Information Graphics and Engineering Design

Prof. Marjan Eggermont, University of Calgary

Associate Dean of Student Affairs Marjan Eggermont works within the Schulich School of Engineering at Calgary. Eggermont is also the interim associate dean-international, the senior instructor design and communication, for mechanical and manufacturing engineering and the editor/designer of ZQ | zqjournal.com.
Information Graphics and Engineering Design

Abstract

Documentation for engineering design requires succinct project descriptions, often with information and data visualizations. In an effort to expose students to these types of visualizations students were asked to summarize each individual chapter of a technology-based book of their choice using a different visualization method. This exercise exposed students to a wide range of methods and gave them tools for future engineering project document design. The Periodic Table of Visualization Methods\(^1\) website was used as a starting point for the types of visualizations students could explore. This site is an e-learning site focusing on visual literacy: the ability to evaluate, apply, or create conceptual visual representations. This paper discusses and describes the visualization methods used to assist students with this project, examples of student chapter summaries (Figs. 1 and 2), and the importance for engineering students to be able to read documents and summarize important information in a graphically concise and relevant manner.

![Figure 1: Visualization methods used to summarize chapter 1 (student work)](image)

Figure 1: Visualization methods used to summarize chapter 1 (student work)
1. Introduction
Students at The University of Calgary Schulich School of Engineering take a Technology and Society course in the third year of their engineering program. This course, in the past, presented an overview of major engineering feats and societal impacts as a result of engineering innovations. Students were tested using standard multiple-choice exams.

For the past three years the course experimented with several communication components vital to the success of engineering students: oral presentations and graphic communication in the form of data and information visualizations. These components are beneficial to the student’s 4th year capstone design course where students present progress reports, give oral presentations and provide documentation to project sponsors to report major milestones in their projects. Instead of writing reports a new approach to class deliverables was developed. This paper focuses on one of the deliverables: a book report in the form of data and information visualizations. A brief description of the visualization methods resource will be provided in the first section followed by examples of student work. The last section will briefly discuss the other components that were required for the course with some examples and descriptions of activities.

2. A Periodic Table of Visualization Methods
In 2007 Ralph Lengler & Martin J. Eppler created a periodic table of 100 visualization methods in the form of a one-page website. Hovering over each visualization method results in a pop-up example of the method (Fig. 3). In their research paper Towards A Periodic Table of Visualization Methods for Management they describe the research as “an effort of defining and compiling existing visualization methods in order to develop a systematic overview based on the logic, look, and use of the periodic table of elements.”
They describe a visualization method as “a systematic, rule-based, external, permanent, and graphic representation that depicts information in a way that is conducive to acquiring insights, developing an elaborate understanding, or communicating experiences.”

The following excerpt and summary is from the paper written by Lengler and Eppler and the blog *The Visual Everything* to concisely describe the design the periodic table in figure 3 above:

“The periodic table is constructed along two dimensions: periods and groups. Of the five dimensions we deemed most relevant for a pragmatic classification of visualization methods, we found the dimension of complexity of visualization most fitting for “periods” and application area most fitting for “groups”.

As we classified the visualization methods along those two dimensions we also tried to organize them in a similar way. That means as you move down a column, you will find similar methods for similar purposes but getting more and more complex. This is an ordinal measure within a group, meaning you will find in one period different amounts of complexity. This is for pragmatic reasons, as we didn’t want to leave any empty spaces in the table. For example, a line chart is a more complex visualization method than a spectrogram (a single line having two extreme poles). On the other hand a tensor diagram is more complex than a spectrogram.

The chart has the application area dimension (“groups”) into the following categories and distinguished them by background color:

- **Data Visualization** includes standard quantitative formats such as Pie Charts, Area Charts or Line Graphs. They are visual representations of quantitative data in schematic form (either with or without axes), they are all-purpose, mainly used for getting an overview of data.”

An example of student work (pie chart and bar chart) can be seen below (fig. 4).
The engine of a Formula One race car is only responsible for 15% of its performance. To maximize this, specific materials are chosen for certain components. High power is not an exclusive requirement to win, but there are some trends of dominating engine manufacturers.

The Materials of F1 Engines

F1 Wins By Engine Manufacturer (Graphic #4)

<table>
<thead>
<tr>
<th>Engine Manufacturer</th>
<th>First Win</th>
<th>Last Win</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrari</td>
<td>1951 British Grand Prix</td>
<td>2011 British Grand Prix</td>
</tr>
<tr>
<td>Ford</td>
<td>1967 Dutch Grand Prix</td>
<td>2003 Brazilian Grand Prix</td>
</tr>
<tr>
<td>Renault</td>
<td>1979 French Grand Prix</td>
<td>2011 Brazilian Grand Prix</td>
</tr>
<tr>
<td>Mercedes-Benz</td>
<td>1954 French Grand Prix</td>
<td>2011 Abu Dhabi Grand Prix</td>
</tr>
<tr>
<td>Honda</td>
<td>1965 Mexican Grand Prix</td>
<td>2006 Hungarian Grand Prix</td>
</tr>
<tr>
<td>Toyota</td>
<td>1958 Argentine Grand Prix</td>
<td>1965 German Grand Prix</td>
</tr>
<tr>
<td>BRM</td>
<td>1959 Dutch Grand Prix</td>
<td>1972 Monaco Grand Prix</td>
</tr>
<tr>
<td>BMW</td>
<td>1982 Canadian Grand Prix</td>
<td>2008 Canadian Grand Prix</td>
</tr>
<tr>
<td>TAG</td>
<td>1984 Brazilian Grand Prix</td>
<td>1987 Portuguese Grand Prix</td>
</tr>
<tr>
<td>Alfa Romeo</td>
<td>1950 British Grand Prix</td>
<td>1978 Italian Grand Prix</td>
</tr>
<tr>
<td>Coventry Climax</td>
<td>1958 Argentine Grand Prix</td>
<td>1965 German Grand Prix</td>
</tr>
</tbody>
</table>

Figure 4: Summary of Chapter 3 of The Science of Formula 1 Design

- “Information Visualization, such as semantic networks or treemaps, is defined as the use of interactive visual representations of data to amplify cognition. This means that the data is transformed into an image; it is mapped to screen space.

- Concept Visualization, like a concept map or a Gantt chart; these are methods to elaborate (mostly) qualitative concepts, ideas, plans, and analyses through the help of rule-guided mapping procedures.

- Metaphor Visualization, like metro map or story template are effective and simple templates to convey complex insights. Visual Metaphors fulfill a dual function, first they position information graphically to organize and structure it.”

Figure 5 shows a temple diagram which required the student to extract all components of complexity from the chapter to create a concise summary.
• **Strategy Visualization**, like a Strategy Canvas or technology roadmap is defined “as the systematic use of complementary visual representations to improve the analysis, development, formulation, communication, and implementation of strategies in organizations.”

• “**Compound Visualization** consists of several of the aforementioned formats. They can be complex knowledge maps that contain diagrammatic and metaphoric elements, conceptual cartoons with quantitative charts, or wall sized info murals. (Note: The Periodic table is a Compound Visualization)”⁶,⁷ Figure 6 shows an information (timeline) and compound (graphic facilitation) visualization summarizing a chapter of the book *The Science of Formula 1 Design*. 

---

Figure 5: Temple diagram summarizing chapter from *Simply Complexity* (courtesy of student Michael Cabrera)
3. Visualization Methods and Engineering

In the winter semester of 2012, students of Engineering 481 Technology and Society were asked to create a visual methods book report (some examples seen in previous section). Each chapter of the book had to be summarized into a one-page visual method graphic. A different method had to be chosen from the Periodic Table of Visualization Methods web page for each chapter. This meant that students had to analyze the content of each chapter and find the best suitable visualization method available to summarize the chapter content. It also meant students had to filter out major themes, timeline elements, and/or data components from each portion of the book. Students were directed to the Recommended Reading for Budding Engineers list created by the University of Cambridge to pick a book of their choice.

Figures 7 and 8 are samples from a student visual method book report. The student reviewed The Science of Formula 1 Design by David Tremayne. In this example the student choose a Gantt chart, a well-known engineering concept visualization, to represent the first chapter of the book and to chart the typical development in an F1 season.
Two distinctive race schedules are performed in each F1 season. While the race has dramatically less in set points for the overall championship, development of next season’s car is taking place simultaneously. With the new car being completed only weeks before the following season, since engine design takes about 12 months, two power engineering teams are required, with each leapfrogging the other, providing one engine per every 9 months car development cycle.

Figure 7: Student work: *Gantt chart* visual method choice for book chapter

Figure 8: Student work: Resulting *Gantt chart* chapter summary
Examples of information visualization can be seen in the same student report in figures 9 and 10 below:

Figure 9: Student work: Cycle diagram and clustering visual method choices for book chapter

Figure 10: Student work: Resulting Cycle diagram and clustering chapter summary
A student who submitted a book report on Neil Johnson’s *Simply Complexity: A clear guide to Complexity Theory* was able to draw succinct parallels that he found in a chapter on connectivity (fig. 11) and extract a decision tree from ‘tackling traffic networks’. Once students enter the workforce they will often be confronted with complex situations, varying levels of management, and disparate sources of information. Allowing students to develop visualization skills will only be an asset and a useful tool once reporting work tasks.

![Networks Diagram](image1)

**Figure 11:** Student work (Michael Cabrera): *Concept Map* chapter summary

![Decision Tree Diagram](image2)

**Figure 12:** Student work (Michael Cabrera): *Decision Tree* chapter summary
3.1 Other deliverables
Two other deliverables that strayed from the norm where introduced in the *Technology and Society* course:

- Oral presentations based on a photo exhibition in a local museum: Edward Burtnskey’s *Encounters*. This exhibition showed 30 works by Canadian photographer E. Burtnskey. He photographs landscapes transformed by industry—quarrying, mining (fig. 13), recycling, manufacturing, rail cutting, and ship breaking among other things. Student groups had to do an oral presentation based on one photograph of their choice from the exhibition. The presentation had to discuss:
  - Industry
  - Location/geography
  - Manufacturing techniques/Science
  - Technological impact
  - Societal impact
  - Environmental impact
  - Government/Politics
  - and other topics inspired by the photograph

Students presented a very interesting variety of material, which made attendance high and marking for the instructor a joy (compared to past presentations that had little to no variety). How students interpreted the photographs was also interesting and varied from culture to culture, which allowed for good discussions after the presentations.

![Image of Edward Burtnskey’s Nickel Tailings #34 Sudbury, Ontario, Canada](image)

Figure 13: Edward Burtnskey “Nickel Tailings #34” Sudbury, Ontario, Canada

- A compare and contrast visualization based on two of five documentaries shown in the seminar portion of the course: students watched five documentaries of varying engineering, science and social science content and were asked to pay attention to the following categories to be used for their visualization:
  - History/historical development
  - Technology
  - Impact on society
An example can be seen in figure 15. The student compared the documentaries *Philosophy and The Matrix* and *Werner von Braun: Rocket Man for War and Peace* focussing on fate and free will.

**4. Conclusion**

This paper looked at new deliverables for a course on technology and society with the goal of improving student’s visualization, analysis, and interpretation skills. The main focus was exposure to different visualization methods summarized by Lengler and Eppler on the *Periodic Table of Visualization Methods* website. A summary of the creation and workings of the site was presented and student examples of resulting book report chapter summaries were shown.

Finally two additional examples of deliverables were briefly mentioned to demonstrate the changes made to a course that traditionally tested students on memorization of facts not on analysis and understanding of content.

The course lecture content itself focussed on themes of the past two hundred years of technology and society (fig. 14), which one of my students summarized as follows: “Thank you for the semester. Only you could make going through the same 200 years over and over again interesting. Have a great summer!”
Figure 15: Student work: Documentary comparison
Bibliography

2. Lengler, R., and Eppler, M. J. Towards A Periodic Table of Visualization Methods for Management, *Institute for Corporate Management*, University of Lugano, Switzerland, p. 1