>Keyboard</td>
<td>Keyboard + mouse</td>
<td>Finger (touch), speech</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>Abstract, text (code)</td>
<td>Metaphors, graphics (icons)</td>
<td>Direct, objects</td>
</tr>
<tr>
<td><strong>User has to think in</strong></td>
<td>Codes</td>
<td>Icons</td>
<td>Objects</td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td>Remembering codes</td>
<td>Recognition of icons</td>
<td>Intuitive as objects are “natural”</td>
</tr>
<tr>
<td><strong>User experience</strong></td>
<td>Simple</td>
<td>Descriptive</td>
<td>Forcing experience</td>
</tr>
<tr>
<td><strong>Typical efficiency</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

*From GUI to NUI by PCs, laptops, tablets with touch screen*
User Interface Evolution on PCs …

Evolution of scroll bars over WINDOWS versions

Scroll bar becomes widespread and less visible over the years. Scrollbar may be obsolete for touch zoom as this might become well known to users.

Source: Henssler, Pf
OSIT Model for Natural User Interfaces

By Prof. Hennsler, PU Design

OSIT = Orientation, Selection, Information, Action („transagieren“)

OSIT = Intuitive interaction of humans

Orientation: Where I am?
Selection: What is available here?
Information: Show me more details
Action: Process performed by user

Source: Hennsler, Pf
OSIT Model Example

ORIENTIEREN
Wo bin ich?

SELEKTIEREN
Was gibt es hier?

INFORMIEREN
Details betrachten

TRANSAGIEREN
In den Warenkorb

Source: Henssler, Pf
## OSIT Model Example

<table>
<thead>
<tr>
<th>Orientieren</th>
<th>Selektieren</th>
<th>Informieren</th>
<th>Transagieren</th>
</tr>
</thead>
<tbody>
<tr>
<td>Übersicht</td>
<td>Auswahl</td>
<td>Detail</td>
<td>Aktion</td>
</tr>
<tr>
<td>Coverflow, Gallery, Liste</td>
<td>Produkt kommt auf Nutzer zu</td>
<td>Vollbild mit allen Details</td>
<td>Optionen zur Aktion</td>
</tr>
<tr>
<td>Filter, Sortieren, Umgruppen, Vergrößern...</td>
<td>Zoom-in/-out</td>
<td>Lesen, Sehen,</td>
<td>Merken, Vergleichen, Kaufen, Bewerten, Empfehlen...</td>
</tr>
</tbody>
</table>

Source: Henssler, Pf
Some Consequences

- Should modern GUI devices be so complicated ?
  - Long term and exhausting adaptation training
  - Even technical freaks use often only a few functions
  - No incentive to buy a new product if the features
    of the old one aren’t fully used
  - Aging society incl. workers

- 2 Types of GUIs – Definition by Frequency of Use
  - Frequent: Trained users like operator, PC standard SW users,
  - Rare: ‘Untrained’ using web pages, public information systems, ...
    consequences of bad GUI design: system is not used
    critical for commercial applications incl. websites
    (easy-to-use GUI will become favourite)
Basics Consequences for GUIs

• Workplace or environment sets ergonomics

• Vision sets GUI objects (size, color, …)

• Display resolution sets number etc. of GUI objects

• Display has to show the GUI in an adequate quality (CR, ambient light, …)

• How many different GUIs can be handled?
  How many do you use frequently? 10s, 100s, 1,000s …?

• Different GUIs at home and office

• Some GUIs are more safety critical (power plant, aircraft, …) as others (advertisement in web – but checkboxes for legal aspects)

See next sections
Overview “§1 Introduction”

- Some Definitions
- Overview with Examples
- Some Fundamentals
- Ergonomics & Displays
Ergonomics

Other unit in use:  Pixel per Inch (ppi)  \((1\,\text{"} = 25.4\,\text{mm})\)

Eye resolution: 0.15 mm / m for pixels
\(\rightarrow\) 170 ppi for 1 m viewing distance
Useful ppi is about 50% … 67% of this value: 100 ppi \(\Rightarrow 1' \equiv 0.25\,\text{mm} / \text{m}\)

e.g. APPLE retina display IPHONE : 326 ppi (78 µm) ; IPAD 3: 264 ppi

<table>
<thead>
<tr>
<th>Viewing Distance /m</th>
<th>~ PPI from Eye Resolution</th>
<th>Eye Res. Pixel Size /mm</th>
<th>Useful PPI</th>
<th>Useful Pixel Size /mm</th>
<th>Typical Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>510</td>
<td>0.08</td>
<td>300</td>
<td>0.08</td>
<td>Smartphone</td>
</tr>
<tr>
<td>0.5</td>
<td>340</td>
<td>0.13</td>
<td>200</td>
<td>0.13</td>
<td>Tablet, PC monitor</td>
</tr>
<tr>
<td>1</td>
<td>170</td>
<td>0.15</td>
<td>100</td>
<td>0.25</td>
<td>“Reference”</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
<td>0.5</td>
<td>50</td>
<td>0.50</td>
<td>TV &gt; 50”</td>
</tr>
<tr>
<td>10</td>
<td>17</td>
<td>3</td>
<td>10</td>
<td>2.50</td>
<td>E-Signage</td>
</tr>
</tbody>
</table>
Font Size (Pixel) vs. PPI

Higher resolution (here dots per inch [dpi = ppi] like printing) and font resolution increase readability.

Monitor @ 0.5m

<table>
<thead>
<tr>
<th>Font Height (Pixel)</th>
<th>100 dpi</th>
<th>200 dpi</th>
</tr>
</thead>
<tbody>
<tr>
<td>622</td>
<td>531</td>
<td>927</td>
</tr>
<tr>
<td>105</td>
<td>870</td>
<td>488</td>
</tr>
</tbody>
</table>

Font resolution

- Reasonable:
  - Font resolution > 7 x 5
  - > 100 ppi for monitor use
Ergonomics

**Recommended Line Number**

Line number \( \approx \frac{25 \cdot \text{Screen Heighth}}{\text{Viewing Distance}} \)

Example: \( h = 30 \text{ cm}, \ d = 50 \text{ cm} \rightarrow Z = 15 \)

**Recommended minimal Character height**

**for large viewing distance**

Character height \( \approx \frac{\text{Viewing distance}}{100} \)

Example: \( d = 30 \text{ m} \rightarrow h = 30 \text{ cm} \ (5 \text{ m} \rightarrow 5 \text{ cm}) \)

**Viewing Cone**: Aperture Angle \( \phi \)

Typically 20° - 40°, recommended: 30°

Office (\( d = 60 \text{ cm} \)) : 14“ (20°) - 28“ (40°)
Human Vision: Aspect Ratio

4:3 ... also landscape or portrait, ....

16:9

old“ PCs, some tablets

Smartphones, tablets, PCs, TVs,

GUI design has to be optimized for aspect ratio
Human Vision: Aspect Ratio

Is this webpage really optimized for 16:9?

Unused

Future Focused

Internet | Geschützter Modus: Aktiv
Graphical User Interface Screen Design (I)

Rule: Golden Cut
- Used by famous photographers and artists
- Area partitions and proportions (~ 1/3 : 2/3) are felt as very harmonious!
- Also many things in nature follow a Golden Cut strategy e.g. snail’s shell
Graphical User Interface Screen Design (II)

Golden Cut arrangement recommended

This is not a “hard” rule, you may use e.g.
- 40 : 60
- 1/3 : 2/3
Information Processing

Recognized

Maximun 1:1

Alphanumeric + graphics + color

Alphanumeric b/w

Speech

Information

Supplied
Information Coding & Recognition

- How many different characters are displayed?
- What is the number of the 'minority'?

Need for color!
Character Height ↔ Number of Colours

Minimum Character Height / ° (arc)

Numerical examples for 1 m observer distance

Reasonable: 22° for one color ≈ 6.5 mm per meter observer distance
Ergonomics: Readability vs. Foreground / Background

Readability depends on character height and color combination

Negative contrast (bright foreground, dark background) recommended at dark illumination.
Ergonomics: Readability vs. Foreground / Background

Positive contrast (dark foreground, bright background) recommended at bright illumination.

Same colors as in example for black background:

- Readability very different → readability depends on fore- and background combination
- Yellow not readable for white background, green (0/255/0) is limited
- (0/150/0) recommended for green
**Color Combinations**

Recommended color combinations = Good recognition

<table>
<thead>
<tr>
<th>Background Color</th>
<th>Foreground Color</th>
<th>Black</th>
<th>White</th>
<th>Magenta</th>
<th>Blue</th>
<th>Cyan</th>
<th>Green</th>
<th>Yellow</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Black</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>White</td>
<td>White</td>
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<td>+</td>
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<td>+</td>
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<tr>
<td>Magenta</td>
<td>Magenta</td>
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<tr>
<td>Blue</td>
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<td>+</td>
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<tr>
<td>Cyan</td>
<td>Cyan</td>
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<tr>
<td>Green</td>
<td>Green</td>
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<tr>
<td>Yellow</td>
<td>Yellow</td>
<td>+</td>
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<td>+</td>
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<tr>
<td>Red</td>
<td>Red</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Many GUI recommendations are as well good for presentations!
## Color Conventions for Coding

<table>
<thead>
<tr>
<th></th>
<th>Symbolic</th>
<th>Cartographic</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blue</strong></td>
<td>Advisory, status light</td>
<td>Water, sky, cool</td>
<td>Deeper saturations = greater depth, colder</td>
</tr>
<tr>
<td><strong>Green</strong></td>
<td>Go, good, on, friend, safe, right or starboard</td>
<td>Vegetation</td>
<td>Deeper saturations = heavier vegetation</td>
</tr>
<tr>
<td><strong>Yellow</strong></td>
<td>Caution, standby, warning</td>
<td>Dryness, medium temperatures, lack of vegetation</td>
<td></td>
</tr>
<tr>
<td><strong>Brown</strong></td>
<td></td>
<td>Land, mountains, warm</td>
<td></td>
</tr>
<tr>
<td><strong>Red</strong></td>
<td>Stop, bad, danger, off, warning, enemy, left or port, unsafe</td>
<td>Important items, roads, cities, hot</td>
<td>Flashing red = emergency</td>
</tr>
<tr>
<td><strong>White</strong></td>
<td>Neutral, data</td>
<td>Ice, high elevations</td>
<td></td>
</tr>
</tbody>
</table>
Other Factors Influencing Readability

Automotive: Driver distraction

‘Visually displayed information should be such that the driver can assimilate it with a few glances which are brief enough not to adversely affect driving.’

How long does it need to get the displayed information?
Other Factors Influencing Readability

**Automotive: Driver distraction**

Lesedauer und zugehörige Wahrscheinlichkeiten von der Straße zu kommen, nach Bruckmayr et al. (1994, modifiziert)

<table>
<thead>
<tr>
<th>Lesedauer</th>
<th>Fahrbahnbreite: 3.66 m</th>
<th>Fahrbahnbreite: 3.05 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 sec.</td>
<td>0.04 %</td>
<td>1.25 %</td>
</tr>
<tr>
<td>4 sec.</td>
<td>1.10 %</td>
<td>6.30 %</td>
</tr>
<tr>
<td>6 sec.</td>
<td>8.69 %</td>
<td>18.14 %</td>
</tr>
</tbody>
</table>
Summary: Vision & Ergonomics

- Vision resolution ~ 1’

- Recommended pixels per inch: 100 ppi for 1 m observer distance
  ➔ 1’ = 0.25 mm / m

- Recommended character height: 22’ @ 1 color: 6.5 mm / m for consumer

- Increase character size (buttons, graphics, …) for professional applications like automotive (driver distraction), automation, medical (safety), …

Readability & speed

- Character height should increase with colors used

- Character font resolution > 7 x 5 pixel

- Take care of recommended fore- and background color combinations

- Colored text readability depends on positive or negative contrast
Group Work: Case Study II

Topics for presentation, GUI prototyping and final documentation:

• Determine typical observer distance

• Determine number of text colors used for GUI

• Calculate font size height (mm)

• Calculate pixel pitch from font size height for 12 x 6 pixel font

• The above topics should result in ~ 2 pages for 1\textsuperscript{st} presentation

• Implement these topics in your case study {in parallel during term}

• Presentation of case studies I – III in a single presentation (1 week after CS III)
Ergonomic (Display) Factors and Their Interaction

- Viewing distance
- GUI element size
- Colour
- Contrast
- Reflections

User

Input devices

Environment

Display
User - Display - Input Devices Geometry

• Requirements
  - Must be ergonomic (readability, size, ambient light, …)
  - Differ in time of use
    ATMs (minutes) vs. database input (hours)

• Geometries
  - Mobile device (e.g. smartphone) → orientation set by user
  - Fixed devices → orientation set by engineer

• Other topics
  - Distance of user to screen and input device
  - Ambient light
  - Privacy
User - Display - Input Devices Geometry Examples

Office (long time use) → Operator (short use)

Von 680 mm ...

... stufenlos ...

... bis 1180 mm
User - Display - Input Devices Geometry: Office

maximale Höhe der obersten Zeile

35°

60°

50 – 80 cm

Abb. 26: Vertikales Blickfeld
Display Resolution

Typical resolutions and features of non-CE devices follow mostly CE mass production:

- **Low res**, mostly monochrome, no grey levels: 96 x 64, 128 x 96, 240 x 128
- **Mid res**, mostly color, available with touch:
  - QVGA (320 x 240), VGA (640 x 480), WSVGA (1024 x 600)
- **High res**, full color, up to WXGA with touch:
  - XGA (1024 x 768), HD (1280 x 720), WXGA (1366 x 768), FHD (1920 x 1080), UHD (3840 x 2160, also Quad FHD)

Take care of portrait or landscape use

Choose typically standard resolutions for your case study.
Display - Technologies

• Reflective
Displays reflect ambient light
Example: monochrome LCDs and e-paper

• Emissive
Generate light direct (OLED) or via backlight (LCD)
Examples: color displays like LCD, OLED, Plasma
Display Technology vs. Illuminance

Reflective LCD

Emissive OLED

Illuminance

800 lx

100 cd/m² in darkroom

20.000 lx

Luxmeter

1 camera shot @ 0.8 and 20 kLx

Display luminance is constant but eye (here: camera) adapts to ‘mean’ illuminance!

Application “decides”:

vivid colors vs. low power & bright ambient light"
Graphical User Interface: Introduction

Contrast Ratio & Ambient Light

- Reflections of ambient light are measured as reflected luminance $L_{\text{reflected}}$

- Those reflections are added to the luminance output of the display

\[
C_R = \frac{L_{\text{White}}}{L_{\text{Black}}} \quad \text{+ ambient light} \quad \Rightarrow \quad C_R = \frac{L_{\text{White}}(0 \text{ lx}) + L_{\text{Reflected}}}{L_{\text{Black}}(0 \text{ lx}) + L_{\text{Reflected}}}
\]

Value in spec Value by measurements

Optimization of CR for bright ambient light:

- Increase display luminance
- Reduce reflections (AR, AG [matte], …)
- Reduce illuminance $E$ if possible by e.g. shields
- Adapt GUI to positive contrast (black characters on white background) and use only saturated colors ($R = B = M: 255$, $G = 127$ \{8 bit\})
Reflection Reduction Methods

'Original without anything'

Anti-Glare
(specular $\rightarrow$ diffuse)

Anti-Reflex
(specular reduced)

Anti-Glare + Anti-Reflex
('best' + most expensive)
Light Reflections vs. Grey Level & Visibility

Reflections are ‘enhanced’ on dark areas and ‘invisible’ for ‘bright areas’

“Bright background” reduces noticeable reflections (and lifetime)!

Same display, geometry, illumination etc.
Improving Readability by Software

- Image enhancement algorithms as known from HDR
- Applications: Better readability at bright light e.g. automotive
- Can be applied for GUIs
- Use in some mobile devices

- Most simple solution is to design GUI (if applicable) to outdoor performance: White background, now low grey levels, saturated colors, …
Static GUI Effects: Burn-In & Image Sticking

Several hours left image
then display dark grey (right)

Panel fulfills 5 point uniformity spec!
Area image sticking

Solutions:
- Animation if possible
- Screen saver
- Panning/orbiting (invisible shift $\pm 1$ pixel h, v)

Lifetime effects are not described in specs → evaluation required

Displaying a static GUI for long time may damage the display e.g. automotive!
Readability - one of the Most Important Factors of GUIs

Summary: Display related topics to be discussed for GUIs:

- Main requirement: GUI information on the display must be readable
- Luminance must be adapted to illuminance \( \Rightarrow L > 1.000 \text{ cd/m}^2 \) outdoors
- Ambient light reflections reduce readability \( \Rightarrow \) reduce reflections
- Contrast ratio reasonable for GUI content (color: \( \text{CR} > 10:1 \))
- Avoid lower grey levels as they will merge for bright light conditions
- Use saturated colors, others will bleach under bright ambient light
- Avoid static GUI content due to (emissive) Burn-In and LCD Image-Sticking.
Summary & Outlook

- GUI / HMI depends strongly on application, input devices, users, displays (output), other output devices, …, system cost, ROI, …

- “Data to be displayed”, user distance, environment, … decide on display resolution, display size, display technology, …

- There are rules for objects on the screen enabling resolution, … to be calculated

- GUI/HMI design is not static - CE influences professional applications (like design, user experience, display resolution, size, touch, gestures, …)
Group Work: Case Study III

Topics: Define display requirements and GUI grey level and colors

- Select a typical screen of your GUI example
- Select a display technology (reflective or emissive) and provide topics to be taken into account.
- Check for lifetime issues
- Calculate operating time for your application (e.g. h/day x days in use)
- The above topics count for ~ 2 slides in the presentation
- Optimize grey levels and colors for best outdoor performance in your prototype
- Update prototype GUI

Group presentations (~ 10 pages) next week of CS I – III