An Empirical Study on the Comprehension of Stereotyped UML Class Diagram Layouts

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Study Goal

- Validate the usefulness of different layouts for UML class diagrams for comprehension
  - by replicating a previous eye-tracking study

- Are questionnaires and eye-trackers comparable media for validating the usefulness of class diagram layouts?
How does this study differ?

Eye-tracking study [Yusuf et al. 07]
- 9 subjects
- Data collected via eye-tracking equipment
- Expert and knowledgeable subjects
- Analysis based on eye fixations
- No statistical analysis

This Study
- 29 subjects
- Data collected via online questionnaires
- More variation in design knowledge among subjects
- Analysis based on accuracy
- Statistically conclusive
Focuses on the minimization of the edge crossings and bends.
Related classes that are responsible for specific functionality of a software system are positioned in a single cluster.
Positions classes into three clusters (i.e., boundary, control, and entity) based on their design or architectural roles.
Hypotheses

- There is a significant difference in UML and design task comprehension between class diagrams based on
  - the orthogonal layout and vs. three-cluster layout
  - the orthogonal layout vs. the multi-cluster layout
Study Setup

- Subject System
  - Hippodraw (C++ with Qt for GUI, ~50 KLOC)
  - 100 out of 240 classes used

- Subjects
  - 29 (14 undergraduates, 15 graduates)

- Tasks [Yusuf et al. ICPC’07]
  - 12 address UML notation
  - 15 address design issues

- Three Layouts [VISSOFT’05]
Experimental Variables

- **Main factor**
  - Layout with three treatments (multi-cluster, orthogonal and three-cluster)

- **Dependent variables**
  - Accuracy
  - Speed
  - Confidence level (not part of the eye-tracking study)
Timing the Study

- A maximum time limit of 60 seconds was allotted to each question
  - Kept subjects on task
  - Replicated timing of the eye-tracking experiment
Running the Study

- Background Questionnaire
- UML Class Diagram Tutorial (optional)
- Main Questionnaire on 27 tasks
  - Each task was accompanied by a class diagram in one of three possible layouts
- Post Questionnaire
UML and Design Task Scores

Box plot of all UML tasks

Box plot of all Design tasks
## Wilcoxon Paired Analysis (p-value)

<table>
<thead>
<tr>
<th>Layout Pairs</th>
<th>UML Tasks</th>
<th>Design Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthogonal and three-cluster</td>
<td>0.923</td>
<td>0.005 *</td>
</tr>
<tr>
<td></td>
<td>0.0004 *</td>
<td></td>
</tr>
<tr>
<td>Orthogonal and multi-cluster</td>
<td>0.0019 *</td>
<td>0.0031 *</td>
</tr>
<tr>
<td>Three-cluster and multi-cluster</td>
<td>&lt; 0.0001 *</td>
<td>0.5431</td>
</tr>
</tbody>
</table>
Question 7: Which classes are derived from Observer? (three-cluster layout)
Other Findings

- A positive correlation was found between
  - Self-rated design and programming skills and design task scores.
  - Self-rated programming skills and UML task scores
  - Self-rated design and programming skills and confidence level for each answer
  - Task scores and Confidence level

- Stereotypes were found helpful in answering questions
Conclusions

- Validates results of the eye-tracking experiment on assessing different class diagram layout schemes

- Multi-cluster layout outperforms the orthogonal layout in both tasks: UML and design
Orthogonal Layout

Focuses on the minimization of the edge crossings and bending.
Three-Cluster Layout

Positions classes into three clusters (i.e., boundary, control, and entity) based on their design or architectural roles.
Multiple-Cluster Layout

Related classes that are responsible for a specific functionality of a software system are positioned in a single cluster.
## Categorization of Subjects

<table>
<thead>
<tr>
<th>UML Categories (U)</th>
<th>Design Categories (D)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DA</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>5</strong></td>
</tr>
</tbody>
</table>

A: Agnostic  I: Intermediate  K: Knowledgeable  E: Expert
Question Classification

- Easy: 14, 15, 16, 26
- Intermediate: 17, 19, 21, 22
- Difficult: 13, 24, 25, 27
- Challenging: 18, 20, 23
- 8 questions matched, 7 didn’t match
Time Taken for UML and Design Tasks

Subjects

Total Time

Time for Design Tasks

Time for UML Tasks
Alternatives
Related Work

- New Layout Schemes
  - Eiglsperger et al.
  - Eichelberger et al.
  - Gutwenger

- Empirical Studies
  - Purchase et al.
  - Sun et al.
Results: Accuracy vs. Layout

![Bar Chart showing Weighted Scores for different layouts and tasks: UML orthogonal, UML 3-cluster, UML multi-cluster, Design orthogonal, Design 3-cluster, Design multi-cluster. The chart includes data points for q1, min, median, max, and q3.]