Data Visualization and Communication

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Course Structure

Fundamentals of Communication:

1. Communicating Clearly
2. Tailoring to an Audience
3. Selecting an Appropriate Form
4. Giving and Getting Feedback

Focus on Visual Communication

5. Creating Visualizations
6. Designing for Human Perception
7. Employing Graphic Design
8. Enabling Interaction

Focus on Verbal Communication

9. Composing a Narrative
10. Writing and Speaking About Statistics

Specialized Applications:

11. Visualizing Complexity
12. Visualizing Time and Place
13. Designing Dashboards; Making Your Work Accessible
14. Evoking Emotion
15. Final Projects

Course Description:

Communicating clearly and effectively about the patterns we find in data is a key skill for a successful data scientist. Both visual and verbal skills are needed to do so. From white papers and spoken presentations to the labeling of graphs, words underpin all types of technical communication. But words alone are limited. Visualization enhances exploratory analysis as well as efficient communication of results. This course focuses on the design and implementation of complementary visual and verbal representations of data in order to discover patterns, answer questions, convey findings, drive decisions, and provide persuasive evidence. The goal is to give you the practical knowledge you need to convey analytical results effectively to all audiences. Assignments will give you hands-on experience with designing data graphics and visualizations as well as reporting your findings in prose. (3 units)

Prerequisite:

Exploring and Analyzing Data

Course Format:

The course will consist of one and one half hour of asynchronous online content ("lecture") and one and one half hour of synchronous (live) online discussion per week. The discussion session offers a chance to consider the readings and lectures with classmates and the instructor. In it, we will consider new visualizations and practice critiquing them as well as each other's work. It is also an opportunity to apply the principles from lecture to your own visual and verbal representations of data and statistical analyses.

Assignments:

There are three design assignments, one of which you will complete with other members of a group, as well as three writing assignments that you will complete individually. For the final project, you will work with your group to produce a report on a statistical analysis of a data set of your choice, using interactive graphics and visualizations to explicate results of interest and support your conclusions.

- Group design assignment (1 total): 10%
- Individual design assignments (2 total): 20%
- Individual writing assignments (3 total): 30%
- Individual participation and critique: 10%
- Final project: 30%

Software and Readings:

This course will use a combination of textbooks and online readings. When both paper and electronic versions of the textbooks are available, you may use either. All students are expected to do the readings before watching lectures and before all discussion sections. In many cases the lecture materials will not make sense if you do not have knowledge of the examples and issues from the readings.

Software

We will use the Tableau Desktop visualization software in this course, and students will be recommended to use D3 (http://d3js.org) for more interactive visualizations. Tableau's data visualization software (http://www.tableausoftware.com/data-visualization-software) is provided by the Tableau for Teaching program. Other tools are optional, and students are encouraged to try as many of them as possible. Software options that we will discuss include Adobe Illustrator, Highcharts (http://www.highcharts.com), VisIt (https://wci.llnl.gov/codes/visit/), and ggplot2 (http://had.co.nz/ggplot2/), a package for R (http://www.r-project.org/) for producing statistical graphics. Students may choose other software tools as appropriate for their final projects.

Required Texts:

- Miller, J.E. (2012). The Chicago Guide to Writing about Multivariate Analysis, second edition, Chicago: University of Chicago Press. ("CGWMA" below)
- Few, Stephen. *Show Me the Numbers*, Analytics Press, 2012. ("SMTN" below)
- Tufte, Edward. *The Visual Display of Quantitative Information,* 2nd Edition. Cheshire, CT: Graphics Press.
- Strunk, W. and E.B. White, *The Elements of Style*, 3rd Edition, Macmillan, 1979 (or 4th edition, or Illustrated edition, or 50th Anniv. edition—or what you already own).
- (for reference) The Chicago Manual of Style, available free to students online, http://www.chicagomanualofstyle.org/16/contents.html

Syllabus

Part I: Fundamentals of Communication

1. Communicating Clearly

Why visualization matters, graphical clarity, graphical integrity, graphical excellence, verbal clarity, journalistic integrity, basic principles for writing about quantitative data

Readings:

— Tufte, E.R. (2001). "Graphical Excellence" (pp. 13-51) and "Graphical Integrity" (pp. 52-77) from *The Visual Display of Quantitative Information,* 2nd Edition. Cheshire, CT: Graphics Press.
— Miller, CGWMA, "Chapter 2, Seven Basic Principles."
— Miller, CGWMA, "Appendix A, Implementing 'Generalization, Example, Exceptions"
— ACM Code of Ethics, http://www.acm.org/about/code-of-ethics
— Principles and Rules of Copyright, Adobe Systems Inc., 2013.
— Ph.D. comic, "The Science News Cycle," May 18, 2009, http://www.phdcomics.com/comics/archive.php?comicid=1174

2. Tailoring to an Audience

The importance of context, understanding the domain, building off previous knowledge, terminology and jargon, editorial style, writing for non-specialists, writing PR, writing for critical readers, needs assessment, exploiting familiarity in design, graphical style, labeling

- Writing assignment 1 given

Readings:

— Miller, CGWMA, "Chapter 20, Writing for Applied Audiences."
— Gould, Stephen Jay (1980) "The Panda's Thumb," in *The Panda's Thumb: More Reflections in Natural History*, pp. 19-26.
— Freedman, David, and Robert Pisani and Roger Purves (2007), "The Law of Averages", Chapter 16 in *Statistics*, 4th Edition, pp. 273-287.

3. Selecting an Appropriate Form

Roles of visualization; data types; taxonomy of visualization; matching data to visualization types; forms of writing; selecting a verbal form; tables; mixing text, table, and image

- Individual design assignment 1 given
- Writing assignment 1 due

Readings:

— Graph Design I.Q. Test, Stephen Few, 2009. http://www.perceptualedge.com/files/GraphDesignIQ.html
— Few, SMTN, "Chapter 3, Differing Roles of Tables and Graphs."

— Few, SMTN, "Chapter 4, Fundamental Variations of Tables."
— Few, SMTN, "Chapter 6, Fundamental Variations of Graphs."
— Tufte, Edward (2000). Exerpt from "Words, Numbers, Images—Together," in *Beautiful Evidence*, Graphics Press, pp. 97-101, 106-109, 114-121.
— Heer, J., Bostock, M., Ogievetsky, V. "A Tour Through the Visualization Zoo," *ACM Queue*, 2010.
— http://xkcd.com/833/
— (optional) "A classification of visual representations", Lohse, Biolsi, Walker, Reuter, CACM 1994.

4. Giving and Getting Feedback

Critique, usability testing, paper prototyping, MoSCoW prioritization, content editing, copy editing, editorial gotchas

- Individual design assignment 1 due
- Individual design assignment 2 given

Readings:

— Nielsen, Jakob, "Chapter 5, Usability Heuristics" and "Chapter 7, Usability Testing" in *Usability Engineering*, 1993.
— Strunk, W. and E.B. White, *The Elements of Style*, 3rd Edition, Macmillan, 1979.

Part II: Focus on Visual Communication

5. Creating Visualizations

Tools for static visualizations, tools for interactive visualizations, charting libraries, visualization on distributed systems

- Individual design assignment 2 due

Readings:

— Murray, Scott, *Interactive Data Visualization for the Web*, O'Reilly, 2013, Chapters 5-8. http://chimera.labs.oreilly.com/books/1230000000345/index.html

6. Designing for Human Perception

The visual system, mechanics of visual perception, preattentive processing, detection, estimating magnitude, change blindness, gestalt principles, perceiving multiple attributes, color perception.

- Final project and group design assignment given

Readings:

— Few, SMTN, "Chapter 5, Visual Perception and Graphical Communication"
— Tufte, E.R. (1990). Exerpt from "Color and Information," in *Envisioning Information*. Cheshire, CT: Graphics Press, pp. 80-85, 90-95
— Borland, D. and R.M. Taylor, "Rainbow Color Map (Still) Considered Harmful," in *IEEE Computer Graphics and Applications*, March/April 2007, pp. 14-17.
— Ware, C. "Chapter 1, Foundations for an Applied Science of Data Visualization," in *Information Visualization: Perception for Design*, 3rd Edition, Morgan Kaufman, Waltham, MA, 2013.

7. Employing Graphic Design

Principles of graphic design: composition, contrast, repetition, visual hierarchy, visual flow, color, typography, icons

Readings:

— Albers, Josef, *Interaction of Color*, Yale University Press, New Haven, 1975, pp.1-11.
— Tinkel, Kathleen, "Taking It In: What Makes Type Easy to Read and Why," *Adobe Magazine*, March/April 1996, pp. 41-45.
— Krause, Jim, *Design Basics Index*, How Design Books, Cincinnati, 2004, pp. 15-19, 21-23, 34-35, 41-45, 63-69, 74-77, 79-85.

8. Enabling Interaction

Interactivity and exploration, response times, Fitts's law, visual tasks, interaction techniques, heuristics for interface design, how users are changing.

Readings:

— Shneiderman, Ben. "The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations," *Proc. IEEE Conference on Visual Languages*, Boulder 1996.
— Wickham, H., Cook, D., Hofmann, H., and Buja, A. "Graphical inference for infovis." In *IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis '10)*, vol. 16, no. 6, 2010, pp. 973–979. http://vita.had.co.nz/papers/inference-infovis.pdf

Part III: Focus on Verbal Communication

9. Composing a Narrative

The relationship between graphic and verbal communication, defining a message, providing context, development and flow, examples and analogies, tips for common pieces

- Group design assignment due – midterm project presentations in live session
- Writing assignment 2 given

Readings:

— Few, SMTN, "Chapter 7, General Design for Communication."
— Miller, CGWMA, "Chapter 7, Choosing Effective Examples and Analogies."
— Miller, CGWMA, "Chapter 8, Basic Types of Quantitative Comparisons."
— Miller, CGWMA, "Chapter 12, Writing Introductions, Conclusions, and Abstracts."
— Miller, CGWMA, "Chapter 13, Writing about Data and Methods."

10. Writing and Speaking about Statistics

Causality, statistical and substantive significance, variables, units of measurement, precision and accuracy, distributions and associations, speeches, posters

- Writing assignment 3 given
- Writing assignment 2 due

Readings:

- Miller, CGWMA, "Chapter 3, Causality, Statistical Significance, and Substantive Significance."
- Miller, CGWMA, "Chapter 4, Five more Technical Principles."
- Miller, CGWMA, "Chapter 11, Choosing How to Present Statistical Test Results."
- Miller, CGWMA, "Chapter 14, Writing about Distributions and Associations."
- Cham, Jorge, "Your Conference Presentation," Ph.D. Comics, http://www.phdcomics.com/comics/archive.php?comicid=1553

Part IV: Applications

11. Visualizing Complexity

Multivariate visualizations, small multiples, heatmaps, parallel coordinates plots, other multivariate plot types, animation, networks, reducing complexity

- Writing assignment 3 due

Readings

- Few, SMTN, Chapter 12, "Multivariate Analysis."
- Fisher, D., "Chapter 19, Animation for Visualization: Opportunities and Drawbacks," in *Beautiful Visualization*, pp. 329-352.
- Inselberg, A. "Multidimensional Detective," IEEE, June 1997, pp. 100-107.
- Marx, V., "Data Visualization: Ambiguity as a Fellow Traveler," Nature Methods, Vol. 10, No. 7, July 2013, pp. 613-615.
- (optional) Gratzl, S., Lex, A., Gehlenborg, N., Pfister, H. and Streit, M. "LineUp: Visual Analysis of Multiattribute Rankings," *IEEE Transactions on Visualization and Computer Graphics,* Vol. 19, No. 12, December 2013. http://data.icg.tugraz.at/caleydo/publication/2013_InfoVis_Gratzl_LineUp.pdf, also http://www.youtube.com/watch?v=iFqCBI4T8ks
- (optional) Wattenberg, M. "Visual Exploration of Multivariate Graphs," *CHI 2006 Proceedings*, Montreal, pp. 811-819.

12. Visualizing Time and Place

Geographic visualization; spatial units of analysis; choropleth and isopleth; time series; temporal patterns; applications of temporal visualizations, geographic visualizations, and combinations of the two.

Readings:

- Few, Stephen, "Time-Series Analysis." in *Now You See It*, Analytics Press, 2009, 143-188.
- Aigner, W., S. Miksch, W. Müller, et al., "Visual methods for analyzing Time-oriented data," *IEEE Transactions on Visualizations and Computer Graphics*, Jan/Feb 2008, pp. 47-60.
- Schmandt, M. "Chapter 1: Introduction to GIS and Mapping,"GIS Commons: *An Introductory Textbook on Geographic Information Systems*, http://giscommons.org.
- Monmonier, M. (1996). Chapter 2: Elements of the Map. In *How to Lie with Maps*. Chicago, University Of Chicago Press.

13. Designing Dashboards; Making Your Work Accessible

Common mistakes, elements of good dashboard design. Universal design, assistive technologies, standards and laws for electronic access, tactile graphics, sonification.

- Final project presentations due in live session (group 1)

Readings:

- Few, Stephen. "Chapter 3, Thirteen Common Mistakes in Dashboard Design" and "Chapter 7, Designing Dashboards for Usability", in Information Dashboard Design: The Effective Visual Communication of Data, O'Reilly Media, 2006.
- WAI-ARIA Introduction http://www.w3.org/TR/wai-aria/introduction
- WCAG 2.0 at a Glance http://www.w3.org/WAI/WCAG20/glance/
- For reference: http://www.w3.org/TR/wai-aria/ http://www.w3.org/TR/WCAG20/ http://www.section508.gov

14. Evoking Emotion

Aesthetics, the value of aesthetics in visualizations, color and emotion, rhetoric, voice, person, tone, defusing emotion, persuasive writing.

- final project presentations due in live session (group 2)

Readings:

— Viégas, F.B. and M. Wattenberg, "Artistic Data Visualization: Beyond Visual Analytics," *HCII 2007*.
— Manovich, Lev, *The Anti-Sublime Ideal in Data Art*, self-published, 2002. http://www.manovich.net/DOCS/data_art.doc. Originally published as The Anti-Sublime Ideal in New media", in the online journal *Chair et métal 7* (2002).
— Williams, Joseph M., Chapter 9, "Elegance," in *Style: Toward Clarity and Grace*, University of Chicago Press, Chicago, 1990, pp. 153-166.
— Reinard, J.C., "The empirical study of the persuasive effects of evidence: The status after fifty years of research," *Human Communication Research*, Vol. 15, No.1, Fall 1988, pp. 3-30 (31-59 optional).

15. Finals Week

No class

- Final projects due