VISUAL ENCODING & DESIGN PROCESS

Miriah Meyer
School of Computing
University of Utah
- visual encodings
- guidelines
- process
visual encodings
how can you visually represent the numbers 4 and 8?
**Magnitude Channels: Ordered Attributes**

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

**Identity Channels: Categorical Attributes**

- Spatial region
- Color hue
- Motion
- Shape
where do these rankings come from?
Graphical Perception and Graphical Methods for Analyzing Scientific Data
William S. Cleveland and Robert McGill

Graphs provide powerful tools both for analyzing scientific data and for communicating quantitative information. The computer graphics revolution, which began in the 1960’s and has intensified during the past several years, stimulated the invention of graphical methods for analyzing and presenting scientific data, such as line plots, two-tiered error bars, scatterplot smoothing, dot charts, and graphing on a base 2 scale.

Summary. Graphical perception is the visual decoding of the quantitative and qualitative information encoded on graphs. Recent investigations have uncovered the basic principles of human graphical perception that have important implications for the display of data. The computer graphics revolution has stimulated the invention of many graphical methods for analyzing and presenting scientific data, such as line plots, two-tiered error bars, scatterplot smoothing, dot charts, and graphing on a base 2 scale.

For constructing graphs, consider the following:

ods: types of graphs and types of quantitative information to be shown on graphs (1-4). One purpose of this article is to describe and illustrate several of these new methods.

What has been missing, until recently, in this period of rapid graphical invention and deployment is the study of graphs and the human visual system. When a graph is constructed, quantitative and categorical information is encoded, chiefly through position, shape, size, symbols, and color. When a person forms with greater accuracy. This article is illustrated by several examples in which some much-used graphical forms are represented, set aside, and replaced by new methods.

Elementary Tasks for the Graphical Perception of Quantitative Information

The first step is to identify elements of graphical-perception tasks that are used to visually extract quantitative information from graphs; theory and experimental data are then used to order tasks on the basis of accuracy. The decoding has an important application: decoding involves tasks as high in ordering as possible, that is, tasks for ecological validity. Crowdsourced experiments may also substantially reduce both the cost and time to result.

Unfortunately, crowdsourcing introduces new concerns to be addressed before it is credible. Some concerns, such as ecological validity, subject motivation and expertise, apply to any study and have been previously investigated [13, 14, 23]; others, such as display configuration and viewing environment, are specific to visual perception. Crowdsourced perception experiments lack control over many experimental conditions, including display type and size, lighting, and subjects’ viewing distance and angle. This loss of control inevitably limits the scope of experiments that reliably can be run. However, there likely remains a substantial subclass of perception experiments for which crowdsourcing can provide reliable empirical data to inform visualization design.

In this work, we investigate if crowdsourced experiments insensitive to environmental context are an adequate tool for graphical perception research. We assess the feasibility of using Amazon’s Mechanical Turk to evaluate visualizations and then use these methods to gain new insights into visualization design. We make three primary contributions:

• We replicate prior laboratory studies on spatial data encoding by using Mechanical Turk.
• We develop and use a new generation of visualizations and performance metrics.
• We evaluate the feasibility and limitations of using Mechanical Turk for crowdsourcing experiments on visual perception.

ABSTRACT
Understanding perception is critical to effective visualization design. With its low cost and scalability, crowdsourcing presents an attractive option for evaluating the large design space of visualizations; however, it first requires validation.

In this paper, we assess the viability of Amazon’s Mechanical Turk as a platform for graphical perception experiments. We replicate previous studies of spatial encoding and luminance contrast and compare our results. We also conduct new experiments on rectangular area perception (as in treemaps or cartograms) and on chart size and gridline spacing. Our results demonstrate that crowdsourced perception experiments are viable and contribute new insights for visualization design. Lastly, we report cost and performance data from our experiments and distill recommendations for the design of crowdsourced studies.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces—Evaluation/Methodology

General Terms: Experimentation, Human Factors.

Keywords: Information visualization, graphical perception, user study, evaluation, Mechanical Turk, crowdsourcing.

INTRODUCTION

Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design
Jeffrey Heer and Michael Bostock
Computer Science Department
Stanford University
{jheer, mbostock}@cs.stanford.edu
how much longer is B?

4x
how much larger is B?

A

B

2X
diameter

4X
area
how much darker is B?

2x
low

high

time

(b)
EXERCISE: encoding deconstruction
a few guidelines...
Points of View: Color Coding.
a few guidelines...

COLOR get it right in black and white
a few guidelines...

COLOR  get it right in black and white

3D
a few guidelines...

COLOR  get it right in black and white
3D    stay in the plane
a few guidelines...

COLOR  get it right in black and white

3D    stay in the plane

ANIMATION
Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing.
a few guidelines...

**COLOR**  get it right in black and white

**3D**    stay in the plane

**ANIMATION**  eyes over memory

**DECORATION**
**Los Angeles Population By Race**

<table>
<thead>
<tr>
<th>Race</th>
<th>Population</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>2.01 million</td>
<td>52.6%</td>
</tr>
<tr>
<td>Asian</td>
<td>438K</td>
<td>11.5%</td>
</tr>
<tr>
<td>Native Hawaiian &amp; other Pacific Islander</td>
<td>6K</td>
<td>0.2%</td>
</tr>
<tr>
<td>Black</td>
<td>358K</td>
<td>9.4%</td>
</tr>
<tr>
<td>American Indian &amp; Alaska Native</td>
<td>17K</td>
<td>0.4%</td>
</tr>
<tr>
<td>Two or more races</td>
<td>131K</td>
<td>3.4%</td>
</tr>
<tr>
<td>Some other race</td>
<td>861K</td>
<td>22.5%</td>
</tr>
</tbody>
</table>

Source: United States Census Bureau, 2012 estimates. *Note:* The concept of race is separate from the concept of origin; 48 percent of respondents identified themselves as “Hispanic or Latino” but fall into one of the above groups.
a few guidelines...

**COLOR**  get it right in black and white

**3D**  stay in the plane

**ANIMATION**  eyes over memory

**DECORATION**  show data variation, not design variation
- visual encodings are ranked

- guidelines:
  - get it right in black and white
  - stay in the plane
  - eyes over memory
  - show data variation, not design variation
process
source: HUMAN
destination: LIZARD
source: HUMAN
destination: LIZARD

MizBee: A Multiscale Synteny Browser
MizBee: A Multiscale Synteny Browser
“Honestly . . . I don't think I would ever have gotten here.”
visualization design is a process
What do you want to visualize?

From patterns of conservation we want to visualize the mechanisms that influence gene regulation.
Design Activity Framework for Visualization Design.
Design Activity Framework for Visualization Design.
Design Activity Framework for Visualization Design.
data counseling
interviews, exploratory data analysis, rapid prototyping
-data counseling benefits from a diverse set of stakeholders
  - talk to many
  - be thoughtful and purposeful in an interview
  - interview in the wild

-fail fast... prototype rapidly
  - your best ideas are usually not your first ones
  - prototypes are a way to learn about problem
From patterns of conservation we want to visualize the mechanisms that influence gene regulation.

Find temporal patterns within a set of time series that are organized hierarchically.
proxy
a partial and imperfect representation of the thing the analyst cares about
Identify good directors.
<table>
<thead>
<tr>
<th>Title</th>
<th>Year</th>
<th>Genre_1</th>
<th>Genre_2</th>
<th>Genre_3</th>
<th>Director</th>
<th>Writer_1</th>
<th>Writer_2</th>
<th>Writer_3</th>
<th>Actors_1</th>
<th>Actors_2</th>
<th>Actors_3</th>
<th>Actors_4</th>
<th>Metascore</th>
<th>imdbVotes</th>
<th>Language</th>
<th>Country</th>
<th>imdbRating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deadpool</td>
<td>2016</td>
<td>Action</td>
<td>Adventure</td>
<td>Comedy</td>
<td>Tim Miller</td>
<td>Rhett Reese</td>
<td>Paul Wernick</td>
<td>Fabian Nicieza</td>
<td>Ryan Reynolds</td>
<td>Karan Soni</td>
<td>Ed Skrein</td>
<td>Michael Benjamin</td>
<td>65</td>
<td>352</td>
<td>English</td>
<td>USA</td>
<td>8.1</td>
</tr>
<tr>
<td>The Jungle B</td>
<td>2016</td>
<td>Action</td>
<td>Adventure</td>
<td>Family</td>
<td>Jon Favreau</td>
<td>Justin Marks</td>
<td>Rudyard Kipli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Shawshank</td>
<td>1994</td>
<td>Crime</td>
<td>Drama</td>
<td>Family</td>
<td>Tim Robbins</td>
<td>Morgan Free</td>
<td>Bob Gunton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Dark Knight</td>
<td>2008</td>
<td>Action</td>
<td>Crime</td>
<td>Drama</td>
<td>Christopher Nolan</td>
<td>No Christopher Nolan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schindler's List</td>
<td>1993</td>
<td>Biography</td>
<td>History</td>
<td>Drama</td>
<td>Steven Spielberg</td>
<td>Ben Cross</td>
<td></td>
<td></td>
<td>Liam Neeson</td>
<td>Ben Kingsley</td>
<td>Ralph Fiennes</td>
<td>Caroline Goodall</td>
<td>93</td>
<td>844</td>
<td>English</td>
<td>USA</td>
<td>8.0</td>
</tr>
<tr>
<td>12 Angry Men</td>
<td>1957</td>
<td>Crime</td>
<td>Drama</td>
<td></td>
<td>Sidney Lumet</td>
<td>John Retino</td>
<td></td>
<td></td>
<td>Martin Balsam</td>
<td>John Fiedler</td>
<td>Lee J. Cobb</td>
<td>E.G. Marshall</td>
<td>431</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.0</td>
</tr>
<tr>
<td>Pulp Fiction</td>
<td>1994</td>
<td>Crime</td>
<td>Drama</td>
<td></td>
<td>Quentin Tarantino</td>
<td>Quentin Tarantino</td>
<td></td>
<td></td>
<td>Tim Roth</td>
<td>Amanda Plummer</td>
<td>Laura Lovelace</td>
<td>John Travolta</td>
<td>94</td>
<td>1</td>
<td>English</td>
<td>USA</td>
<td>8.1</td>
</tr>
<tr>
<td>Star Wars: Ep 1</td>
<td>1980</td>
<td>Action</td>
<td>Adventure</td>
<td>Romance</td>
<td>George Lucas</td>
<td>Irvin Kershner</td>
<td>Lawrence Kasdan</td>
<td>Mark Hamill</td>
<td>Harrison Ford</td>
<td>Carrie Fisher</td>
<td>Billy Dee Williams</td>
<td>226</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Forrest Gump</td>
<td>1994</td>
<td>Drama</td>
<td>Romance</td>
<td></td>
<td>Robert Zemeckis</td>
<td>Robin Williams</td>
<td></td>
<td></td>
<td>Tom Hanks</td>
<td>Sally Field</td>
<td>Michael Coniglio</td>
<td>Bruce Dern</td>
<td>84</td>
<td>712</td>
<td>English</td>
<td>USA</td>
<td>8.8</td>
</tr>
<tr>
<td>Inception</td>
<td>2010</td>
<td>Action</td>
<td>Mystery</td>
<td>Sci-Fi</td>
<td>Christopher Nolan</td>
<td>Christopher Nolan</td>
<td></td>
<td></td>
<td>Leonardo DiCaprio</td>
<td>Ellen Page</td>
<td>Tom Hardy</td>
<td>1</td>
<td>7</td>
<td>English</td>
<td>USA</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>The Lord of the Rings: The Two Towers</td>
<td>2002</td>
<td>Adventure</td>
<td>Adventure</td>
<td>Fantasy</td>
<td>Peter Jackson</td>
<td>J.R.R. Tolkien</td>
<td>Fran Walsh</td>
<td>Philippa Boyce</td>
<td>Edward Norton</td>
<td>Viggo Mortensen</td>
<td>Ian Holm</td>
<td>Sala Baker</td>
<td>88</td>
<td>1</td>
<td>English</td>
<td>USA</td>
<td>8.3</td>
</tr>
<tr>
<td>One Flew Over the Cuckoo's Nest</td>
<td>1975</td>
<td>Drama</td>
<td></td>
<td></td>
<td>Milos Forman</td>
<td>Fred Schepisi</td>
<td>Jack Nicholson</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodfellas</td>
<td>1990</td>
<td>Biography</td>
<td>Crime</td>
<td></td>
<td>Martin Scorsese</td>
<td>Nicholas Pile</td>
<td>Nicholas Pile</td>
<td>Nicholas Pile</td>
<td>Robert De Niro</td>
<td>Joe Pesci</td>
<td>Lorraine Bracco</td>
<td></td>
<td></td>
<td>89</td>
<td>711</td>
<td>English</td>
<td>USA</td>
</tr>
<tr>
<td>The Matrix</td>
<td>1999</td>
<td>Action</td>
<td>Sci-Fi</td>
<td></td>
<td>Lana Wachowski</td>
<td>Lisa Wachowski</td>
<td></td>
<td></td>
<td>Keanu Reeves</td>
<td>Laurence Fishburne</td>
<td>Hugo Weaving</td>
<td></td>
<td>73</td>
<td>1</td>
<td>English</td>
<td>USA</td>
<td>8.7</td>
</tr>
<tr>
<td>Star Wars: Ep 4</td>
<td>1977</td>
<td>Action</td>
<td>Adventure</td>
<td>Fantasy</td>
<td>Mark Hamill</td>
<td>Howard Stenning</td>
<td>George Lucas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Se7en</td>
<td>1995</td>
<td>Crime</td>
<td>Drama</td>
<td>Mystery</td>
<td>David Fincher</td>
<td>Andrew Kevin</td>
<td></td>
<td></td>
<td>Morgan Freeman</td>
<td>Andrew Kevin</td>
<td>David Carradine</td>
<td>Matthew Lillard</td>
<td>65</td>
<td>991</td>
<td>English</td>
<td>USA</td>
<td>8.2</td>
</tr>
<tr>
<td>The Silence of the Lambs</td>
<td>1991</td>
<td>Crime</td>
<td>Drama</td>
<td>Thriller</td>
<td>Jonathan Demme</td>
<td>Ted Tally</td>
<td></td>
<td></td>
<td>Jodie Foster</td>
<td>Lawrence Kasdan</td>
<td>Lawrence W. Fishburne</td>
<td></td>
<td>84</td>
<td>857</td>
<td>English</td>
<td>USA</td>
<td>8.1</td>
</tr>
<tr>
<td>It's a Wonderful Life</td>
<td>1946</td>
<td>Drama</td>
<td>Family</td>
<td>Fantasy</td>
<td>Frank Capra</td>
<td>Frances Gifford</td>
<td>Albert Hacke</td>
<td>Frank Capra</td>
<td>James Stewart</td>
<td>Donna Reed</td>
<td>Lionel Barry Thomas</td>
<td></td>
<td>258</td>
<td>English</td>
<td>USA</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>The Usual Suspects</td>
<td>1995</td>
<td>Crime</td>
<td>Drama</td>
<td></td>
<td>Bryan Singer</td>
<td>Christopher Nolan</td>
<td></td>
<td></td>
<td>Stephen Bochco</td>
<td>Gabriel Biel</td>
<td>Don Johnson</td>
<td>Kevin Pollak</td>
<td>77</td>
<td>718</td>
<td>English</td>
<td>USA</td>
<td>8.6</td>
</tr>
<tr>
<td>Léon: The Professional</td>
<td>1994</td>
<td>Crime</td>
<td>Drama</td>
<td>Thriller</td>
<td>Luc Besson</td>
<td>Luc Besson</td>
<td></td>
<td></td>
<td>Jean Reno</td>
<td>Gary Oldman</td>
<td>Natalie Portman</td>
<td>Jean Reno</td>
<td>64</td>
<td>707</td>
<td>French</td>
<td>France</td>
<td>8.7</td>
</tr>
<tr>
<td>Saving Private Ryan</td>
<td>1998</td>
<td>War</td>
<td>Drama</td>
<td></td>
<td>Steven Spielberg</td>
<td>Robidget Roan</td>
<td></td>
<td></td>
<td>Tom Hanks</td>
<td>Tom Sizemore</td>
<td>Edward Burns</td>
<td>Edward Burns</td>
<td>80</td>
<td>138</td>
<td>English</td>
<td>USA</td>
<td>8.8</td>
</tr>
<tr>
<td>Casablanca</td>
<td>1942</td>
<td>Drama</td>
<td>Romance</td>
<td></td>
<td>Michael Curtiz</td>
<td>Julius J. Epstein</td>
<td>Phillip G. Epstein</td>
<td>Humphrey Bogart</td>
<td>Ingrid Bergman</td>
<td>Paul Henreid</td>
<td>Claude Rains</td>
<td></td>
<td>377</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.7</td>
</tr>
<tr>
<td>City Lights</td>
<td>1931</td>
<td>Comedy</td>
<td>Drama</td>
<td>Romance</td>
<td>Charles Chaplin</td>
<td>Charles Chaplin</td>
<td></td>
<td></td>
<td>Virginia Cherrill</td>
<td>Lee Tracy</td>
<td>Harry Myers</td>
<td>Albert Garnett</td>
<td></td>
<td>104</td>
<td></td>
<td>English</td>
<td>USA</td>
</tr>
<tr>
<td>Psycho</td>
<td>1960</td>
<td>Comedy</td>
<td>-Mystery</td>
<td>Thriller</td>
<td>Alfred Hitchcock</td>
<td>Joseph Stefano</td>
<td>Robert Bloch</td>
<td>Charles Bronson</td>
<td>Glenn Ford</td>
<td>John Cassavetes</td>
<td>Janet Leigh</td>
<td></td>
<td>408</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.6</td>
</tr>
<tr>
<td>Raiders of the Lost Ark</td>
<td>1981</td>
<td>Adventure</td>
<td>Action</td>
<td></td>
<td>Steven Spielberg</td>
<td>George Lucas</td>
<td></td>
<td></td>
<td>Harrison Ford</td>
<td>Karen Allen</td>
<td>Paul Freeman</td>
<td>Ronald Lacey</td>
<td>639</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.5</td>
</tr>
<tr>
<td>Rear Window</td>
<td>1954</td>
<td>Mystery</td>
<td>Thriller</td>
<td></td>
<td>Alfred Hitchcock</td>
<td>Anthony Mann</td>
<td></td>
<td></td>
<td>James Stewart</td>
<td>Grace Kelly</td>
<td>Wendell Corey</td>
<td>Thelma Ritter</td>
<td>309</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.6</td>
</tr>
<tr>
<td>Modern Times</td>
<td>1936</td>
<td>Comedy</td>
<td></td>
<td></td>
<td>Charlie Chaplin</td>
<td>Charles Chaplin</td>
<td></td>
<td></td>
<td>Charles Chaplin</td>
<td>Paulette Goddard</td>
<td>Henry Bergman</td>
<td>Tiny Sandford</td>
<td>138</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.5</td>
</tr>
<tr>
<td>The Green Mile</td>
<td>1999</td>
<td>Drama</td>
<td>Fantasy</td>
<td></td>
<td>Frank Darabont</td>
<td>Stephen King</td>
<td></td>
<td></td>
<td>Tom Hanks</td>
<td>David Morse</td>
<td>Michael Clarke Dorn</td>
<td>Hunter Ellis</td>
<td>61</td>
<td>758</td>
<td>French</td>
<td>France</td>
<td>8.7</td>
</tr>
<tr>
<td>The Game</td>
<td>2000</td>
<td>Drama</td>
<td>Thriller</td>
<td></td>
<td>Michael Mann</td>
<td>Martin Sheen</td>
<td></td>
<td></td>
<td>Michael Douglas</td>
<td>Kevin Spacey</td>
<td>Kevin Spacey</td>
<td>Aaron Eckhart</td>
<td>482</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.5</td>
</tr>
<tr>
<td>Back to the Future</td>
<td>1985</td>
<td>Adventure</td>
<td>Drama</td>
<td>Sci-Fi</td>
<td>Robert Zemeckis</td>
<td>Robert Zemeckis</td>
<td></td>
<td></td>
<td>Michael J. Fox</td>
<td>Christopher Lloyd</td>
<td>Lea Thompson</td>
<td>Crispin Glover</td>
<td>704</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.7</td>
</tr>
<tr>
<td>Whiplash</td>
<td>2014</td>
<td>Drama</td>
<td>Music</td>
<td></td>
<td>Damien Chazelle</td>
<td>Damien Chazelle</td>
<td></td>
<td></td>
<td>Miles Teller</td>
<td>J.K. Simmons</td>
<td>Paul Reiser</td>
<td>Melissa Benoist</td>
<td>377</td>
<td></td>
<td>English</td>
<td>USA</td>
<td>8.6</td>
</tr>
</tbody>
</table>
Identify good directors.
Identify good directors.

**select proxies**

- **action**: thing you want to do
- **object**: items you want to take action on
- **measure**: value you are interested in for the objects
Identify good directors.

**select proxies**

- **action**: thing you want to do
- **object**: items you want to take action on
- **measure**: value you are interested in for the objects

*D. Fisher, M. Meyer, O'Reilly 2018.*
Identify good directors.

Director :: movie

Select proxies

Action: thing you want to do
Object: items you want to take action on
Measure: value you are interested in for the objects

D. Fisher, M. Meyer, O'Reilly 2018.
Identify good directors.

director :: movie
good :: high IMDB rating

Identify movies with high IMDB ratings.

select proxies

**action**: thing you want to do

**object**: items you want to take action on

**measure**: value you are interested in for the objects

D. Fisher, M. Meyer, O'Reilly 2018.
high rating vs popularity
- identifying proxies is a core part of (data) science

- visualization helps in refining and validating by providing context

- defining the problem you are trying to solve is iterative and benefits from data counseling
EXERCISE: proxies
How do Facebook users’ online behavior change when their parents join Facebook?

Hint: consider behavior, change, and parents
- creating visualizations is a design process
- find proxies in the data for what you care about
- use data counseling to identify, refine, and validate proxies
 Visualization Analysis & Design
Tamara Munzner
A K Peters Visualization Series
Illustrations by Eamonn Maguire

“A must read for researchers, sophisticated practitioners, and graduate students.”
—Jim Foley, College of Computing, Georgia Institute of Technology

“Munzner’s new book is thorough and beautiful. It belongs on the shelf of anyone touched and enriched by visualization.”
—Chris Johnson, Scientific Computing and Imaging Institute, University of Utah

“This is the visualization textbook I have long awaited. It emphasizes abstraction, design principles, and the importance of evaluation and interactivity.”
—Jim Hollan, Department of Cognitive Science, University of California, San Diego

“Munzner is one of the world’s very top researchers in information visualization, and this meticulously crafted volume is probably the most thoughtful and deep synthesis the field has yet seen.”
—Michael McGuffin, Department of Software and IT Engineering, École de Technologie Supérieure

“Munzner elegantly synthesizes an astounding amount of cutting-edge work on visualization into a clear, engaging, and comprehensive textbook that will prove indispensable to students, designers, and researchers.”
—Steven Franconeri, Department of Psychology, Northwestern University

“Munzner shares her deep insights in visualization with us in this excellent textbook, equally useful for students and experts in the field.”
—Jarke van Wijk, Department of Mathematics and Computer Science, Eindhoven University of Technology

“The book shapes the field of visualization in an unprecedented way.”
—Wolfgang Aigner, Institute for Creative Media Technologies, St. Pölten University of Applied Sciences

“This book provides the most comprehensive coverage of the fundamentals of visualization design that I have found. It is a much-needed and long-awaited resource for both teachers and practitioners of visualization.”
—Kwan-Liu Ma, Department of Computer Science, University of California, Davis

This book’s unified approach encompasses information visualization techniques for abstract data, scientific visualization techniques for spatial data, and visual analytics techniques for interweaving data transformation and analysis with interactive visual exploration. Suitable for both beginners and more experienced designers, the book does not assume any experience with programming, mathematics, human–computer interaction, or graphic design.

recommended reading
www.cs.utah.edu/~miriah
miriah@cs.utah.edu