Visualizing Multivariate Data
### Multivariate Data?

Data based on more than one variable per sampling unit.

#### Example: Weather data (Munich)

<table>
<thead>
<tr>
<th></th>
<th>Temperatur °C</th>
<th>Niederschlag mm</th>
<th>relative Feuchte</th>
<th>Sonne h/Tag</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>max. Ø</td>
<td>min. Ø</td>
<td>Tage</td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>1,6</td>
<td>-5,1</td>
<td>53</td>
<td>16</td>
</tr>
<tr>
<td>Feb</td>
<td>3,6</td>
<td>-4</td>
<td>52</td>
<td>15</td>
</tr>
<tr>
<td>Mär</td>
<td>8,1</td>
<td>-0,8</td>
<td>56</td>
<td>13</td>
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<tr>
<td>Apr</td>
<td>12,6</td>
<td>2,6</td>
<td>75</td>
<td>14</td>
</tr>
<tr>
<td>Mai</td>
<td>17,4</td>
<td>6,8</td>
<td>107</td>
<td>15</td>
</tr>
<tr>
<td>Jun</td>
<td>20,5</td>
<td>10,2</td>
<td>131</td>
<td>16</td>
</tr>
<tr>
<td>Jul</td>
<td>22,8</td>
<td>12,1</td>
<td>116</td>
<td>16</td>
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<tr>
<td>Aug</td>
<td>22,3</td>
<td>11,8</td>
<td>116</td>
<td>15</td>
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<tr>
<td>Sep</td>
<td>19,1</td>
<td>8,9</td>
<td>79</td>
<td>13</td>
</tr>
<tr>
<td>Okt</td>
<td>13,6</td>
<td>4,4</td>
<td>57</td>
<td>12</td>
</tr>
<tr>
<td>Nov</td>
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<td>64</td>
<td>14</td>
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<tr>
<td>Dez</td>
<td>2,6</td>
<td>-3,7</td>
<td>60</td>
<td>14</td>
</tr>
</tbody>
</table>

Glyphs

- Small-sized visual symbols
- Variables are encoded as properties of glyph
- Each case is represented by a single glyph

**Main Limitation:** Have to be learned
- Not suitable for large data sets.
Star Glyphs

• aka web diagram, spider chart, star diagram ...
• Radial axes representing the variables
• Allows for comparison based on the shape of the resulting object

• Limitations:
  • Works for small data sets only [5]
  • Hard to compare fine differences in spoke lengths
  • Thus better suited for identifying outliers
Chernoff Faces

• Theory
  • Humans are able to recognize small changes in facial characteristics
  • Data is encoded by stylized faces using up to 18 characteristics

• Limitations
  • Extreme values negatively influence the impression of a face and the recognition of other values [1]
  • Experiments [2] reveal that recognition of Chernoff faces is a serial process and thus there is no significant advantage over other iconic visualization
## Your Turn

<table>
<thead>
<tr>
<th>Student</th>
<th>Course</th>
<th>Relationship</th>
<th>MMI 1</th>
<th>Infovis</th>
<th>DBS</th>
<th>Theor.</th>
<th>DS</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>MI</td>
<td>yes</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Inf</td>
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<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>KuM</td>
<td>yes</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>KuM</td>
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<td>2</td>
<td>3</td>
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<td>2</td>
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<tr>
<td>5</td>
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<tr>
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<td>3</td>
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<tr>
<td>7</td>
<td>Inf</td>
<td>no</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>8</td>
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<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>KuM</td>
<td>yes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Nominal**

**Ordinal**
Some Background on Data Types & Evaluation
Types of Data
Qualitative vs. Quantitative Data

- deals with descriptions
- data can be observed but not measured
- colors, textures, smells, tastes, etc.
- Qualitative -> Quality

- deals with numbers
- data which can be measured
- length, height, area, volume, speed, costs etc.
- Quantitative -> Quantity

Oil Painting

Qualitative data:
- blue/green color, gold frame
- smells old and musty
- texture shows brush strokes of oil paint
- peaceful scene of the country

Quantitative data:
- picture is 40 cm by 60 cm
- with frame 45 cm by 65 cm
- weighs 4 kilogramm
- costs 300€
Types of Data

From [3]

- Nominal
- Ordinal
- Interval
- Ratio

non-parametric
parametric

more information

From [3]
Ordinal vs. Interval

- ordinal provides an order
- doesn't tell anything about the differences
- example: triangle race

looks the same in the data
Evaluating InfoVis
Cause and Effect

Goal: Find causal links between variables

Precondition: Cause has to precede effect

How to infer causality:
• Two controlled conditions
  • Cause is present (experimental condition)
  • Cause is absent (control condition)
Hypotheses

- Prediction of the result:
  - „how will the independent variables effect the dependent variables?“

- Hypotheses must be formulated before running the study
  - By doing the experiment, the hypotheses is either proved or disproved
Variables

- Independent variables: „What do I change?“
  - Manipulated by the experimenter
  - Conditions under which the tasks are performed
  - The number of different values is called level, e.g.
    - Traffic light can be red, yellow or green (3 levels)

- Dependent variables: „What do I observe?“
  - Affected by the independent variables
  - Measured in the user study
  - Dependent variables should only depend on the independent variables
Study Designs

Basic approaches
- Observational: „observe what naturally happens“
- Experimental: „manipulate some aspects“

Design types
- Within subject („repeated measures“)
  - Each subject is exposed to all conditions
  - The order of conditions must be randomized to avoid ordering effects

- Between groups („independent measures“)
  - Separate groups (participants) for each condition
  - Careful selection of groups is essential

- Hybrid („mixed“) designs
Learning Effect

- people get better over time
- to avoid influences on the experiment:
  - use perfect counterbalancing if possible
  - Latin square designs
  - randomization
  - other designs

Example: One variable with 3 levels. $3! = 6$ arrangements.

1. ▲ ▲ ▲
2. ▲ ▲ ▲
3. ▲ ▲ ▲
4. ▲ ▲ ▲
5. ▲ ▲ ▲
6. ▲ ▲ ▲

counterbalanced
Participants

• Should be representative for the target group
• Avoid bias (e.g. not only men, students)
• Choose the right sample size

• Choose domain experts [4] if possible (especially in infovis)
  • More realistic results and tasks
  • Busy people with few time
  • Hard to get a big enough sample size
Principles

• The results of the experiment should be

1. Valid
   – Measurements are accurate and due to manipulations (internal validity)
   – Findings are representative and not only valid in the experiment setting (external validity)

2. Reliable
   – Consistency of measurement
   – A persons score doing the same test under the same conditions twice must be similar

3. Generalizable
   – Results should be valid for all people
   – Test users must be representative
Infovis Specifics [4]

• Find out:
  • If the visualization supports the user in the information task
  • How to improve the visualization to better support them
• Participants:
  • Domain experts if possible
• Data sets
  • Usually extremely large sets
  • Don’t just choose a subset
• Time:
  • It is not unusual for a task to take weeks or months
  • Hard to reproduce this in an experiment
• Tool status:
  • Hard to provide a fully functional tool rather than a prototype
# Likert Scales

- used to „measure“ opinions
- participants give ratings
- **Attention:** there is a huge discussion going on whether likert scale data is ordinal (non-parametric) or interval (parametric)*

<table>
<thead>
<tr>
<th>centered</th>
<th>uncentered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. fully agree</td>
<td>1. fully agree</td>
</tr>
<tr>
<td>2. agree</td>
<td>2. agree</td>
</tr>
<tr>
<td>3. neutral</td>
<td>3. disagree</td>
</tr>
<tr>
<td>4. disagree</td>
<td>4. totally disagree</td>
</tr>
<tr>
<td>5. totally disagree</td>
<td></td>
</tr>
</tbody>
</table>

* Computer scientists believe it is ordinal. Please read the following blog entry for information and implications: [http://cacm.acm.org/blogs/blog-cacm/107125-stats-were-doing-it-wrong/fulltext](http://cacm.acm.org/blogs/blog-cacm/107125-stats-were-doing-it-wrong/fulltext)
• Don’t report the mean
• If possible, report and visualize frequencies

For example:

Visualization by Max Maurer. Script available here [http://www.paje-systems.de/likert/](http://www.paje-systems.de/likert/)
Visual-Analog Rating Scales

- no categories
- advantage: users cannot remember their response

How easy to use was the prototype?

not easy at all

very easy
Boxplot

- good for quantitative data
Analysis

- Choose the right statistical tests
  - Heavily influenced by the choice of measurement tools
  - ... and the types of data used
  - Parametric tests (e.g. ANOVA, T-Test) vs. non-parametric tests (e.g. Wilcoxon, Kruskal-Wallis)

- Choose the right visualization (yes, you have to visualize the results of your visualization study ;-)
References


