Glyph-based Visualization

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ABSTRACT
Multivariate data visualization (MDV) is nowadays a common requirement across different disciplines, from the sciences to the social sciences, from engineering to arts and humanities, and from media to industry. Glyph-based visualization is a form of MDV. In comparison with other forms of MDV, such as parallel coordinates plots, glyph-based visualization exhibits some unique advantages as well as limitations. For example, glyphs can be superimposed on top of their spatial or temporal contexts (e.g., a map or a time series plot), while most other forms of MDV cannot. Well-designed glyphs can facilitate effective visual search and pattern identification, and are intuitive to learn and use. Meanwhile, because of their sizes, the visual channels used in glyphs have relatively limited bandwidth capacities. The costs of designing a glyph set for a specific application, and the demands for familiarization and memorization are usually the main stumbling block hindering the deployment of this technique. There has been a resurging interest in glyph-based visualization in recent years. This tutorial is built on a series of surveys on glyph-based visualization [Ward [20], Ward [19], Borgo et al. [4]], and offers a timely introduction to the fundamentals, techniques and applications of glyph-based visualization. The tutorial authors team includes Professor Matthew Ward (who wrote the first survey on glyph-based visualization), Professor Sine McDougall (who is well-known for her cognitive studies of signs and icons), Dr. Rita Borgo (who led the most comprehensive survey on glyph-based visualization in 2013), Eamonn Maguire (who first introduced computer-assisted methods for glyph designs), and Professor Min Chen (who has experience of employing glyph-based visualization in a variety of applications, such as sports, poetry, biology, audio/visual media, and collaborative environments).

1 KEYWORDS:
Glyph-based visualization, history, visual design, perception, cognition, techniques, and applications.

2 DURATION:
Half-day tutorial.

3 LEVEL:
Intermediate

4 INTRODUCTION AND MOTIVATION
Glyph-based visualization is a common form of visual representation, where glyphs are used to encode information graphically. In a broad interpretation, a glyph is a small visual object that can be used independently and constructively to depict attributes of a data record or the composition of a set of data records. Each glyph can be placed independently from others, while in some cases glyphs can be connected spatially to convey the topological relationships between data records or geometric continuity of the underlying data space. Glyphs are a type of visual sign that can make use of visual features of other types of signs such as icons, indices and symbols. In the era of data deluge, visualization is playing an indispensable role in improving human abilities to make observations efficiently, make connections between data and our experience, knowledge, and intuition, generate and visually evaluate hypotheses, monitor the correctness and performance of computational models and other automated mechanisms, and deliver effectual communication to others. Historically, glyphs have served as visual languages in many disciplines, such as schematic diagrams in science and engineering, metaphoric signs in cartography and traffic management, semaphores and signal flags in maritime communication. Usually through much iteration, such glyph-based schemes gradually evolved into standard visual languages, and became relatively optimised for information encoding as well as human perception, learning and memorisation.

Multivariate data visualization (MDV) is nowadays a common requirement across different disciplines, from the sciences to the social sciences, from engineering to arts and humanities, and from media to industry. Since glyph-based visualization is a form of MDV, it is highly desirable and timely to introduce glyphs-based visualization to those who are yet to have the opportunity to study the background literature in visualization and psychology, and/or have the experience of designing and implementing glyph-based visualization for an application.

In this tutorial, we will take the participant through a far-reaching journey, from the history of semiotics to computer-assisted glyph design techniques, from perceptual and cognitive aspects of glyphs to a broad range of applications, and from their comparison with other MDV techniques to methods for evaluating glyph designs. A wide range of applications will be discussed, including:

- sports [Legg et al. [11], Chung et al. [5]],
- biology (workflow) [Maguire et al. [13]; Maguire et al. [12]]
- biology (video) [Duffy et al. [7]]
- poetry [Abdul-Rahman et al. [1]]

5 TUTORIAL SCHEDULE (HALF DAY TUTORIAL)
1. Introduction (10 min)
   [Presenter: Min Chen]
   • A brief introduction of history and motivation
   • Describe the tutorial organization

2. History of Semiotics and Glyphs (25+5 min)
   [Presenter: Min Chen]
   • History of Visual Communications
   • Theory of Signs and Sign Systems

3. Design Space of Glyphs and Application Case Studies (55+5 min)
   [Presenter: Rita Borgo]
   • Overview of multivariate techniques
   • Advantages and limitations of glyphs
   • Visual Channels
   • Channel Composition and Visual Multiplexing
   • Semantic Relevance
   • Application Case Studies
   • Evaluation Methodologies of Glyph Designs
   Coffee Break

4. Perception and Cognition of Glyphs (45+5 min)
   [Presenter: Sine McDougall]
   • Theories of visual search
   • Pre-attentiveness
   • Just-noticeable difference
   • Perception experiments on visual channels and glyphs
5. Systematic Creation of Glyphs (30+5 min)  
[Presenter: Eamonn Maguire]  
- Taxonomic structure of multivariate data  
- Ordering of visual channels  
- Algorithmic mapping from a taxonomy to visual channels  
- Macro-glyphs  
- Algorithms for motif discovery and search  
- Algorithmic mapping from state-transitions to pictogram

6. Summary and Future Challenges (15 min)  
[Presenter: Min Chen]

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7 TARGET AUDIENCE AND NECESSARY BACKGROUND  
This tutorial is designed for the general audience of IEEE VIS Conferences, and it is especially suitable for new PhD students who are looking for new and exciting areas to develop their PhD projects as well as experienced researchers who wish to broaden their research horizon. The tutorial requires a minimal level of pre-requisites, though the pace of this tutorial may appear to be fast to beginners. Many fundamental topics, such as glyph design, glyph-based visualizations, and evaluation methods, will be covered in the tutorial.

8 COURSE NOTES AND MATERIALS  
All course material will be made available at:  
http://ovii.github.io/IEEEVisGlyphTutorial/

9 BRIEF RESUMES OF THE PRESENTERS  
Rita Borgo  
received her BSc and MSc (Laurea with commendation) from the University of Bologna and PhD in Computer Science from the University of Pisa in collaboration with the Visual Computing Lab. at the Italian National Research Council in Pisa. Since 2011 she has been a Lecturer in the Department of Computer Science, Swansea University, UK. Her research interests include video visualization, time series visualization, human computer interaction, perceptual cognition, hierarchical meshes and progressive algorithms. Her main current research focus is on video visualization and 3D image analysis and synthesis. Her contributions to the field have touched upon both aspects of video summarization and user-centred video visualization. She is a member of BCS Women in Computer Science and IEEE.

Min Chen  
received the Ph.D. degree from University of Wales in 1991. He is currently a professor of scientific visualization at Oxford University and a fellow of Pembroke College. Before joining Oxford, he held research and faculty positions at Swansea University (i.e., research officer from 1987, lecturer from 1990, senior lecturer from 1998 and professor from 2001). His research interests include visualization, computer graphics and human-computer interaction. He has co-authored about 140 publications, including his pioneering works on video visualization. His services to the research community include papers co-chair of IEEE Visualization 2007 and 2008, co-chair of Volume Graphics 1999 and 2006, papers co-chair of Eurographics 2011, associate editor-in-chief of IEEE Transactions on Visualization and Computer Graphics, associate editor of Elsevier Computers & Graphics, member of a number of program committees, and co-director of Wales Research Institute of Visual Computing. He is a fellow of British Computer Society, European Computer Graphics Association, and Learned Society of Wales.

Eamonn Maguire  
is completing his DPhil in Computer Science at Oxford University, focusing on computational techniques for the creation of glyph-based visualizations. He is also a researcher at the research associate at the Oxford e-Research Centre, Oxford University and is involved in a number of projects in bioinformatics and cyber security. His interests are focused on glyph-based visualization techniques, visual analytics and interface design with a focus on the interesting perceptual challenges of combining many different layers of information in the same visualization.

Sine McDougall  
is Professor and Associate Dean of the Department of Psychology at Bournemouth University. She received a Master, with Honors, in Psychology from the University of Glasgow and a PhD from Goldsmiths’ College, University of London. She is an established figure in the field of cognitive processing with focus on sign and iconic visualization design and interpretation. Her research has focused on how we understand, learn, and use icons and signs used on computer interfaces and on traffic and public information signs. Her recent research has therefore explored the cognitive processing underpinning the visual appeal of interfaces with the aid of explaining how consumer appeal develops over time and how this influences decision making. Her research has attracted funding from BAE Systems, Cisco Systems, the EPSRC, the Nuffield Foundation and Sure Start. She is a member of the British Psychological Society (Chartered Psychologist) and the Interaction Design Foundation.

Matthew Ward  
is a Full Professor in the Computer Science Department at Worcester Polytechnic Institute. Dr. Ward received his B.S. degree in Computer Science from Worcester Polytechnic Institute in 1977 and his M.S. and Ph.D. in Computer Science from the University of Connecticut in 1979 and 1981, respectively. He was employed as a Member of the Technical Staff in the Robotics and Computer Systems Research Laboratory at AT&T Bell Laboratories between 1980 and 1984 and as a research scientist at Skantek Corporation until 1986. His research interests include data and information visualization, visual languages, and scientific data management and analysis. He has authored or co-authored more than 70 publications, and a textbook in the area of data visualization. His research has been funded by government agencies, including NSF, NSA, the Air Force Research Labs, and the DOT, and by industry, including IBM, Sun Microsystems, and SGI. Dr. Ward is the primary architect on several public-domain software packages for multivariate data visualization and exploration, including XmdvTool, MAVIS, and SpiralGlyphics. He serves on the organizing committees for the IEEE Symposium on Information Visualization and IEEE Conference on Visualization, and is an associate editor for IEEE Transactions on Visualization and Computer Graphics.
FURTHER READING (WITH PRESENTERS' NAMES HIGHLIGHTED)


