ISCTE IUL
REPOSITÓRIO
INSTITUTO UNIVERSITÁRIO DE LISBOA

Repositório ISCTE-IUL

Deposited in *Repositório ISCTE-IUL*:
2023-07-25

Deposited version:
Accepted Version

Peer-review status of attached file:
Peer-reviewed

Citation for published item:
Botelho, M. C., Vilar, E. T., Cardoso, E., Silva, A. A., Almeida, P. D., Rodrigues, L. M....Rodrigues, S. (2017). The four faces of information visualization: A conceptual framework for a postgraduate program. In Reis, L. P., Rocha, Á., Alturas, B., Costa, C., and Cota, M. P. (Ed.), 2017 12th Iberian Conference on Information Systems and Technologies (CISTI). Lisbon, Portugal: IEEE.

Further information on publisher's website:
10.23919/cisti.2017.7975878

Publisher's copyright statement:
This is the peer reviewed version of the following article: Botelho, M. C., Vilar, E. T., Cardoso, E., Silva, A. A., Almeida, P. D., Rodrigues, L. M....Rodrigues, S. (2017). The four faces of information visualization: A conceptual framework for a postgraduate program. In Reis, L. P., Rocha, Á., Alturas, B., Costa, C., and Cota, M. P. (Ed.), 2017 12th Iberian Conference on Information Systems and Technologies (CISTI). Lisbon, Portugal: IEEE., which has been published in final form at https://dx.doi.org/10.23919/cisti.2017.7975878. This article may be used for non-commercial purposes in accordance with the Publisher's Terms and Conditions for self-archiving.

Use policy

Creative Commons CC BY 4.0
The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a link is made to the metadata record in the Repository
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Serviços de Informação e Documentação, Instituto Universitário de Lisboa (ISCTE-IUL)
Av. das Forças Armadas, Edifício II, 1649-026 Lisboa Portugal
Phone: +(351) 217 903 024 | e-mail: administrador.repositorio@iscte-iul.pt
https://repositorio.iscte-iul.pt

The four faces of Information Visualization

A conceptual framework for a postgraduate program

Maria do Carmo Botelho
Escola de Sociologia e Políticas Públicas, Instituto Universitário de Lisboa (ISCTE-IUL), CIES-IUL
Lisboa, Portugal
maria.botelho@iscte.pt

Emílio Távora Vilar
Faculdade de Belas Artes, Universidade de Lisboa
Lisboa, Portugal
e.vilar@belasartes.ulisboa.pt

Elsa Cardoso
Escola de Tecnologias e Arquitetura, Instituto Universitário de Lisboa (ISCTE-IUL), INESC-ID
Lisboa, Portugal
elsa.cardoso@iscte.pt

Ana Alexandrino da Silva
Instituto Universitário de Lisboa (ISCTE-IUL), CIES-IUL
Lisboa, Portugal
graficosemapas@gmail.com

Pedro Duarte de Almeida
Faculdade de Belas Artes, Universidade de Lisboa
Lisboa, Portugal
p.almeida@belasartes.ulisboa.pt

Luís Manuel Rodrigues
Universidade dos Açores
IMAR - Instituto do Mar
Açores, Portugal
lmcrod@gmail.com

Ana Pinto Martinho
Instituto Universitário de Lisboa (ISCTE-IUL), CIES-IUL
Lisboa, Portugal
anapintomartinho@gmail.com

Sara Rodrigues
Faculdade de Belas Artes, Universidade de Lisboa
Lisboa, Portugal
mail@sararodrigues.com

Abstract — **The multidisciplinary nature of information visualization is today fairly consensual in both professional and academic communities: data analysis, information design, storytelling, among other subjects, are common drivers in this field. The systematic study of this cross-fertilization, patent in the way the concept's definition varies according to the perspective being adopted, represents an important and needed addition to the critical mass of a relatively recent area of knowledge. The proposal of a single unified definition of information visualisation being beyond the scope of this paper, it instead summons and discusses its multiple viewpoints to help designing a postgraduate program on the topic, aiming to simultaneously start an open debate as its implementation phase goes on and new questions are subsequently raised.**

Keywords – Information visualization; Data analysis and visualization; Information design; Data journalism; Visual analytics.

I. INTRODUCTION

Information visualization (Infovis) has become a privileged medium of mass visual communication [1]. As data volume grows at an exponential rate, so does the need for instruments that allow extracting meaning and value from them. At the same time, the increasing number and sophistication of edition and design tools and the scientific acknowledgment of the cognitive potential of visual perception are two of the many factors that contribute to the contemporary presence of visualization in both academic and professional fields. Nevertheless, research on educational processes and methods for this specific area is still lacking. This paper aims to contribute to a much needed and current debate on Information Visualization, considering four main areas: information design, data (analysis) visualization, visual analytics and data journalism (Figure 1).

The first university program on graphical methods occurred in 1913/14. Even though graphical representation of statistics was already disseminated by then [2], this subject was specifically mentioned as one of the program contents for the first time: "The subjects treated in this program are averages, graphical representation of statistics, frequency curves, correlation, smoothing of statistics; with applications to statistical problems in economics, biology, insurance, and physics." [3]

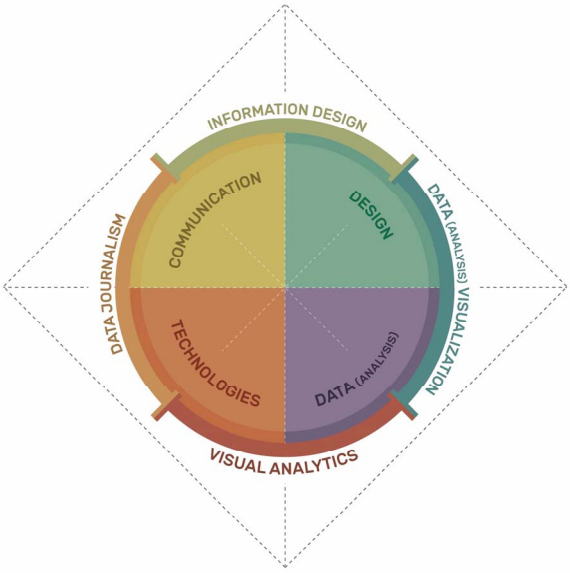

Figure 1. Conceptual framework for Information Visualization.

Technologies were absent from this arena, but statistical graphics, thematic cartography, communication design and data journalism already played an important role. Nowadays, it is impossible to look at Infovis without taking technologies into account. The technological development is a major booster for Infovis. The increasing scope of the

Internet, the broad access to online data analysis and visualization software, the trend to release and use open data and the potential of collaborative datasets are only a few of the reasons that sustain a growing general interest in this field. Infovis is increasingly becoming an independent research field with a specific research agenda [4], seeking to provide people with better and more effective ways to understand and analyse datasets. By allowing novel discoveries, Infovis empowers users, enabling them to formulate opinions, make decisions and act upon their findings.

Based on profuse discussions about the teaching methods for Information Visualization a postgraduate program was designed. The connections between the four main areas above mentioned - information design, data visualization, visual analytics and data journalism -, was visually represented through a metaphor referring to the children's game "the cootie catcher". Each time a triangle is opened, an area's perspective is revealed, as it is also revealed its interaction with the others (Figure 2).

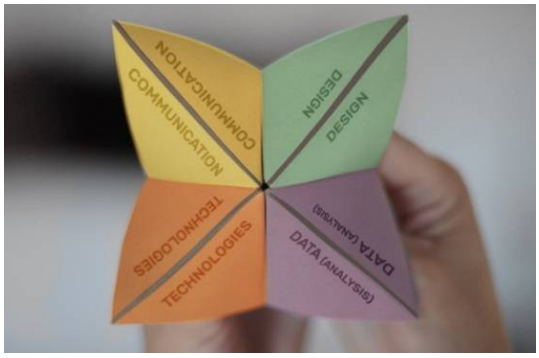

Figure 2. The complexity of the conceptual framework hidden in a children's game. Adapted from [5]

Section II of this paper presents each area's perspective on Infovis and points out links with other fields. This multidisciplinary approach is the foundation of the proposed postgraduate program, that brings together two universities and three schools (in the areas of Social Studies, Design and Technologies).

II. A MULTIDISCIPLINARY APPROACH

Distinction between data and information demonstrates the different perspectives the four areas assume regarding specific tasks involved in the practice of Infovis. It is possible to identify some shared issues regarding these perspectives, as highlighted in Table 1.

A. Information design

Design can be defined by the triangular relationship between a user, a tool and the purposeful action through which a task is performed, such as, for example, the need to find a way using a map [6]. If one considers that "information is the juxtaposition of data to create meaning" [7:10] then information design describes "the art and science of translating complex, unstructured data into useful information that can be used with efficiency and effectiveness" [8:111].

TABLE I. DIFFERENT APPROACHES TO DATA AND INFORMATION

How to read this table: "Data visualization *explores* data to *discover* information"		
Areas	***Data***	***Information***
Data (analysis and) visualization	explore and analyse	discover and reveal
Information design	organize and structure	display and communicate
Data journalism	filter	publish and storytelling
Visual analytics	explore and analyse	decide and monitor

Information design encompasses communication design tools and techniques in which the main goal is to inform the user, as opposed to the more persuasive approaches used in domains such as advertising [9]. An information designer is a 'transformer' who converts a quantitative dataset - a sequence of actions or any complex situation or event - into a visual model that reveals and communicates relevant information in a manner the audience can understand [10].

A printed infographic or an interactive visualization are just two of the possible outputs of an information design process. In fact, these are the sort of visual tools that turns visible and understandable phenomena or portions of reality that are not accessible to the bare eye or not even of visual nature [11]. Therefore, from a designers point of view, 'information visualization' is a visual representation of data intended to enable exploration and analysis of information, discovery and communication of knowledge [12].

As aforementioned, creating information visualizations is a complex process that combines know-how from various areas. Ultimately, for the reader or user to be able to understand a static object or an interactive device, its visual appearance should be coherent and appropriate, and designed according to his/her conceptualisation of the way it should work. Each person's conceptual models are a result of one's experience, training and instruction [13]. As Kirk [14:17] resumes, "exploiting our visual perception abilities relates to the scientific understanding of how our eyes and brains process information most effectively, (...). This is about harnessing our abilities with spatial reasoning, pattern recognition, and big-picture thinking."

The main goal of information design is to maximize efficiency and effectiveness in the way the user processes data and uses information through vision. In this sense, information design is a methodological process transverse to the visualization of information regardless of the context in which it develops – whether in the domains of data analysis and business intelligence or in the fields of journalism or statistics. The imperative need for effective visual organization of the graphical elements in static visualizations, and an efficient usability in the interactive ones, discloses the intrinsic relationships between information design and the other two sides of the proposed framework: visual analytics and data (analysis) and visualization.

B. Data analysis and visualization

For Tukey [15: 2], data analysis includes procedures for exploring and analysing data, techniques for interpreting the results of such procedures, ways of "gathering of data to make its analysis easier, more precise, or more accurate and all the machinery and results of statistics which apply to analysing data". Exploratory data analysis is considered as the first step, the corner stone of data stories. Tukey [16] advocates that graphical methods are useful not only to reassure us of what we already know but also to makes us notice what we have never expected to see. Few [17] emphasises data visualization procedures and refers practical analytical techniques and graphs as tools for "thinking with our eyes".

Statistical techniques play an important role in data analysis, but in order to reveal information it is necessary to have also visualization concerns, e.g. how should a table be structured or which statistical graphic is more suitable for which type of information, audience, objective among other conditionality. There are countless examples of statistical graphics where design played an important role, but a special reference needs to be made to the XVIII century Statistical Breviary that contains the first examples of line charts, bar graphs and pie charts. William Playfair drew these charts to overcome the difficulty of using tables to convey information and presenting data easily [18].

The main branches of data visualization – statistical graphics and thematic cartography – share common goals: they are both concerned with the visual representation of categorical and numerical data, accomplished by a powerful "set of methods of mapping data into visual properties – spatial and otherwise" [12:123], aiming to explore, compare, portray and reveal evolution trends, relationships or patterns.

The maps, as the expression of spatial communication design, link various types of data visualization and provide new means for interpretation. Today, fortunately, lots of data with spatial connotation (geospatial big data) are available to integrate large geodatabases and, subsequently, attractive thematic maps. There are many trends in map design that relate to a transdisciplinary approach. Specifically, geo-knowledge teaching empowers graduates to effectively engage with spatial data and this becomes a key dimension to understand reality [19]. Traditional concepts of cartography remain significant; however, it is necessary to consider new technologies (web maps) and the experience of interoperability that has brought change in the way how maps are used [20].

The links between data visualization and technology are obvious in a world in which volume, velocity, veracity and variety of data seems to have no limits. The computational development that has occurred in the last decades has allowed more frequent application of more complex data analysis (e.g. statistical, neural networks) and visualization procedures. The accuracy and reliability of data is critical when broad communicating is at stake, as in data journalism. Using visual techniques is a key factor when communicating academic results or data stories either to peers or the general public.

C. Data journalism

Data journalism means obtaining, reporting on, curating and publishing data in the public interest [21]. It is a multidisciplinary field by definition. Specially, if we treat it as a process or workflow, as described by some authors [21] [22], [23]. For instance, Lorenz [22] suggests that in the data journalism workflow, composed by four main stages – obtain data, filter, visualizing, and transforming it into a journalistic story (storytelling) – as we advance along the process the information value rises to the public. So, learning data journalism skills is important to report on data, especially if one wants to broaden its audiences, as people are in general more interested in stories than in simple data being displayed. Data visualization is of extreme importance for data journalism: "A well-designed data visualization can give viewers an immediate and profound impression, and cut through the clutter of a complex story to get right to the point" [24:191]. Data journalism stresses the importance of a multidisciplinary approach when visual information communication is thought upon.

The geojournalism approach is based on the development of maps and data visualization products that simplifies cartographic rules and principles (maps constructed by non-cartographers). Data journalism emphasizes simple processes to carry out thematic maps and other related visualizations [24].

D. Visual analytics

From a decision-making point of view, visual analytics is the science of analytical reasoning facilitated by visual representations of data (Figure 3). Being "analytical" implies the use of different types of analysis, data and a systematic reasoning in order to make decisions [25]. Therefore, the area of visual analytics is highly linked with performance management and business intelligence (BI). BI systems are designed to gather, store, analyse, and provide access to the different business users to the right information in order to support their decision-making needs.

Typically, a BI system has four layers: (1) the source systems where the initial data is stored; (2) an extract, transformation, and loading (ETL) layer, in which data is cleaned and transformed in order to be stored in the next layer; (3) the data warehouse, which is an integrated repository of clean, historical and reliable data for the analytical process; and (4) the BI applications layer, in which data is explored and visualized in different ways. The fourth layer is also known as the "Getting data out" layer [26], transforming data into information that will have a direct impact in management of key areas of an organization. Examples of BI applications include reports (to detail what has happened), scorecards and dashboards (to monitor the current status and provide alerts), OLAP (online analytical processing to explore the data) and data mining applications (to determine hidden patterns in data). Detailing the area of visual analytics requires understanding the different types of analysis that can be performed for decision support (e.g., simple reporting, alerts, extrapolation, modelling, recommendations, predictions or

simulations). Depending on the type of analysis and the final user, different Infovis techniques may be applied. Data visualization in BI contexts needs to have a clear goal and an awareness of the specificities of the business user or decision-maker.

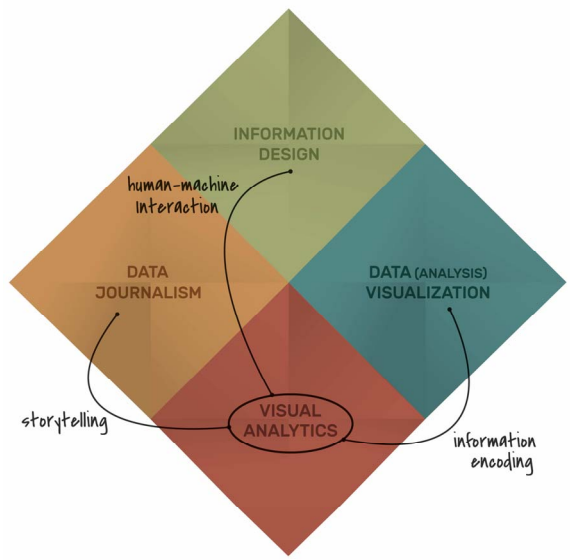

Figure 3. Bridges between visual analytics and other areas: exemplifying bilateral synergies and curricular unit contents

The principles of information design and data analysis and visualization should be used in the design of BI applications. However, one finds several examples of BI interfaces that do not comply with these principles [27]. Effective BI applications need to consider human-machine interaction theories, including usability aspects, as well as the entire user experience and the best practices of information encoding (see Figure 3). Visual analytics also uses storytelling, a basic technique in data journalism. BI interfaces can be more effectively designed considering the data stories of the business events that are being monitored. Tableau Software® can be considered a self-service BI tool, with an intuitive and user-friendly interface enabling the exploration and visualization of data using data stories.

III. CONCLUSIONS

This article proposes a conceptual model that explains information visualization based on the interrelationship of concepts such as data, technology, communication and information. This model supports the curricular structure of a new postgraduate program in this field, with 60 ECTS and 10 curricular units. This structure is organized around four articulated areas – information design, data visualization, visual analytics, and data journalism – constituting an internationally innovative learning product in Infovis. Definitions of each area were presented, as were the links between them in the scope of information visualization. It is concluded that, even if there are specificities in each area, a common language may be adopted and synergies may be generated. The debate on the matter will continue and new challenges will certainly arise upon the implementation of the postgraduate program, planned for the Fall of 2017. Today, the use of technology in Infovis is unquestionable. Designers, statisticians, data journalists and BI/visual analytics developers use different technological tools to provide interactive and digital visualizations. The program promotes an integrated and coherent view of Infovis and aims to train specialists in this relevant field; specially, considering the challenges that lie ahead, relating to the unprecedented generation of massive data.

REFERENCES

[1] P. A. Hall, "Bubbles, lines and string: How visualization shapes society", in Graphic Design Now in Production, Blauvelt, A. & Lupton, Eds, USA: Walker Art Center, 2011, pp. 170-185.

[2] W. S. Cleveland, "Research in statistical graphics," J. American Statistical Association, vol. 82, no. 398, pp. 419-423, June 1987.

[3] University of Michigan. (2000, accessed: February 18, 2017). *The University of Michigan, an encyclopedic survey*. W. B. Shaw, Eds. Digital Library Production Service. Available: http://name.umdl.umich.edu/AAS3302.0002.001

[4] D. Keim, J. Kohlhammer G. Ellis, and F. Mansmann, Mastering the information age: solving problems with visual analytics, Eurographics Association: Goslar, Germany, 2010.

[5] R. Machado. (2014, accessed: February 18, 2017) *O jogo "quantos queres"*. Available: www.ricardomachado.pt

[6] G. Bonsiepe, Interface: an approach to design. Maastricht: Jan van Eyck Akademie, Department of Design, 1999.

[7] A. Wright, Glut: mastering information through the ages. New York: Cornell University Press, 2007.

[8] G. Schuller, Designing universal knowledge. Baden: Lars-Müller Publishers, 2009.

[9] I. Meirelles, Design for information: an introduction to the histories, theories, and best practices behind effective information visualizations, Rockport, USA, 2013.

[10] P. Wildbur and M. Burke, Information graphics: innovative solutions in contemporary design. London: Thames & Hudson, 1999.

[11] J. Costa, La esquemática – visualizar la información. Barcelona: Ediciones Paidós Ibérica, 1998.

[12] A. Cairo, The truthful art: data, charts, and maps for communication. Berkeley: New Riders, 2016.

[13] D. Norman, The design of everyday things. New York: Doubleday, 1990.

[14] A. Kirk, Data visualization: a successful design process. Birmingham: Packt, 2012.

[15] J. W. Tukey, "The future of data analysis", The Annals of Mathematical Statistics, Vol. 33, no. 1, pp. 1-67, Mar. 1962.

[16] J. W. Tukey, Exploratory data analysis. Addison-Wesley Publishing Company, 1977.

[17] S. Few, Now you see it: simple visualization techniques for quantitative analysis. Analytics Press, 2009.

[18] A. Alexandrino da Silva, Gráficos e mapas – representação de informação estatística. Lisboa: Lidel, 2006.

[19] N. Bearman, N. Jones, I. André, H. Cachinho and M. DeMers. "The future role of GIS education in creating critical spatial thinkers." J. Geography in Higher Education, vol. 40, no. 3, pp. 394-408, 2016.

[20] M. Craglia, K. Bie, D. Jackson, M. Pesaresi, G. Remetey-Fülöpp, C. Wang, A. Annoni. "Digital earth 2020: towards the vision for the next decade". Int. J. Digital Earth, vol. 5, no. 1, pp.4–21, 2012.

[21] J. Stray (2011, accessed: February 18, 2017). *A computational journalism reading list*. Available: http://jonathanstray.com/a-computational-journalism-reading-list

[22] M. Lorenz, "Status and outlook for data-driven journalism," in *Data driven journalism: What is there to learn?*, European Journalism Centre, Eds. Amsterdam, 2010.

[23] P. Bradshaw, (2011, accessed: February 18, 2017). *The inverted pyramid of data journalism*. Online Journalism Blog. Available: https://onlinejournalismblog.com/2011/07/07/the-inverted-pyramid-of-data-journalism/

[24] J. Gray, L. Bounegru and L. Chambers (Eds.), The data journalism handbook, Sebastopol: O'Reilly, 2012.

[25] T. Davenport, J. Harris and R. Morison, Analytics at work – smarter decisions, better results. Harvard Business Press, 2010.

[26] H. Watson and B. Wixom, "The current state of business intelligence," Computer, vol. 40, no. 9, pp. 96-99, 2007.

[27] S. Few, Information dashboard design – the effective visual communication of data. O'Reilly, 2006