MDS 651
Unit 6: Evaluating Visualization Techniques and Issues

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Outline

- User and Data Characteristics
- Visualization Characteristics
- Structures for Evaluating Visualizations
- Visualization Bench Marking
- Issues of Data
- Issues of Cognition
- Perception and Reasoning
- Issues of Hardware and Software

Introduction

- A common question from users of visualization tools is "Which visualization technique(s) should I use to solve my problem?"

- In general, there is no simple answer to this question; many factors go into the evaluation process, such as:
  - User task
  - User Characteristics
  - Data Characteristics

User Tasks

- To perform a valid assessment of a particular visualization technique, or to compare two or more techniques, it is important to identify the specific actions or tasks one wishes to accomplish with the assistance of visualization.
- **E.g.,**
    - Identify
    - Locate
    - Distinguish
    - Categorize
    - Cluster
    - Compare
    - Correlate

User Characteristics

- The term user refers to anyone who interact with visualized data.

- Users can include data analysts, decision-makers, researchers, or general audiences seeking insights from the visual representations.

User Characteristics

- The effectiveness of a visualization technique is tightly associated with the users of the visualization.

1. Domain Knowledge

- How much expertise does the user have with the domain of the data being explored? Has the user studied the field for a long time, or is relatively new to the field?

User Characteristics

2. Cognitive Abilities:

- Take into account the cognitive abilities and limitations of the users. Consider factors such as attention span, memory capacity, and visual perception capabilities. Design the visualization to match the cognitive abilities of the target audience.
- **E.g.,:** When creating a visualization for children, it is crucial to use simple and intuitive visual elements that are easy for them to understand and remember.

3. Familiarity with data.

- Has the user examined this data previously and formed a reasonable mental model of its contents, or is this her first exposure to it? Is it similar to other data sets she has examined?

User Characteristics

4. Familiarity with Visualization Techniques:

- Is this the user's first attempt to interpret the data using this particular kind of visualization, or has she spent considerable time using the technique?
- **E.g.,:** In an educational setting, when presenting data to students who are new to data analysis, it is advisable to start with basic visualizations such as bar charts and gradually introduce more advanced techniques

Data Characteristics

- The characteristics of the data being visualized can have a profound influence on the effectiveness of the visualization technique, and they must be considered in the evaluation process.

1. Data type
   - Dataset can contain mixture of data types , such as categorical, numerical, temporal, or textual.
   - Different visualization techniques are suitable for different data types.
   - **E.g.,:** If visualizing the sales of different items, a bar chart could be used to compare sales figures (categorical data), while a line chart may be employed to show the trend in sales over time (temporal data).

Data Characteristics

2. Data Structure:

- In a data set, the structure of the data can be simple (e.g., a uniform grid or a table) or complex (e.g., hierarchical).
- The visualization technique should align with the underlying data structure for effective representation.

- **E.g.,:** When visualizing a hierarchical organization chart, a tree diagram can effectively represent the hierarchical relationships between departments and employees.

3. Data Dimensionality:

- This considers the dimensionality of the data, whether it is low-dimensional or high-dimensional. High-dimensional data may require dimensionality reduction techniques to convey meaningful insights.

- **E.g.,:** dimensionality reduction techniques like PCA can be used to reduce the data to two or three dimensions for visualization purposes

Data Characteristics

4. Data Size

- Data sets in a particular domain can often take on a wide range of sizes, from a few records to thousands or millions of records.

5. Data Distribution

- Data can be uniformly or nonuniformly distributed, both in values and in attributes (such as spatio-temporal position).

6. Real vs Synthetic

- Many researchers perform evaluations using synthetic data, as it allows tight control of the data characteristics. For some types of evaluation (e.g., size tests) this is fine, but in general it is more convincing to use real data.

Visualization Characteristics

- Once the task, user, and data have been characterized, we can focus on the specific visualization technique(s) to be assessed. There are many aspects of the visualization that can be evaluated.

1. Computational Performance: How quickly can the visualization be generated, using data sets of various sizes?

2. Memory Performance: How much computer memory is required to generate the visualization?

3. Degree of Occlusion: What is the likelihood that some subset of the data to be displayed will be occluded by other parts of the visualization? How many views does the user need to see the entire data set?

Visualization Characteristics

4. Degree of Complexity: How many parameters does the user need to set in order to generate views? How much knowledge is needed to set and adjust these parameters in an effective manner? Considers: Layouts and composition, Color schemes, Interactivity.

5. Degree of usability: How easy is it to perform the task? How intuitive is the interpretation of the visualization?

6. Degree of Accuracy: How frequently is the user successful or unsuccessful in performing the desired task with this technique? Under what conditions are errors made, and how bad are the errors?

Structures for Evaluating visualizations

1 . Usability Tests:

- Concentrate on 'The Five E's": effective, efficient, engaging, error tolerant, and easy to learn
- Usually carried out by observing users attempting to perform tasks, and noting the types of difficulties they are having, the features they commonly use, and their level of comfort/satisfaction with the tool.

2. Expert Reviews:

- A visualization expert is someone who has studied visualization design and has likely used or developed a number of successful tools. He or she may have a checklist of desirable features for an effective visualization against which the object of the evaluation is assessed
- (this is sometimes referred to as heuristic evaluation).

Structures for Evaluating visualizations

3. Field Tests:

- Unlike usability tests, which are often carried out in a controlled environment over a short period of time field tests are performed in the natural environment of the typical user and may last for weeks or months.
- Field tests attempt to assess the degree to which the new technique or tool becomes an integral part of a user's activities.

4. Case Studies and Use Cases:

- Some visualization researchers attempt to validate the effectiveness of their techniques by showing real examples of how their method can be used in solving a particular problem or performing a given task.
- To ensure that the case studies are sufficiently realistic so that someone with a particular task to perform can be convinced that at least one of the case studies is sufficiently similar to his or her own task, and that the tool will effectively support it.

Visualization bench marking

- Benchmarking involves comparing visualizations against standards or best practices to ensure quality.
- Benchmarking is a formal procedure for evaluating the performance of some object or set of objects.

Procedures:

1. Formulate a hypothesis:
   - A benchmark requires a specific statement about one or more attributes of the object being assessed. Such as:
   - In terms of comparing visualization techniques, a more complete hypothesis would be "System A allows novice users to more easily identify clusters in data sets containing 5– 10 dimensions and 1000 to 10000 data points than system B."

Visualization bench marking

2. Design the experiments:

- The key to designing benchmark experiments is to create tests that vary only a single attribute at a time.
- **E.g.,** a test of computational speed for a set of algorithms would require that all experiments be run on the same computer, using the same data.

3. Execute the experiments:

- There are many ways a well-designed experiment can be executed so that little in the way of reliable conclusions will result.
- The audience should be of sufficient size to make the results statistically significant. For testing a single attribute of a visualization, it is best to have at least 15–20 subjects with similar backgrounds.

Visualization bench marking

4. Analyze the results and validate the hypothesis:

- Given the results of the experiments, it is then necessary to ascertain whether
  - the hypothesis is supported,
  - the hypothesis is refuted, or
  - there is insufficient evidence to support or refute the hypothesis.

An example of visualization benchmarking

- In an article by Ward and Theroux , a set of experiments is described for assessing the strengths and weaknesses of three multivariate visualization techniques:
  - namely scatterplot matrices, parallel coordinates, and star glyphs
- in performing two distinct tasks: cluster analysis and outlier detection.

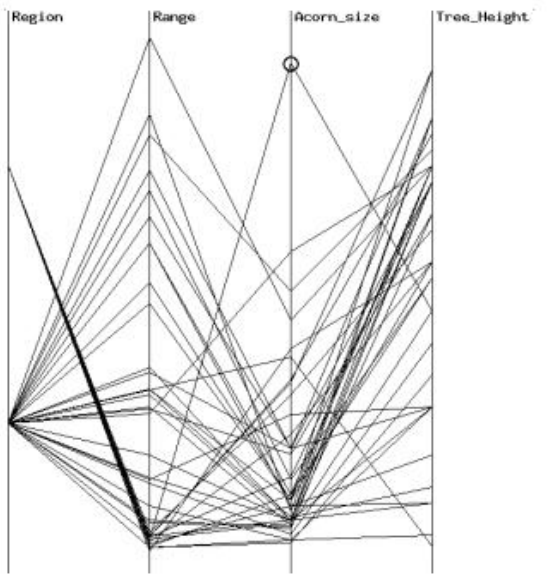
Outlier Detection and Measurement Experiments

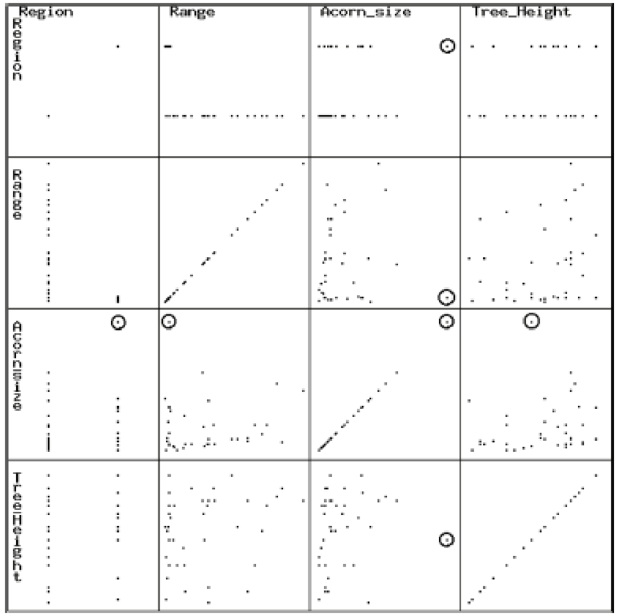
- Stage 1:
  - The first step was to develop a quantifiable definition for an outlier and create an algorithm capable of labeling data points appropriately.
  - The standard deviations of the measures of fit for each dimension were then calculated and compared against a threshold standard deviation to determine if the point was an outlier.

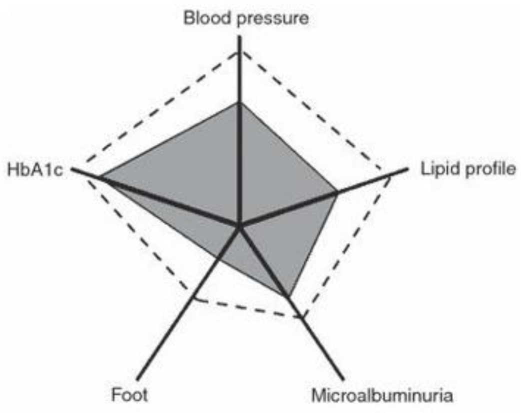
An example of visualization benchmarking

Outlier Detection and Measurement Experiments

- Stage 2:
  - Data sets, both real and simulated, were then acquired or generated that contained outliers, according to the definition in Stage 1.







An example of visualization benchmarking

Outlier Detection and Measurement Experiments

- Stage 3:
  - After the subjects (19 computer science graduate students with minimal exposure to data visualization) were trained to interpret the visualization technique(s) to be assessed and given examples of data sets with identified outliers (approximately one hour of training)
  - they were shown a set of 18 images of data sets containing between 0 and 6 outliers.
  - The subjects were asked not to spend more than one minute per image.

An example of visualization benchmarking

Outlier Detection and Measurement Experiments

- Stage 3:
  - The subjects were asked not to spend more than one minute per image. The tasks given to them were:

1. Determine if an image contains one or more outliers.
2. Identify the points believed to be outliers.
3. Estimate the degree of separation of each outlier on a 5-point scale (marginal to extreme).

An example of visualization benchmarking

Outlier Detection and Measurement Experiments

- Stage 4:
  - Given the subject responses, the usefulness of each visualization method tested was assessed in terms of outlier detection and measurement across data sets with different characteristics.
  - The percentages of correctly and incorrectly detected outliers were tallied, as well as the average error in estimating the degree of separation

An example of visualization benchmarking

Cluster Detection and Measurement Experiments

- Stage 1:
- Stage 2:
- Stage 3:
  - 19 computer science graduate students were given a packet containing 48 images of data sets that contained between 0 and 4 clusters. The subjects were asked to not spend more than one minute per image.
  - Question asked:

  1. Determine if an image contains one or more clusters.
  2. Highlight the groups of points believed to lie in distinct clusters.
  3. Estimate the size of each cluster on a 5-point scale (small to very large).
- Stage 4:

An example of visualization benchmarking

Result:

- For both tasks, scatterplot matrices generally fared best, followed by star glyphs positioned by principal component analysis, and lastly by parallel coordinates.
- Each had measurable strengths and weaknesses, as outlined below.

1. Scatterplot matrix

– less effective for overlapping clusters;

– less effective in size assessment for large clusters;

– less effective when outliers fell between clusters;

An example of visualization benchmarking

2. Glyphs

– best for identifying internal outliers (between clusters);

– poor for differentiating nonoutliers;

– good for conveying outlier separation;

– good for overlapping clusters;

– good for measuring moderate sized clusters;

3. Parallel Coordinates

– good for differentiating nonoutliers.

Topics

- Issues of Data
- Issues of Cognition
- Perception and Reasoning
- Issues of Hardware and Software

Issues of Data

- Issues of data refer to challenges or problems that can be found on data which is a serious challenge for data visualization, decision making and research.

- Data visualization relies heavily on the quality and integrity of the data being used.

Common issues include:

- **Data Quality:** Inaccurate, incomplete, or inconsistent data can lead to misleading visualizations.
- **Data Volume:** Too much data can overwhelm users, making it difficult to extract meaningful insights.
- **Data Structure:** Poorly structured data can be difficult to visualize effectively.

Issues of Data

Handling the issues:

- **Data Cleaning:** Use tools and techniques to clean data, removing errors and filling in missing values, handling inconsistence values.

- **Data Transformation:** Structure data in a way that is suitable for visualization, such as normalizing values or aggregating data points.

- **Data Abstraction:** Use techniques of data abstraction to handle large datasets.

Issues of Cognition

- These issues can encompass difficulties in processing complex visual information, identifying patterns or outliers, and making accurate judgments or decisions based on the visualized data.
- Can arise from factors such as information overload, cognitive biases, lack of domain knowledge, or cognitive impairments that affect attention, memory, or problem-solving abilities.

  - **Cognitive Load:** Complex visualizations can overwhelm the brain's processing capacity, making it hard to understand the data.
  - **Cognitive Biases:** Preconceived notions can affect how users interpret data, leading to biased conclusions.
  - **Perceptual Limitations:** Human perception has limits, such as difficulty in distinguishing between similar colors or interpreting 3D visualizations.

Issues of Cognition

Handling these issues:

- **Simplification:** Focus on key insights and avoid clutter. Use clear labels, legends, and scales.

- **Consistency:** Maintain consistency in design elements like colors, fonts, and symbols to help viewers quickly understand the visualization.

- **User Testing:** Conduct user testing to ensure that the visualization is easily understood by the target audience.

Issues of Hardware and Software

- Issues of hardware and software refer to challenges and problems that can arise in the technical infrastructure and tools used to create, process, and display visualized data.
- Hardware issues *may include limitations in computational power, insufficient memory*, compatibility issues.

  - **Hardware Limitations:** Insufficient processing power or display capabilities can hinder the effectiveness of visualizations.

  - **Software Limitations:** Some software tools may not support advanced visualization techniques.

  - **Compatibility:** Ensuring that visualizations work across different devices and platforms can be challenging.

Issues of Hardware and Software

Handling these issues:

- **Responsive Design:** Ensure that visualizations are responsive and can adapt to different screen sizes and resolutions.

- **Tool Selection:** Choose software tools that meet the needs of your visualization project. Consider tools that offer advanced features and compatibility with various devices.

- **Performance Optimization:** Optimize visualizations for performance, especially when dealing with large datasets or complex visuals.

End of Unit - 6

Thank you