Visualizing data visualization: a systematic literature mapping by Brazilian design researchers

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data visualization, Brazil, design tool, methodology

This paper integrates and expands reflections in the academic Brazilian literature on data visualization from a design perspective between the years 2010 and 2020. It is based on a systematic literature mapping method of 42 articles. The results show the institutions affiliation of researchers and their geographical distribution; the evolution over the years of publications; the methodological approaches and authors cited; the types of studies; and the visualization artifact generated and the design tools employed in this process. Specifically, the results show that The Federal University of Rio de Janeiro (UFRJ) is the institution with the highest concentration of papers and that the southeast region concentrates the most significant number of institutions. The years with the most publications are 2015 and 2019. Although most articles adopt an ad-hoc methodology, two publications use the Ben Fry methodology and its adaptations. Edward Tufte is the most cited author. There is a concentration of authors in the conceptualization of infographics and data visualization. Finally, the creation of artifacts is the most common type of study, Processing is the most popular design tool to create a data visualization, and visualization in Processing is the most frequent result of a study.

1 Introduction

This paper integrates and expands reflections in the academic Brazilian literature on data visualization. In the last decade, there has been an increase in this theme's interest among designers in Brazil. This is visible in the emergence of numerous initiatives such as academic events (e.g., the Brazilian Congress of Information Design), research groups (e.g., LabVis, Lab DSI, 2ID), community initiatives (e.g., as Dataviz Brasil and dataviz.Rio) and podcasts (e.g., visual+mente). Besides, data visualization has become an important topic in journalism, arts, computing, and statistics. There is also growing interested in Brazilian information technology and design companies in providing data visualization to facilitate complex data analysis.

In light of such emerging debate, there is a particular need for an overview of the field's state. Therefore, this article maps the publications made by Brazilian design researchers on data visualization. The following sections describe the methods and results.

2 Methodology

Systematic literature mapping is an empirical method based on a systematic literature review approach (SLR). Kitchenham & Charters (2007) confirm the creation of the method in evidence-based software engineering. Through systematic literature mapping, it is possible to identify, interpret, and categorize the studies by research questions or knowledge area (Petersen et al., 2015).

Systematic literature mapping is a formal method characterized by the rigor, systematicity, and reproducibility of science. Therefore, Budgen et al. (2008) recommend systematic literature mapping to identify gaps in current research to suggest areas for further investigation and provide a framework for adequately positioning new research activities. This mapping type is a well-defined methodological process, making the literature results less likely to be skewed. The protocol adopted in this mapping follows the guidelines presented by Kitchenham & Charters (2007), Petticrew & Roberts (2008), Budgen et al. (2008), and Petersen et al. (2015) and consists of the following steps:

1. **Research questions**: Identifying fundamental questions for the review analysis;
2. **Selection and exclusion criteria**: Defining of explicit inclusion and exclusion criteria for the mapping;
3. **Search process**: Identifying search protocols (manual or automatic), data sources, and search terms.
4. **Selection and Snowballing**: Describing all the steps involved in the pre-selection and selection of studies. The snowballing process is also described, which consists of checking the bibliographic references of the articles selected in the search for potential studies to be included in the mapping.
5. **Data collection and analysis**: Identifying what data was extracted from publications and the form of registration (database, spreadsheet, etc.).
6. **Limitations of the protocol**: Defining the limitations of the systematic method.

Data visualization is an interdisciplinary area, and it is essential to collaborate with researchers from other areas (e.g., computing, arts, statistics, and geolocation). Therefore, a systematic literature mapping represents an ideal method for revealing research trends about data visualization in design given the heterogeneous nature of the literature.

3 Systematic literature mapping

The Systematic Literature Mapping steps are described in this section in the following order: research questions, selection and exclusion

criteria, search process, selection and snowballing, data collection, and analysis and protocol limitations.

3.1 Research questions

This study's central question is "How is data visualization produced from a design perspective in Brazil?". The following specific research questions were defined to answer the central question: **RQ1**: What are the research affiliation of researchers involved in this area, and how are they distributed geographically?; **RQ2**: What is the number of studies over the years?; **RQ3**: What are the methodological approaches and authors cited in the studies?; **RQ4**: What are the most common types of studies?; **RQ5**: What is the kind of artifact is the result of a study?; **RQ6**: What are the most common design tools utilized in the studies?

3.2 Selection and exclusion criteria

The review considered articles written in Portuguese or English published in conferences, journals, or book chapters between 2010 and 2020 on data visualization from a design perspective. The articles also needed to contain at least one Brazilian researcher as an author and be relevant to at least three of the research questions outlined above. On the other hand, publications were excluded if they were published only as a summary; address only printed infographics; approach data visualization from the perspective of another related area such as computing, art, etc.; or if a subsequent article derived from the same research already published previously (duplicated studies). In the case of duplicate studies, only the most recent were included.

3.3 Search process

For the automatic search process, the search string was assembled from the keywords found in the articles on data visualization in Brazil based on the author's experience as a researcher in the design field. The terms chosen were visualização de dados; visualização; *dataviz*; *data visualization*. Therefore, the search string was constructed based on the combination of the terms found, which were concatenated using the Boolean operators "OR" and "AND" and producing the string as the final result: "Visualização" OR "visualização de dados" OR "dataviz" OR "data visualization".

In terms of manual search, the journals "*InfoDesign*" and "*Estudos em Design*" were selected since they are the most relevant in the field and therefore central for this review. The manual search process consists of consulting conference proceedings websites and manually accessing all publications, and selecting papers on the basis of their

titles, abstracts, and keywords. This manual search process included the following conference proceedings: Congresso Internacional de Design da Informação (CIDI), Congresso Nacional de Iniciação Científica em Design da Informação (CONGIC) e Congresso Brasileiro de Pesquisa & Desenvolvimento em Design (P&D).

3.4 Selection and snowballing

The article selection process involved two stages. In the pre-selection stage, the title, keywords, and abstract of articles were screened according to the inclusion criteria. Then, the full text of the pre-selected articles was analyzed, and duplicate papers were excluded. The manual search yielded 40 potentially relevant articles, of which 30 were pre-selected. The automatic search provided 20 potentially relevant articles, of which 15 were pre-selected. Together, this yielded a total of 45 pre-selected articles. In the second phase of the selection process, 08 articles from the manual search and 26 articles from the automatic search were selected, totaling 34 relevant articles. Running the snowballing process on these 34 selected articles evidenced 18 other relevant articles, of which 08 were selected. In total, 42 articles were selected for analysis. This process took place between March and September 2020.

3.5 Data collection and analysis

The following data were extracted from each study and recorded in the codebook (in spreadsheet format): Search engine (manual, automatic or snowballing) and source (name of the journal, the proceedings of the event or the database, respectively); Title, keywords, authors, type (periodical or proceedings), and year; Methodology; Authors; Design Tool; Type of work (Case study, Theoretical, Artifact creation, Experience report or Experiment) and Result artifact.

A bottom-up inductive approach was adopted to analyze the articles and answer the research question motivating this study. First, the keywords of each article were collected. This revealed different terms used to refer to similar concepts, showing the absence of standard terminology and suggesting that authors freely choose words when discussing a topic. Thus, a list of most common terms consolidating all synonymous keywords. Then related concepts were grouped into categories in each research question. The complete list of selected articles can be viewed at http://bit.ly/3hMOl58.

3.6 Protocol limitations

This study shares the most common shortcomings of the systematic method: limited search coverage and possible biases introduced during study selection, data extraction, and analysis. These limitations were addressed following the general recommendations for systematic mapping - using a combined search between manual and automatic complemented by a snowballing process (Kitchenham & Charters, 2007; Petticrew & Roberts, 2008).

4 Analysis of the results

This section starts by applying the literature's systematic mapping to analyze literary production regarding data visualization in Brazil and then describes the research questions carried out among the 42 selected articles.

4.1 Research institutions involved with data visualization (RQ1)

During the period under review, 16 Brazilian research institutions published articles on data visualization. Some of these publications were made in partnership with 6 international research institutions. Among the articles analyzed, some were written based on partnerships between authors from different Brazilian and international institutions, such as Harvard University and University of the Arts London.

Of the 42 articles analyzed, 30 were published by authors from a single institution, 7 had authors from two different institutions, and 3 had authors from 3 different institutions. Table 1 presents the articles analyzed according to their author's affiliation. It is clear that some institutions have a greater concentration of published works, such as the Federal University of Rio de Janeiro, which features 11 publications, many with Professor Doris Kosminsky participation.

Another example is the 5 publications from the State University of Rio de Janeiro made at the Superior School of Industrial Design (ESDI). As well as those at the Federal University of Espírito Santo, which had a significant impact due to Professor Dr. Mauro Pinheiro's work at both institutions.

The three publications at Northeastern University are also noteworthy. They refer to the work of Professor Isabel Meirelles. The latter contributed to the internationalization process of data visualization research by cooperating with other institutions, such as Harvard University and Massachusetts Institute of Technology, in the United States, and with Tongji University in China.

Table 1 Publication of articles by the institution.

Institution	Number of articles published
Universidade Federal do Rio de Janeiro (UFRJ)	11
Universidade Estadual do Rio de Janeiro (UERJ)	05
Universidade Federal do Espírito Santo (UFES)	05
Universidade de Brasília (UnB)	05
Universidade de São Paulo (USP)	05
Northeastern University	03
Universidade Anhembi Morumbi	03
Instituto Federal da Paraíba (IFPB)	02
Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio)	02
Universidade Federal de Santa Catarina (UFSC)	02
Bauhaus-Universität Weimar	01
Fundação Getulio Vargas (FGV-Rio)	01
Harvard University	01
Instituto Brasileiro de Informação em Ciência e Tecnologia	01
Massachusetts Institute of Technology (MIT)	01
Tongji University	01
Universidade Federal de Pernambuco (UFPE)	01
Universidade Federal de Pelotas (UFPel)	01
UniBrasil	01
Universidade Positivo	01
University of the Arts London	01

4.1.1 Distribution of publications by region of Brazil (RQ1)

Analyzing the distribution of articles published by region of the country reveals some geographic differences (see Table 2). Specifically, analyzing articles by region, it is noteworthy that, in the last decade, there were no publications in the northern region of Brazil.

Table 2 Articles published by region of Brazil.

Region of Brazil	Number of articles published
Southeast	31
Midwest	06
South	06
Northeast	03
North	00

On the other hand, there is a concentration of articles in the southeastern region of Brazil. This region alone is responsible for more than 67% of the production of data visualization in the country. Further analyzing the articles published in the southeastern region in more detail reveals another discrepancy in the intellectual production on this theme, as shown in Table 3. Namely, that the state of Rio de Janeiro is responsible for more than 58% of publications in this region.

Table 3 Articles published in the Southeast region of Brazil.

States of Southeast region of Brazil	Number of articles published
Rio de Janeiro	18
São Paulo	08
Espírito Santo	05
Minas Gerais	00

4.2 Evolution of the number of articles over the years (RQ2)

The chronology of the articles is shown in Table 4. During this period, there were 30 publications in conference proceedings and 12 in journals. Specifically, the number of publications was higher in 2011, 2015, 2017, and 2019—the years when the Congresso Internacional de Design da Informação (CIDI) took place.

Table 4 Chronology of publications.

Years	Number of articles published
2010	02
2011	06
2012	03
2013	01
2014	03
2015	09
2016	01
2017	05
2018	03
2019	09

4.3 Methodologies, authors, and topics used in the studies (RQ3)

In this subsection, the results from the review were organized by methodological approach, authors cited, and the topics most covered.

4.3.1 Methodologies used in the studies (RQ3)

The methods used by the analyzed articles is shown in Table 5. Most articles do not use any particular method for data collection, data analysis, and the creation of data visualizations. While most articles do not reference whether the data visualization process was based on any established methodological approach, two publications describe using the method developed by Ben Fry (2007). This method has the following steps: extract the data; analyze them; filter them according to design goals; mine them; represent them in some visual way; refine presentation; and, finally, add elements to facilitate interaction with this data.

Two articles also describe using the user-centered design philosophy (Rogers, Sharp, & Preece, 2008), even though this method is primarily used in user experience design (UX Design) to create digital artifacts such as websites and applications. Another method with primary use in UX Design mentioned in an article is the double diamond, developed by the British Design Council (Design Council, 2015). A physical data visualization publication mentioned the constructive visualization method proposed by Huron et al. (2014).

Other relevant methods in the area of infographics appear in a handful of articles. Specifically, idX - Information Design by Core Competences (2007), the method <6> <6> by Roam (2013), and materials from Cairo (2011) and Sless (2004). Also mentioned are Steele & Iliinsky (2010) process for data visualization and the Ricardo Cunha Lima (2009) method on the use of graphic elements applied to journalistic infographics.

Table 5 Methodologies used in studies.

Methodologies	Number of articles	Primary use
Ad-hoc model	09	Data visualization
User centered design	02	UX Design
Ben Fry's method (2007) and adaptations	02	Data visualization
Methodology adapted from Steele and Iliinsky (2010)	01	Data visualization
Methodology adapted from Cairo (2011)	01	Infographics
Roam's method <6><6> (2013)	01	Infographics
Methodology adapted from Sless (2004)	01	Infographics
Core Competences idx methodology (2007)	01	Infographics
Use of the Ricardo Cunha Lima method (2009)	01	Infographics
Constructive visualization methodology by Huron et al. (2014)	01	Physical data visualization
Double Diamond Methodology	01	UX Design

4.3.2 Authors cited in the studies (RQ3)

The authors most cited in the publications are shown in Table 6. This study choice was to consider only authors who had three or more citations. The three most-cited authors were Edward Tufte, Alberto Cairo, and Lev Manovich. Four Brazilian authors are among the most cited. Namely, Isabel Meirelles, Mauro Pinheiro, Priscila Farias, and Ricardo Cunha Lima. The first one has six citations, the most citations among Brazilian authors. Among the most cited authors, there are renowned researchers from the design as well as related areas such as computing and communication. This confirms that the topics covered in the articles reviewed are considerably interdisciplinary.

Table 6 Authors most cited in studies.

Authors	Number of citations
Edward Tufte	16
Alberto Cairo	13
Lev Manovich	13
Stuard Card	10
Jacques Bertin	08
Michael Twyman	06
Yuri Engelhardt	06
Robert Horn	06
Isabel Meirelles	06
Richard Wurman	06
Colin Ware	05
William Cleveland	04
Robert Spence	04
Steven Few	04
Jorge Frascara	04
Nathan Yau	04
Jeanne Preece	04
Edward Segel	04
Donald Norman	03
Mauro Pinheiro	03
Priscila Farias	03
Ricardo Cunha Lima	03
Mark Weiser	03

4.3.3 Topics covered in the studies (RQ3)

The main areas addressed in the analyzed articles were categorized and are represented in Figure 1. The topic with most references is the conceptualization of infographics and data visualization with a

total of thirteen appearances. Graphic language, cognition, and visual metaphors appear with seven references; and the environmental information system with six references. Data journalism, and graphic representations have four references. Then how to do data visualization and narratives (storytelling) have four references. Visualization of physical data and visual perception have three each. The topics of data visualization related to the history of design and information anxiety had two references. Finally, the topics democratize information, visual literacy, visualization of synesthetic data, content analysis, identification of absences, and UX Design had only one reference.

1 The complete references of the authors cited in Figure 1 are available at https://bit.ly/3259zEf

Figure 1 Topics and their references.[1]

Topics	References
Conceptualization infographics and data visualization	Tufte (1983); Card, Mackinlay, & Sheneiderman (1999); Shedroff (2000); Engelhardt (2002); Kosara (2007); Few (2009); Cairo (2008; 2011); Bertin (2010); Manovich (2010); Frascara (2011); Meirelles (2011); Ciuccarelli (2012).
Graphic Language	Twyman (1979); Engelhardt (2002); Lima (2009; 2015); Meirelles (2013).
Cognition and visual metaphors	Lakoff (1987); Norman (1993); Gershon (1992); Card et al (1999); Ware (2004); Meirelles (2007); Lima (2018).
Ambient information systems	Pinheiro (2010 and 2011); Weiser & Brown (1997); Weiser, Brown, & Gold (1999); Hazlewood, Coyle, and Consolvo (2007); Mankoff & Dey (2003).
Data journalism	Peltzer (1991); Cairo (2008); Miranda & Spinillo (2012); Miranda (2013); Giannella (2014).
Graphical representations	Horn (1998); Bertin (2010); Lankow, Ritchie, & Crooks (2012); Miranda, Spinillo & Fontoura (2012); Andrade (2014).
How to do data visualization	Spence (2007); Fry (2008); Steele and lllinsky (2010); Yau (2013).
Storytelling	Segel and Heer (2010); Munzer (2014); Knaflic (2015); Tufte (2016).
The physicality of Information Visualization	Lau & Vande Moere (2007); Vande Moere (2008); Jansen, Dragicevic, & Fekete (2013).
Visual perception	Healy et al. (1996); Lima (2005); Healy (2017).
Data visualization and design history	Farias (2019); Farias, Hanns, & Dixon (2016).
Information anxiety	Wurman (1991); Richtel (2010).
Democratization of data visualization	Viegas et al. (2007).
Visual literacy	Horn (1998).
Visualization of synesthetic data	Cox (2014).
Content analysis	Krippendorff (2004).
Absence identification	Floridi (2011).
UX Design	Preece, Rogers, & Sharp (2008).

4.4 Types of studies (RQ4)

Regarding the types of studies, Table 7 shows the differences among publications. Specifically, twenty-one articles focus on the creation of artifacts, eleven focus on data studies, six are theoretical, three are

experience reports (in general teaching), and one has an experimental approach. The first category stands out because it represents a promising number of works developed in that period.

Table 7 Type of studies.

Type of studies	Number of articles
Artifact creation	21
Case study	11
Theoretical	06
Experience report	03
Experiment	01

4.5 Types of artifact used as a result (RQ5)

The artifacts presented as a result of the studies are shown in Table 8. This includes a column with the type of study from Table 7. Among the articles which focus on artifact creation, visualization of data in Processing is the most common and appears in five publications. Four articles featured functional prototypes. Static maps or cartograms, interactive PDF, physical visualization, and websites appear in two articles. Finally, the following artifacts were mentioned in only one article: robot on Twitter, animated videos, graphs on Gephi, visualizations on Tableau, and visualization in javascript in the browser. A created artifact was added as Interactive PDF and Maps or static cartogram.

In the articles that carried out a case study, five used data visualization four used infographics, and two included ambient information systems. An article also created a comparative table on the use of time in visual representations. Among experience reports articles, two feature curators by the lectures for the event, one shows the creation of a methodology for making infographics. Finally, a theoretical article featured a list of the types of visual representations.

4.6 Tools used in studies (RQ6)

The design tools for data visualization are shown in Table 9. The most used design tool was Processing, and it was mentioned in five articles. Processing is a tool for creative programming and is widely used in the creation of data visualization. Adobe Indesign and ManyEyes were tools cited in two studies. Adobe Indesign was used to create interactive PDFs. ManyEyes (Viegas et al., 2007) was a platform created, currently deactivated, by IBM in the team led by Brazilian Fernanda Viegas and Martin Wattenberg. Other tools cited by at least

Table 8 Type of artifact used as a result in studies.

An artifact used as a result	Number of articles	Type of study
Data visualization in Processing	05	Artifact creation
Functional prototypes	04	Artifact creation
Static maps or cartograms	02	Artifact creation
Interactive PDF	02	Artifact creation
Physical visualization	02	Artifact creation
Websites	02	Artifact creation
Twitter robots	01	Artifact creation
Animated videos	01	Artifact creation
Graphs in Gephi	01	Artifact creation
Data visualization in Tableau	01	Artifact creation
Data visualization in javascript	01	Artifact creation
Data visualization case study	05	Case study
Infographics case study	04	Case study
Ambient information systems case study	02	Case study
A comparative chart on the use of time in visual representation	01	Case study
Curator of lectures for event	02	Experience report
Creation of the methodology for creating infographics	01	Experience report
List with the types of visual representations: maps, statistical graphs, network diagrams, statistical maps, network maps, statistical network diagram, statistical network maps	01	Theoretical

one article, with different focuses, include: creating the mind map (freemind, ideographer, iMap for inventor, InfoRapid, Thortspace), connection for physical artifacts (Arduino), prototyping for digital interfaces (Figma), georeferenced maps (GIS), graph (Gephi), creative programming (Javascript), content analysis (MAXQDA), tabulated data (CSV, Google Spreadsheets, Microsoft Excel), layer overlay (Adobe Photoshop), vectorization (Adobe Illustrator), image preview in large size (Closr), data collection (Python), database (PostgreSQL), word cloud (visuWords and Wordle.com), timeline (xTimeLine.com) and data visualization (RAW Graphs and Tableau).

5 Conclusion

A systematic mapping of the literature was carried out in 42 articles to improve the understanding of data visualization from a design perspective in Brazil. This article aims to both stimulate this debate by mapping the topics covered by these publications and thus outline relevant questions for future research in the area.

Table 9 Tools mentioned in the studies.

Tools	Number of articles	Goal
Processing	05	Creative programming
Adobe Indesign	02	Interactive PDF
Manyeyes	02	Data visualization
Arduino	01	Connection for physical artifacts
Adobe Illustrator	01	Vector drawing
Adobe Photoshop	01	Photomontage
Closr	01	View large images
CVS	01	Tabulated data
Figma	01	Prototype for digital interfaces
Freemind	01	Mindmap
Geographic Information System (GIS)	01	Georeferenced maps
Gephi	01	Graph visualization
Google Sheets	01	Tabulated data
Ideographer	01	Mindmap
iMap for inventor	01	Mindmap
InfoRapid	01	Mindmap
Javascript	01	Creative programming
MAXQDA	01	Content analysis
Microsoft Excel	01	Tabulated data
Python	01	Data collect
PostgreSQL	01	Database
RAW Graphs	01	Data visualization
Tableau	01	Data visualization
Thortspace	01	Mindmap
VisuWords	01	Word cloud
Wordle.com	01	Word cloud
XTimeLine.com	01	Timeline

Regarding RQ1, the Federal University of Rio de Janeiro (UFRJ) was the institution with the highest concentration of articles reflecting the research concentration in the southeast region of Brazil. There is no article from institutions in the country's northern region from 2010 to 2020. Moreover, the international collaboration of researchers stands out and involves eight institutions abroad. In this context, Professor Isabel Meirelles seems to have a particular role in these international partnerships. As a result of RQ2, the years 2015 and 2019 had the highest number of publications, nine in each. In this regard, it is evident that the years with the greatest concentration of works coincide with the realization of CIDI in the country.

Regarding RQ3, although nine articles seem to use an ad hoc methodology, without providing any detailed description, two

publications used the Ben Fry methodology (2008) and its adaptations. There are also citations to the methods of Cairo (2011) and Steele and Illinsky (2010). Edward Tufte (1983, 2016) was the most cited author with sixteen appearances, accompanied by Alberto Cairo (2008, 2011) and Lev Manovich (2010), which appear in thirteen articles. There is also a clear concentration of authors in the conceptualization of infographics and data visualization and the topics of graphic language, cognition, and visual metaphors.

About RQ4, the creation of artifacts is the type of study most common with twenty-one publications, followed by a case study carried out in eleven studies. Regarding RQ5, visualization in *Processing* is the most common artifact produced in studies, appearing in five publications (four publications of which made functional prototypes). Finally, in RQ6, Processing also appeared as the most used design tool.

Some considerations need to be made when analyzing the results. The number of Brazilian authors on data visualization is still tiny, and the production in Portuguese is similarly limited. Greater incentive is needed for institutions and research groups to stimulate the theme among design researchers. This is relevant for the South, Midwest, North, and Northeast regions and particularly important for the North region. It also seems that the design tools for creating data visualization are constantly changing. Some of those cited in the articles are not even common today. Although the type of work most common in the articles analyzed is the creation of data visualization, the Brazilian national production on this theme is still little known worldwide. This highlights the need for further diffusing at an international scale the studies and projects carried out in the country.

Acknowledgment

The author would like to thank Dr. Pedro Monteiro for reviewing and carefully reading the manuscript.

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Submission date: 11/4/2021
Approvement date: 28/8/2021