Data Visualization (CSE 578)

Note: Below outline is subject to modifications and updates.

About this Course

Visual representations generated by statistical models help us to make sense of large, complex datasets through interactive exploration, thereby enabling big data to realize its potential for informing decisions. This course covers techniques and algorithms for creating effective visualizations based on principles from graphic design, visual art, perceptual psychology, and cognitive science to enhance the understanding of complex data.

**Specific topics covered include:**

- data transformations
- exploratory querying
- statistical graphics
- time series analysis
- exploratory spatial data analysis

Learning Outcomes

**Learners completing this course will be able to:**

- Develop exploratory data analysis and visualization tools using Python and Jupyter notebooks
- Apply design principles for a variety of statistical graphics and visualizations including scatterplots, line charts, histograms, and choropleth maps
- Combine exploratory queries, graphics, and interaction to develop functional tools for exploratory data analysis and visualization

Projects

- Project 1: Analyzing Theme Park Patronage
- Project 2: Analyzing Wait Times and Dynamics of Theme Park Patronage
- Project 3: Exploring and Clustering Trajectories in a Theme Park
- Project 4: Finding Commonalities Between Theme Park Patrons
- Project 5: Design a Visual Analytics System for Exploring Theme Park Dynamics
Course Content

Instruction
- Video Lectures
- Other Videos
- Readings
- Interactive Learning Objects
- Live office hours
- Webinars

Assessments
- Practice activities and quizzes (auto-graded)
- Practice assignments (instructor- or peer-reviewed)
- Team and/or individual project(s) (instructor-graded)
- Final exam (graded)

Estimated Workload/Time Commitment Per Week
Approximately 15-20 hours per week.

Required Prior Knowledge and Skills
- Basic statistics and computer science knowledge including computer organization and architecture, discrete mathematics, data structures, and algorithms
- Knowledge of high-level programming languages (e.g., C++, Java) and scripting language (e.g., Python)

Technology Requirements

Hardware
- Standard with major OS

Software and Other
- To complete course projects, the following application will be required: Jupyter Notebooks.
Course Outline

Unit 1: Introduction to Data Visualization

Learning Objectives
1.1 Define visualization.
1.2 Describe key purposes of visualization.
1.3 Identify the data types of elements within a dataset's data.
1.4 Demonstrate the process of loading datasets for analysis into Python.
1.5 Explain data warehouses and exploratory querying.
1.6 Define the properties of Bertin's visual variables.
1.7 Identify appropriate color schemes for different data types.
1.8 Explain how combinations of visual variables impact the usefulness of a graphic.

• Unit Introduction
• Core Concepts
  • What is Data Exploration?
  • Data Challenges
  • Common Data Representations: Data Models and Data Organization
  • Common Data Representations: Vector Data
    • Basis of Vector Data
    • Vector Features
    • Vector Distance Measures
    • Vector Norms
  • Common Data Representations: Strings and Spaces
  • Exploratory Querying
  • Visual Variables Used in Data Exploration and Visualization
    • Color Schemes and Design
  • Jupyter Notebook: Loading Data in Python
• Assignment 1: Dino Fun World

Unit 2: Introduction to Statistical Graphics

Learning Objectives
2.1 Describe exploratory data analysis
2.2 Define design principles for pie charts and donut charts
2.3 Define design principles for bar charts and line charts
2.4 Define design principles for histograms and the impact of parameter choices on the visualization
2.5 Understand how to create and use box-plots and Q-Q Plots

- Unit Introduction
- Exploratory Data Analysis
  - What is Exploratory Data Analysis?
- Design principles for Pie and Donut Charts
  - Introduction to Pie Charts
- Design Principles for Bar Charts and Line Charts
  - Bar and Line Charts
  - Design Considerations for Non-Data Components of Graphs
- Design principles for Histograms
  - Creating Histograms
- Design Principles or Box-plots and QQ Plots
  - Understanding Quartiles
  - Box and Whisker Plots
  - Q-Q Plots
- Module 6: Jupyter Notebook: Introduction to Statistical Graphics

**Unit 3: Multivariate Analysis**

**Learning Objectives**

3.1 Describe attributes of multivariate data visualization
3.2 Apply methods of visualizing discrete data values along two axes
3.3 Identify issues associated with parallel coordinate plots
3.4 Compare correlation and covariance

Define supervised learning and describe supervised learning methods
Describe methods for evaluating supervised learning
Define unsupervised learning and describe unsupervised learning methods
Describe methods for evaluating unsupervised learning

- Unit Introduction
- Multivariate Analysis
  - Introduction to Scatterplots
- Mosaic Plots and Pixel Based Displays
  - Mosaic Plots
  - Pixel Based Displays
- Parallel Coordinate Plots
- Text Visualization
- Jupyter Notebook: Advanced Graphics in Python
- Supervised and Unsupervised Learning
  - Data Visualization and Machine Learning Connection
  - Supervised Learning
  - Nearest Neighbor Classifier
  - Regression
  - Evaluation
• Unsupervised Learning
  • Introduction to Unsupervised Learning
  • Evaluation
• Jupyter Notebook: Machine Learning
• Assignment 1: Dino Fun World Analysis

Unit 4: Temporal Analysis

Learning Objectives
4.1 Learners completing this course will be able to:
4.2 Apply methods of temporal analysis
4.3 Perform a multivariate visual analysis

• Unit Introduction
  • Module 1: Aigner classification
  • Module 2: Time series modeling
  • Module 3: Time series motifs

Unit 5: Geographical Data Analysis

Learning Objectives
5.1 Describe tools and techniques that are designed to support analyses that focus on datasets with a geographic component
5.2 Differentiate types of geographic visualizations
5.3 Explain spatial statistics
5.4 Apply methods of spatial analysis
5.5 Develop a geographic visualization

• Unit Introduction
  • Module 1: Introduction to Geographic Analysis and Visualization
    • Introduction to Geographical Analysis
    • Thematic Maps
    • Coordinate System
    • Map Design: Map projections
    • Map Design: Map Elements and Typography
  • Module 2: Choropleth Maps
    • Introduction to Choropleth Maps and Color Schemes
    • Data Classifications
  • Module 3: Common Geographic Visualizations
    • Common Geographic Visualizations
  • Module 4: Spatial Statistics
    • Spatial Statistics
Module 5: Spatial Autocorrelation
• Spatial Autocorrelation
Module 6: Spatial Scan Statistics
• Spatial Scan Statistics
Module 7: Geovisual Analytics Systems
• Geovisual Analytics Systems

Unit 6: Hierarchical Data Analysis

Learning Objectives
6.1 Explain hierarchical representation schemes
6.2 Apply methods of hierarchical data analysis
6.3 Appraise a cluster visualization
   • Unit Introduction
   • Module 1: Hierarchical Clustering
     • Single Link
     • Centroid
     • Ward’s Distance
   • Module 1: Hierarchical Clustering
     • Tree Maps
     • Dendrogram

<LOs and outline not yet confirmed>

Unit 7: Additional Tools Used for Data Visualization

In development

In development
About ASU

Established in Tempe in 1885, Arizona State University (ASU) has developed a new model for the American Research University, creating an institution that is committed to access, excellence and impact.

As the prototype for a New American University, ASU pursues research that contributes to the public good, and ASU assumes major responsibility for the economic, social and cultural vitality of the communities that surround it. Recognizing the university’s groundbreaking initiatives, partnerships, programs and research, U.S. News and World Report has named ASU as the most innovative university all three years it has had the category.

The innovation ranking is due at least in part to a more than 80 percent improvement in ASU’s graduation rate in the past 15 years, the fact that ASU is the fastest-growing research university in the country and the emphasis on inclusion and student success that has led to more than 50 percent of the school’s in-state freshman coming from minority backgrounds.

About Ira A. Fulton Schools of Engineering

Structured around grand challenges and improving the quality of life on a global scale, the Ira A. Fulton Schools of Engineering at Arizona State University integrates traditionally separate disciplines and supports collaborative research in the multidisciplinary areas of biological and health systems; sustainable engineering and the built environment; matter, transport and energy; and computing and decision systems. As the largest engineering program in the United States, students can pursue their educational and career goals through 25 undergraduate degrees or 39 graduate programs and rich experiential education offerings. The Fulton Schools are dedicated to engineering programs that combine a strong core foundation with top faculty and a reputation for graduating students who are aggressively recruited by top companies or become superior candidates for graduate studies in medicine, law, engineering and science.

About the School of Computing, Informatics, & Decision Systems Engineering

The School of Computing, Informatics, and Decision Systems Engineering advances developments and innovation in artificial intelligence, big data, cybersecurity and digital forensics, and software engineering. Our faculty are winning prestigious honors in professional societies, resulting in leadership of renowned research centers in homeland security operational efficiency, data engineering, and cybersecurity and digital forensics. The school’s rapid growth of student enrollment isn’t limited to the number of students at ASU’s Tempe and Polytechnic campuses as it continues to lead in online education. In addition to the Online Master of Computer Science, the school also offers an Online Bachelor of Science in Software Engineering, and the first four-year, completely online Bachelor of Science in Engineering program in engineering management.
Ross Maciejewski (Dr. Ross) is an Associate Professor at Arizona State University in the School of Computing, Informatics & Decision Systems Engineering and Director of the Center for Accelerating Operational Efficiency, a Department of Homeland Security Center of Excellence. His primary research interests are in the areas of geographical visualization and visual analytics focusing on public health, dietary analysis, social media, criminal incident reports, and the food-energy-water nexus.

Professor Huan Liu joined ASU in 2000 after conducting research in Telecom (Telstra) Australia Research labs and teaching at the National University of Singapore. He has extensive experience in research and development. Liu’s research and teaching focuses on machine learning, data mining, and real world applications.

K. Selcuk Candan is a professor of computer science and engineering at Arizona State University and the director of ASU’s Center for Assured and Scalable Data Engineering (CASCADE). His primary research interest is in the area of management and analysis of non-traditional, heterogeneous, and imprecise (such as multimedia, web, and scientific) data.