TUM School of Engineering and Design

Data-driven design and analysis of map-based storytelling

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Vollständiger Abdruck der von der TUM School of Engineering and Design
der Technischen Universität München zur Erlangung des akademischen Grades

einer Doktorin der Ingenieurwissenchaften (Dr.-Ing.)

genehmigten Dissertation.

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Die Disertation wurde am 15.03.2022 bei der Technischen Universität München
eingereicht und durch die TUM School of Engineering and Design
am 19.05.2022 angenommen.

Acknowledgments

Doctoral research is a personal journey, but it is never one hero's story. Throughout the process, I was fortunate to have been surrounded and supported by many inspiring people who influenced me and my work.

Prof. Liqiu Meng, my Supervisor and Mentor, has given me the freedom to explore multiple research ideas and to creatively express them. She taught me many valuable lessons, not just about cartographic research, but also about personal resilience and the importance of life enjoyment.

I would also like to thank my Reviewer, Prof. Robert E. Roth, for his valuable guidance. With his methodological advice, I was able to narrow down myriads of storytelling concepts and complete my content analysis. Special thanks go to Prof. Uwe Stilla, the Chairman of my PhD defence, who made it such an enjoyable experience.

While I was working on my case studies, I had the opportunity to explore new places and research environments. I would like to thank the community behind the Berlin-based School of Machines, Making, and Make-Believe – Rachel Uwa, Andreas Refsgaard, Gene Kogan, Carlo De Gaetano, Gabriele Colombo and my course cohorts. The artistic programmes they led helped me to make use of machine intelligence in my own cartographic design practice.

I am particularly grateful for the internship time I spent with the members of the Social Dynamics Team of Nokia Bell Labs. The stimulating environment in Cambridge, UK, inspired me very much and has greatly influenced my work. I owe a sincere thank you to Prof. Daniele Quercia, Luca Maria Aiello, Marios Constantinides, Sanja Šćepanović, Sagar Joglekar and my amazing intern cohort: Bon Adriel Aseniero, Wonyoung So, Shaun Park, Minje Choi, and Charlotte Qin.

Importantly, I have immensely benefited from the interdisciplinary collaboration with Researchers from the Chair of Economic History at the Department of Economics, The Ludwig Maximilian University of Munich. I had the privilege of working with and learning a lot from Prof. Davide Cantoni, Felix Hagemeister, Cathrin Mohr and Britta Pohr.

I am very grateful for the research community created by my Colleagues from the Chair of Cartography and Visual Analytics at the Technical University of Munich and University Partners around the Master of Science Programme in Cartography. Thank you for pushing me professionally and for making it such a pleasure to be at work each day, especially to enjoy our regular coffee breaks and consortium meetings.

Last but not least, I would like to give thanks to my beloved Family and Friends for always being at my side, and for the unconditional support and inspirations they share with me.

Edyta Paulina Bogucka

Munich, May 2022

Abstract

Map-based storytelling is a process of building social relationships by sharing meaningful knowledge with maps. The development of these practices was heavily influenced by two disciplines – cartography that emphasizes the scientific value of mapmaking, and journalism that focuses on the practice of narrative-sharing. In the data-driven era, both disciplines face the same challenge of growing complexity in map-based communication. The newly created stories account for much more than human experiences and facts. The new crucial component of the story is data. Designers rely on them in their search for convincing narratives and visualize them in media-rich digital formats. Getting insights into the practice of data-driven storytelling is very challenging due to multilayered relationships between data, narrator, story and audience. Although it is possible to reverse-engineer the presence of certain components of the data-driven stories, the recipes behind them remain hidden.

This thesis is dedicated to the development of map-based storytelling. To establish a theoretical framework for the exploration, the literature review reflects on the presence of narremes – the theoretical and practical building blocks of data-driven story maps – in the related disciplines of visual rhetoric, narrative design, data visualization, data science and cultural analytics.

The thesis involves two essential parts of data-driven explorations. The first part of the exploration is driven by curiosity about the most and the least prevalent patterns in map-based storytelling in a number of representative news media. This part of the thesis develops a proof of concept for novel combination of three data-driven research methods – Quantitative Content Analysis, image tagging using Machine Learning and Visual Analytics with metaimages. This research protocol was used to analyze 215 map-based stories shared by journalistic outputs between 2014 – 2021.

The second part of the thesis investigates the practical implications of theoretical findings through hands-on design. The author developed an annotated portfolio with four map-based stories. Annotations for each story included a report on data sources, presentation of storytelling approaches, analysis of story requirements, prototype visualization, and dissemination of the final interface. The portfolio concludes with eight prompts for cross-disciplinary practices in map-based storytelling.

The analysis shows that there is a discrepancy between theoretical possibilities of map-based storytelling and their practical implementations in news media. This gap can be addressed in three time perspectives – present, near future and long-term future. For the time being, cartographers can continue to look for added value in the already existing hybrid forms of storytelling. Research for the near future may address the supporting functions of text in cartographic story design. The long-term research direction is to adapt spatial knowledge graphs as integral parts of stories.

These two directions of top-down and bottom-up exploration have demonstrated that there is a synergetic effect between cartography and journalism. The developed framework is also applicable to other domains researching on data-driven visual stories. The presented workflow for understanding the visual and rhetorical properties of map-based stories constitutes the first step towards the use of stories in spatial knowledge communication.

Zusammenfassung

Kartenbasiertes Geschichtenerzählen ist ein Prozess, bei dem soziale Beziehungen aufgebaut werden, indem bedeutendes Wissen mit Karten geteilt wird. Die Entwicklung dieser Praktik wurde stark von zwei Disziplinen beeinflusst – der Kartografie, die den wissenschaftlichen Wert der Kartenerstellung betont, und dem Journalismus, der sich auf die Praxis des Erzählens konzentriert. In der datengesteuerten Ära stehen beide Disziplinen vor der gleichen Herausforderung, nämlich der zunehmenden Komplexität der kartenbasierten Kommunikation. Die neu geschaffenen Geschichten umfassen viel mehr als nur menschliche Erfahrungen und Fakten. Die neue zentrale Komponente der Geschichte sind Daten. Designer stützen sich auf sie bei ihrer Suche nach überzeugenden Erzählungen und visualisieren sie in medienreichen digitalen Formaten. Einblicke in die Praxis des datengesteuerten Geschichtenerzählens zu bekommen ist aufgrund der vielschichtigen Beziehungen zwischen Daten, Erzähler, Geschichte und Publikum eine große Herausforderung. Obwohl es möglich ist, das Vorhandensein bestimmter Komponenten der datengesteuerten Geschichten zurückzuverfolgen, bleiben die Rezepte dahinter verborgen.

Diese Dissertation widmet sich der Entwicklung des kartenbasierten Storytellings. Um einen theoretischen Rahmen für die Untersuchung zu schaffen, wird in der Literaturübersicht das Vorhandensein von Narremes – den theoretischen und praktischen Bausteinen datengesteuerter Story Maps – in den verwandten Disziplinen der visuellen Rhetorik, des narrativen Designs, der Datenvisualisierung, der Datenwissenschaft und der kulturellen Analytik untersucht.

Die vorliegende Arbeit umfasst zwei wesentliche Teile datengetriebener Explorationen. Der erste Teil wird von der Neugier auf die am meisten und am wenigsten verbreiteten Muster des kartenbasierten Geschichtenerzählens in einer Reihe repräsentativer Nachrichtenmedien getrieben. Im Rahmen der Arbeit wurde ein Proof-of-Concept für die neuartige Kombination von drei datengetriebenen Forschungsmethoden – Quantitative Content Analysis, Image Tagging mit Machine Learning und Visual Analytics mit Metaimages entwickelt. Dieses Forschungsprotokoll wurde verwendet, um 215 kartenbasierte Geschichten zu analysieren, die in verschiedenen journalistischen Medien zwischen 2014 und 2021 geteilt wurden.

Der zweite Teil untersucht die praktischen Implikationen der theoretischen Erkenntnisse durch verschiedene Gestaltungsmöglichkeiten. Der Autor entwickelte ein so genanntes kommentiertes Portfolio mit vier kartenbasierten Geschichten. Die Anmerkungen zu jeder Geschichte umfassen einen Bericht über die Datenquellen, die Darstellung der Erzählansätze, die Analyse der Anforderungen an die Geschichte, die prototypische Visualisierung und die Verbreitung der endgültigen Schnittstelle. Das Portfolio schließt mit acht Empfehlungen zu disziplinübergreifenden Praktiken des kartenbasierten Geschichtenerzählens ab.

Die Analyse zeigt, dass es eine Diskrepanz zwischen den theoretischen Möglichkeiten des kartengestützten Storytellings und ihrer praktischen Umsetzung in Nachrichtenmedien gibt. Diese Diskrepanz kann in drei Zeitperspektiven – Gegenwart, nahe Zukunft und langfristige Zukunft – thematisiert werden. In der Gegenwart könnten Kartographen weiterhin nach einem Mehrwert in den bereits existierenden hybriden Formen des Storytellings suchen. Die Forschung für die nahe Zukunft könnte sich mit den unterstützenden Funktionen von Text im kartografischen Storydesign befassen. Die langfristige Forschung könnte in die Richtung gehen zu untersuchten, wie räumliche Wissensgraphen als integraler Bestandteil von Geschichten adaptiert werden könnten.

Diese beiden Richtungen der Top-down- und Bottom-up-Exploration haben gezeigt, dass es einen Synergieeffekt zwischen Kartografie und Journalismus gibt. Das entwickelte Forschungsprotokoll ist auch auf andere Bereiche anwendbar, die sich mit datengestützten visuellen Geschichten beschäftigen. Der vorgestellte Arbeitsablauf zum Verständnis der visuellen und rhetorischen Eigenschaften von kartenbasierten Geschichten stellt einen ersten Schritt zur Nutzung von Geschichten in der räumlichen Wissenskommunikation dar.

Table of contents

List of Figures

List of Tables

List of abbreviations

A
API Application Programming Interface. 22, 36, 48, 50, 76

C
CSS Cascading Style Sheets. 108

E
ESRI Environmental Systems Research Institute. 31, 46

G
GDR German Democratic Republic. 24
GIS Geographic Information System. 1, 2, 115
GUI Graphical User Interface. 48

J
JPG Graphics file format developed by the Joint Photographic Experts Group. 47

K
KO The Kontinentalist. 46, 47, 128

M
MFA Multiple Factor Analysis. 50, 123
ML Machine Learning. 75, 76

N
NYT The New York Times. 46, 47, 128

P
PDF Portable Document Format. 122
POI Point of Interest. 22
PU The Pudding. 46, 47, 128

Q
QCA Quantitative Content Analysis. 35, 36, 42, 44, 73

S
SCMP South China Morning Post. 46, 47, 128

U
UES User Engagement Scale. 28
URL Uniform Resource Locator. 48

V
VGI Volunteered Geographic Information. 22

X
XAI Explainable Artificial Intelligence. 113

Z
ZO Die Zeit Online. 46, 47, 128

1 Introduction

Storytelling is the oldest form of creating and sharing knowledge through combining factual or fictional experiences. Our brains are biologically adapted to recognize and memorize the building blocks of oral, written, and visual stories. Maps, throughout the history of mankind, were one of such blocks. Yet, there are two unique characteristics that distinguish them from other story-supportive elements. The first is the usage of spatial mental model during story creation and reading (Certeau 1980). When communicating with maps, narrators create imaginative spaces and imply specific spatial relations between story elements (Gasher 2021). The second unique trait of maps is the unwarranted trust we put in them, assuming their objectivity and strive for showing truth (Tyner 1982, Mode 2017).

1.1 Significance and importance of the research

The development of map-based and fact-based storytelling was influenced by two intertwined disciplines of cartography and journalism. Both use maps to communicate certain messages, both create mental maps in their readers' consciousness, and both operate on the objectivity-subjectivity continuum. Fact-based storytelling utilizes journalistic and thematic maps, that strive to follow the academic and practical rigour, leaving little space for visual ambiguity and multiple interpretations. Therefore, journalistic maps published in news media tend to fall into one of two categories: locative, that show the exact locations of the story and expositive, that reveal spatial relations between story elements and other elements meaningful for the story context (Gilmartin 1985). The opposite side of the continuum is marked by suggestive and persuasive maps, that pretend to communicate spatial components of the story. In practice, they purposefully frame them to influence readers' opinions or beliefs. Their designs resemble journalistic or thematic maps, yet they diverge in their use of geographical projections, emotive symbology, or map embellishments (Muehlenhaus 2013).

To further understand the phenomena of map-based storytelling, one need to take a closer look at the relationships between both disciplines: cartography, the science of map-making, and journalism, the practice of narrative-sharing. Initially, these two threads run separately. The milestones of journalistic cartography are correlated with international conflicts and their resolutions. World War I, World War II and Cold War drove public interest in maps and stimulated design experiments, that re-appeared in the post-war advertisement maps (Schulten 2015). In the twentieth century, journalistic maps were almost exclusively created by professionals trained in art, graphic design and architecture (Mode 2017). The previously separated disciplines started to converge toward the end of the twentieth century. Gilmartin envisioned that GIS systems would become standard working environments not only for cartographic, but also journalistic map production (Gilmartin 1985).

She called cartographers to investigate how journalistic maps were designed and read, as their visual patterns would become more prevalent and would influence the perception of other map types in multiple use cases. Indeed, only eight years later, the Pulitzer Prize went to Miami Herald for their pioneering map-based investigative piece "What went wrong". The work revealed that damages caused by hurricane Andrew in 1992 were most likely to happen to the newest dwellings due to gradual decrease of urban and building standards (Doig et al. 1992). This publication established a new path for the growing use of geodata and GIS in journalism (Herzog 2003), that preceded the emergence of data-driven journalism (Gray et al. 2012).

Cartographic community raised multiple concerns on the development of journalistic maps, situating them between "persuasive cartography", "pop-cartography", or even "pseudo-cartography" (Green 1999). The comparison between journalistic and thematic maps using cartographic criteria of right projections, scales, and generalizations was not favorable to the former ones (Balchin 1985). Cartography acknowledged the unique aim and purpose of journalistic maps but opted for introducing more cartographic trainings for journalists. The goal of this critique was not to discredit the contributions of journalism in raising spatial awareness. On the contrary, cartographers recognized that imposing the scientific rules of map construction on the genre would lead to "sterile cartography" — growing number of blunt, similarly-looking maps (Green 1999).

Two decades later, we experience the pivotal point brought by the development of media-rich and data-driven storytelling (Lorenz 2010, Riche et al. 2018). Data became the new fuel for the story, claiming to be an unbiased representation of facts and human experiences. The visual stories produced by media became more pervasive, engaging and impressing. The two unique characteristics of maps — spatial mental modelling and unwarranted assumption of truth telling — set a common goal for the two now intertwined domains: to tell better data-driven stories with maps. Journalism recognized itself as a practice of cartography responsible for shaping the social imaginaries of the world (Gasher 2021). On the other hand, cartographers want to extend the scientifically rigorous designs with impact factors of emotional reactions, vividness (Fish 2020) or virality (Shannon and Walker 2020, Robinson 2019), that were previously attributed to journalistic maps. The calls from Gilmartin became again valid: learning about the circulation of new forms of maps in digital environments is crucial to understand the entire process of cartographic communication (Gilmartin 1985).

1.2 Research aims, questions and tasks

The thesis aims to explore the development of map-based storytelling in the data-driven era. It faces the challenge of building this meta-story by combining in a novel way multiple data-driven research protocols from cartography, data science and cultural analytics. The research is conducted from a cartographic perspective, but it equally recognizes the stance of journalism. The two perspectives interact with each other over three research questions:

RQ1 How to organize the design space of data-driven map-based stories?
RQ2 What are the characteristics of map-bases stories disseminated in news media?
RQ3 How can cartography contribute to the ongoing storytelling practices?

The research questions are addressed by defining three research objectives and their corresponding tasks.

Objective 1 is to develop a design framework that organizes the design space of data-driven map-based stories. Therefore, the first part of the thesis summarizes the cartographic considerations on story construction and updates them with interdisciplinary insights on story dissemination by completing two research tasks:

RT1 Review of the storytelling concepts present in cartography, journalism, literature, fine art, data visualization, and computer science.
RT2 Summary of the adequate storytelling principles, structures, forms, and characters that are also relevant to story maps.

Objective 2 is to implement and evaluate the proposed design framework using journalistic maps as case studies. The second part of the thesis expands the interdisciplinary perspective to:

RT3 Operationalize the design framework through chaining manual and automated data analysis methods.
RT4 Analyze maps shared by journalistic outputs using a novel analytical protocol.
RT5 Evaluate the completeness of the initial design framework.

Objective 3 is to identify real-world themes and to experiment with their communication through data-driven story maps. The third part of the thesis documents practical efforts of extending the existing story maps approaches by:

RT6 Proposal, development and dissemination of story maps for politics, culture, urban design, and art.
RT7 Evaluation to what extent the new stories deepen the mutual understanding of cartographic and journalistic storytelling.

1.3 Thesis outline

Following this introductory chapter, this thesis contains seven further chapters.

Chapter 2, **Foundations and State-of-the-Art**, lays out the characteristics of the stories in domains neighboring to cartography and journalism, such as literature, visual arts, and computer science. Instead of enumerating multiple storytelling concepts, the chapter summarizes them through the lenses of cartographic narremes – theoretical and practical building blocks of data-driven story maps.

Chapter 3, **Methods of analysis**, walks through methods used so far to capture the design spaces of storytelling artifacts such as maps, paintings or newspaper covers. The chapter reflects on the prevalent approach of manual Quantitative Content Analysis and theorizes its two possible extensions. The first one is the use of Machine Learning to automatically describe the content of the story map. The second is the use of metaimages – visual representations displaying all story maps in different similarity groups.

Chapter 4, **Research protocol**, guides through the rationale behind operationalizing the design concepts. The chapter explains construction of the codebook and clarifies how design variables and codes will be assigned by both human coders and algorithms. It also illustrates the methods of data analysis and reporting.

The next two chapters document the results of the study.

Chapter 5, **Implementation of data-driven approach for story analysis**, reports on the diversity of story maps and highlights dependencies between design variables. It also evaluates the completeness of the initial design framework with the multiple factor analysis.

Chapter 6, **Research through design**, reflects on the discovered storytelling practices by creating an annotated portfolio of visualization case studies. The annotations for each case include coverage of data sources, presentation of storytelling approaches, analysis of story requirements, prototyping of the visualization, and dissemination of results in news media.

Chapter 7, **Discussion**, reviews the achieved results in the context of previous literature and the newly acquired knowledge. It also contains a list of design pitfalls and opportunities.

Chapter 8, **Statement of impact**, reflects on the overall contributions of this research, points to their limitations and outlines future research directions.

Design space of map-based stories

Foundations and State-of-the-Art 2

The content of this chapter adapts and follows the structure of rhetorical triangle (Harvey 2015) to analyse the relationships between story map, narrator, and map users. These three elements are essential for map-based storytelling, influence each other and follow three principles (Figure 2.1):

- ↪ the principle of **cartographic design** - story maps are constructed based on domain knowledge and strive to be highly functional, yet visually appealing,
- ↪ the principle of the **product design** - story maps appeal to users' perspectives, consider their personal perception and use context, induce emotional responses and influence decision making,
- ↪ the principles of **communication design** - the relationship between cartographer and audience shapes the story, therefore it should be strengthened by establishing mutual credibility, following feedback loops and agreeing on ethical codes.

The review contains glossary of terms from multiple disciplines related to cartography and journalism, such as visual rhetoric, narrative design, data visualization, data science and cultural analytics. The terms are introduced for each part of the storytelling triangle to highlight their use in the context of cartographic communication with story maps.

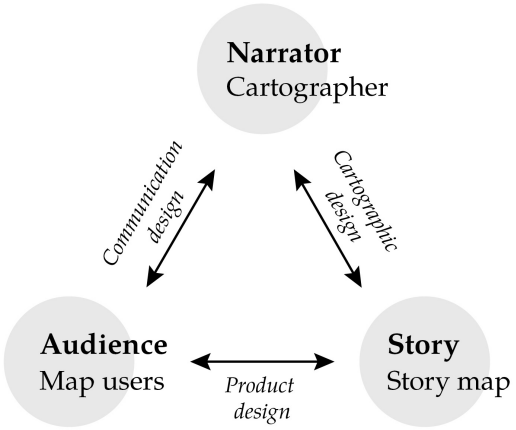


Figure 2.1: Map-based storytelling involves design relationships between narrator, story and audience. Figure compiled by the Author based on the concept of storytelling triangle by Harvey (2015).

2.1 What is visual storytelling?

2.1.1 Linguistic origins of visual storytelling

The term **narrative** stems from two Latin words: *narrāre* – "telling a story, relating, recounting and explaining" and *gnārus* – "knowing" (deSouza 2018). This linguistic origin of the narration clearly points to the main purpose of storytelling, that is building social relations through sharing knowledge (Tkaczyk 2017).

In order to create a story, one must account events, places and characters in a raw, chronological order, so called **fabula**. Cohn (2013) argues that humans express stories in three languages that are similarly processed in our minds - spoken, gestural and visual. Each language can be further broken into **morphems** - the smallest units of meaning. Spoken stories consists of phonemes, and visual stories are built up by **visual morphemes**. Narrative is regarded as a way of storytelling. While story is a collection of event properties, **plot, narrative** or **syuzhet** refers to their rhetorical organisation (Figure 2.2). Narratives can be further subdivided into spoken, signed and visual types, with their basic building blocks conceptually defined as **narremes**.

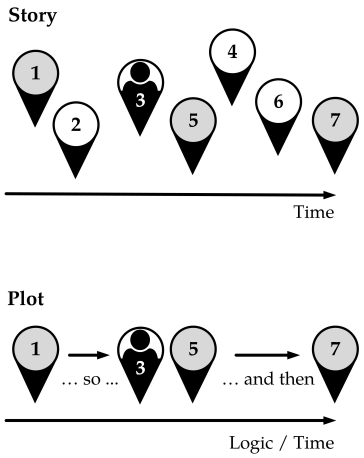


Figure 2.2: Difference between story and narrative plot. Schema adapted from Dibell (1999).

2.1.2 Visual storytelling with maps

The cartographic understanding of plots and narratives is traced back to the above-mentioned literary origins. Cartographic **story** stands for "an account of specific events, places and people", while **narrative** formalizes the "structure and visual presentation of these properties" (Roth 2021). Cartographic narratives are therefore a part of visual narratives, that "convey a continuous event sequence" by placing selected images in a consecutive manner (Cohn 2019).

What makes cartographic narratives different from other visual narratives is the usage of spatial mental model during their creation and reading. As noticed by De Certeau (1980), a map is a visual-spatial narration that integrates living experiences, private perceptions, memories and fantasies (Certeau 1980) with information about their location, size, and orientation. Therefore, a **story map** shares characteristics of both maps and narratives (Robinson, Demšar, et al. 2017).

2.1.3 Data-driven map-based stories

Spatio-temporal narratives can be extracted from datasets with quantitative and qualitative information (Robinson, Demšar, et al. 2017, Roth 2021). Yet, previous approaches on communicating insights from data mining focused on informing readers about geometries, topologies, outliers or directions of changes in data. In recent years, the geospatial communities kept developing a growing body of knowledge on how to build, interpret and evaluate their data-driven narratives (Robinson, Demšar, et al. 2017, Tong et al. 2018), which can be further developed into **data-driven stories** (Roth 2021). Data-driven storytelling is a multi-layered story

communication process that may rely on geovisual analytics (Chen et al. 2020) and separate visualization from narration (Bradshaw 2011). The **story synthesis** process starts from data compilation and cleaning. In the exploratory phase surprising, yet plausible insights and findings, are placed into **story slices**, that are carefully selected, managed, and organized into meaningful layouts (Chen et al. 2020).

Although modern maps claim to be visually self-containing and "worth a thousand words", the oldest maps known to us were narrated and discussed orally (Mariani 2019). After the invention of an alphabet and print, maps were placed alongside the text and mutually supported their understandings. With the latest technological developments, we increasingly observe hybrid forms of storytelling (Table 2.1), that merge spatio-visual narratives not only with oral and written languages, but also with audio-visual and imaginative practices (Roth 2021).

Table 2.1: Examples of hybridization points between cartographic design and various modes of storytelling.

Storytelling mode	Hybrid domain	Resulting story maps
Written	Literary cartography	Literary atlas (Piatti, Reuschel, and Hurni 2011)
Oral	Cultural mapping	Place-based oral stories (Kemper, Peluso, and Roldan Usesche 2019)
	Ethnographic mapping	Oral maps (Kemper, Peluso, and Roldan Usesche 2019)
Written-visual	Comic cartography	Maps in cartoons (Vujaković 1990), comic strips (A. B. Moore et al. 2018)
Audio-visual	Cinematic cartography	Location maps (Caquard, Naud, and Gonzalès 2012)
	Soundscape mapping	Soundscape maps (Aiello et al. 2016)
	Game design	Gaming maps (Edler, Keil, and Dickmann 2018)
Imaginative	Dream cartography	Dream space and content maps (Iosifescu Enescu, Montangero, and Hurni 2015)
	Emotional cartography	Emotion maps (Nold 2009)
	Smellscape mapping	Smell maps (McLean 2017)
	Psychogeography	Mental maps (Brennan-Horley et al. 2010)

The hybridization efforts come both from the cartographic community as well as neighboring visual domains such as journalism and art. Cartographers investigate concepts of **intrinsic storytelling** (Bonassi and Sieber 2017) and **story focus** (Mocnik and Fairbairn 2018) to integrate narrative structures in story map prototypes. On the other hand, interactive journalistic essays often appropriate the familiar user interface of online maps and their interaction patterns (Figure 2.3). This results in new types of verbo-spatio-visual compositions that can be both viewed and read. As an example, location-based poems (Figure 2.4) and calligrams merge typography with spatial reference to create expressive artistic maps (Figure 2.5) or intrinsic tag maps (Yang, MacEachren, and Domanico 2020). The most persuasive and evoking maps were made by creators whose training does not classify them as cartographers (Mode 2017, Demaj and Field 2012, Fish 2020).

Given the interwoven threads of spoken, signed and visual narratives and omnipresence of data, it is necessary to explore what elements can serve as **cartographic narremes** – the theoretical and practical building blocks of data-driven story maps.

Figure 2.3: The "Close read" series in The New York Times introduces artworks using map interactions of panning and zooming.

The article by Farago (2020) narrates the woodblock print "Ejiri in Suruga Province" made ca. 1930-32 by Katsushika Hokusai.

Figure redrawn from (Farago 2020) using the digital file from The Met Collection API (unrestricted use under Creative Commons Zero - CC0.

Figure 2.4: Geographical reference serves as a starting point to develop text-based narratives.

The verses of OpenStreetMap Haiku were assembled by querying data tags and weather data around selected place (Escoffier, Alonso, and Parreño 2019).

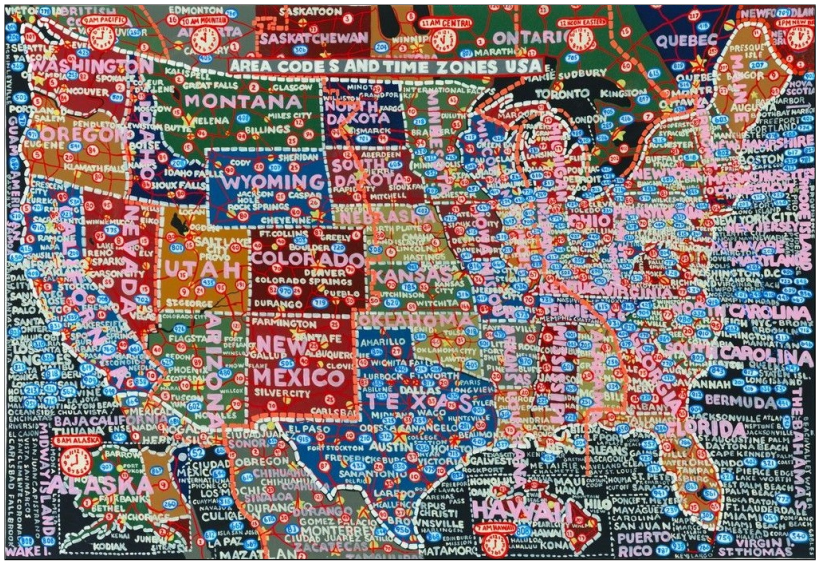


Figure 2.5: Boldly coloured typographic maps by Paula Scher blur the borders between personal narration, cartography and art (Scher 2011).

2.2 Narremes in map-based storytelling

2.2.1 Narrator

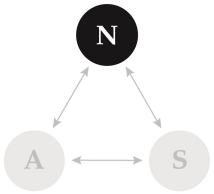


Figure 2.6: The following section of the thesis reviews the terms related to story narrators.

Each time and society has its name for a person who collects, develops and shares stories, be it orator, bard, cantadora, or narrative designer. The role of the storyteller is to manage the relationships between the audience and the story, as well as between audience and the storyteller themselves (Quesenbery and Brooks 2010). Mariani (2019) recommends that narrators should reveal personally touching situations or phenomenons, because if "something reaches your heart, it can be made to reach a reader" (Mariani 2019).

Narratology distinguished between several types of narrating styles. The **ominiscent** narrator has a full knowledge about story world and characters, therefore can freely choose what elements should be revealed to the audience. On the contrary, the **limited** narrator is restricted to the elements known to the story characters. Narrator can choose to present the story from a single perspective of one character — the **focalizer** — or multiperspective with several characters (focalizers). In the **first-person** focalization the main character speaks about own experiences as "I" or "we". The story narrated from the first-person perspective gives a natural feeling, as it mimics the way people share their daily experiences (Mariani 2019). The **second-person** focalization uses the "you" and "your" pronouns, while the **third-person** reports the experiences of "he", "she" or "they". The third-person narration invites audience to observe the story development and to draw their own assumptions. In oral and written storytelling the narration is predominately personified, meaning that the focalizer is either a person or a living form with human-like characteristics. Establishing not-personified focalizers is very challenging, but possible – Phillips (2012) derived eight storytelling plots told from the perspective of Earth systems phenomenons: genesis, emergence, destruction, metamorphosis, cause and effect, oscillation, convergence and divergence (Figure 2.12b).

2.2.2 Characters

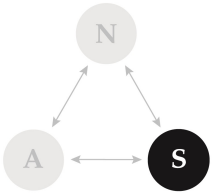


Figure 2.7: The following sections of the thesis review the terms related to visual stories and story maps.

Characters are the most important components of the stories. When seeing or hearing the stories, our brains activate parts responsible for processing own and other people's emotions, impulses and beliefs (Yuan, Major-Girardin, and Brown 2018). Stories are therefore told through set of main **characters** and **supporting characters** from their certain points of view. The characters in visual narrative can be presented using the "Five Ws" principle: "What they are? Why they became it? How, Where and When that could have happened?" (Mariani 2019).The typical story setup introduces the main character (**protagonist**) and its opponent (**antagonist**) that confront each other in an open conflict or inexpressible tension. Other versions of character conflict might evolve around internal struggles, societal and technological pressures, as well as natural and supernatural interference.

Story characters can be placed on three dichotomous scales (Mariani, 2019):

Linear vs. non-linear – linear characters strictly follow their determined path, whereas non-linear ones look for their appropriate path or change between multiple paths.

Static vs. dynamic – static characters do not undergo substantial changes, even if their emotional states change significantly. Contrary, the dynamic characters evolve as the story unfolds.

Well-rounded vs. blurred – well-rounded characters are known for their appearance, motivations and background, while blurred remain ambiguous for the audience.

2.2.3 Space

The environment where story unfolds is defined as its **space**. An effective narrative establishes a humanised environment appealing to feelings, so that audience can sink in the "atmosphere of history" and "the air that the protagonist breathes" (Mariani 2019). In map-based storytelling the mood of the space should be set up at the start of the narrative by designing forms, colours, types, and textures of map elements and embellishments (Roth 2021). As the story progresses, the narrator can re-define the space and its mood to either match with story characters and audience expectations (so called **harmonic** environment) or confuse and challenge them with **dysharmonic** environment (Figure 2.11). Re-definition of story space can be achieved by creating **color worlds** - new visual representations introduced when story characters enter a new path or cross the symbolic border (Lupton 2017). The visual appearance and extent of story space can be planned with prototyping tools such as wireframes, story boards (Walker 2013, Thöny et al. 2018) or mood boards (Sieber et al. 2016). Such organisation is particularly important for interactive story maps, that might suffer from infinite story space of unlimited scrollable screens.

2.2.4 Time

Narratives unfold in two parallel timelines that can be referred as audience time and story time (Tkaczyk 2017). The **audience time** is the actual time of exposure to the narrative, whereas the **story time** redirects audience attention from what happened "here and now" to what happens "there and then". The relationships between the story and audience timelines should be carefully planned as the following **story phases** (ibid.):

Description – in this phase audience time flies faster than story time (Figure 2.8). The storyteller uses audience time to introduce the story context, place and characters.

Summary – in this phase story time passes faster than audience time (Figure 2.9). The storyteller skips trivial events or descriptions to keep the audience attention.

Dramat – in this phase story time passes as quickly as audience time (Figure 2.10). This is achieved by including character's **voice** in monologues, dialogues or quotations, but also when the storyteller comments on real-time events.

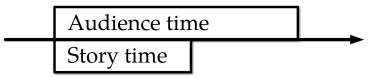


Figure 2.8: In the description phase story time progresses slowly.

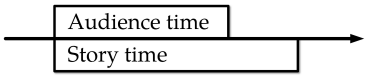


Figure 2.9: In the summary phase story time speeds up.

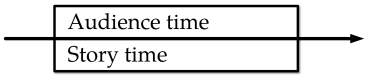
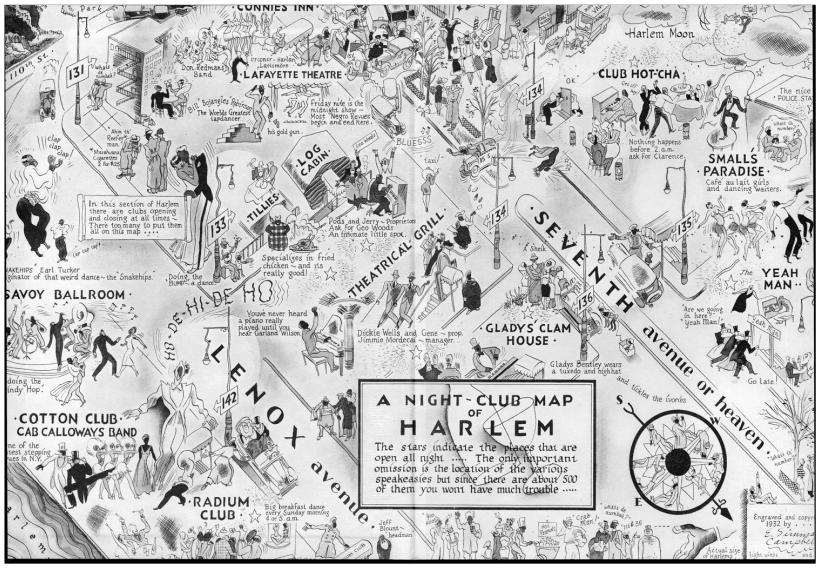


Figure 2.10: In the dramat phase story time passes as quickly as audience time.



(a) Cartoonist Elmer Simms Campbell illustrated the vibrant night scene of Harlem in the Jazz Age using multiple pictorial micro-stories (Campbell 1933).

(b) Campbell shapes a story both as a narrator and a supporting character, who takes active part in the evening...

(c) ...and gives recommendations to the reader. The environment of the story is therefore dysharmonic, yet engaging

Figure 2.11: Blending space, time and point of view within a story map.

To create a coherent story time, the theories of **kairos** and **decisive moments** propose to narrate only significant, opportune or transitory moments, that create a sense of "before, now and after". If the story time is missing or is weakly defined, the temporal organisation of story map might be replaced with non-temporal narrative arcs.

2.2.5 Plots

A plot can be decomposed into a main plot and several subplots. The **main plot** evolves with the tension or conflict between **protagonist** and **antagonist**. On one hand, the main plot can be divided into **parallel plots** – equally important, yet separate narratives of each character. On the other hand, secondary **subplots** introduce **supporting characters**, reveal new information about the story space and intensify the conflict in the main plot. The actions within plots can be divided into **plot elements** – significant events or places that influence the actions, and **pauses** between them. In order to enhance the linearity of visual stories, their elements need to be carefully selected, arranged and visualized. For instance, pauses between plot elements can result from incomplete data about characters, but they can also be left blank intentionally.

Dependent on the degree of plot organization, we can differentiate between non-linear and linear narratives.

Non-linear narrative

A non-linear narrative does not provide a recognizable organisation of plot. For instance, it might be guided by logical rules of cause and effect rather than following a chronological order. In visual stories non-linear narratives are often presented with the **reader-driven** approach and high degree of interactivity, that allow **random access** to events, characters and places or synchronous exploration of multiple parallel plots (Segel and Heer 2010). Other examples of unstructured story organization include **embedded narratives** – stories told within a story.

Linear narrative

Linear narratives organize plot points and pauses into coherent, logical and progressive tracks, referred as **narrative arcs** or **narrative paths** (Segel and Heer 2010). Linear arcs usually settle plot elements in a one-dimensional (temporal) order or two-dimensional space by coupling time with additional story dimensions, such as:

Emotional load – plot elements follow the emotional states of the main character (Figure 2.12a). For instance, the **story shapes** of famous fables (Reagan et al. 2016) move on the fortune - unfortune continuum,

Tension – plot elements introduce tension, its development into conflict and eventual resolution (Figure 2.12b). This arc structure is particularly prevalent in stories on Earth system dynamics (Phillips 2012).

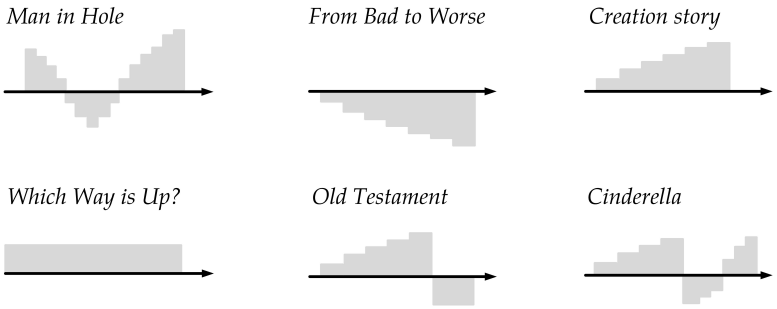
Function – the neighboring story elements are paired based on the functional relationships between them, such as problem-solution or question-answer (Figure 2.12, Weissman 2008).

Space – elements are organized according to the geographical location of their action, or they follow an artificial spatial arrangement, e.g., from the center out (Figure 2.12d, Weissman 2008).

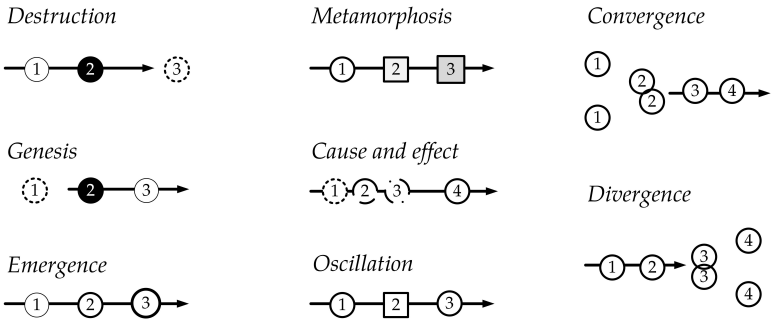
Recently Roth proposed a concept of linear three-act spatial narrative that places narrative elements into the set-up, conflict, and resolution of the story (Roth 2021).

Plot controllers

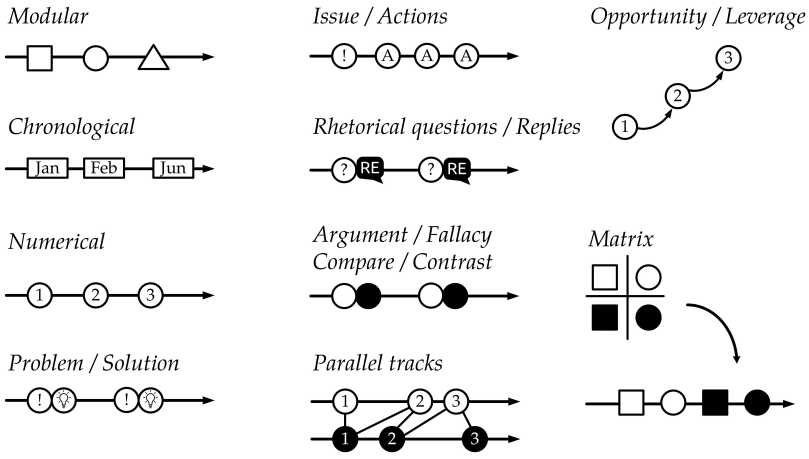
Several techniques can be used to indicate story time and to unveil the narrative in the assumed order and pace. Historical maps presented the plot as shapes of environmental features (Figure 2.13), conceptual directions of mappings (Figure 2.14) or origin-destination movements (Figure 2.15). Lupton (2017) proposed two universal design strategies to control the narrative path – labyrinths and mazes, that correspond with author-driven and reader-driven techniques from data visualization (Segel and Heer 2010).



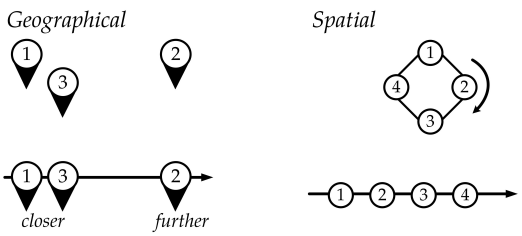
(a) Following the emotional states of the main character (Reagan et al. 2016).



(b) Following tension points (Phillips 2012). Schema redrawn from Roth (2021).



(c) Pairing plot elements based on the functional relationships between them (Weissman 2008).



(d) Organizing plot elements in space (Weissman 2008).

Figure 2.12: Possible organisation of linear plots.

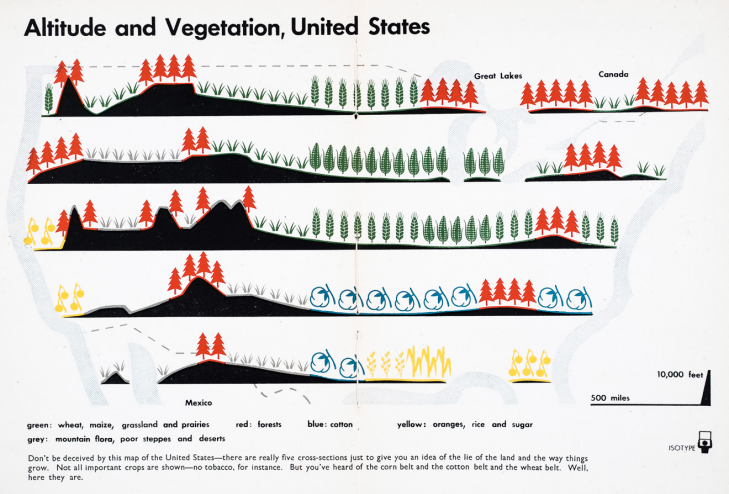


Figure 2.13: Linear and horizontal unfolding of the story.

The isotype map by Lella Secor Florence uses pictograms to present a simplified, memorable image of American terrain and farm production (Florence 1943). The reader is encouraged to follow the developments in a linear way, glancing between west and east coasts.

Figure 2.14: Numerical and spatial unfolding of the story.

The Persian astronomer Azofi created a series of astronomical maps that gave foundations to the later star catalogue (Azofi 15th century). The position of the stars in constellation is numbered and supported by a highly associative, anthropomorphing picture.

Figure 2.15: Linear and vertical unfolding of the story.

John Ogilby's developed a method of strip maps to show roads from Whitby to Durham and Durham to Tinmouth (1675). The maps are engraved on strips unfolding as bands of ribbon.

The labyrinth stories consist of one entry point, one non-branching path and one exit (Figure 2.16). Although they are easy to navigate, they might be long and contain some twisting and turning points on the way. Labyrinth stories are rooted in the **author-driven** approach (Segel and Heer 2010), where narrator fully controls the freedom of story exploration and provides one pre-defined **linear path** to be followed by the reader. The reader usually moves along the path by looking at automatically played animations or by interacting with story content through panning, clicking or zooming (Roth 2013).

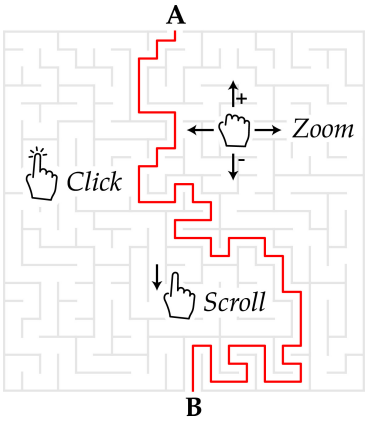


Figure 2.16: Labirynth-like organisation of the story.

The second strategy, a maze, consists of various entry points, multiple branches and numerous exit points (Figure 2.17). In data visualization such a high freedom of exploration is achieved by implementing Drill-Down (Segel and Heer 2010) or layered Martini Glass structures (So et al. 2021) with story access points and **user-directed paths**.

Finally, some stories follow the mixed labiryth-maze or Martini Glass structures. The first part of such story contains one entry point and author's linear introduction to story. After the introduction, user is presented with multiple alternative paths and exit points.

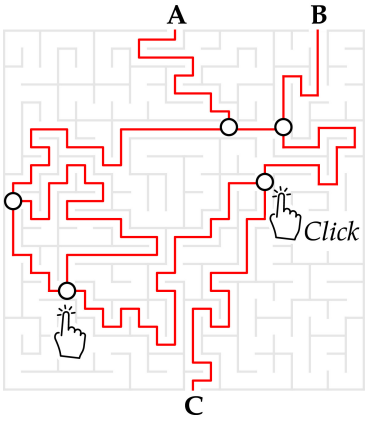


Figure 2.17: Maze-like organisation of the story.

Visual storytelling tropes

Visual tropes are design elements that ensure that story audience keeps moving through labirynths and mazes of text and images. Yet, the implementation of tropes is strongly dependent on story medium. Roth (2021) introduced seven general tropes suitable for story map design: continuity, mood, dosing, attention, redundancy, metaphor and voice. Static maps utilize visual hierarchy and accenting techniques such as annotations, numeric labels and call-outs. Online maps, in addition to the above-mentioned controllers, advance the plot also through carefully designed user interactions and interface elements, that help readers to locate themselves within the plot and encourage the transition between plot elements. The **story layering** approach from data visualization utilizes interactive techniques such as animations, transitions, selections and scrolls to highlight different data states (Schwabish 2019).

2.2.6 Frames

Story path can be represented by a sequence of visual elements, so called frames or doses (Roth 2021). Frames serve different purposes depending on their position within the path (Figure 2.18):

Opening frames are mostly present in the set-up of the story. Their main purpose is to introduce the general place, time, characters and problem context of the action. Opening frames often contain a **hook** that captivate readers' attention. For instance, cold opening frames draw audience into the story before presenting any set-up. Other hook options include question, factoid, anecdote, quotation, aphorism or analogy (Weissman 2008).

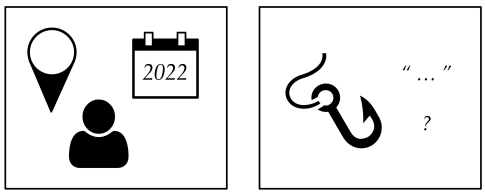
Flash-back frames temporarily move the narrative backward in time from the previous frame.

Foreshadowing frames give a hint or suggestion of the upcoming frames.

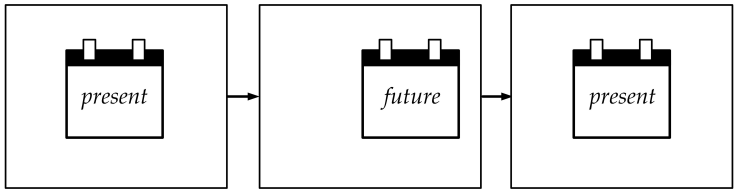
Cliffhangers are unexpected, dramatic plot twists (Mariani 2019). The key characteristics of cliffhanger include incompleteness, stimulation, openness, anti-intuition and urge to multiple interpretations.

Final frames bring closure to the story by presenting an image, question, surprise, lesson or call-to-action. If the story has a **closed ending**, final frames resolve all unclear issues, for example reveal main motifs of characters. In contrast, the **open ending** keeps the story unresolved and open to interpretation by the audience.

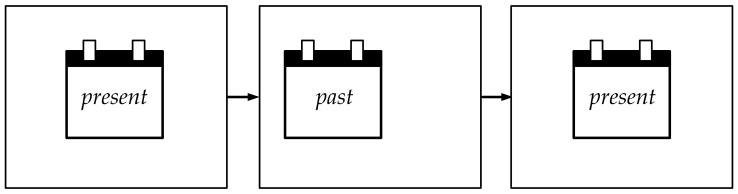
Circular frames appear multiple times on the path, e.g., as opening frames and ending frames.



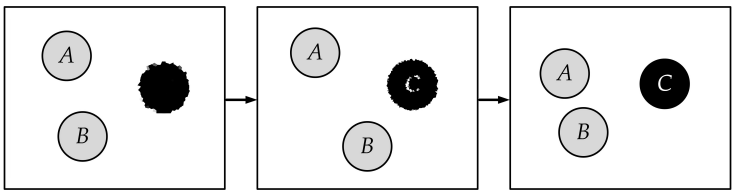
(a) Opening frames introduce the set-up of the story and captivate audience attention.



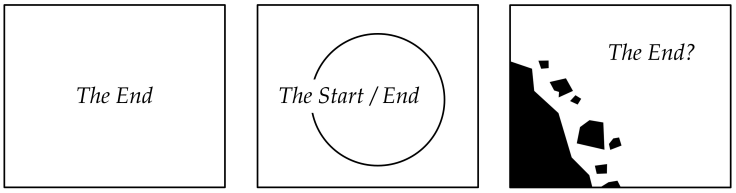
(b) Flash-forward frames temporarily move the plot forward in time.



(c) Flash-back frames temporarily move the plot backward in time.



(d) Foreshadowing frames give suggestions on what will happen in the plot.



(e) Ending frames conclude the story in the closed, circular or open manner.

Figure 2.18: Story frame types.

2.3 Visual persuasion

Storytelling is a process of building relationships by sharing meaningful knowledge (Tkaczyk 2017). Visual storytelling achieves this goal using visual media, be it static images (e.g., photographs, graphics, maps) or motion images (e.g., videos, animations). As such, storytelling distinguishes itself from the rhetoric. While stories include just a call for transformation, rhetoric, known as art of persuasive communication, aims at effective change in behaviors and attitudes. Rhetoric is often viewed in a negative way as a mean for misinformation and manipulation. Yet, there is some overlap between storytelling and rhetoric. On one hand, storytelling uses rhetorical devices to effectively communicate knowledge. On the other hand, rhetoric treats storytelling as one of the multiple formats for persuasion.

2.3.1 Persuading with images

Rhetoric dates back to ancient Mesopotamia and Greece. The first persuasion techniques were codified by Aristotle as logos, pathos and ethos. The rhetoric of logos persuades with reasoning, facts, and figures. Pathos evokes feelings and emotions, while ethos convinces with establishing speaker's credibility. For centuries the rhetoric studies in Western cultures were concentrated on oral and written languages. The development of visual rhetoric - a study of persuasive visual properties of images and texts - dates back to 1960s and 1970s. During this period, television and press exhibited multiple advertisements in which images were placed in a particular order to mimic the usage of words in oral rhetorical figures such as metaphor and antithesis (Durand 1987). The period was also marked with mass protests (mostly in US) against the Vietnam War (Figure 2.19), that were for the first time recognized as **image events** – acts of disagreement accompanied with photographs, posters, and signs designed for broad media coverage (Delicath and DeLuca 2003, Gries 2020).

Figure 2.19: Protest march against the Vietnam War, Helsinki (Sirén 1967).

In the last decades visual rhetoric extended its scope to study other images, such as static memes, maps, charts and infographics, as well as interactive visual essays (Gries 2020). Visual rhetoric became also interested in persuasive possibilities of blending visual elements with the properties of digital mediums (Fogg 2003). Modern websites and mobile applications follow the principles of visual **attractiveness** and **tailoring**, meaning that they are carefully designed to appeal to personal taste, interest or personality. Moreover, their users are guided through multiple interactive experiences (principle of **tunneling**), and persuaded at opportune moments (principles of **suggestion** and **kairos**).

2.3.2 Persuading with maps

Drawing the theoretical boundaries between cartography and visual rhetoric is very challenging since they intersect in three tension points. First, the process of map-making includes several steps that are rhetoric in their nature, such as data generalization or classification (Harley 2011). Second, the perception of a map cannot be separated from reader's context. This duality is aptly summarized by Denil (2017), who argues that "one does not read a story previously embedded in a map; one writes a story of one's own through interpreting rhetorical arguments forward by a map". Third, due to ongoing hybridization of map-making it is hardly possible to derive a definite set of characteristics that could distinguish "objective maps" from "story maps" (Roth 2021). Therefore Mode (2017) proposed to start organizing the persuasive properties of maps along two dimensions: "what" – their subjects, and "how" – their design methods.

Subjects of persuasive mapping

Persuasive maps are as old as cartography itself. Their presence is related to the ongoing events, their content depends on the current state of knowledge, and their design reflects the developments in technology and communication (Tyner 2015). The Persuasive Cartography - The Paul Mode Collection published by Cornell University Library presents over 800 persuasive maps published between 1491 and 2006 (Figure 2.20). Practically all of them were released as printed images, mainly journalistic maps, but also posters, leaflets, atlases or post stamps. By comparing the metadata of the collection with high-level news map themes derived by Vujaković (2014), one could see that persuasive maps are present in all information contexts (Table 2.2). Their over-representation is particularly visible in advertisement, political conflicts and social morality.

Table 2.2: Subjects of persuasive maps from the Persuasive Cartography - The Paul Mode Collection matched to the general news map themes (Vujaković 2014).

Theme	Map subject
Disasters	Disaster
Economics	Money
	Finance
	Advertising
	Promotion
	Alcohol
Culture	Romance
	Love
	Marriage
Environment	City
	Railroads
Science	Health
	Environment
Politics	Government
	Suffrage
	Imperialism
	Ethnocentrism
	Russo-Japanese War
	Spanish-American War
	U.S. Civil War
	World War I
	Interwar period
	World War II
	Communism
	Cold War
	War
	Peace
Society	Poverty
	Prostitution
	Crime
	Slavery
	Race
	Bias
	Religion
	Heaven and Hell
	Conduct of Life
	Moral and Social

Figure 2.20: Sample of 860 persuasive maps from the Persuasive Cartography – the Paul Mode Collection.

Methods of persuasive mapping

What differentiates persuasive maps from thematic or topographic mapping is the persistence of rhetorical choices that deviate from cartographic standards or contrary, that stress these standards. Harley (2011) used the order of the Aristotelian rhetoric triangle to argue that persuasive maps might over-emphasize the cartographic methods (the rule of logos) and give more credit to the authorities (the rule of ethos).

The design and composition of persuasive maps aim at inducing emotional responses (the rule of pathos). This can be fostered both through geodata management and map design itself. Based on two orthogonal dimensions of data density (from data-light to data rich) and data symbolization (from rationalist to emotive), Muehlenhaus (2011; 2011; 2013), clustered maps into four rhetorical styles: authoritative, sensationalist, propagandist, and understated.

Single maps can incorporate persuasive techniques through deliberate placement of visual rhetorical figures - typography, images or parts of the images, which presence and design vary from their common usage (Harley 2011). Inspired by the research on rhetoric of advertisements (Durand 1987), the following sections introduce how maps can be used as visual rhetorical figures in four contexts: **addition**, **suppression**, **substitution** and **exchange**.

Addition

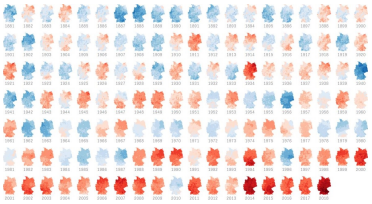
Additive rhetorical figures are the easiest to create, as they rely on adding and arranging the objects of the composition (Figure 2.21). Addition is widely represented in story map design as:

Repetition – presentation of identical elements multiple times.

Similarity – juxtaposition of multiple elements sharing similar form (rhyme) or concept (comparison). Examples include small multiples that share the same base maps, color schemes and layouts to highlight subtle differences in spatial patterns (Figure 2.21a).

Accumulation – visual impression of density and diversity, that might be perceived by audience as confusing, unstructured, chaotic and visually cluttered (Figure 2.21b). Accumulation often appears in map-based mashups – interactive base maps overlapped with POIs queried through APIs or entered by the map users as user-generated content and Volunteered Geographic Information (VGI) (Huang and Gartner 2012). While accumulation of multiple map icons reduces the legibility and stands against interactive map design principles, it might be purposefully used to impress over the density and omnipresence of the phenomena. Therefore, it is often seen on image events, e.g., in the form of protest maps.

Antithesis – comparison of two opposite, competitive views, that highlights the unique characteristics of each view. In interactive mapping, such comparisons are often achieved with vertical sliders that divide two map views, e.g., before and after a certain event. Using this technique might result in unintentional devaluation of one of the views by the audience.



(a) Similarity. Small multiples of the average annual temperature in Germany between 1881 - 2018. Similar forms build a visual tension and highlight the significant climate changes in the last years (Blickle, Erdmann, Fravio Gortana, et al. 2019).

(b) Accumulation. Map of Actions, Fridays for Future. The density of point markers gives the impression of the global movement of students demanding climate actions from politicians and industries (N.N. 2019a).

Figure 2.21: Rhetorical figures of addition.

Suppression

Suppresive figures, contrary to addition, are built by removing the objects (Figure 2.22). Maps applying this strategy give audience visual cues that some element is missing in the communication. The role of the audience is then to decode what elements are missing and what is the purpose of this omission. Suppression is analogous to the narrative pattern of **silent data**, in which the designer purposefully shows or hides subsets of data (Bach et al. 2018).

Ellipsis – emphasizing the key element of the image by hiding it and drawing the audience's attention to its absence (Figure 2.22a).

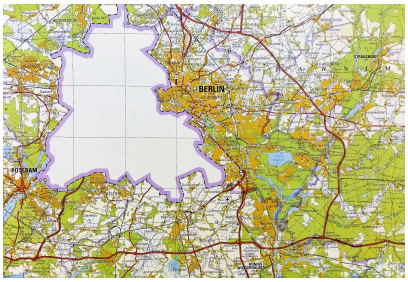
Suspense – delaying, holding back or revealing the map after presenting another unrelated element. This technique aims at creating anticipation, tension and curiosity, but if the transition between unrelated and key element lasts too long, it might irritate the audience.

Reticence – contrasting two elements – one visible and one hidden due to taboo, restrictions or prohibitions.

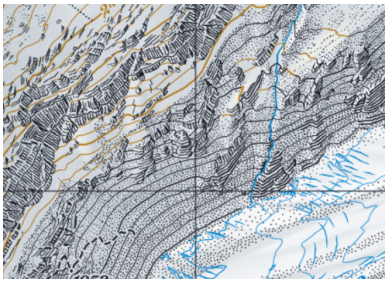
Preterition – camouflaging an element of the image or implying a secret while the element remains accessible to the viewer. In interactive maps the secret can be revealed after the certain action of the user, e.g. scanning the QR code. Spatial preteritions are a specialty of cartographers from Swiss Federal Office of Topography, who purposefully arrange the contour lines on topographic maps to hide tiny drawings related to the mapped area since early 1980s (Figure 2.22b).

Tautology – multiple repetition of the same image with different meaning in each repetition (Figure 2.22c).

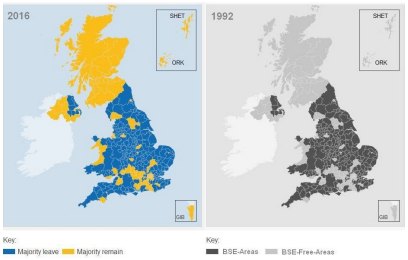
Circumlocution – connecting missing element of the image with similar objects (Figure 2.22d).



(a) Ellipsis. Topographic map released in 1988 by the GDR's Ministry of the Interior (N.N. 1988). Intentional removal of the urban representation of West Berlin concentrates the viewer's attention on filling in the gap.



(b) Preterition. The Aletsch Glacier marmot was created in 2011 by Paul Ehrlich, a cartographer specialising in rock drawings (Ehrlich 2013). The location of the marmot has been publicly revealed in September 2016.



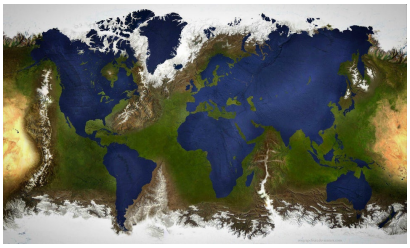
(c) Tautology. This viral map aimed at comparing the spread of Brexit voters in 2016 and mad cow disease in 1992 (N.N. 2016). Although both maps are the same, the way they are repeated is an ironic commentary to the political situation. The map has been firstly published on Facebook and has been shared over 50 000 times since then.

(d) Circumlocution. Satirical map of Europe in 1914 by Walter Trier. The missing extent of European countries is replaced by symbolic drawings of their national armies (Trier 1914).

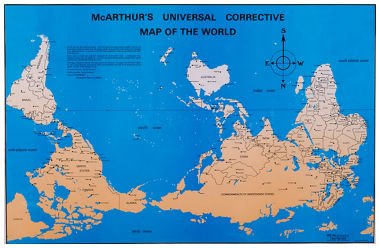
Figure 2.22: Rhetorical figures of suppression.

Exchange

Exchange figures "modify the relations between some elements" of the image (Durand 1987). **Anastrophe** is "an inversion of images with respect to the sequence expected by the viewer" (Mariani 2019). Examples in cartography include works that revert the standard representation conventions, such as maps switching land and water textures (Figure 2.23a). Also, the elements of the maps might remain the same, but appear in a surprising order, such as world maps with the "default" north-up orientation changed to south-up orientation (Figure 2.23b).



(a) Anastrophe. Land and water masses are mapped with opposite textures (N.N. 2021a).



(b) Anastrophe. South-up map orientation used as a political statement (McArthur 1979).

Figure 2.23: Rhetorical figures of exchange.

Substitution

Substitution figures replace some elements of the image or the image itself with other somehow similar elements or images:

Hyperbole – exaggeration of selected "aspect of reality in a qualitative or quantitative way" (Mariani 2019), such as visual exaggeration (Figure 2.24a).

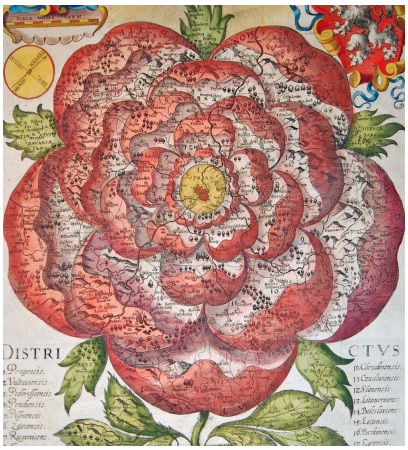
Metaphor – visual analogy between two elements based on similarity of their forms, contents or associations. In data visualization, visual metaphors are referred as **visaphors** and use characteristics of one object to emphasize features of another object (Cox 2006). A particular type of visaphors are **spatial visual metaphors** and spatializations (Skupin and Fabrikant 2003) that rearrange non-spatial information to be visualized and comprehended as a geographic space.

Anthropomorphism - assigning the qualities of a person or living form to something that is not human (Figure 2.24b) or other living creatures (Figure 2.24c).

Metonymy – substitution of one element with another closely associated element. In cartographic symbolization, metonymy is a main strategy for creating associative map icons - signs, that "closely resemble an activity or object related to the referent, but do not resemble the referent itself" (S. Bell 2020).

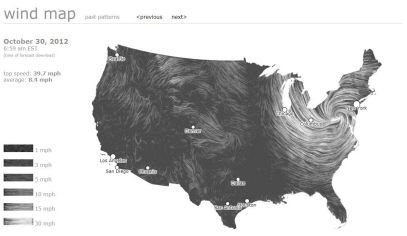
Periphrasis – capturing in one image "what was on the move a moment ago" (Mariani 2019, Figure 2.24d) or presenting a set of static images instead of a dynamic continuum (Figure 2.24e).

(a) Hyperbole. Anthony Hearsey visualized one month of data of locations where fire was detected in Australia in 2020. Due to the render's glow and scale exaggeration, many viewers mistakenly interpreted this image as a real-time map showing current extent of fires (Hearsey 2020).



(b) Anthropomorphism. Cartographic personification turns a map of Bohemia into a stylised Hapsburg rose (Vetter 1668).

(c) Anthropomorphism. Leo Belgicus - rhetorical symbol of Low Countries (Strada 1648).



(d) Periphrasis. Animated Wind Maps explore the variety of wind speed patterns across US (Viégas and Wattenberg 2012). The gallery of the project contains the captures of this constantly changing phenomena during hurricanes in 2012.

(e) Periphrasis. This world map tries to capture the continuum of the Earth's surface and human activities by using ten hemispheres with various projections (Nolin 1742).

Figure 2.24: Rhetorical figures of substitution.

2.4 Story audience

2.4.1 Narrative values for audience

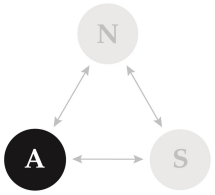


Figure 2.25: The following sections of the thesis review the terms related to story audience.

Storytelling does not need to be factual (e.g. fairy tales), but data-driven visual stories are more persuasive, engaging, memorable and desirable than news full of facts. Yet, as noted by Harley (1990), the "socially relevant content and an imaginative design contribution to a civilized society" should "go far beyond the provision of useful spatial data". Therefore, cartographers should seek ways to extend their evaluation criteria from effective story understanding to effective depictions of people and places (Roth 2021). May (2015), proposed a term **narrative value** – a common theme or label that can be used to assess the sense of human meaning as if they were a character in a story. As such, story maps can depict and promote a variety of narrative values, including creativity, courage or wittiness. Finally, story maps should assign certain narrative values not only to the story characters, narrators and depicted places, but also to people broadly associated with the story space.

Although the countless stories of humankind can be narrowed down to several plots, there are still "no ebays selling plots for home delivery" (Mariani 2019). The narratives need to be carefully crafted in an audience-centered design process. To make the audience care about the story, narrator should appeal to their values and offer something in return for taking the audience time. This approach can be summarized as "design for values" or WIIFY – "What's in it for you?" (Weissman 2008). A good storyteller learns about the audience and adapt story content so that people re-own the story (make them their story) and retell it in the same way or differently. This can be achieved by using audience archetypes or personas. For instance, Falk (2012) and Bond (2012) investigated the storytelling experiences offered by museums and distinguished five audience archetypes. Explorers are driven by interest and curiosity, while facilitators encourage the experiences of others. Professionals or hobbyists look for specific content related to their occupation or passion, contrary to re-chargers, who want to escape daily routines. Finally affinity seekers want to connect trough stories to their identity and heritage. Each of these groups will experience different consequences of their engagements with narratives.

Visual stories should have a transformative function for the audience (Tkaczyk 2017) and create a **virtual rehearsal** environment, where the audience can observe links between cause and effect of their simulated behavior. "Reading, viewing, hearing, or imagining narratives of another's situation and condition" causes emotional response such as perspective-taking or compassion (Hühn et al. 2009). This **narrative empathy** helps the audience to experience katharsis, learn a moral lesson, or amuse (Tkaczyk 2017). Story maps can also describe spatial events leading to certain complications, suggest a solution and strengthen positive patterns of behavior (Cobley 2005). The transformative function of stories can be viewed in the context of apperception – the "mental process by which a person makes sense of an idea by assimilating it to the body of ideas he or she already possesses" (Oxford English Dictionary, 2022). Such assimilation can result both in additive learning as well as unlearning – modifying or replacing the already possessed ideas.

2.4.2 Audience engagement

The perception of map-based story "starts from understanding basic graphic forms (graphic literacy), though understanding mapping conventions (map literacy) up to user interpretation and knowledge construction" (Denil 2017). Harley (2011) argued that many cartographers tended to evaluate maps "according to the standards of "objectivity", "accuracy" and "truthfulness", even if other metrics might be more appropriate. Traditional storytelling approaches would rather point to behavioral, cognitive and emotional gains from receiving a story. Stories prompt to a behavioral change, teach a lesson, or induce in the audience emotional responses such as laugh, tears, fear or relief (Tkaczyk 2017). How to evaluate to which extent map-based stories are effective along these three dimensions?

On one hand, research in data-driven visualizations couple the degree of engagement with the complexity of cognitive tasks (Mahyar, Kim, and Kwon 2015). The engagement level grows while moving from viewing and interacting, to analyzing, synthesizing and decision making. On the other hand, story effectiveness can be indirectly measured through audience engagement. In human-computer interaction such engagement can be assessed with behavioral metrics, neurophysiological techniques and self-reports (O´Brien, Cairns, and Hall 2018). Audience time was probably the first behavioral metrics for story evaluation. It included the time audience spent on the story reception as well as the time used for reflecting on the story. But in the last decades we experience the shortening of the attention span, that dropped from 12 seconds in the year 2000 to 8 seconds in the year 2013 (Microsoft Canada 2015). That means visual stories are very rarely read in a committed way and their life cycle is very short. Instead, the audience develops F- and Z-shaped scanning patterns to save time and cherry-pick the content highlighted in story headers. Being aware of this pattern, initiatives such as JournalismAI have developed data-driven algorithms to indicate where are the drop-off points along this digital user journey. Other engagement measurements involve neurophysiological techniques such as functional magnetic resonance imaging or eye tracking. The former one was used to show that our brains perceive characters as more important story components than plots (Yuan, Major-Girardin, and Brown 2018). Finally, engagement can be measured with self-reports such as dedicated questionnaires or interviews. The User Engagement Scale (UES) defines six dimensions of engagement: aesthetic appeal, endurability, felt involvement, focused attention, novelty, and perceived usability (O'Brien and Cairns 2015). Similarly, the AttrakDiff test can be used to place the story on the several adjective scales such as alienating - integrating, separates me from people - connecting, discouraging - motivating or repelling - appealing (Hassenzahl, Burmester, and Koller 2022).

2.5 Ethics of visual storytelling

Visual stories are rooted in **metanarratives** - recurrent narrative schemes that order and explain knowledge of individual readers and cultures. Storytelling and persuading techniques could be potentially combined to create power-supportive narratives (Harley 2011). Due to this world-creating function of maps (Gasher 2021), it is important to raise the question on the ethical issues in cartography. However, the word "ethics" did not appear in any of the four recent research agendas of International Cartographic Association, which define challenges and opportunities for cartographic research in a decade-long perspective.

Therefore, the following ethical considerations on map-based storytelling are discussed through the lenses of the emerging fields of narrative ethics (Phelan 2014) and visual ethics (Clark 2020). Both domains operate on their intersections with moral values – narrative ethics relates them to storytelling, while visual ethics links them to images. Using both these organizational framework, ethics of map-based storytelling is considered along the segments communication as the ethics of creating the story, the ethics of the told (story or image), the ethics of telling, and the ethics of reception of the story by the audience (Phelan 2014).

2.5.1 Ethics of story creation

What might make a difference between map-maker and professional cartographer is the ethics of cartographic design (Kent 2017). One of the first ethical guidelines for modern cartographic creation were created by Harley in 1990 in response to the rapid development of mapping technologies. Firstly, he called cartographers to "embrace structures or context within which [they] acted to produce their maps" (Harley 1990). Secondly, he pointed out that cartographers follow discipline-specific metanarratives and therefore they should keep reflecting about them. Almost twenty years later, one of the first broad codes of cartographic ethics was formalized in the context thematic map design and reconsidered the following ten rules (Dent, Torguson, and Hodler 2009):

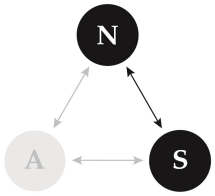


Figure 2.26: The following section of the thesis reviews the terms related to ethics of story creation.

↪ "Have a straightforward agenda,
↪ Strive to know your audience,
↪ Do not intentionally lie with data,
↪ Always show all relevant data when possible,
↪ Don't discard contrary data because it is contrary,
↪ Strive for accurate portrayal of data,
↪ Avoid plagiarizing,
↪ Symbol selection should not bias map,
↪ Map should be repeatable,
↪ Pay attention to different cultural values and principles".

Recently Caquard and Cartwright postulated that cartographers should develop self-narratives to critically reflect on their cartographic process (Caquard and Cartwright 2014). In similar vein, Kent called for more openness in the process of map creation and proposed keeping a backlog of story ideas or recording the design process (2017). However, he also pointed that ethical guidelines, in order to succeed in cartography, should be very pragmatic. Exemplary action points could include providing links to underlying data, informing about data manipulations and justifying map design choices.

Neighboring domains of data science and data visualization achieve more progress in developing practical solutions for ethical story creation. The Open Data Institute prepared The Data Ethics Canvas - a tool that helps to identify and manage ethical issues in data-driven projects. The resulting services, analysis, insights, stories and visualizations should follow the ethical design rules (The Open Data Institute 2021). The AI + Automation Lab of Bavarian Broadcasting uses web analytics to adjust the story content to user preferences. Their ten AI Ethics Guidelines include points such as conscious data culture, responsible personalization and interdisciplinary reflection (Bayerischer Rundfunk 2020).

Only recently data science was shaken up with the idea of **data feminism** – investigating the powers behind data-driven practices through the theories of intersectional feminism. The work offers seven prompts to do so: "examine power, challenge power, rethink binaries and hierarchies, elevate emotion and embodiment, embrace pluralism, consider context", and "make labor visible" (D'Ignazio and Klein 2020). In data visualization community, Wood, Kachkaev, and Dykes (2019) proposed the concept of **literate visualization** that integrates in one code the remarks on the design choices and the actual data visualization code. Using several narrative schemes, designers can mark and validate the rhetoric choices that led to certain design implementation, for instance double-check if the process follows a feminist data visualization schema or if it facilitates the knowledge exchange between the designer and domain expert. Taking the feminist principles into account, Roth (2021) proposed the following four starting tenets of visual storytelling with maps: "show your work", "show yourself", "speak to power" and "speak to each other". With the growing interest in ethics of cartographic design, cartography might soon experience its "ethical turn".

2.5.2 Ethics of story as a product

Although single stories are unique, when viewed at scale, multiple stories begin to form a **story system** with some stories sharing an overarching theme, presentation style or interaction scheme. These patterns of narratives and visual presentation can be referred as **codes** or **genres** (Segel and Heer 2010). Stories utilize genres because they effectively convey the key messages and reflect what the audience wants to see. There are two ethical dangers in relying on pre-defined, digital implementations of genres for data-driven stories.

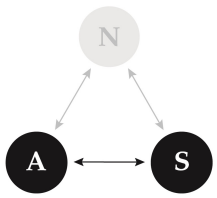


Figure 2.27: The following section of the thesis reviews the terms related to ethics of story being a final product.

First, data-driven, plug-and-play storytelling templates generate visual stories on the fly by allowing storytellers to simply drag and drop pieces of texts, images and videos. Such visual stories become less convincing and memorable with time. Instead, genres should be creatively adapted and mixed by storytellers to establish personal and outstanding styles of stories, for instance as new genre mash-ups. Second, visual stories can be contaminated with manipulations, exaggerations and call to actions. Since the stories are crafted based on the known users' expectations, they might visually persuade users to perform some unwanted actions. These types of storytelling patterns are often referred as dark patterns and include visual distraction or force continuity of use (Brignull 2022).

The ethical visual story should get audience exactly where they want to go and do not try to manipulate them along this way through deliberate design decisions (Lupton 2017). The credibility of interactive stories can be also increased by means of persuasive technologies (Fogg 2003):

- ↪ "incorporating knowledge, experience and competence of domain experts,
- ↪ introducing the people, process or organization behind the story content,
- ↪ allowing users to verify the story content, underlying data and external sources,
- ↪ fulfilling positive expectations of the users (recognizing narrative code),
- ↪ being easy to use and responsive to user's actions".

2.5.3 Ethics of telling and reception

Ethic of telling considers the relationship between storyteller or narrator and audience. Shortening this **narrative distance** can be achieved by meta-narrative that takes audience behind the scenes and gives them a feeling of uniqueness along the professional transparency. Although there are many examples of story maps in public discourse, their omnipresence is not reflected in the number of publications showing such metanarratives. Most of the visual cartographic stories covered by research articles were created and evaluated within the Story Map environment developed by ESRI (Zuo et al. 2019). Journalists tend to have more channels to share their storytelling approaches, for instance through newsletters, podcasts, conference talks and behind-the-scenes articles. One of such examples is The Pudding, a digital publisher that deliberately reflects on the storytelling rights in the blog post series. In their decision tree for data-driven storytelling (Figure 2.29), one of the step is to ask if the data for the story is acquired in an ethical way and if the journalist is the right person to tell the story. If not, the journalist should search for other data sources and collaborate with other storytellers (Thomas 2020).

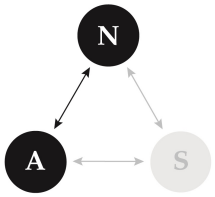


Figure 2.28: The following section of the thesis reviews the terms related to ethics of story telling and story reception.

Ethic of story reception asks what are the consequences of audience engagements with narratives. It researches on story reception, counter-reading, or re-telling practices, which can be controllable by the narrator only to a certain extent. Topographic or thematic maps can be rather faithfully decoded by comparing map content with the assigned legend.

In the story interpretation process audience might want to re-create the story from their point of view. The practice of counter-reading relies on recognizing the rhetorical arguments made by map and fitting them to the audience story (Denil 2017). The data-driven research quantifies the fitting process based on the types of online comments that are placed below data stories. Kauer et al. (2021) distinguished the following nine reactions to visualizations: opinion, critique, observation, conclusion, hypothesis, clarification, proposal, testimony and strive for additional information. Engagement can also reflect bigger societal issues such as group identity, place identity or relations to academic expertise (Shannon and Walker 2020). C. Lee et al. (2021) noted that different audience groups might look at the same visualizations, but draw different conclusions from them. Such audiences have varying levels of trust in data sources and the resulting data-driven stories. Instead, they may want to seek access to the raw, narrative-free data. Eventually, "one is not compelled to find any particular story in any particular map" (Denil, 2017) and in any particular dataset.

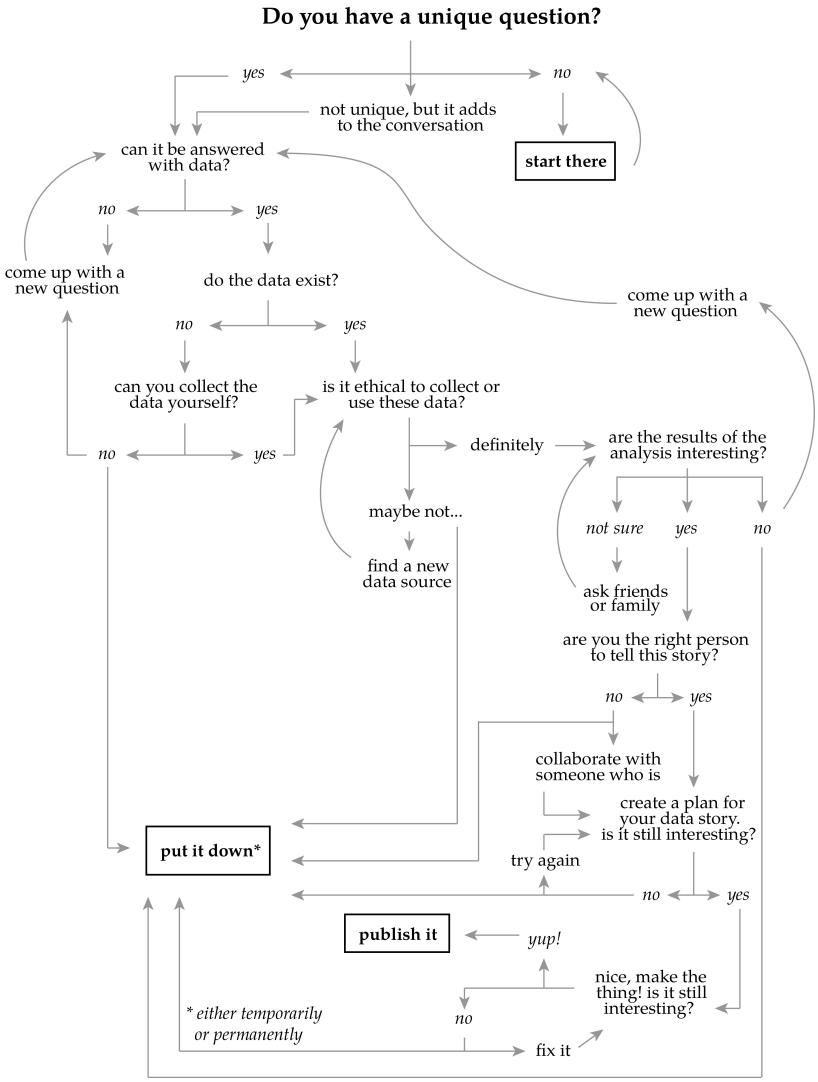


Figure 2.29: This decision tree from The Pudding decomposes the process of data-driven storytelling into a set of questions. Schema redrawn from Thomas 2020.

Analysis of map-based stories

Methods of analysis | 3

3.1 Subjects of study

This chapter provides the overview of two main approaches that are used to study visual storytelling and are relevant to this research. These approaches recognize visual stories as both communicative artifacts and distributed events (Gries 2020).

3.1.1 Communicative artifacts

The communicative artifact approach uses the visual narremes as core units of analysis. The visual narremes are stand-alone images and the accompanying typography that are related to other narremes. The first step in rhetorical analysis is to engage with the single narreme through a close reading – a careful look on the image and corresponding texts. The second step is to search for the connections between single narremes. During the reading one counts a presence of certain image elements or design implementations. The following checklist by Gries (2020) presents a set of exemplary dimensions and questions to be asked during the close reading of an image or the entire story:

Metadata – Who created the image? When, where and how it was published?
Image organization – What are the parts of the image? How they are arranged? Do they constitute any particular visual flow?
Emphasis and Contrast – Which parts of the image attract audience attention? Why? Which elements of the image stand out?
Color – What colors are used in the image? What factors might have influenced such choice? What are the connotations of these colors in the cultural context of the image?
Proximity – What is the distance between audience view and the space in the image? What types of perspectives are used?
Rhetorical figures – Which, if any, rhetorical figures can be found in the image? What is their function?

With the rise of data-driven approaches, narremes can be also defined in the automatic way as digital pieces that constitute the story. Traditional journalistic approaches refer to well-established structures of written narrations, such as Inverted Pyramid or Martini Glass (Harrower 2010). The modular journalism decomposes stories into interchangeable modules based on the feedback from linguists and the preference of audience (Kunova 2022). Once such modules are defined, multiple story versions can be created to target various sub-groups in the audience.

3.1.2 Distributed events

This second approach looks on the images or stories from the distant perspective of distributed events. Images are analyzed at scale as networked events that circulate in the phygital (physical and digital) spaces. This approach utilizes computational analysis such as reverse search to find the digital traces of the images in the network (Niederer and Colombo 2019). With data visualization techniques such traces can be then analyzed and grouped into prevalent or unique storytelling approaches (Manovich 2020). The following checklist by Gries (2020) presents a set of exemplary dimensions and questions that can be operationalized with the data-driven distant reading:

Futurity – What elements of the story have the potential to become viral? What design decisions or interactions were provided to facilitate this potential?

Re-telling – What happened to the image after its publication? Where did it appear? Was it reproduced or remixed? If so, what were the design changes? How does the remix differ from the original?

Speed – How fast was the circulation of the image? What factors might have influenced the fast or viral spread?

Resonance – Was the image used in other activity contexts such as image events or campaigns?

In the following sections four methods that cross these two methodological approaches are described in details – quantitative content analysis, automatic content analysis, metaimages, and research through design. These methods have either been used in the cartographic research or they will be adapted to the cartographic needs throughout this thesis.

3.2 Selected methods of study

3.2.1 Quantitative content analysis

Quantitative content analysis (QCA) is a widely utilized approach in studying visual materials such as photographs, cartoons and films (Pauwels and Mannay 2020). It involves systematical collection and categorization of images according to the pre-defined codes, also referred to as tags or labels. The application of QCA for cartographic research was described in great detail by Muehlenhaus (2011), who used it to analyze persuasiveness of maps in atlases and newsrooms. Since then it has become more popular and is used to study both static and interactive maps with high social impact. As an example, Roth, Quinn, and Hart conducted a competitive analysis of 25 water level visualization tools that aid water management in response to climate change (2015). Fish (2020) traced the visual agenda of maps communicating climate change, particularly novel map formats, visual salience and color use. QCA served also a tool to study similarities and differences between certain types of map-based visualizations. Muehlenhaus (2013) used it to distil the visual traits of persuasive maps in comparison to scientific geovisualizations, while Zuo et al. (2019) addressed the differences in cartographic design and interaction primitives between two map-driven visualizations – story maps and map-based dashboards.

However, applying the QCA method for story map analysis has four shortcomings related to stories and their analysts. To start with, story maps are polysemous and evoke different emotional reactions that might not be captured in the code definitions. Secondly, the voice of the story creator is missing during the analysis and one can only speculate what were the design challenges and rationale behind the final story map. Thirdly, content analysis is rarely executed and cross-checked by several researchers. Typical setup includes manual work being done by one (Muehlenhaus 2011a) or two trained coders (Zuo et al. 2019, Fish 2020) or crowdsourced workers with basic coding instructions. Therefore QCA is time consuming and hardly reproducible, especially if codes were dedicated to the purpose of one study rather than supporting longitudinal studies in cartography.

Finally, researchers often stop looking at the actual map samples after the coding phase. Making sense of research results ends up in counting occurrences and proportions of certain tags within the sample. Only a few visual methods have been used to report the findings in a non-numerical way, e.g., through treemaps and image grids (Robinson 2019). However, this usage of data visualization for QCA was limited. The treemap provided a hierarchical overview of tags for map content, but actual map designs are hidden behind this descriptive data. Similarly, image grids based on hue do not point to more complex stylistic clusters of map images. In effect, researchers report on the key findings in a "numeric and somewhat mechanized" way (Muehlenhaus 2011a, Fish 2020), missing the possibilities to capture visual patterns and details outside of tag collection (Manovich 2020).

3.2.2 Automated content analysis

Services such as Clarifai or Google Cloud Vision API can be used to study images as both communicative artifacts and distributed events. Multiple variables can be automatically detected by these object recognition algorithms. The first type of variable is the label description, that might consist of multiple keywords – names of objects to be found in the whole image. Such a method has been already proven successful to study the content of climate change images posted in social media (Niederer and Colombo 2019). Other variables mark the presence of faces, their emotional expressions, landmarks, logos or texts. Finally, these algorithms can also extract some of the image properties such as palette of dominant colors or the average brightness. Robinson (2019) used the visual property of hue to analyze the diversity of viral maps. Similarly, median brightness and saturation values have been used to reflect on design variations of maps made by cartography students (Robinson and Nelson 2015). Automatic content tagging can be also helpful to study distributed events. Functionalities of the reverse search allow to find the links to fully and partly matching images, such as maps that are the same or similar to primary map. One can also extract a list of names of individuals and events associated with a map as well as a label that predicts the function of the image.

There might be three reasons why automatic content analysis is not widely used in cartography. First, a high entry-level skill set is required to start automatic tagging, including skills such as web scraping for data acquisition, machine learning and image analysis (Bogucka and Meng 2021). Second, the process of image collection can not violate the existing copyrights and license terms. Third, there is a lack of understanding on how the automatically-derived tags reflect the actual map content and where these limitations originate from. Object recognition networks have been predominantly trained on photographs, but not on high-level, abstract depictions such as maps or charts. Therefore the commercially available algorithmic services are not able to return a set of labels describing specific layout elements or symbology choices such as legends or diverging color schemes. In order to customize the algorithms, one need to collect own map-oriented dataset, label it, train and validate such networks. Although there is a lack of specific cartographic tagging services, the currently available services can be still used to help cartographers to understand how their content is perceived by machines.

3.2.3 Metaimage design

Metaimages provide an overview of all images in the image collection or their parts. The internal arrangement of images within a metaimage varies according to their characteristics (Manovich 2020), such as metadata (e.g., dates of creation, authors), visual properties (such as dominant colors, size, layout), or content properties (e.g., presence of certain objects in the image). In order to create metaimages, one needs to extract several characteristics of single images or image groups. The following characteristics of image samples (including maps) have been extracted and studied so far (Figure 3.1):

Spatial reference – locations that the image is depicting or its georeferenced spatial extent (Manovich 2020).

Visual weight – number of images depicting the phenomena within a selected time period (Hochman and Schwartz 2021).

Chronological order – sequence in which the images or maps were published, the arrangement from the oldest to the newest appearance. Temporal ordering allows to detect both gradual changes in map design as well as visual reactions to events, e.g., before and after event comparison (Gries 2020).

Thematic groups – clustering images into separate themes from one or multiple tags (Niederer and Colombo, 2019).

Color order – placement of the map sample in a selected color space (Robinson 2019). For instance in the HSV (hue, saturation and value) color space hue follows the circular order (from 0° to 360°), while saturation and value range from 0% to 100%. The hue wheel starts from red (0°), goes through shades of green (120°) and blue (240°) until it reaches red again (360°).

Layout – the arrangement of elements of the image, for instance placement of photographs on a newspaper page or website (Huber, Zepel, and Manovich 2010).

Content similarity – a presence of certain objects in image that can be confirmed by manual tag assignment or automatic image tagging (Niederer and Colombo 2019).

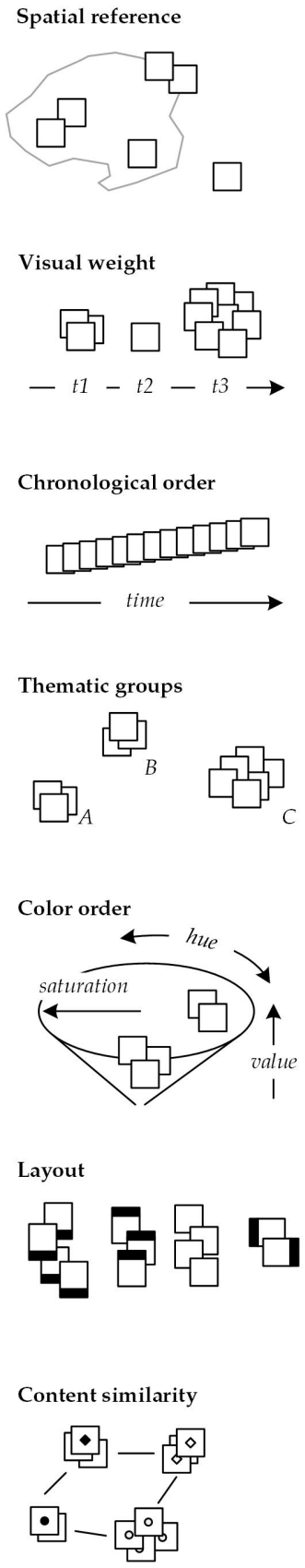


Figure 3.1: Arrangement possibilities for maps in metaimages.

The above-mentioned list is not exhaustive, but serves as a starting point for combining characteristics for in-depth queries. For instance, by intersecting the thematic and color order dimensions, one could ask "Which types of maps display the richest color palettes?". Once the images are tagged with their characteristics, the process of creating a metaimage can start. Windhager et al. (2019) distinguished two main groups of methods to guide such process: (multi)linear overviews and spatial encodings.

(Multi)linear overviews organize the images based on one or multiple characteristics present in the metadata (Figure 3.2). In linear arrangements, the sequence of images is determined by one aspect, e.g., date of image creation. Take, for example, the simple **list**, that arranges the images in one row or one column and can provide users with interactions to click or scroll through the collection. Multi-linear overviews, such as **image grids** (**montages**) and **mosaics**, arrange images into multiple rows and columns that encode multiple aspects present in the data. **Grids** are designed to give equal visual weight for each image. By re-scaling and cropping image samples, the differences between single objects are easier to grasp (Manovich 2020). As an alternative, **mosaics** maintain the relative size of the samples.

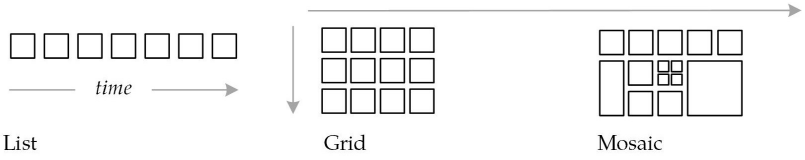


Figure 3.2: Arrangement principles for (multi)linear overviews (Windhager et al. 2019, Manovich 2020).

Spatial encoding refers to grouping the image samples based on the actual geographical space or data space (Figure 3.3). **Maps** show the spatial distribution of images based on their origin or the topic they refer to. **Image-tag networks** visualize relationships and distances between images in relational data space (Niederer and Colombo 2019). In **image plots** the placement of images in a two-dimensional space is based on the selected metadata dimensions. Image plots allow for comparisons between multiple data sets or subsets of one dataset, as well as offer categorical and hierarchical views into data.

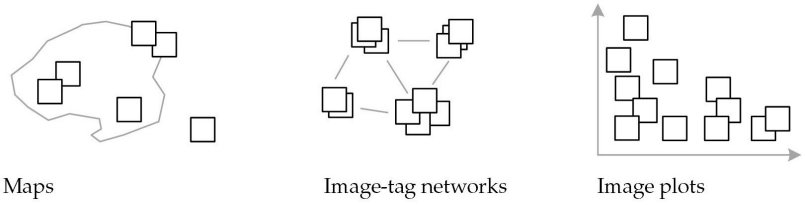
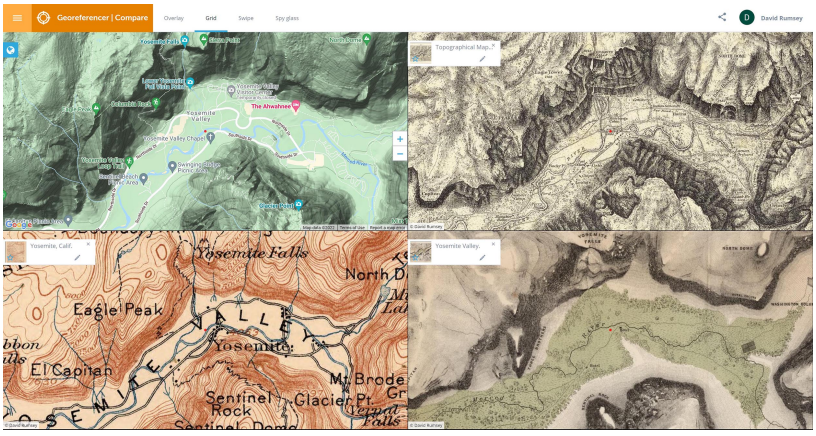


Figure 3.3: Arrangement principles for spatial encodings (Windhager et al. 2019, Niederer and Colombo 2019, Manovich 2020)

The cartographic community uses metaimages as a method of organizing vast map collections. As such, the most striking examples of metaimages were published by the David Rumsey Map Collection, that refers to them as “interpretive composite maps, views or texts” (Rumsey 2022). The key methods behind their creation are georeferencing and manual composition. Such metaimages are mostly used to unveil the full extent of previously separated map sheets (Figure 3.4a) and to compare the temporal map design variations (Figure 3.4b).

(a) The General Plan of the City of Paris and its Surroundings published on the order of Georges-Eugène Haussmann in 1868. Sixteen previously separated maps show the real extent of the modernisation of the city (N.N. 1868).



(b) Grid overview presents four maps of the Yosemite Valley made in different times and design styles (top-left: OSM Contributors 2022; top-right: Wheeler 1876; bottom-left: U.S. Geological Survey 1906; bottom-right: Gardner 1868).

Figure 3.4: Metaimages created by David Rumsey for the David Rumsey Map Collection (2022).

Metaimages are not only the stand-alone research methods. The role of metaimages in generating insight is twofold. Folowing the "overview first" mantra (Shneiderman 1996), metaimages provide the initial orientation in the dataset and act as an entry point for generating research hypothesis (Windhager et al. 2019). On the other hand, zooming, selections and filtering operations allow to find entangled cross-relations between image samples. Metaimages do not provide the context of the underlying images, therefore the observed patterns might require additional qualitative explanations. To do so, metaimages could be overlayed with layers of interpretation including textual notes on the findings, schematic drawings or highlights of different image clusters (Figure 3.5).

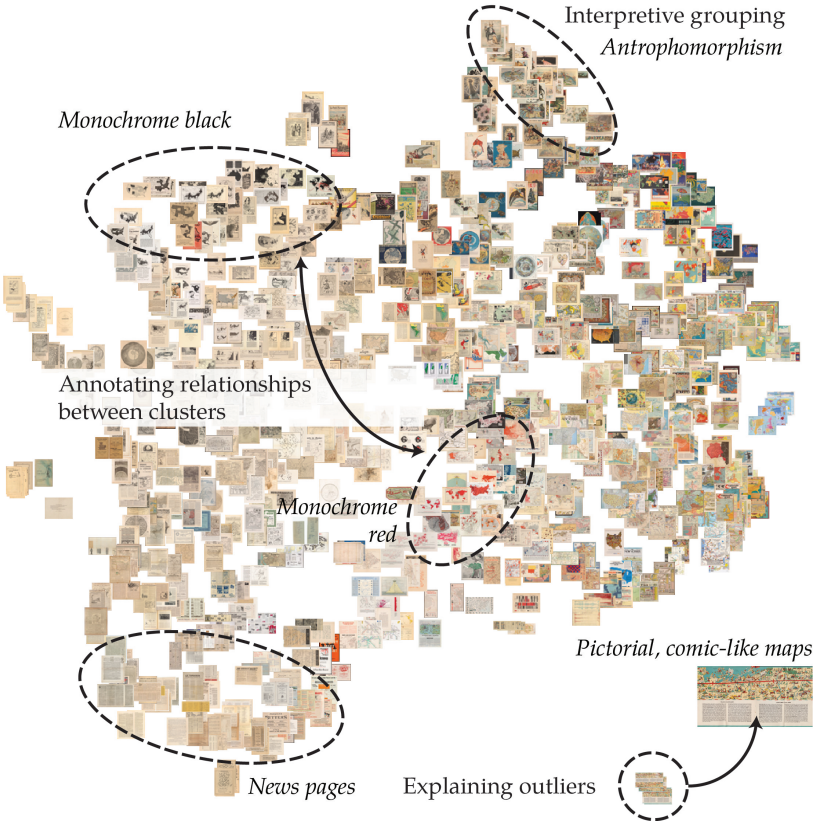


Figure 3.5: Sense-making from metaimages – image network from the Persuasive Cartography - the Paul Mode Collection.

3.2.4 Research through design

No matter if we use the manual content analysis or automatic tagging or metaimages, there is a clear drawback of generating insights from the data-driven approaches. The images themselves will not provide access to the whole world of constraints and design choices made by mapmakers. A remedy can be provided by the **research through design** (Gaver 2012, Herriott 2019) an approach that aims at creating a new body of knowledge through personal, practical work on creating a story map (Figure 3.6).

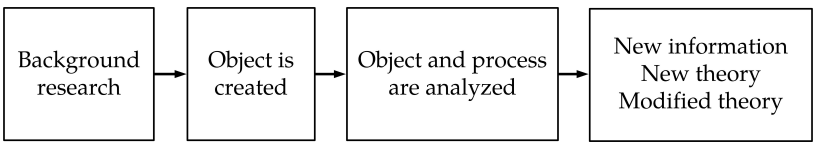


Figure 3.6: Workflow of research through design. Schema redrawn from Herriott (2019).

To make a contribution to the cartographic research, the newly created maps need to be evaluated and annotated with transferable design insights such as design choices, possible design alternatives or resulting user feedback. Such annotations can be formulated as a result of structured user evaluations or as self-narratives.

In user-centered design, transferable design insights do not aim at providing universal, strict design rules fitting all users and contexts. Instead, they act as stimuli for future projects by providing archives of the design revisions and "lessons learned" from the map creation (Roth 2019). Similarly, among minimum 25 types of contributions that can be made in data visualization research (Lee et al. 2019) we can find:

- ↪ "Artistic design – practices and evaluative reflection on expressiveness of visualization,
- ↪ Deployment – discussion of insights gained from real world deployment of a tool or technique,
- ↪ Lessons from failure – discussion of unsuccessful ideas and negative results, including identification of pitfalls to be avoided,
- ↪ Presentation – methodology or discussion of insights for storytelling and expository applications such as data journalism and education".

While the importance of user evaluations in cartography is widely acknowledged (Griffin, Robinson, and Roth 2017), it is not a common practice for cartographers to record and develop critical self-narratives on their own design processes (Caquard and Cartwright 2014, Kent 2017). For instance, Shannon and Walker created and observed the spread of their two viral maps (2020). Based on their personal experiences, they identified three transferable design insights that can help in making maps more appealing to social media users: inducing affective reactions, reaffirming collective identity and reacting to spatial and temporal context (Shannon and Walker 2020).

In human-computer interaction self-narratives can be achieved with annotated portfolios (Gaver and Bowers 2012), that can take a form of design journals, data visualization diaries or design sketches (Greenberg et al. 2012, Lupi and Posavec 2016, Bremer and Wu 2021). In general, portfolios group together various hands-on design implementations on the same overarching theme. Design implementations can be annotated in multiple ways dependent on the intended audience. The annotation style can also reflect the designer archetype, be it the evaluator, the autonomist, the didacticist or the rationalist (Wood, Kachkaev, and Dykes 2019). Portfolios do not have to include own work or feature the original authors' statements. Instead, domain experts can comment on the contributions of the designs to the entire domain (Demaj and Field 2012) or they can collect the examples of the best practices in the domain (see the series of Atlas of Design published by the North American Cartographic Information Society between 2012 - 2022).

3.3 Justification of the selected methods

The proposed use of four different methods of analysis – quantitative content analysis, automated content analysis, metaimage design and research through design – allows for addressing stories and their parts as both communicative artifacts and distributed events. While the individual methods have been used to some extent in the cartographic research, the innovation of this thesis lies in coupling them to overcome the limitations of a single use and provide their mutual support.

First, since the voice of the story creator is missing during the content analysis, we can try to resemble it with own personal practice. On one hand, annotating own experiences contributes to the growth of the body of knowledge. On the other hand, creating stories that are similar to the analyzed ones helps us to clarify or justify the design choices or implementations of other storytellers. Second, the problem of lacking images behind the aggregated manual QCA statistics is solved by creating the metaimages. Metaimages complement the descriptive statistics and help to see the typical or exceptional map designs.

Finally, automatic labelling defines the digital pathways for map circulations in the internet. Regardless of whether we accept it or not, knowing how the algorithms classify maps offers us new ways of cartographic interpretations. Automatic labelling provides us hints on how maps live after the completion of the design, how they are reaching their audiences and how they are re-purposed. This might be an element of our cartographic unlearning – to understand why some diverging map designs which we know from own metanaratives become closer to each other due to the hidden data properties.

Research protocol 4

The subsequent sections outline the practical steps of combining four interdisciplinary methodologies into one cartographic research protocol. Figure 4.1 presents a diagram of this process, including the flow of research tasks and their expected outcomes.

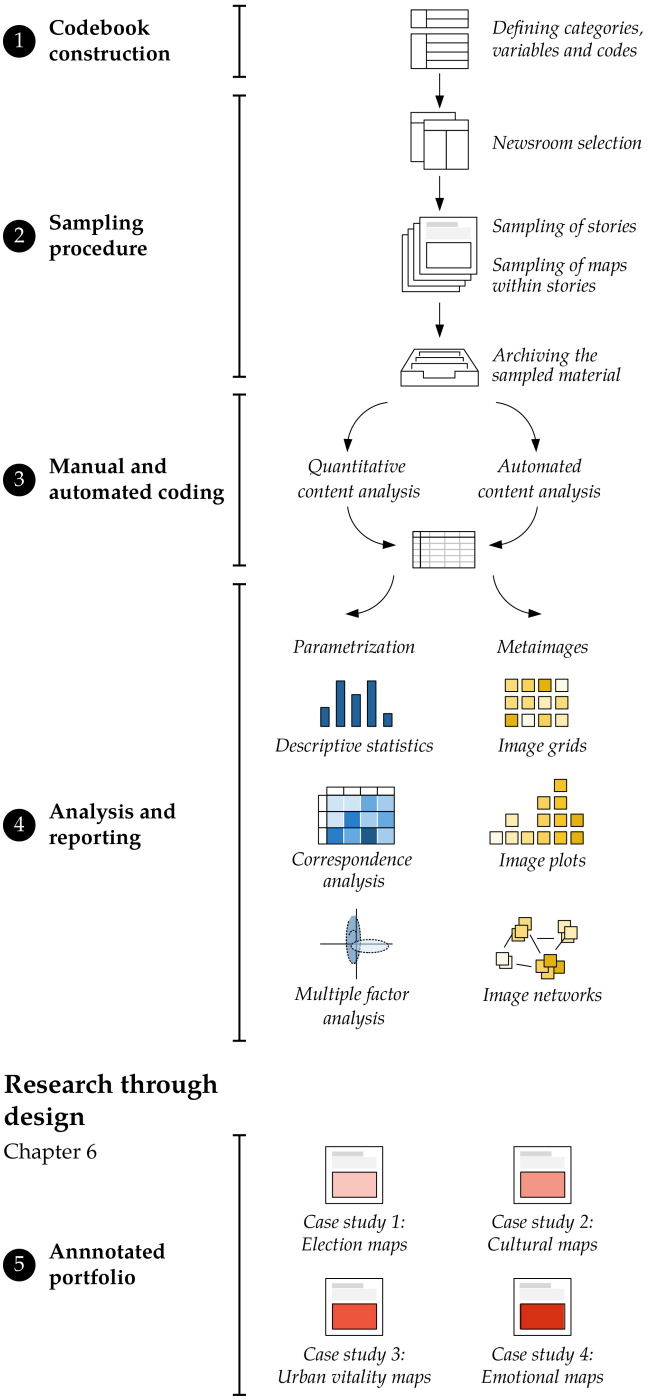


Figure 4.1: Workflow of the data-driven approach for story analysis and design.

4.1 Codebook construction

Visual rhetorical analysis was performed on two primary units: a story and a map. For the purpose of this research, a visual story was defined as an interactive article or essay that contains textual, visual or multimedial elements, including at least one map. Within each story, the most impactful map was chosen, which is either the first map mentioned in or the map most often referenced. Wherever relevant, maps were analyzed along with the title and data source caption.

Following the terminology established in the handbook of methods for visual rhetoric (Parry 2020), this research used the term **variable** to describe the design dimension recorded for each story or map. Each variable was then subdivided into **codes** – mutually exclusive and exhaustive design implementations (Bell 2000). Selected variables for a story and a map were then thematically grouped into high-level **categories**.

To ensure that the categories, variables and codes were analytically meaningful, previous cartographic QCAs were revised and several variable and code definitions were taken over. By doing so, the obtained results were partly situated in the previous research and allowed for longitudinal comparisons. The final variables were grouped into six categories. For the primary unit of a story, metadata, rhetorical techniques and story layout were documented. For the primary unit of map, the analysis addressed rhetorical techniques, visual design, and motion and interaction design strategies. Figure 4.2 presents the structure of the codebook as a set of categories, variables and codes. The full codebook is available as Appendix A to this thesis (Figure A.1, Figure A.2).

While certain codes proved to be timeless for studying rhetoric of map design (e.g., types of thematic maps), some codes were outdated or did not match the scope of this research. For instance, the QCA of thematic maps in atlases (Muehlenhaus 2011a) was attentive to the presence of accompanying bar and pie charts. Yet, modern visual stories tend to contain other non-map elements, such as videos or experimental 3D-scenes. Similarly, the presence of certain static map elements such as north arrow did not prove meaningful in the context of journalistic and viral maps (Green 1999, Robinson 2019). Therefore several new variables were created based on the literature review. These include codes for narrative structures (Harrower 2010), visual rhetorical techniques (Durand 1987), site layout (Babich 2019), map framing, map scale, story time, relation to event or virality carrier. Part of the developed categories, codes and variables was tested during the pilot comparative study between two visualization forms – map-based dashboards and story maps (Zuo et al. 2019). During collaborative coding authors discussed potential ambiguities, omissions, overlaps and coding conventions.

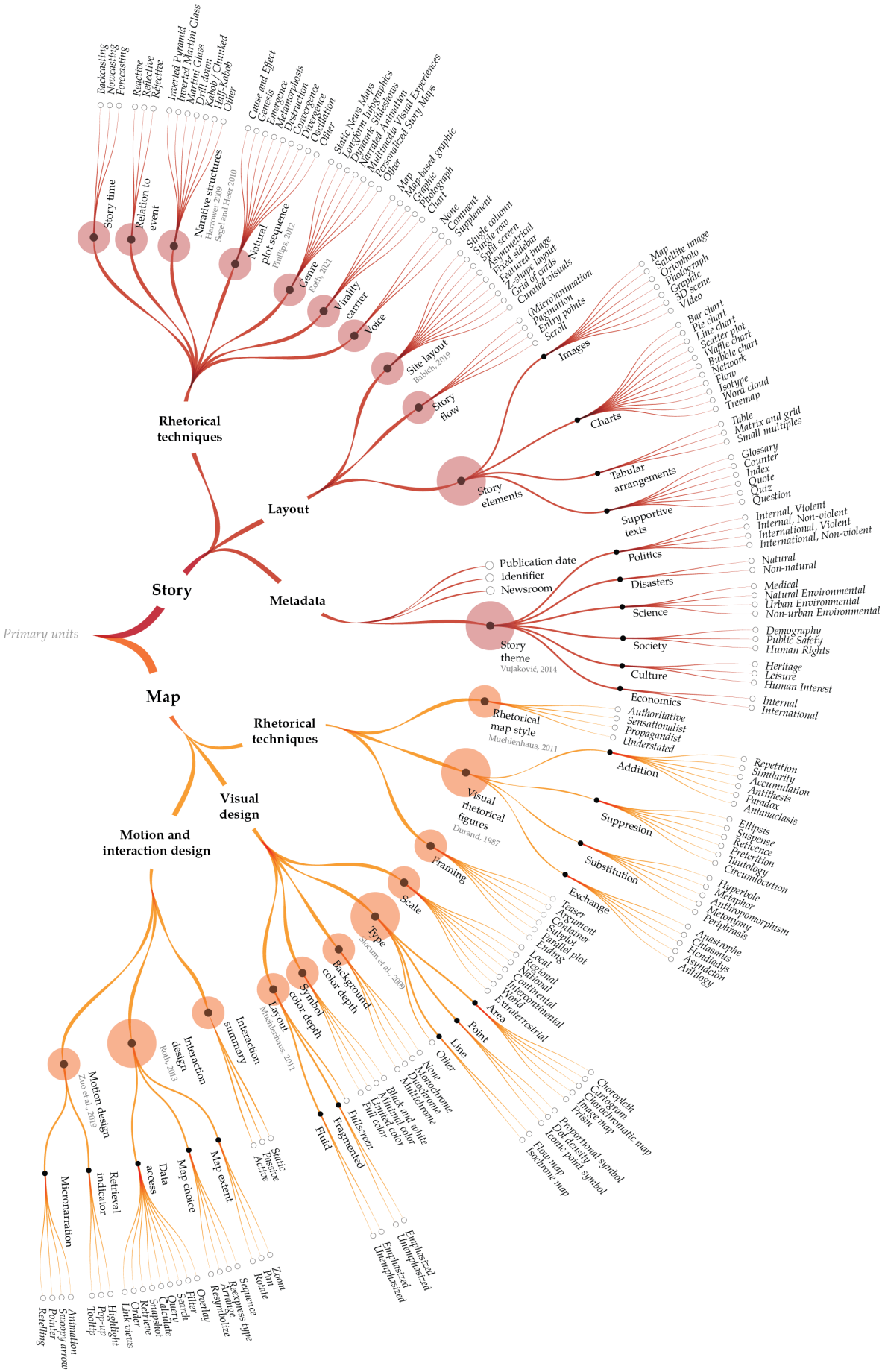


Figure 4.2: Decomposition of stories and maps into categories, variables and codes.

4.2 Sampling procedure

The initial story search during the pilot study (Zuo et al. 2019) resulted in gathering eleven papers describing the process behind story creation, from data selection and processing through rhetorical encoding to user evaluation. Unfortunately, seven of these stories were entirely developed in the Story Map environment from ESRI. The three genres of Map Journal, Cascade and Map Series did not sufficiently cover the variety of rhetorical techniques. The new story searching procedure was conducted using two criteria. First, a representative journalistic source was chosen, second, single significant stories were to be identified within each source.

4.2.1 Newsroom selection

Five newspapers were selected for the detailed investigation - The New Your Times (USA), The South China Morning Post (Hongkong), Die Zeit Online (Germany), The Pudding (USA) and Kontinentalist (Singapore). These five newspapers hire independent data visualization teams and their work is recognized with national and international journalism awards. Moreover, they openly share their storytelling practices with researchers and broad public, through newsletters, conference talks and behind-the-scenes article series, what helps to understand their story creation context. The selected newspapers represent different working cultures and storytelling approaches:

The New York Times (NYT) is a daily newspaper originating from 1851 and publishing online since 1996. NYT Graphics Team is considered one of the most influential and pioneer groups in visual storytelling since "Snow Fall" – their ground-breaking multimedia article published in 2012.

The Pudding (PU) is a digital publisher crafting data-driven visual essays since 2017. The motto of the group is to inform, explain and entertain with longform data journalism formats. PU's stories are created by a small committed team and freelance creators who pitch their story ideas. Visual essays are freely accessible, but the publisher finances additional stories through a crowdsourcing model.

Zeit Online (ZO) is an interactive web medium created in 2009 and one of the most frequently visited websites in Germany. Interactive tools, graphics and experimental forms of presentation are prepared by the Interactive Team, that brings together journalists, designers and developers. The Team is currently being transformed into the new department of Data and Visualization.

South China Morning Post (SCMP) is a Hong Kong–based, English language newspaper founded in 1903. Their articles are available online since 1996. A separate Infographics Team develops long-term projects on the intersection of illustration and data visualization.

Kontinentalist (KO) is a digital studio from Singapore that creates interactive articles about the culture of Asia. The mission of the studio is to bridge the gap between research and the public by presenting culturally empathetic data-driven stories from Asian perspective.

4.2.2 Sampling of stories

For the full access to some story content behind the paywall, the online subscriptions were set up where applicable. The newsrooms were also contacted by e-mail to clarify the licensing and citation right for using their content in this research.

Data collection took place between 01.06.2020 – 25.11.2021. The sampling strategy and searching for representative stories was different for each output. To find significant stories from NYT, their articles were filtered by type ("Interactive Graphics") and keyword ("map"). The returned search results were then sorted by relevance and date. In ZO, the visual stories were collected on the special subpage, which was then manually browsed to find all articles featuring maps. Similarly, SCMP featured their stories in the special infographic section, which was manually inspected to find single articles including maps or map-like graphics. The interface of KO allowed to display all stories of "map-driven" craft type, while essays from PU were searched for "map" keyword.

In the next step each story was opened in the Google Chrome web browser using the full screen mode and displayed on the Dell monitor with 2560 x 1440 pixel resolution. Stories were viewed as interactive objects directly on the websites of each newsroom. Other variations of the same story, for instance responsive designs on mobile devices, were not investigated.

4.2.3 Sampling of maps within stories

First, the stories were quickly passed over to search for map content. If a map or maps within the story did not influence the rhetorical power of the story (e.g., they simply presented the story locations), such stories were excluded from further analysis. Finally, one primary map per story was identified. The depth of the selected **215** representative stories and **22** variables was similar to the sample sizes reported in previous research. Muehlenhaus (2011) analyzed 118 maps from atlases by coding them across 19 dimensions – 3 metadata (name, page number, atlas edition) and 16 design variables. Similarly, Fish (2020) analyzed 242 maps of climate change along 29 dimensions (including 9 vividness components).

4.2.4 Archiving the sampled material

The close reading of interactive stories showed that there were three types of images that could be extracted from a single pass: the most impactful map (the primary set), all maps in the story (the secondary set) and map for social media dissemination. To do so, the source code of the story was investigated in Developer Tools provided in the browser. If the maps were embedded in the story as static images, it was possible to save them directly in the JPG image format using two Google Chrome extensions: Image Link Grabber and Tab Save. Otherwise (if maps were interactive or generated on-the-fly), one of their interaction states was captured in a screenshot. Static maps serving as social media image cards were extracted manually by searching for the source link in the metadata of the story's code.

To situate the design of the newest journalistic maps in the wider context, additional two historical image sets were collected. The first one consists of the maps published in the Persuasive Cartography - the Paul Mode Collection. The second contains journalistic maps published between 1920 - 1950 in David Rumsey Map Collection. Both sets were collected with Image Link Grabber and Tab Save extensions. The final number of maps in visual archive reached 1965 images (Table 4.1).

Table 4.1: Number of maps in image sets.

Image set	Nº
Primary set	215
Secondary set	686
Social media cards	129
Persuasive maps	860
Journalistic maps	290

4.3 Manual and automated coding

Manual coding started with close reading – a careful and detailed pass on the story. Then the presence of certain codes was marked in the spreadsheet. To ensure the consistency of the single-author coding (so called "intra-coder" reliability), the whole dataset was coded two times at different intervals (Bell 2000).

In the next step manually assigned codes were extended with two automatically computed codes: one dominant color and list of content tags. Dominant color was extracted using custom Python script. Content tags were derived by the Google Cloud Vision API tagging service. To do so, a Memespector GUI – a graphical user interface for the API – was used. The local folder with map images was first loaded to the Memespector and then connected with the API. The tagging service returned the following variables:

- ↪ **Label descriptions** – 4 – 10 keywords (tags) that may apply to the whole map,
- ↪ **Web entity descriptions** – names of individuals and events associated with a map,
- ↪ **Fully and partly matching images** – Uniform Resource Locators (URLs) of maps that are the same or similar to primary map,
- ↪ **Best guess** – a content label guessed based on the similar image search.

4.4 Methods of analysis and reporting

4.4.1 Parametrization methods

Three specific parametrizations were chosen to study data samples — one-dimensional, two-dimensional and multidimensional. In 1D parametrization each variable was summarized in descriptive statistics. The 2D parametrization reported on associations between two variables, while the multidimensional one dealt with associations between groups of variables (categories). The outcomes of each parametrization were demonstrated visually in three ways – as tables with resulting numbers, plots and metaimages. Where applicable, visualizations were annotated with key findings on rhetorical characteristics of samples.

1D – Descriptive statistics
Diversity of patterns within each primary unit – a story and a map – was interpreted using aggregated counts of codes and image plots.

2D – Correspondence analysis
The general question addressed in the correspondence analysis was whether certain combinations of categories, variables and codes were common, rare, over-represented or under-represented in the data sample. Correspondence analysis between variables was based on contingency tables – cross-tabulations of codes within and between primary units. To start with, patterns of association were examined by comparing observed and expected code frequencies across table cells. The dimensionality of the data was reduced to two principal components containing the maximum of information from the table. To visually understand links between variables and code groupings, samples were graphically summarized in two-dimensional plots.

The statistical validity of associations was tested on the basis of contingency tables that passed the following assumptions (Yates, Moore and McCabe 1999):

Assumption 1: Variables were nominal and consisted of two or more mutually exclusive codes without any intrinsic order.
Assumption 2: Absence of structural zeros (empty observations) that occurred due to cross-tabulating contradicting variables and codes.
Assumption 3: Adequate observed sample size for each of the variable being analyzed. If some code was never used across all cells, it was removed from the table.
Assumption 4: The expected cell frequencies (counts predicted by the theoretical distribution) were larger than 1 as well as less than 20% of all cells contained frequencies smaller than 5.

The workflow of the statistical analysis included five steps:

Step 1: Selection of two nominal variables within a primary unit (story-story, map-map) or between the primary units (story-map).
Step 2: Construction of the contingency table for the variables and calculation of expected code frequencies.
Step 3: Validation of the contingency table and expected frequencies against the analysis assumptions.

Step 4: Statistical testing with Chi-Square test of independence to discover if there is a relationship between the selected variables and whether the observed relationship is also likely to be found in the population.

Step 5: Check for the effect size. Effect size is a measure of the power of the association between two variables. As all contingency tables were larger than 2 x 2, Cramer's test was used to quantify the strength of the association into "weak", "moderate", "strong", and "very strong".

n-D – Multiple factor analysis
Categories, variables and codes were placed in two-dimensional plots by utilizing Python Prince library for multiple factor analysis (MFA). Since the variables were grouped into six categories (metadata, rhetorical techniques in story, story layout, rhetorical techniques in map, visual map design, and interaction design), MFA was conducted to find how these categories relate to each other. Moreover, MFA was used to identify if there are some hidden concepts not captured by the coding scheme.

4.4.2 Research toolbox

After manual and automatic coding the resulting spreadsheet and image archive were loaded into a set of interconnected Jupyter notebooks. Computational notebooks such as Jupyter can be considered as interactive research diaries, that combine textual descriptions, code, and visualizations. Due to their capacity to integrate multiple programming languages, notebooks become the standard tools used by data scientists. Moreover, they can be used to facilitate visual data exploration and generate high quality vector figures for each exploration step.

Python was used as a main programming language for scripting in Jupyter notebook. The mainly used packages were:

- ↪ Pandas and Numpy - for loading the spreadsheet and summarizing the data,
- ↪ Pillow, OpenCV, Colorsys - for extracting dominant colors and conversions between color spaces,
- ↪ Prince - for correspondence analysis,
- ↪ Matplotlib - for creating data visualizations,
- ↪ Ivpy - for grids and image plots.

The design space of each parametrization was visually explored by creating tables, plots and metaimages (Figure 4.3). The methods allow for displaying samples at different levels of iconicity. Tables summarize single samples with numeric counts, plots display single samples as geometric symbols, while metaimages provide access to image miniatures. The only visualizations created outside of the computational notebook were image-tag networks. To create them, the spreadsheet and images from the visual archive were loaded into Gephi. This tool was used to create a bipartite network with two types of nodes -– codes and images. Image-tag networks were created in two ways – using codes from the manual tagging and tags delivered by the Google Cloud Vision API. The size of the code node was adjusted based on the code frequency while keeping the relative size of the image node.

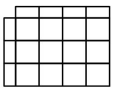
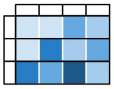
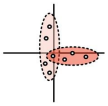
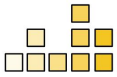
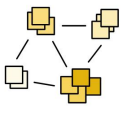
Iconicity level	Type of view	Visualization method	
Abstract	Frequency comparison	Bar chart	
		Mosaic plot	
	Tabular views	Contingency table	
		Heatmap	
Figurative	Point views	Scatterplot	
		Scatterplot with ellipses	
Realistic	(Multi)linear overviews	Lists	
		Grids	
	Spatial encodings	Image plots	
		Image-tag networks	

Figure 4.3: Data visualization methods used in the exploratory analysis.

Results of story analysis and hands-on design

Implementation of data-driven approach for story analysis

5

This chapter reports on the diversity of story maps and highlights dependencies between design variables. It also evaluates the completeness of the initial design framework with the multiple factor analysis.

5.1 1D – Diversity of visual stories

5.1.1 Visual weight, story sources and themes

The final story sample included **215** stories published between 2014 - 2021 (as of November 2021). The shares of samples varied across the year and output (Appendix B). In order to keep the sample less biased, stories created by The New York Times were only coded for the period of 2017 - 2021. For the remaining newsrooms, their contributions were coded from the earliest story found on their websites. The most prolific newsroom was The New York Times (33% of all stories), followed by Die Zeit Online (21%) and South China Morning Post (20%).

The publishing **frequency** and **distribution** of stories by newsroom is presented in Figure 5.1. It is important to note that the sample is temporally skewed towards 2019 (26% of all stories) and 2020 (28%). The majority of stories from 2014 - 2017 were published by Die Zeit Online (68%).

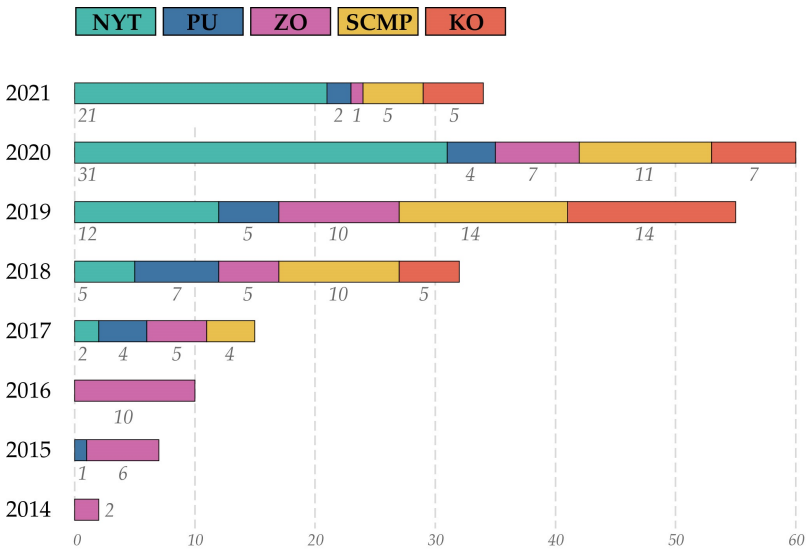


Figure 5.1: Visual weight of story maps.

The most popular story **themes** were Science and Politics, especially between 2020 - 2021 (Figure 5.2, Figure 5.3, Table C.1). As such, the majority of scientific stories discussed medical and environmental issues. When writing about Politics, 22 stories referred to domestic and non-violent affairs, for instance election results. The local focus was evenly covered by interactive demographic analyses (23 stories). Cultural topics were split between heritage (18 stories) and entertainment (16 stories). Finally, natural disasters and economic affairs were the least popular topics. Although the stories were often immersed in native advertisements, none of them targeted advertisement as an independent story topic.

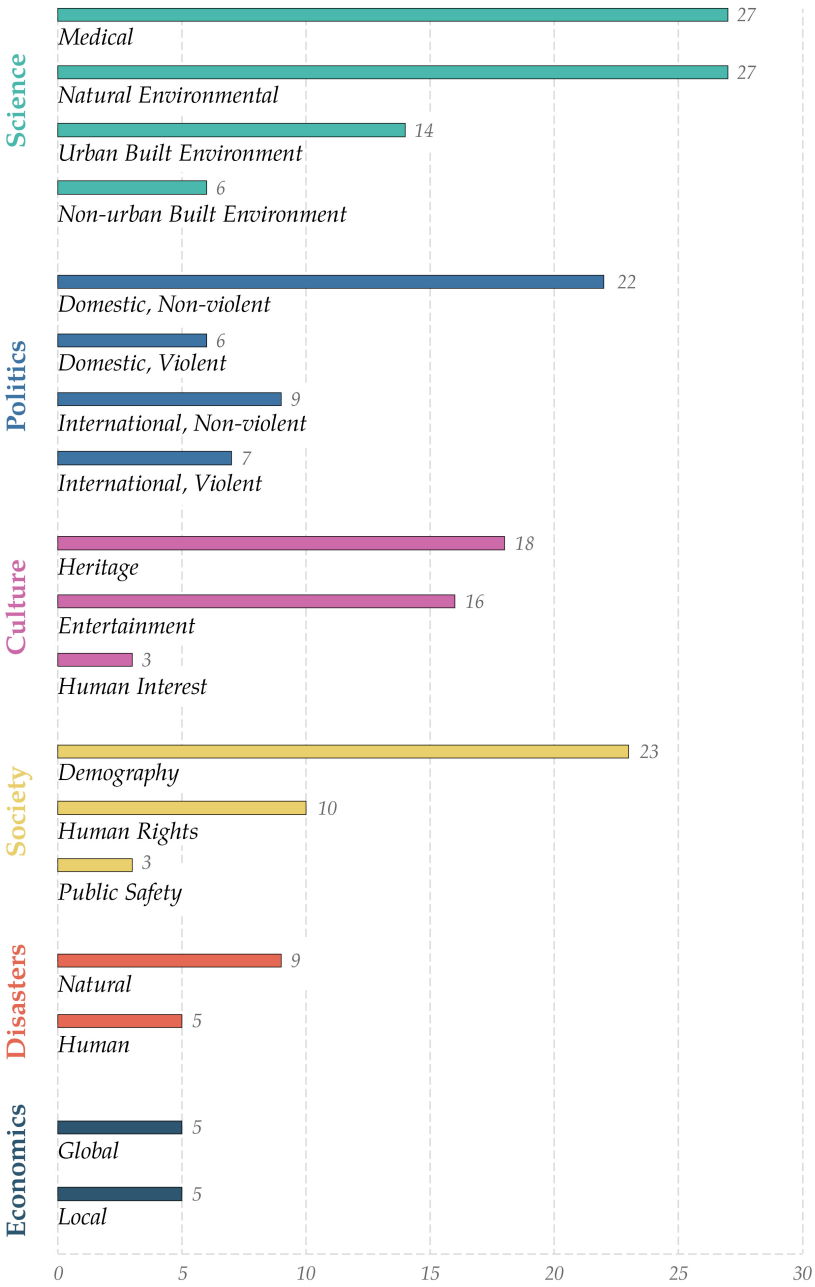


Figure 5.2: Main themes and subthemes of map-based stories between 2014 - 2021.

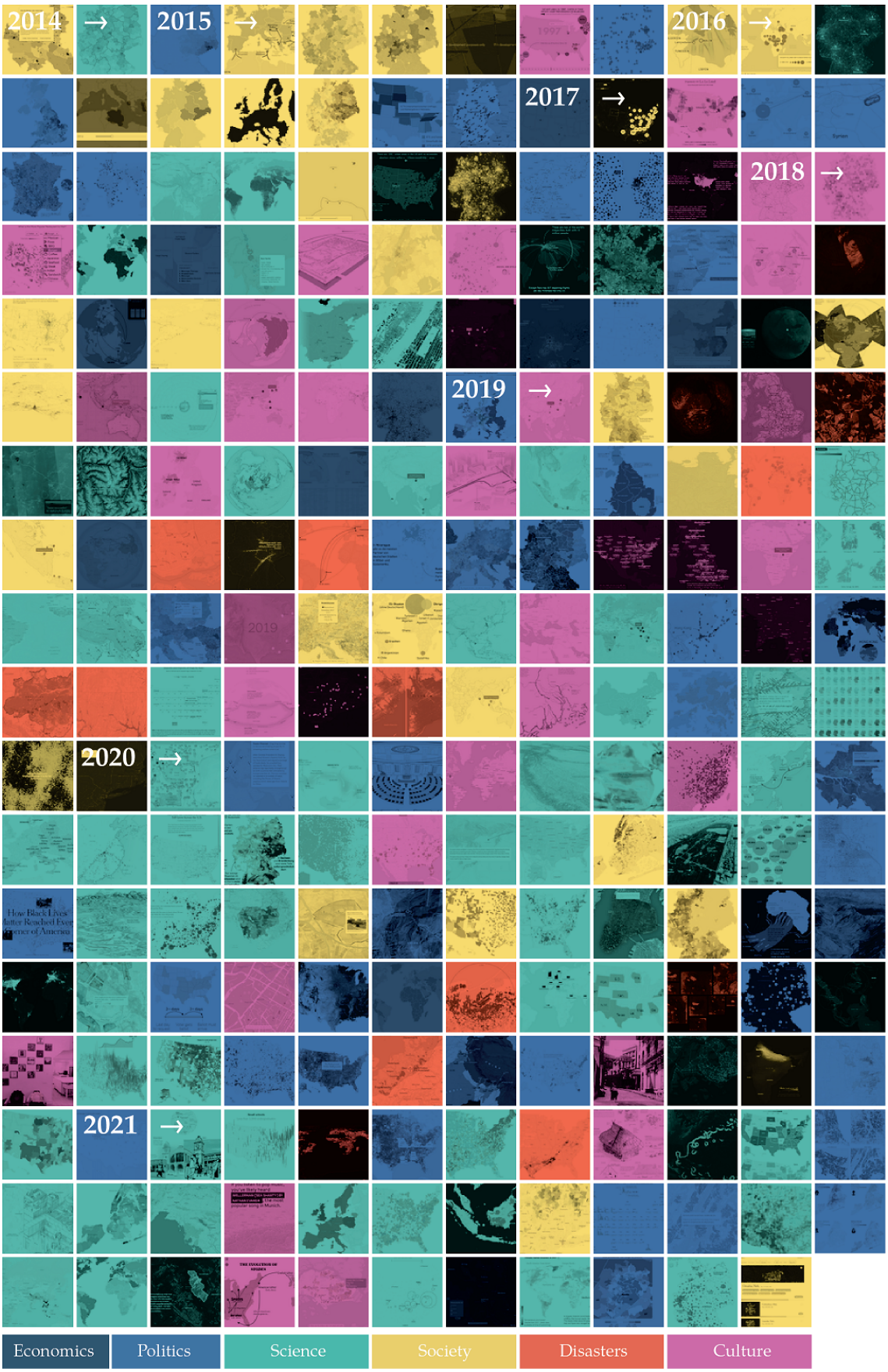


Figure 5.3: Temporal grids of topics. Graphic features 215 stories listed in Appendix B.

5.1.2 Story times and their relations to events

The dominant **times of story** are present and past (Figure 5.4). Half the stories falls into nowcasting – describing events that are happening, just happened or are about to happen very soon (52%). Slightly more than one-third of stories analyzes past events (39%), while not long-term predictions or speculations about the future remain rare. Readers do not have many possibilities to contribute to the story content with their **voice**. They can supplement it with answers to polls built into the story flow (3%) or re-tell it via social media sharing shortcuts (87%).

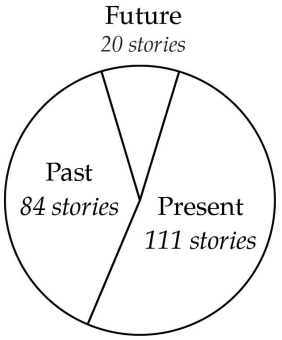


Figure 5.4: Temporal focus of stories.

Concerning the relation between story and **event**, only 53 stories were created as an immediate reaction to a special event and contained well-articulated calls to actions. The dominant practice was to present reflective analyses on past or future events (92 stories). One fourth of the stories did not clarify the role of one single event as a story impulse – they seemingly hid it or presented to readers multiple, loosely connected events (53 stories).

One cannot discern a dominant strategy on how events are supposed to unfold in the story (Table 5.1). The three most popular **plot types** were Cause and Effect, Divergence and Destruction. The next two plots involved stories about creation, either through unpredictable events (Emergence, 27 stories) or progressive events (Genesis, 26 stories).

Table 5.1: Event-driven plot distribution (Phillips 2012).

Plot	Nº (%)
Cause and Effect	39 (18%)
Divergence	37 (17%)
Destruction	33 (15%)
Emergence	27 (13%)
Genesis	26 (12%)
Metamorphosis	23 (11%)
Oscillation	14 (7%)
Convergence	10 (5%)
Other	6 (3%)

5.1.3 Story plots and layouts

The linearity of visual stories was considered threefold – as a **written structure** of the story, as a story **layout** and as visual or interactive techniques for **controlling the flow**.

One third of the stories read as Inverted Pyramid, with story summary coming as the first rhetorical statement (Table 5.2). Slightly less popular was Inverted Martini Glass (29%) that narrated chronological event sequence after short introductory text. On the contrary, the following popular plots – Martini Glass (13%) and Drill down (12%) – started with limited information and encouraged reader-driven exploration.

Majority of stories (58%) was arranged in vertical order, where the story content was placed in a column. The opposite, horizontal order of placing content in a row was the least popular layout (1%). The second popular layout group consisted of asymmetrical arrangements with floating text containers (20%), or fixed sidebars (12%). Symmetrical layouts dividing screen in two sections of equal visual importance were implemented only in 3% of the stories. As such, experiments with story layout were very rare – only 10 stories used a mixed vertical-horizontal pattern, 3 stories unfolded around curated visuals and 2 stories were told through a stack of cards.

Table 5.2: Writing plots (Phillips, 2012).

Writing plot	Nº (%)
Inverted Pyramid	68 (32%)
Inverted Martini Glass	62 (29%)
Martini Glass	28 (13%)
Drill down	26 (12%)
Kabob	20 (9%)
Half-Kabob	4 (2%)
Other	4 (2%)
Chunked	3 (1%)

The layout of the story was supported by interactive techniques used to unfold the plot (Figure 5.5). Vast majority of content was revealed through scrolling (79%), while other interactions were less common – 13% of stories allowed access through entry points, 4% by pagination and 4% by microanimations. With prevalent vertical layouts and scrolling, it does not come as a surprise that Longform Infographics were the most popular genre of stories (53%). Almost one third of storied was categorized as Multimedia Visual Experiences (31%) and 10% as Personalized Story Maps.

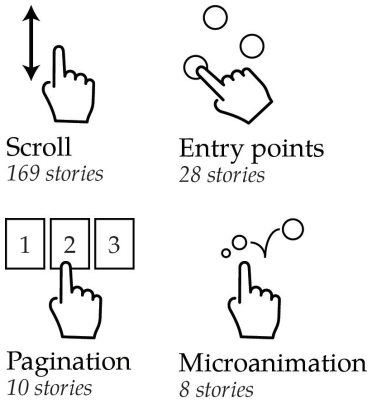


Figure 5.5: Interactive techniques used to unfold the plot.

5.1.4 Role of the map within a story

Visual stories consist of multiple elements and a map was one of them. Indeed, 45% of stories contained only one map around which the main story was woven. However, it was also common to combine multiple maps. 40% of stories unfolded through 2-5 maps. These maps were either variations of the initial primary map or new thematic depictions not associated with the primary map. More than 6 maps were used in 15% of stories, with one presenting user with 19 maps.

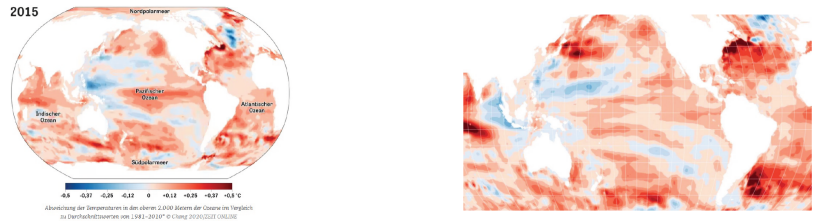
Since all the stories included some spatial component, it was important to investigate to what extent maps were re-used as visual summaries and attention-grabbers for **social media dissemination**. Half of the summary cards kept the spatial reference (114 stories) by presenting a map (102 stories), a map-based graphic (7 stories) or an orthophoto image (5 stories). There were 55 stories that placed a graphic (e.g., drawing) as their dissemination teaser and 27 stories that used photographs, but only 3 stories used charts for this purpose.

Maps used as social media cards were more simplified than their originals. The most common editorial choice was to remove map legend and map title, as only 24 cards contain both of these elements. There were eights strategies for preparing a card from story content. The simplest was to take a screenshot of the original map and pair it with a short captivating lead (Figure 5.6a) or swoopy arrows (Figure 5.6b). Such pairing could also involve adding other maps or images that give context to the story (Figure 5.6c). Less common operations were cropping the map to interesting data patterns (Figure 5.6d), distorting map perspective (Figure 5.6e) and merging multiple maps into one animation.

(a) Pairing the map with a short captivating lead (left: N.N. 2021b; right: Blinderman 2020).

(b) Pairing the map with pointers (Cheng 2021) or swoopy arrows (Daniels, Blinderman, and Samora 2017).

(c) Combining maps into small multiples (Blickle, Erdmann, Flavio Gortana, et al. 2019) or pairing with non-map elements (Ehmann, Fischer, et al. 2020).



(d) Cropping the map to interesting data patterns (Ehmann, Flavio Gortana, et al. 2020).

(e) Distorting map's perspective (Blickle, Polke-Majewski, et al. 2015).

Figure 5.6: Strategies for preparing a social media card from story content.

An overview about what **other visual elements** were integrated in stories is given in Figure 5.7 and Table C.2. Static graphics are most popular (e.g. drawings, illustrations, 34%), followed by photographs (29%). However, the share of motion graphics such as video or animations stays high (25%) since 2017. With the increasing support of browsers for 3D displays, embedding tridimensional scenes and developing a model-driven storytelling has become trendy since 2018.

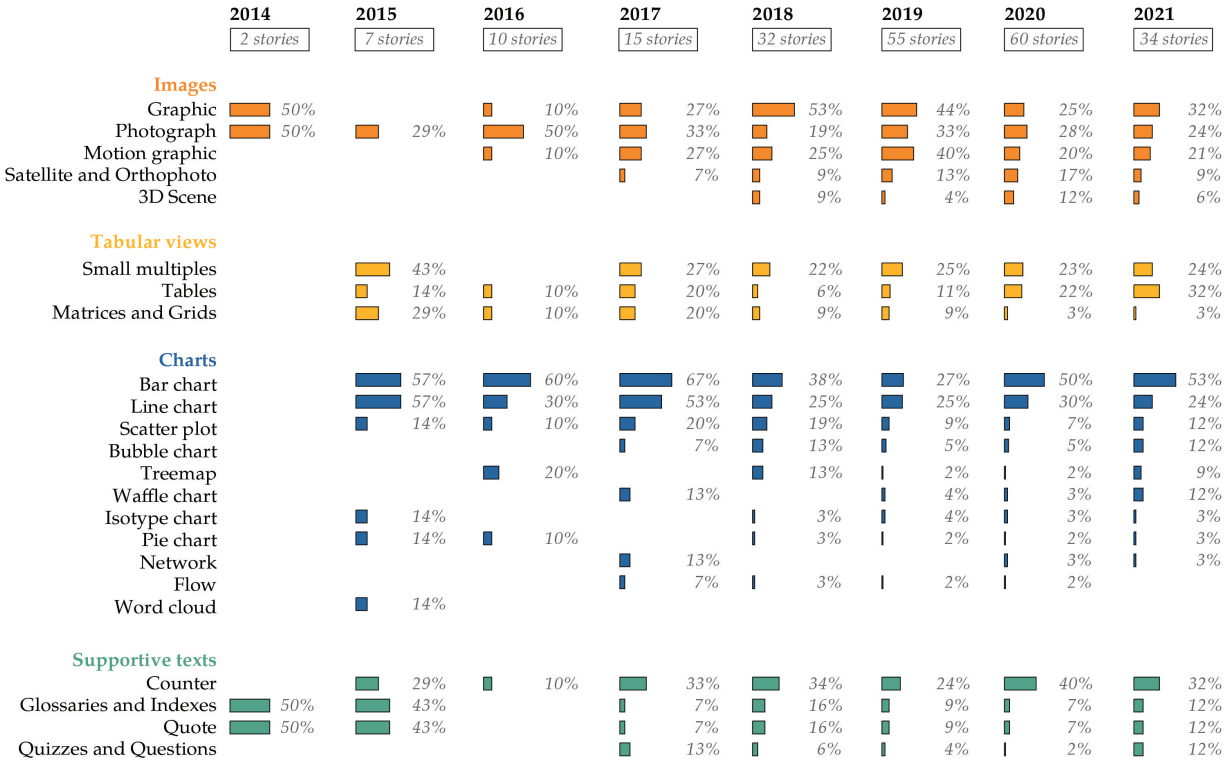


Figure 5.7: Annual share of non-map elements in visual stories.

5.2 1D – Diversity of maps within stories

5.2.1 Map framing

More than half of the stories visually blended map and non-map components (55%), while one third separated them into different frames (34%). In 11% of stories the map itself was the only component of the page.

When any map from the secondary set appears in the story flow, it is preferably placed as a visual argument and a visual teaser (Figure 5.8). Closing the story with a map frame and creating a circular ending was not popular (3%). In 19% of stories the map itself served as the container for unfolding the plot.

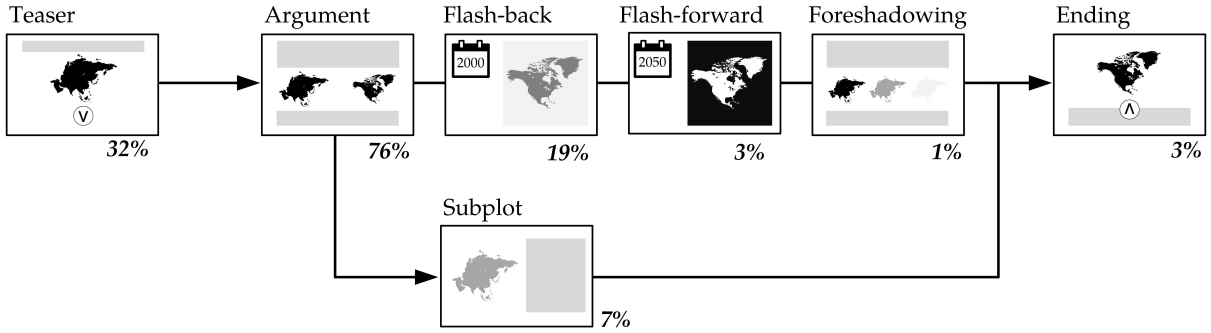


Figure 5.8: Placement of the map frame within other story frames.

5.2.2 Visual rhetoric design

Rhetorical typology of maps (Figure 5.9) was dominated by understated, minimalist maps (90 maps), followed by propaganda depictions with high visual contrast and embellishments (60 stories). One quarter of maps (54 samples) looked seemingly objective and scientific (authoritative), while 11 stories made use of emotive icons and symbols. Understated and authoritative maps shared similar visual characteristics – their key messages were highlighted with vibrant colors and placed on minimalist background. To distinguish between these two rhetorical types, one must carefully looked at the marginalia to see if the map was accompanied by links to data sources or explanations on mapping methods. The style of propaganda maps was mostly achieved by high visual contrast between data and background.

Two-thirds of the maps utilized one dominant rhetorical figure (66%) from the group of addition (61%) or substitution (23%). Two co-existing figures were found in 21% of maps, while the lack of figures was perceivable in 13% of maps. If two co-existing figures were present, they were mostly the addition figures that came together with another addition (23 maps) or substitution figures (16 maps), but less often with suppression (4 maps). Other combinations between figure groups were almost not present: double substitution was applied in two maps, while addition and exchange in one map.

Figure 5.9: Distribution of rhetorical map styles in the stories. Graphic features 215 stories listed in Appendix B.

5.2.3 Thematic design

The majority of maps represented areas (45%) and point-like phenomena (36%). The most prevalent map found in every fifth story was choropleth (Figure 5.10). Flow maps appear 27 times to depict trajectories. The "other" category contained several experimental designs such as pictorial maps, simple locator maps and 3D-like depictions.

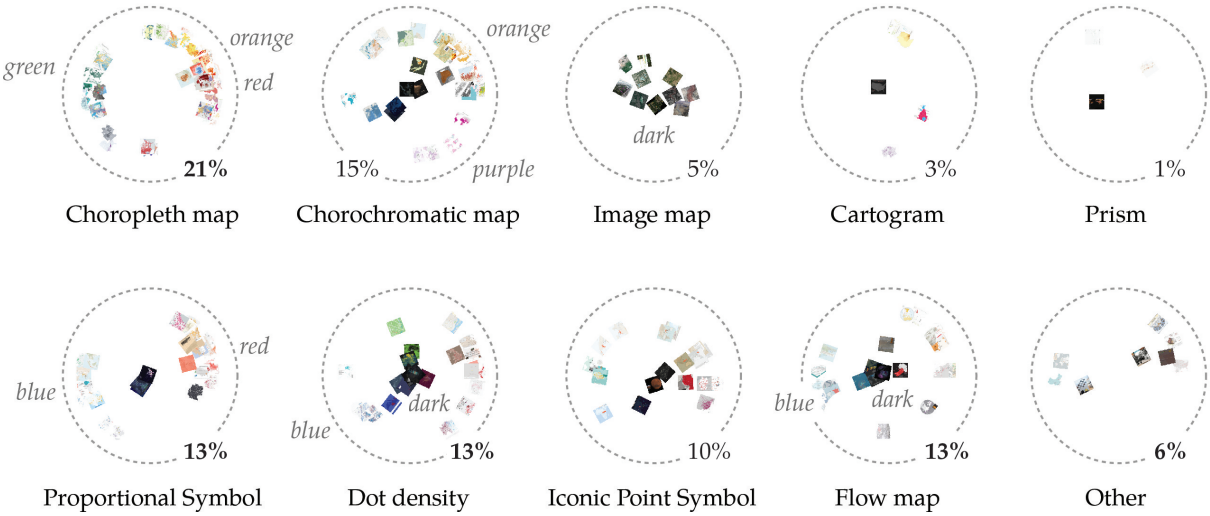


Figure 5.10: Distribution of thematic map types in the stories. Graphic features 215 stories listed in Appendix B.

An overview about **color depths** is given in Figure 5.11 and Figure 5.12. If one would need to design a "typical" map for visual story, that would mean using a monochrome background (138 of maps) and fixed palette of colors, either 2-3 colors (87 maps) or slightly more if the variety follows a strict classification (87 maps). Less popular were stylized duochrome (12 maps) and multichrome backgrounds (32 maps). 30 stories made free use of multiple symbol colors, while 11 maps were kept simple with black and white glyphs.

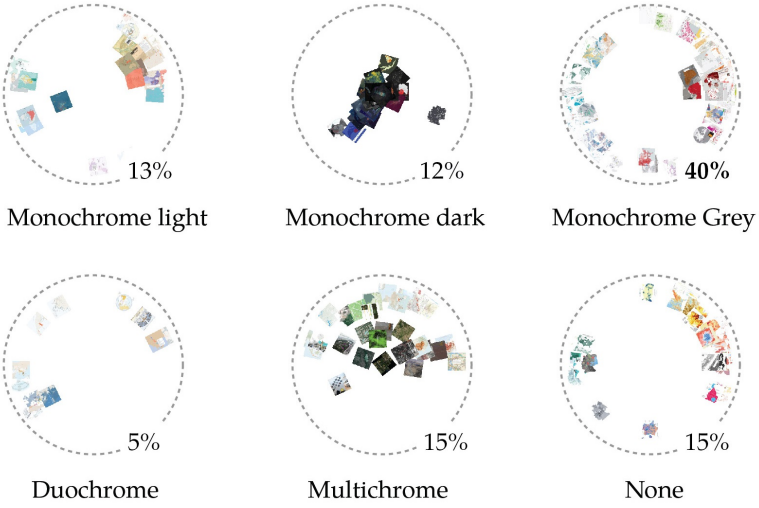


Figure 5.11: Background color depths. Graphic features 215 stories listed in Appendix B.

Figure 5.12: Symbol color depths. Graphic features 215 stories listed in Appendix B.

Online maps very rarely indicated their actual **cartographic scales**, but it was possible to approximate them based on the extent of the shown data (Figure 5.13). Maps in visual stories tended to cover national scale and depict a single country without referring to its neighbors. The second most popular scale – continental – allowed for viewing adjacent countries or fragments of continents. The relations between continents were mapped less often, only 13 times. The views of the world (35 maps) were almost as prevalent as large scale maps of cities and neighborhoods (41 maps). Finally, the 3 remaining maps shown extraterrestrial objects.

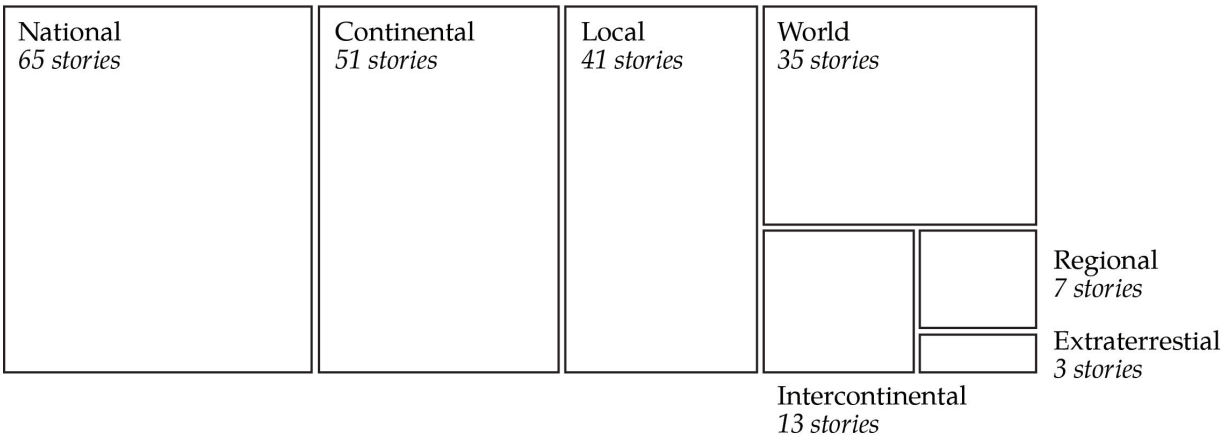


Figure 5.13: Distribution of map scales in the story sample.

5.2.4 Interaction, micronarration, and motion design

Active maps with user-controlled interaction comprised only 42% of samples, while 58% of maps were not responsive to user actions. These were either passively initiated (31%) such as automatically played animated maps or embedded as static images (27%). Static maps pointed to interesting data patterns by swoopy arrows with narrative commentaries (35 times) or pointer with simple labels (21 times).

Interactive maps offer very limited possibilities to change the extent of data (Figure 5.14, Table C.3). Panning was supported 64 times, zooming 59 times and rotating only 6 times. When we consider map as an interface to the data, 69 maps allowed for retrieval of a single data point. The retrieval result was then mostly indicated by highlighting (61 maps), sometimes accompanied with additional information available in tooltip (45 maps) or pop-up (32 maps). The search for data points was enabled 20 times and data filtering – 10 times.

In line with previous findings on the growing importance of motion graphics, half of all maps contained some form of animation, either automatically played transition between map sequence or animated symbols (109 samples). Every fifth map contained a controller to change map, e.g., choose another map from the pre-defined sequence (36 times) or adjust current map with time slider (9 times).

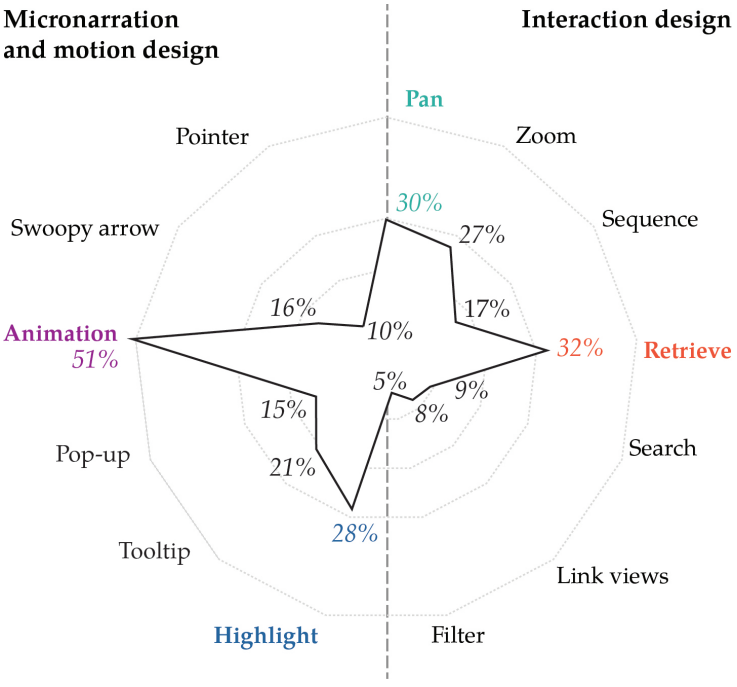


Figure 5.14: The most prevalent map interactions and forms of micronarration.

5.3 2D – Correspondence analysis

Following the research protocol, associations between variables were first investigated based on their contingency tables. Due to limited overall data amount, it does not make sense to create and test the statistical hypotheses. Therefore this section reports on the nature of associations, without drawing generalizable conclusions on all visual stories published between 2014 - 2021.

5.3.1 Depicting themes

The presence of overarching themes within the sample was influenced by the journalistic profiles of the newsrooms. Figure 5.15 illustrates which newsrooms follow similar topics. The stories from Die Zeit Online tended to move between Politics and Society, while The New Your Time reported on Politics, Science and Disasters. The stories from Asia-based newsrooms were quite similar to each other (since they were placed in the same quadrant) and spanned over Science and Culture. The Pudding strongly holds to their mission of delivering visual stories on contemporary culture, staying away from Disasters and Politics.

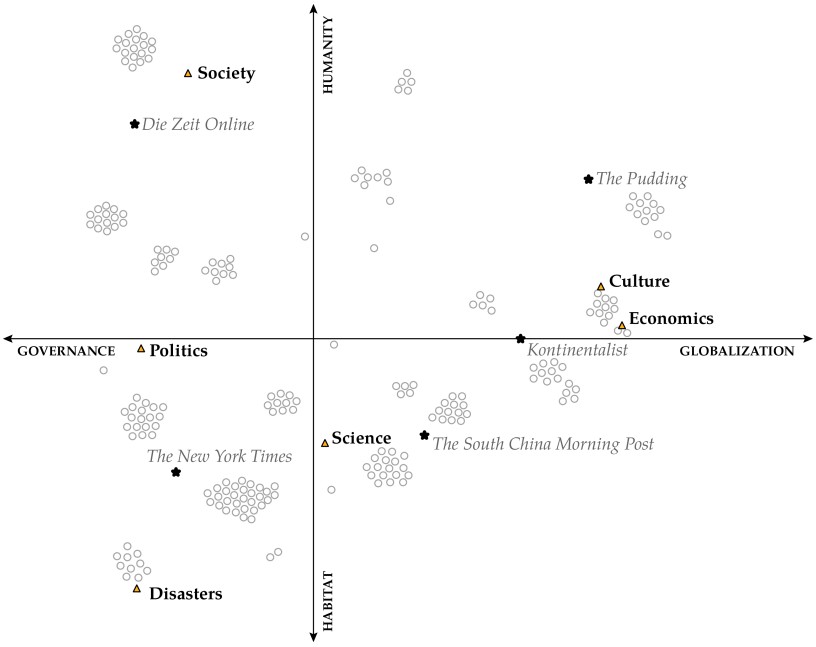


Figure 5.15: Topic coverage by output.

Figure 5.16 illustrates the distribution of rhetorical map styles among themes. The understated rhetoric map style was used in 42% of all stories, but its biggest share was found in Science (46%) and Politics (48%). Similarly, authoritative styles were also used to report on Science (19 maps) and Politics (13 stories), but also Society (12 stories). On the other hand, propagandist maps tended to narrate Science (17 stories), Society and Culture (15 stories each). The sensationalist style was found not found predominant within any theme.

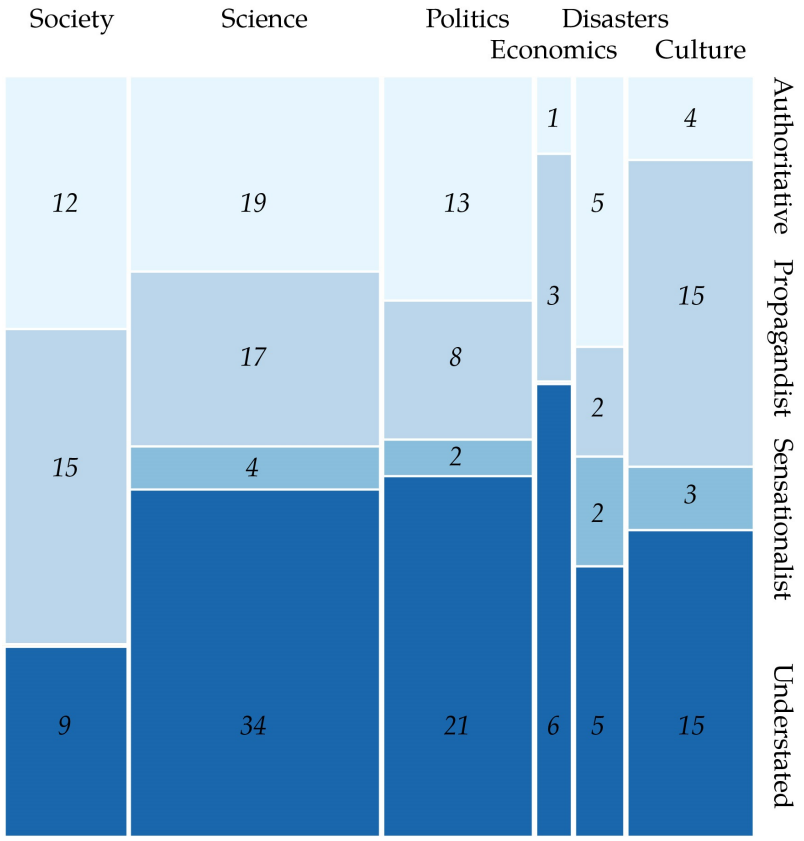


Figure 5.16: The distribution of rhetorical map styles among themes.

Finally, the heatmap view reveals that map types were deliberately chosen to illustrate certain story themes (Figure 5.17) and the nature of these associations was the same for subthemes. Choropleth maps and dot density maps were more prevalent in political and societal stories, but avoided in narrating culture, disasters and economics. Science relied on chorochromatic depictions and flow maps, while cultural issues were presented with proportional symbols and iconic point symbols. The least popular map types among all themes were image maps, cartograms and prisms.

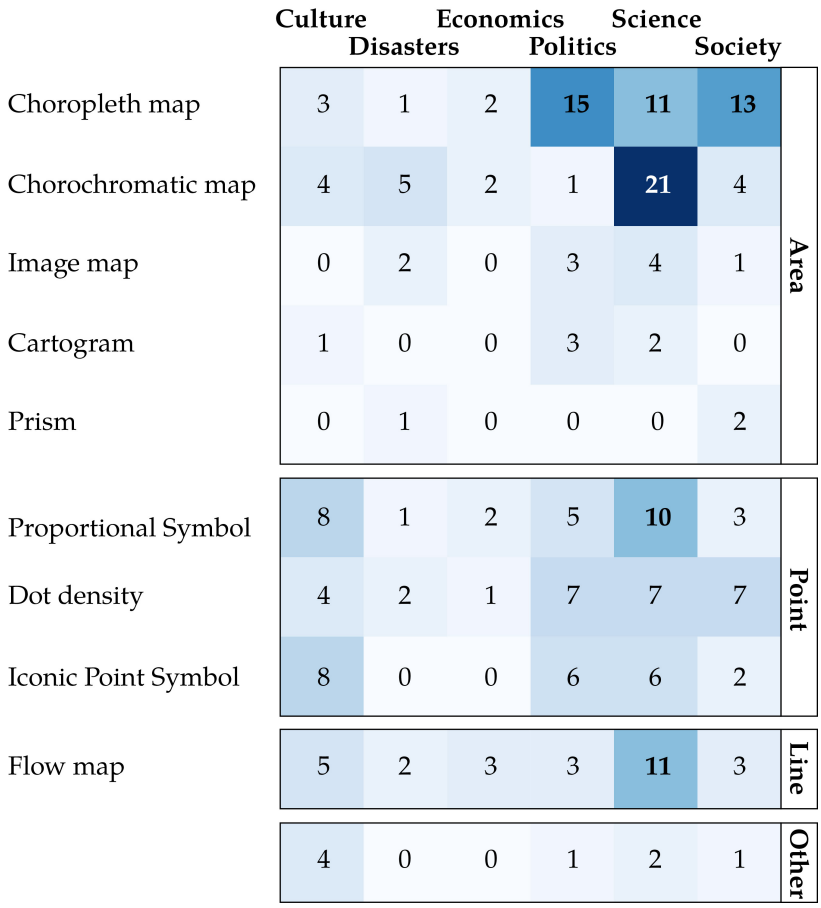


Figure 5.17: The distribution of map types among themes.

5.3.2 Narrating events

The heatmap below highlights the dominating plots in each year (Figure 5.18). The sample size for 2014 - 2017 might not be sufficient to reason about general narrating trends in this period. Yet 2018 can be described as the year of Genesis, Emergence and Divergence, when most of the stories evolved around culture and society. The tone of these stories could be summarized in one sentence as "how similar we are in terms of local and global cultures, where do we differ and how that happened". The examples of Genesis and Divergence include stories on wealth gaps, gender and social divisions in the cities or varying Christmas traditions worldwide.

The clear shift was visible in 2019, when the story tone contained more explanations on Causes, Effects and Destruction. Between 2019 and 2020 the Cause and Effect structure kept its strong presence, yet it got overtaken by the Emergence. Indeed, one could see that 2020 was the year that followed the cycle of Emergence, Divergence and Destruction. This corresponds to the global event of the COVID-19 pandemic. Visual stories kept reporting on the emergence and spread of the coronavirus, diverging resilience of communities and countries and finally on the losses. As of November 2021, the patterns for that year were similar to 2020, yet Metamorphosis got more traction. This was due to multiples stories on changes and adaptations caused by pandemic in citizens life, urban structures and natural environment.

	2014	2015	2016	2017	2018	2019	2020	2021
Oscillation	0	0	1	3	1	3	5	1
Metamorphosis	0	0	0	1	4	5	5	8
Genesis	1	2	1	4	6	7	4	1
Emergence	0	2	0	1	5	4	10	5
Divergence	0	0	0	3	8	9	11	6
Destruction	0	1	1	1	0	11	14	6
Cause and Effect	1	1	7	3	4	9	8	6
Convergence	0	1	0	0	4	4	1	0
Other	0	0	0	0	0	3	2	1

Figure 5.18: The distribution of writing plots between 2014 - 2021.

5.3.3 Coupling maps with texts

The image-tag network was created based on the mentions of nouns in story titles. The center of the network presents multi-temporal chain of stories, while the peripheries of the network contain unconnected stories with year-specific keywords. By looking at image-tag co-occurence, one could examine the variety of maps for similar concepts as well as rhetorical framing of map in relation to story title (Figure 5.19). The network was subdivided into three periods (2014 - 2017, 2018 - 2019 and 2020 - 2021) and annotated with eleven major events and topic clusters.

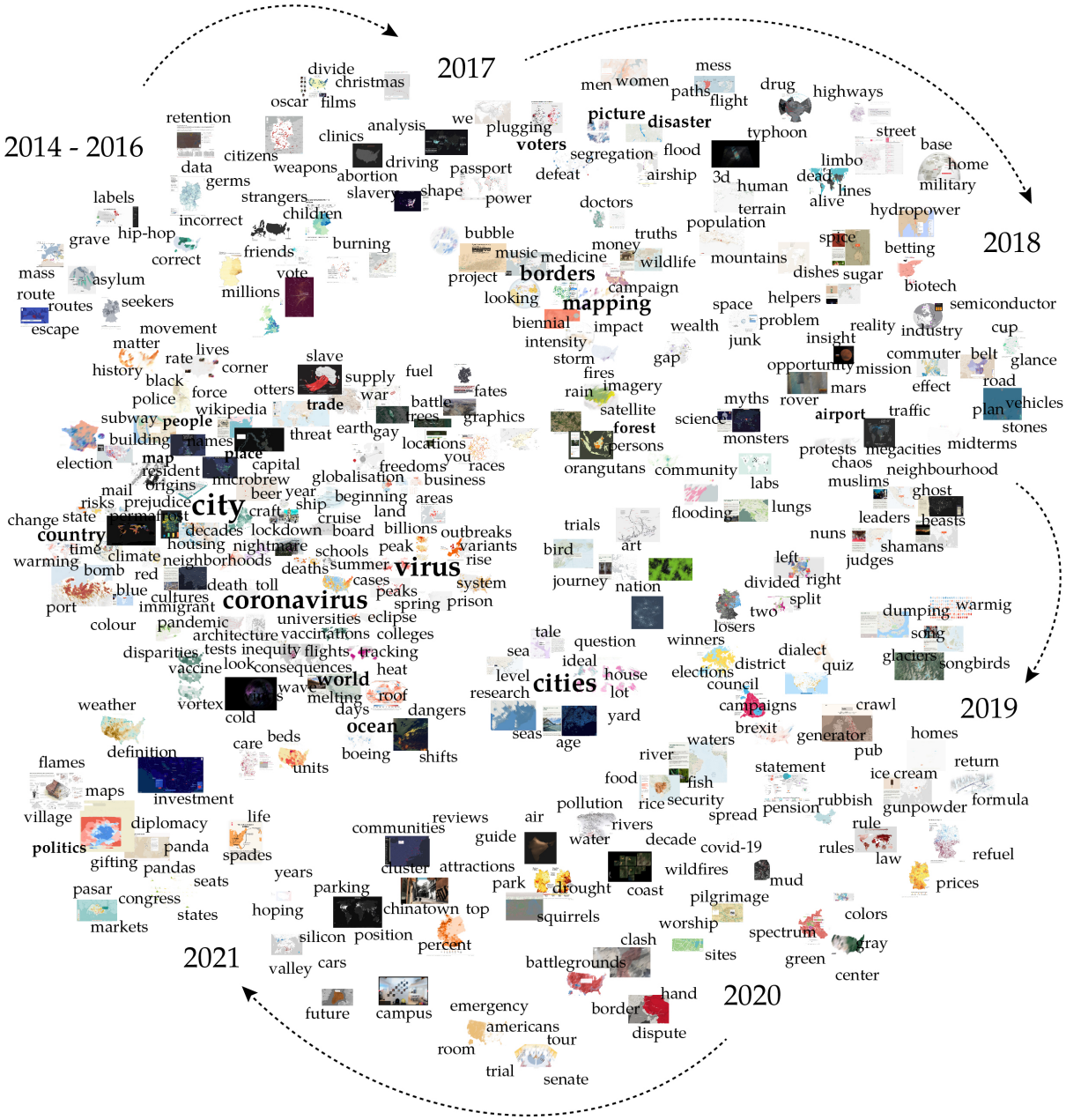


Figure 5.19: Keywords and map miniatures between 2014 - 2021. Graphic features 215 stories listed in Appendix B.

In the first period (Figure 5.20) maps were used to illustrate zeitgeist, since they stay on the peripheries of the network. The dominant narrations referred to the European migrant crisis in 2015 (cluster **A**), contrasting relationships between people (cluster **B** of "strangers", "friends", "correct" and "incorrect") and voting results (cluster **C** containing the Brexit referendum in 2016 and the French presidential election in 2017).

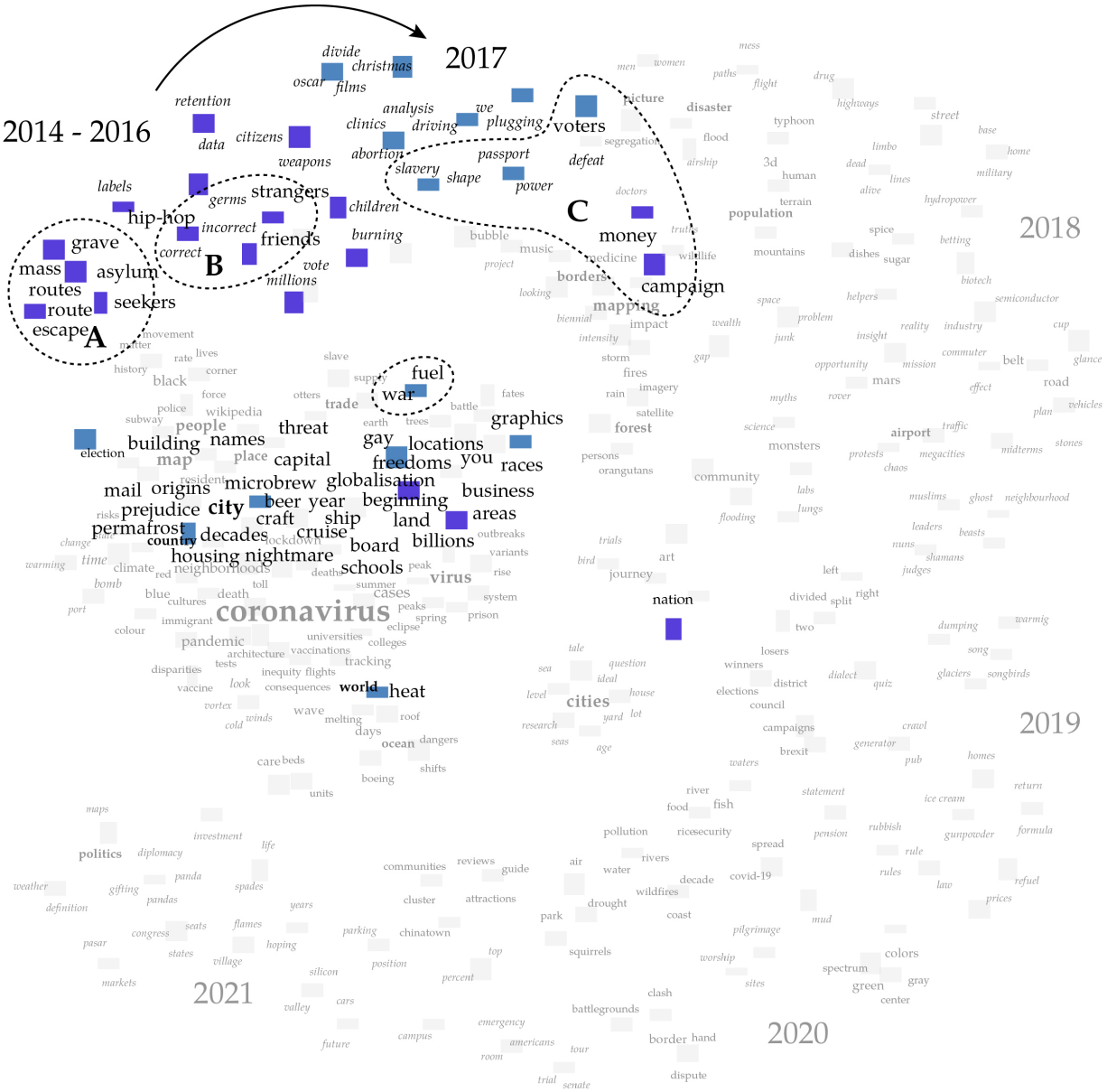


Figure 5.20: Keyword activities between 2014 - 2017. Graphic features 215 stories listed in Appendix B.

The second period (Figure 5.21) kept reflecting on voting results in the binary way (cluster **F** with keywords such as "winners", "losers", "divided", "split", "left", "right"). Yet the bigger focus was devoted to "evergreen" topics such as urban life (cluster **D**), environmental impacts (cluster **E**) and cultural explanations (cluster **G**).

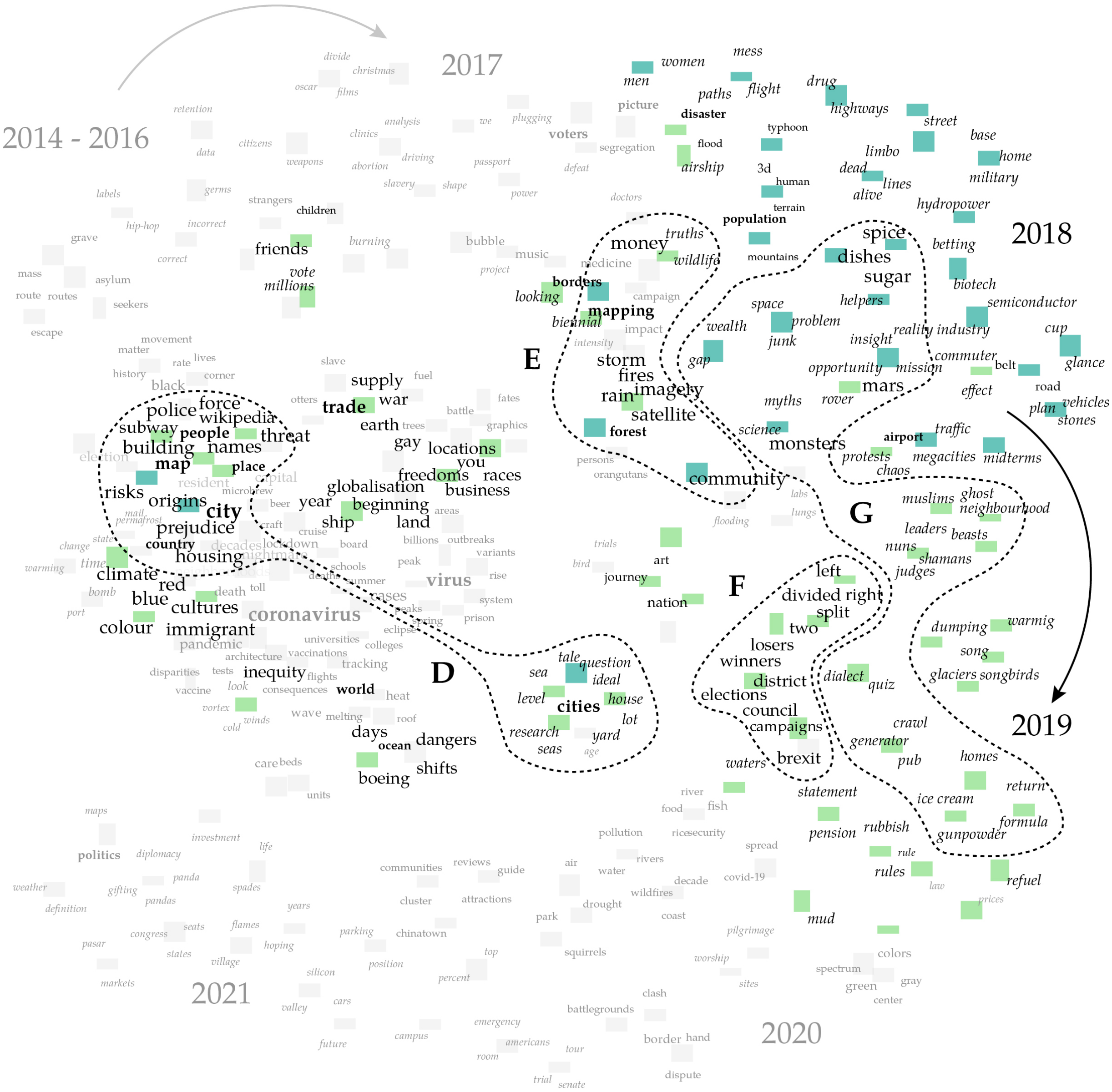


Figure 5.21: Keyword activities between 2018 - 2019. Graphic features 215 stories listed in Appendix B.

The third period (Figure 5.22) was dominated by the COVID-19 pandemic (cluster **H**) and its omnipresence in human experience (“tracking”, “disparities”, “consequences”, “schools”, “colleges”, “universities”). The remaining two politically relevant clusters reflected on the George Floyd protests (cluster **I**) and the 2020 United States presidential elections (cluster **K**). The tone of the nature-focused cluster **J** was also not optimistic (“droughts”, “pollution”, “wildfires”).

The appearance of the image-tag network is strongly dependent on its temporal scale. While recent maps visually support the “coronavirus” stories, it is feasible that due to the future developments that global event will remain attached to “evergreen” topics or move its position to network peripheries.

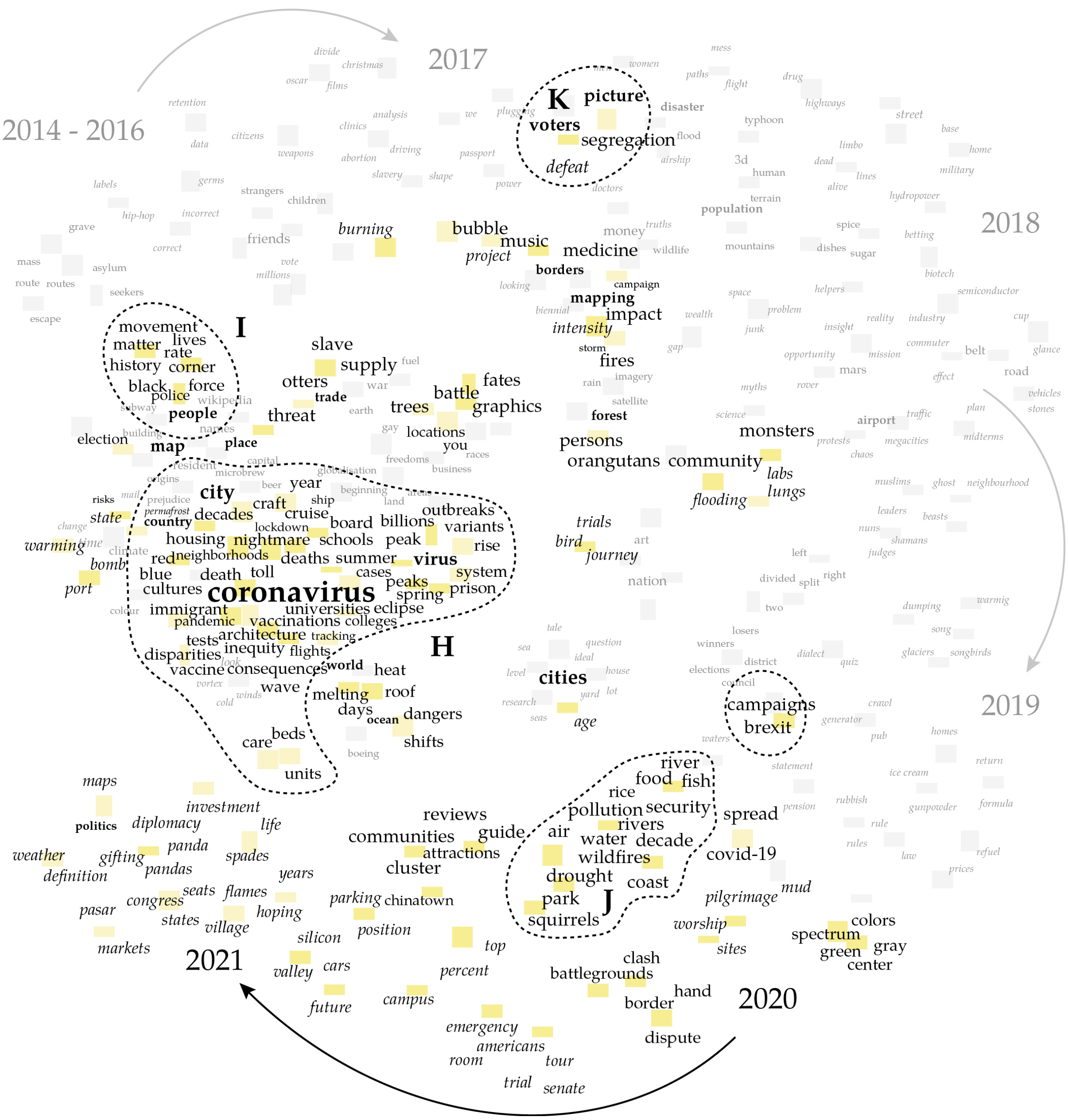


Figure 5.22: Keyword activities between 2020 - 2021. Graphic features 215 stories listed in Appendix B.

5.4 n-D – Multidimensional analysis

The goal of the multidimensional analysis was twofold: first, to find to what extend the manual QCA can capture the design dimensions of stories and maps, and second, what might be the common, yet unknown structures present in the data. To do so, we used two methods – Multiple Factor Analysis on the manually labelled content data and Visual Dimensionality Reduction on map.

5.4.1 Multiple Factor Analysis

For each primary unit of analysis – a story and a map – we computed five principal components, that took into account the distribution of categories, variables and codes to find new, non-existing design dimensions. Data points were firstly placed in bi-plots comparing two components, e.g. the first and the second. We then compared with each other multiple bi-plots and annotated the findings in the joint plot.

Visual stories

Categories derived for visual stories – themes, rhetorical techniques and story layout – explained 30% of the total variance. By looking at the bi-plot, one could see that there are two orthogonal design dimensions of stories (Figure 5.23).

The vertical dimension (**A**), contains stories organized in columns or rows, that unfold on the reader's scroll. If the story gets too long, the content is divided in multiple scrollable pages, either vertical or horizontal . The length of the canvas is used to grab readers attention at first and then guide them through increasing levels of details (Inverted Pyramid) or chronological event sequence (Inverted Martini Glass). Such stories tend to explain political and scientific issues as chains of cause and effect or developing and destructing events.

The opposite, horizontal dimension (**B**) contains stories of asymmetrical layouts (fixed sidebars, divided screens, cards). The exploration freedom is higher, as readers can choose their own path through the data to compare similarities or dissimilarities between conditions, especially in the context of cultures and societies.

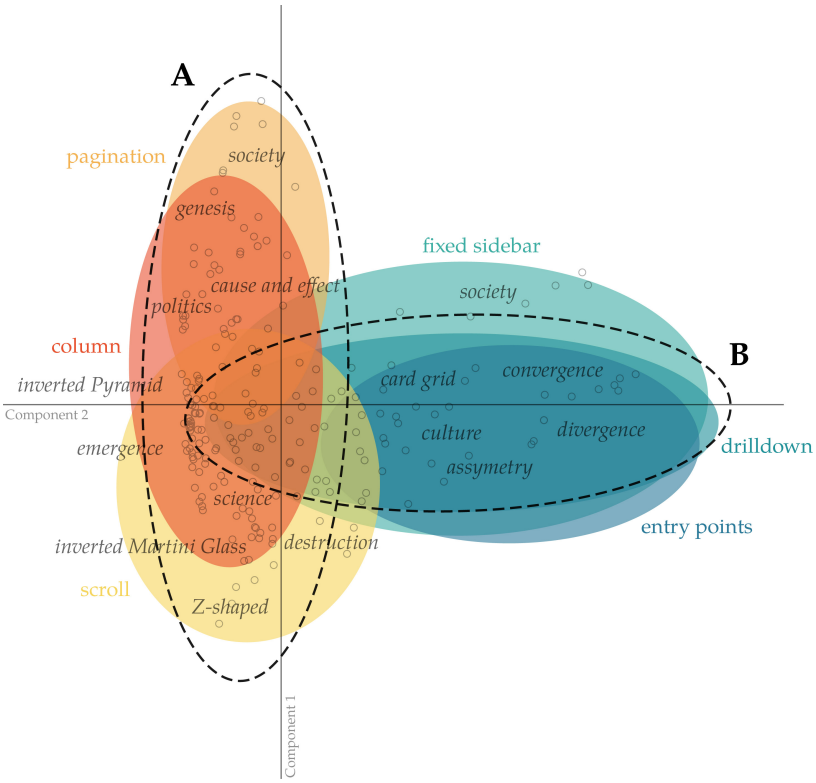


Figure 5.23: Vertical and horizontal dimensions of story space.

Maps within stories

Categories derived for maps – rhetorical techniques, visual design, and interactions – explained 40% of the total variance. By looking at the bi-plot, one could see that the design space of maps is more complex than stories and that it is not driven by the thematic map types (Figure 5.24). Instead, it can be divided into four quadrants of along two axes – fragmented vs fluid, and active vs inactive.

Cluster **A** contains active maps that allow for panning, zooming, selecting and highlighting objects. Active map cluster mixed understated styles along with authoritative and propagandist. The authoritative maps tend to blend with the non-map content of the story, while propaganda maps are visually separated into different frames.

Clusters **B** and **C** belong to inactive maps, that might be embedded in the page as multiple static images (cluster **B**) or can be triggered by scroll (cluster **C**). Inactive, fragmented maps tend to be visually persuasive by utilizing substitutions – visual exaggerations, metaphors and periphrasis.

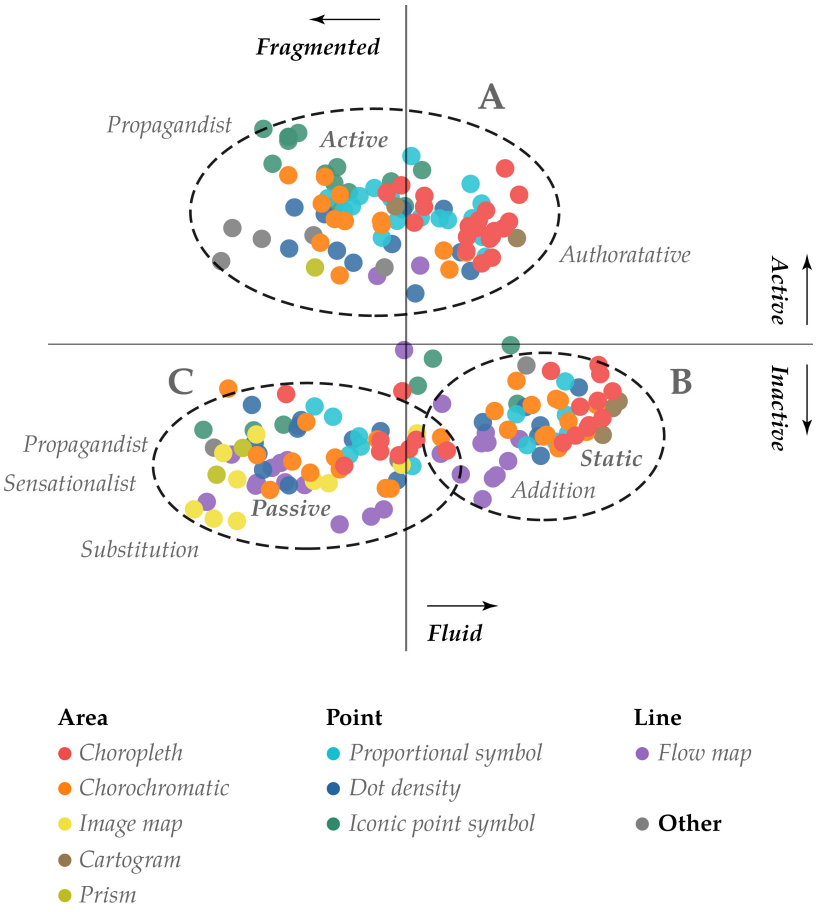


Figure 5.24: Multiple dimensions of map design space.

5.4.2 Visual Dimensionality Reduction

Another way of looking at the story maps is to narrow them down to a set of visual features, that might not be directly expressed in the codebook. ML-based image tagging provides machine-like view of the data, that may help to derive general patterns of map production at scale. Using an artificial neural network and the t-SNE dimension reduction algorithm it was possible to view maps in the new similarity space. Figure 5.25 presents such space for the secondary image set (686 samples). The resulting visual clusters were manually annotated as the following semantic groups:

Globes and spheres contain views of the world and other planets as well as maps where data was cut to the circular extent,

The grey zone dominates the network center and contains images with low contrast, grey backgrounds and modest symbols.

The vibrant zone contains vivid choropleth maps without background, presenting data limited to the extent of the countries. Two vivid sub-clusters include thematic depictions of US, with the red-blue election maps on the peripheries of the network.

The dark zone shows image maps presenting environmental risks, deaths, and other losses.

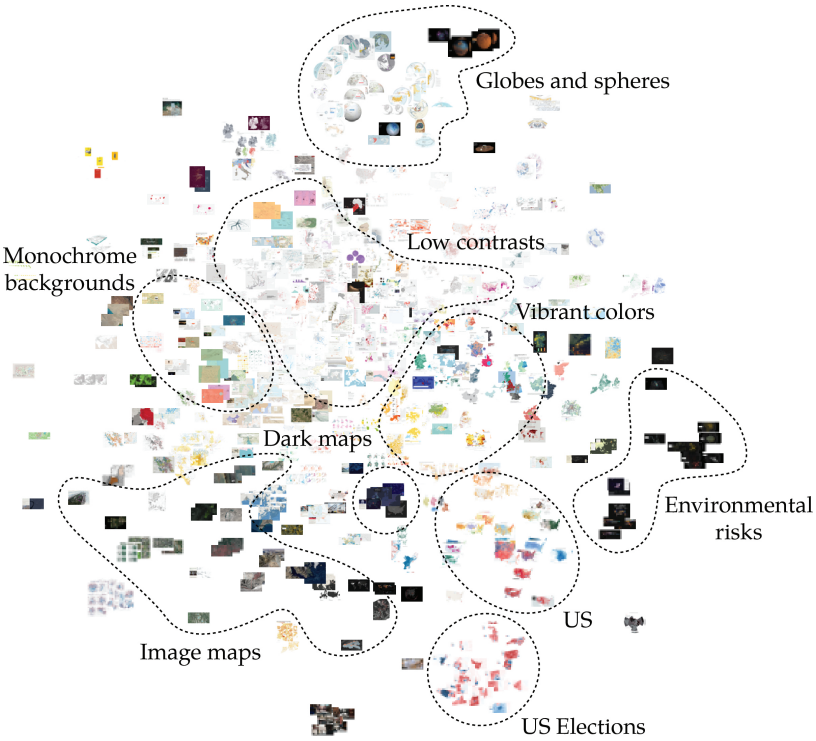


Figure 5.25: Visual and semantic groupings of maps extracted with the t-SNE dimension reduction algorithm. Graphic features 215 stories listed in Appendix B.

The interpretations of the image clusters can also be derived automatically by placing image samples between multiple label keywords. Labels describe the single objects that can be recognized on the image. Figure 5.26 shows the same secondary set of images from the perspective of "machine interpretator". Algorithms see the majority of story maps as combinations of worlds, fonts and designs. The outliers in the networks are image maps. As they tend to be very similar to realistic photographs, networks tend to perform better in distinguishing their components. Finally, ML-algorithms can also predict the general purpose of the image. The graphic in Figure 5.27 presents best guesses made by the Google Cloud Vision API on "what this image is". Machines span the samples between maps, graphic design and nature.

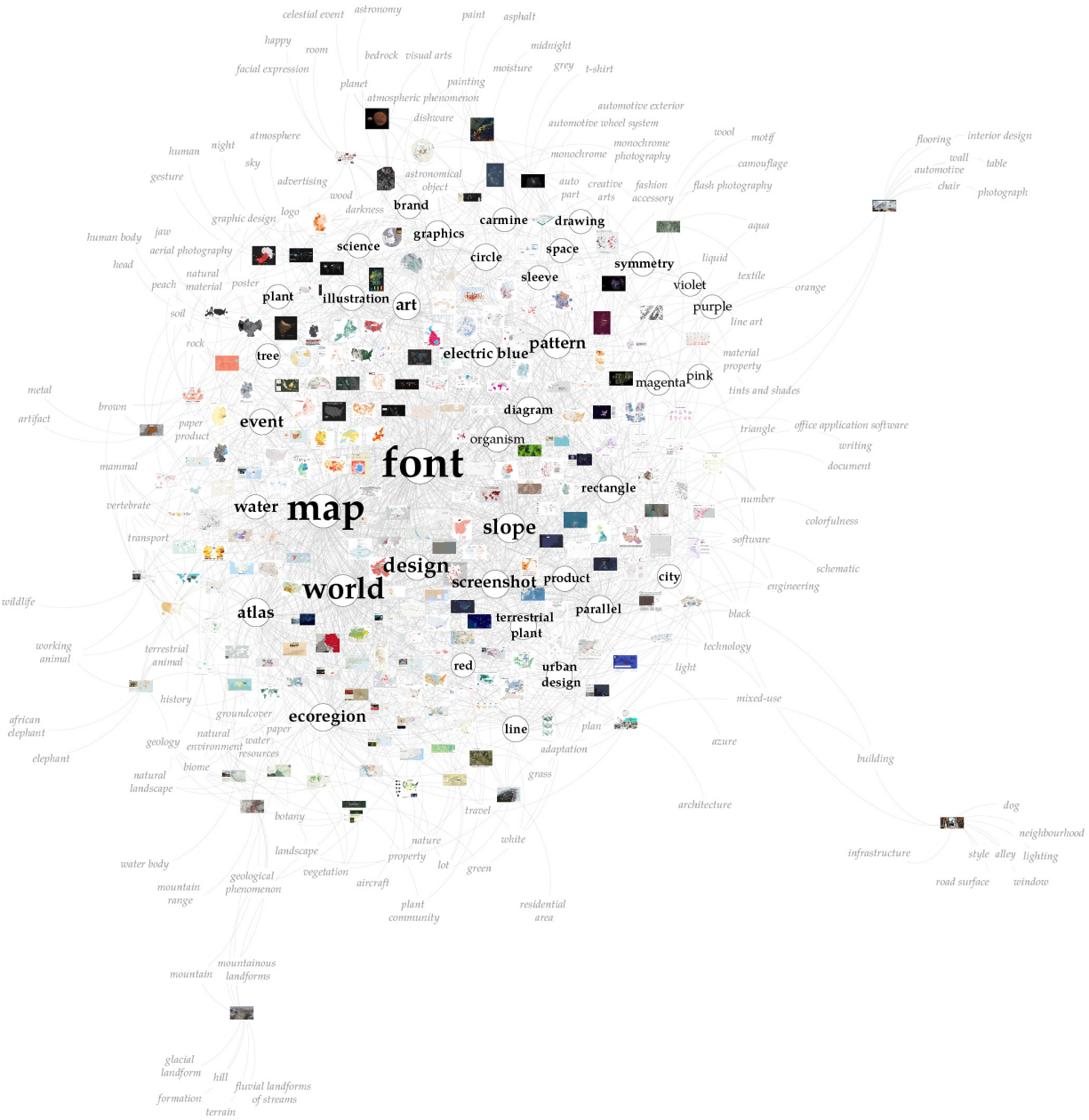


Figure 5.26: Visual and semantic groupings of maps based on the label descriptions provided by Google Cloud Vision API. Graphic features 215 stories listed in Appendix B.

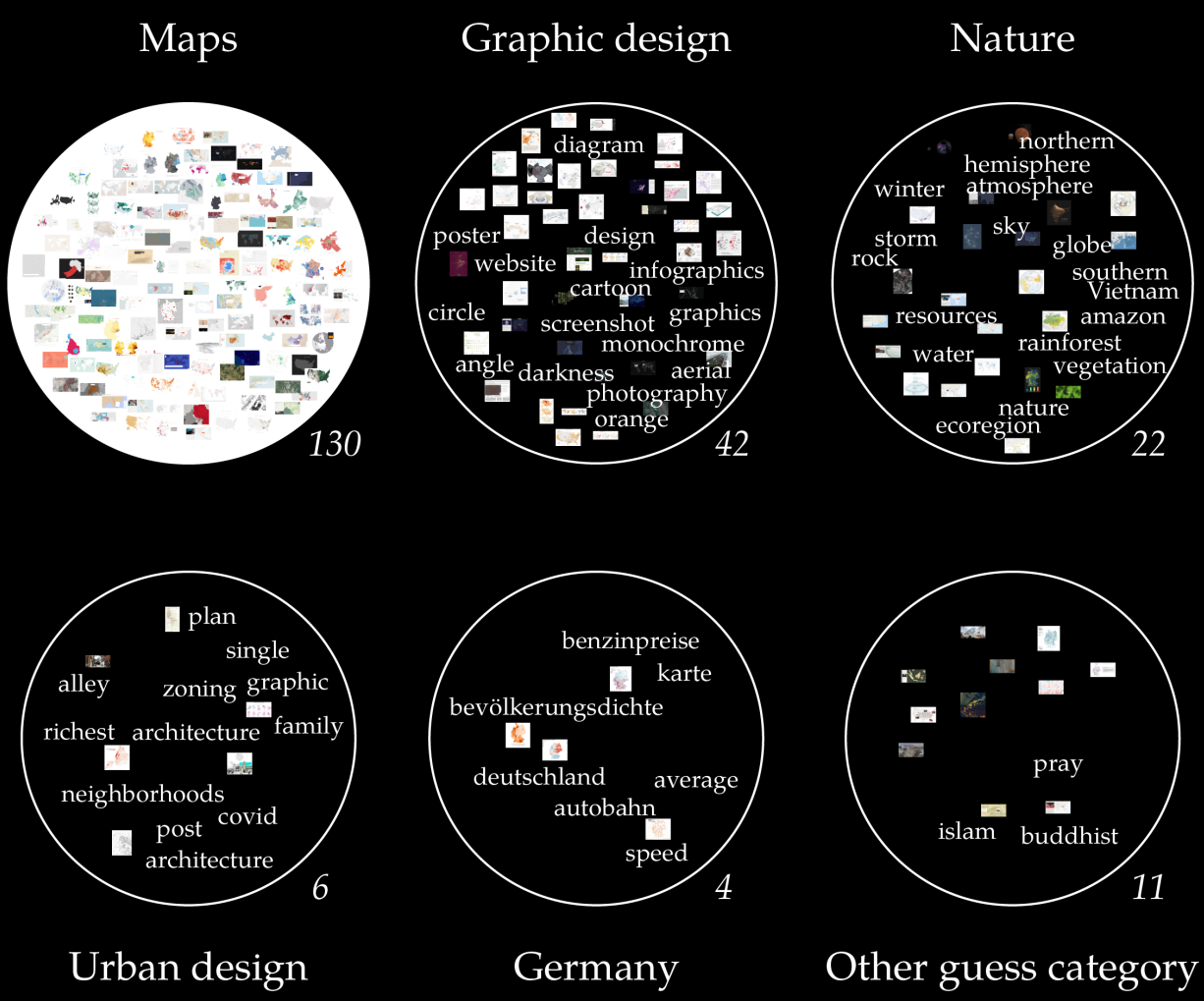


Figure 5.27: Best guessed labels – predictions made by Google Cloud Vision API. Graphic features 215 stories listed in Appendix B.

Research through design | 6

The practical part of this thesis aimed at creating the understanding of data-driven storytelling through own hands-on work on four case studies comprising the **annotated portfolio**:

Case study 1: Election maps for the Chair of Economic History at the Ludwig Maximilian University of Munich, accompanied research on far right voting patterns in Germany. In March 2019 the created election maps appeared in print and online in The Economist and Ara, but they were re-designed to follow the journal guidelines.

Case study 2: Cultural maps for the Social Dynamics Team, Nokia Bell Labs was a set of interactive cultural maps showing honorific names in London, Vienna, Paris and New York. Cultural maps got international coverage in web, print and radio. The annotations reflect on how have the images been reproduced, remixed and recirculated.

Case study 3: Urban vitality maps for the Social Dynamics Team, Nokia Bell Labs discussed spatial patterns of vitality in six Italian cities through their satellite images. The story was created without any standard cartographic software. Instead, map-like visualizations were created using several data science modeling techniques, generative artwork frameworks, and data-driven interactive visualization libraries.

Case study 4: Emotional maps maps for the Chair of Cartography and Visual Analytics at Technical University of Munich, and School of Machines, Making and Make Believe used the novel technique of the neural style transfer to create evocative, emotional maps of Berlin.

The four pieces were related to each other, since their main goal was the same – introduction of novel and engaging map-based stories that promote among broad public the data-driven research results. The effectiveness of the presented map-based stories was not evaluated in the controlled user studies. Instead, the hallway usability testing was used such as the internal feedback from the stakeholders, feedback from journalistic outputs and digital traces – comments on these projects in online media. Although I developed these case studies with various interdisciplinary researcher groups, I annotate them from my own perspective. For this reason, I use "I" to refer to the design decisions that I have taken for my research. The annotations for each project included reporting on data sources, presenting previous storytelling approaches, analyzing story requirements, prototyping visualization and disseminating the final interface (Roth 2019).

6.1 Case study 1: Election maps

Election maps are publicly available under the following link: edytabogucka.gitlab.io/page/kontinuitaeten.

Election maps were created as a part of a research collaboration with economists and historians on mapping the continuity of the far-right voting patterns in Germany. The purpose of mapping was to illustrate the main findings from the research on continuity of these voting patterns (Cantoni, Hagemeister, and Westcott 2019). The collaboration started in 2017 and finished in 2022.

6.1.1 Data

The input data sources included over 11 000 points (centroids) of German municipalities (Figure 6.1). Each data point contained five variables to be mapped – shares of the Nazi Party (NSDAP) votes in 1933, share of the German expellees in the total population in 1950 and election results for the right-wing party Alternative for Germany (AfD) in 2013, 2017 and 2021. Researchers used the term persistence to indicate the correlation between the 1933 and 2017 voting results.

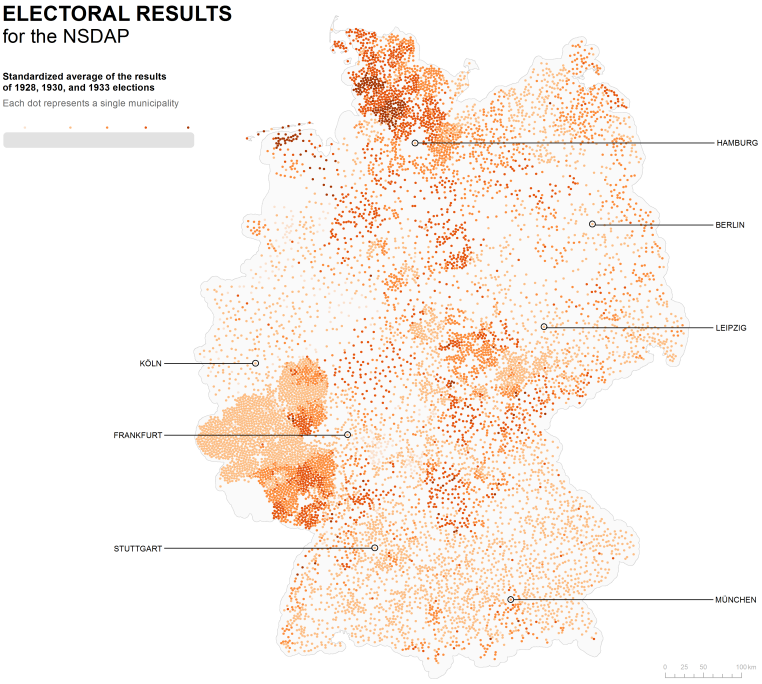
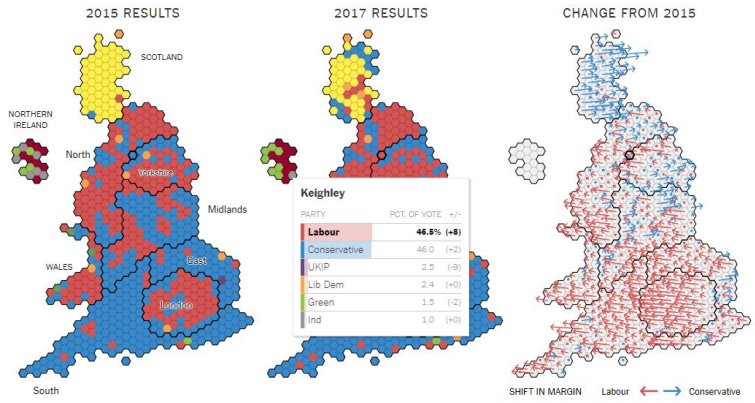


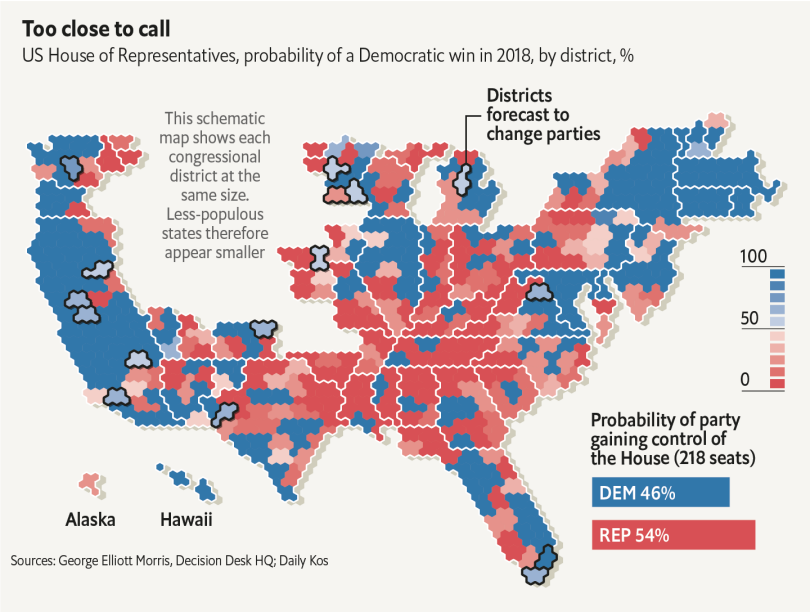
Figure 6.1: Density of the input electoral data. Datase provided by Cantoni, Hagemeister, and Wescott (2019).

6.1.2 Needs assessment

The prevalent cartographic approaches for mapping elections in newsrooms were mostly based on uni-variate choropleth maps and hexagonal cartograms (Figure 6.2a). The visual arguments were constructed by means of similarity, for instance comparisons between sets of maps. Previous attempts on showing US states with many congressional districts next to less-populous states resulted in similar unconventional shapes (Figure 6.2b). The researchers wanted to re-create these journalistic approaches for their study, and so we defined our needs that should be met by the story.



(a) Hexagonal cartograms for 2015 and 2017 UK elections (Aisch et al. 2017).



(b) Hexagonal cartograms for 2018 US elections (Rosenheck and Fransham 2018).

Figure 6.2: Types of hexagon maps for mapping election results.

First, researchers found that there was a **difference in the persistence** depending on the size of the municipality. A very strong persistence was present in small municipalities, and little or no persistence was visible in large municipalities. Choropleth maps with realistic borders would de-emphasize dense municipalities with small areas and highlight municipalities with large areas. Also, aggregating municipalities into larger statistical units would weaken their hypothesis. To satisfy these constraints, I narrowed down the choice of thematic map to the cartogram.

Second, researchers wanted each municipality to be represented by **one "cell" or "symbol"**, so that it showed visually that each municipality (each observation) was weighted equally in their regressions. I chose the hexagon shape since it allowed for placing six neighbors around a single municipality. That shape fitted the density of the data better than triangles and squares.

Third, the data density required to develop a **new cartographic method** for placing 11 000 symbols should minimize the distortion of shapes of federal states. Available tools to create cartograms for Germany (e.g., Tilegram with hexagons for 299 electoral districts) were not feasible for manual hexagon placements. Therefore, it was necessary for me to design a custom mapping tool.

Finally, researchers pointed out that not every Nazi Party stronghold remained an AfD stronghold. On the contrary, there were many areas where there was no such historical correlation, so it is crucial to choose the right **unit of spatial representation**. The analysis was meaningful when conducted state by state, rather than by looking at Germany in an aggregated way. Comparing multiple uni-variate maps with thousands of symbols each would make it impossible to highlight these local patterns of persistence. This is why the differences from the state average (and not nationwide average) were presented by me on bivariate maps. Those maps were crucial for the researchers to make their point, as they accurately showed where the local low-low, average-average and high-high correlations were present.

6.1.3 Prototyping elective maps

The main question behind creating the custom mapping tool was how I can the re-arrange the irregular data points to regular grid points while keeping the shape and location of the federal states and Germany consistent. This was achieved in a three-steps semi-automated process repeated separately for each of the federal states (Figure 6.3):

Step 1: Generation of a regular point grid, where point density matched the number of municipalities in each state and the shape of the grid was similar to the shape of the state.

Step 2: Implementation of the Hungarian optimization algorithm to move the municipality points from the original positions to the new positions in the regular grid. This involved identifying the solution where the total distance between the centroid and the new grid point was minimised. For this I utilized the linear sum assignment from the SciPy Python package.

Step 3: Once centroids were moved to their new positions, hexagons were drawn around them. I manually adjusted the placement of the hexagons to ensure that the cartograms of federal states stacked to one cartogram of Germany. I chose such approach to speed up the processing times – a cartogram for state with 2000 municipalities was generated within an hour, while the simulation for the whole Germany run for a week and did not result in feasible shapes.

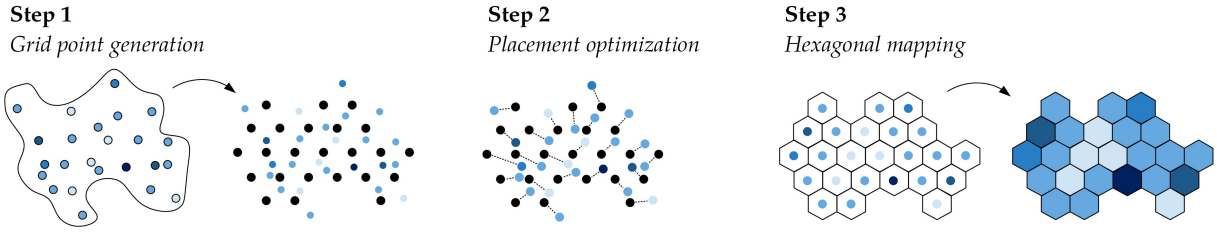
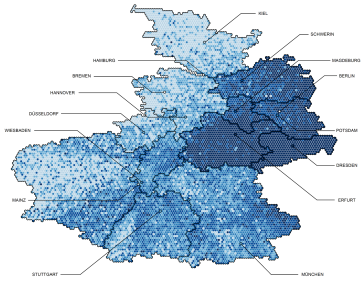
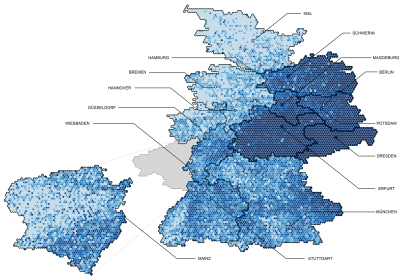


Figure 6.3: Three steps of the semi-automated process for hexagonal mapping.

Due to the regional differences in the number of municipalities, the shapes of Rhineland-Palatinate and North Rhine-Westphalia were not recognizable anymore (Figure 6.4a). To mitigate this effect, I decided to create the inset map for Rhineland-Palatinate and annotate the state capitals (Figure 6.4b).



(a) The distorted view of Germany-wide cartogram



(b) Inset map for Rhineland-Palatinate

Figure 6.4: Adjustments on the cartographic design.

The goal of bivariate mapping was to show the agreement between two variables – deviations from state averages of the 2017 federal election (AfD, horizontal dimension), and deviations from the 1933 election (NSDAP, vertical dimension). Since in 2017 there was no GIS tool to create bivariate maps, I had to manually divide each variable combinations into 9-classes, with 3 classes per each dimension (Figure 6.5). The first prototypes utilized the sequential color scales of grays to show weaker correlations and purples to show stronger correlations. Based on the feedback from the researchers, I changed the color scheme to blues.

Once the shapes and the mapping conventions were established, multiple design variations were made to support different stories emerging from the research. The created cartograms presented deviations from state averages of 1933, 2013 and 2017 elections as well as differences in the share of expellees in the total population in 1950. Finally, the project was closed in 2022 and resulted in a broad range of cartographic products: sets of static maps for academic publications (see Cantoni, Hagemeister, and Westcott 2019) and interactive story map for broad public.

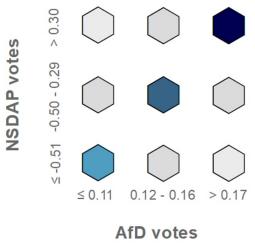


Figure 6.5: A draft of bivariate scale for mapping political persistence.

6.1.4 Dissemination and story feedback

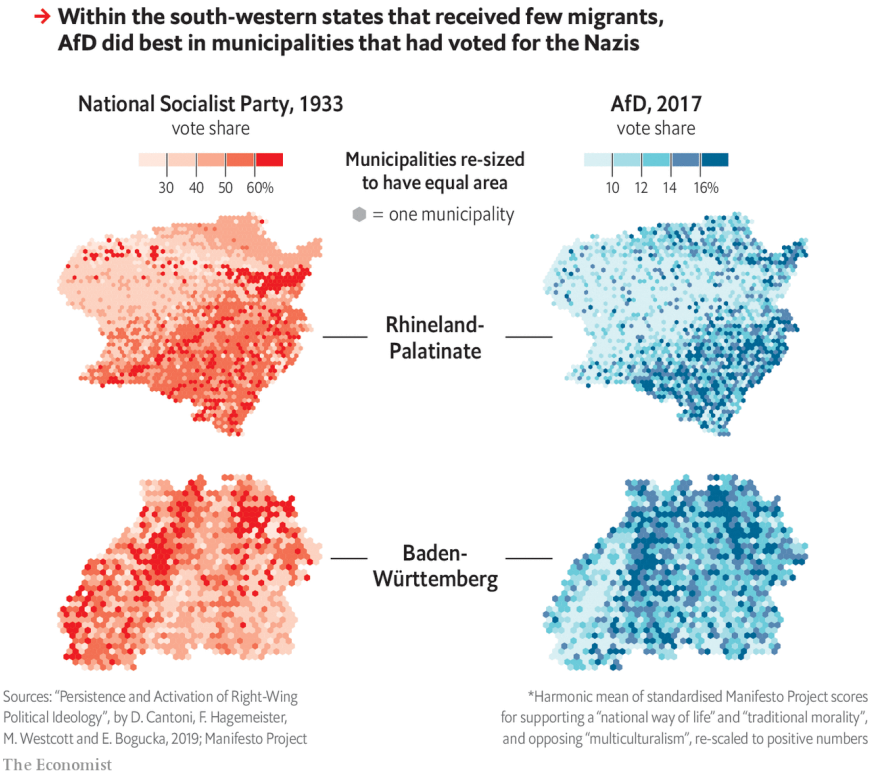
The manifesto paper (Cantoni, Hagemeister, and Westcott 2019) was released in February 2019 and quickly gained the attention from six national and international newspapers, such as The Times, The Economist and Bloomberg.

Three newsrooms contacted the researchers to get access to the maps and the underlying data. Finally two newsrooms decided to publish the article together with hexagonal maps. Ara – a Catalan daily Spanish newspaper – published the original bivariate map with adjusted legend and names of the cities translated to Catalan language (Figure 6.6a). The Economist Data Team decided to feature only two federal states where the persistence was particularly visible – Baden-Württemberg and Rhineland-Palatinate. Following their in-house style guidelines, they re-designed the cartograms as univariate maps of AfD and NSDAP vote shares (Figure 6.6b).

The third newsroom provided via e-mail very detailed explanations on why they decided against featuring maps in their article. Since they wanted to cover the topic in the interview-like article, featuring the data-driven analysis was beyond the scope of a single article. Moreover, they assessed the concept of hexagonal mapping and bivariate maps as interesting, yet too novel for their readers: Journalist 1: *Such forms of representation are (unfortunately) not yet really established in the journalistic field and require a detailed introduction in terms of content and methodology*. Finally, their visual stories were strongly supported on mobile displays. Once they tried to adjust the hexagonal map to fit smartphone extent, they noticed that interaction with single hexagons was not feasible. Therefore they proceeded with the aggregation of the data from municipalities to administrative districts, but, as stated in the story requirements, this level of details was de-emphasizing the original research findings.

The published maps circulated on social media as static images and image cards embedded in the link to the article from The Economist. We received the following comment from Journalist 2: *The aesthetic quality of the cards is truly outstanding. The depiction of the communities as hexagons is unusual, but prevents a false visual impression due to areas of different sizes. One should do that more often, also in data journalism*.

(a) Map re-design published by Ara on 10th March 2019 (Jerez 2019).



(b) Map re-design published by the Economist on 16th March 2019 (N.N. 2019b).

Figure 6.6: Re-designs of the original hexagonal map.

6.1.5 Transferable storytelling insights

Design with domain experts

Although the dominant approach to election mapping at such scale was to use choropleth maps, the choice of hexagonal maps was reasonably justified in the methodology and key findings of the research. Mapping thousands of municipalities started as my personal cartographic challenge of remaking existing cartograms at scale. Moreover, it required me to go from the designer-centred point of "what do I typically do" to "what do I need to do to support someone's story".

Design for multiple audiences

The collaborations with the newsrooms revealed that the created story maps are just placeholders for multiple stories. Sometimes they will be used on full-page spreads to show the complexity of the analysis. On the other hands, they might be dissected into self-containing chunks and framed as story arguments. This made me more aware of the importance of organizing the cartographic workflow into reproducible steps. That includes not only annotating the design decisions, but also designing in exchangeable spatial and graphic data formats. Moreover, introduction of the novel story form is not only a matter of technical possibilities. Publishing certain interactive map types comes with a responsibility to familiarize users with the data and mechanisms behind map creation. Eventually, all visual stories compromise multiple voices of authors, audience, and journalists.

Design and re-design

Keeping these insights in mind, for the last dissemination project in 2022 I created the interactive *Longform Infographics* that summarized the results of the research and utilized the codebook design variables (Table 6.1). I started with the working assumption that readers might look at the hexagonal map very critically and they might interpret the hexagonal distortions as bad intentions. I wanted to avoid the claims that I aligned the hexagons in a way that I showed patterns that did not exist, especially that the similarities between hexagonal maps and choropleth maps were present.

Therefore I used the *Drill down* narration strategy to show and comment voting patterns in different scales and through both types of maps: choropleth map and hexagonal cartogram (Figure 6.7). To ensure that users will learn the general voting patterns, I started the story with choropleth maps explaining the global patterns (Figure 6.7A, Figure 6.7B). Then I introduced the hexagonal maps as large-scale static excerpts (Figure 6.7C). The story comes to an end with a circular *Ending* – an interactive choropleth view, that can be changed to hexagonal cartogram (Figure 6.8D). The views are supplemented with two sub-sites explaining the methodology behind the research and the mapping procedure (Figure 6.8E).

Table 6.1: Variables and codes used in the election maps design.

Variable	Code
Story theme	Politics, Internal Non-violent
Genre	Longform Infographics
Site layout	Split screen Scatter plots
Story elements	Maps Small multiples
Story flow	Scroll
Type	Cartogram Choropleth
Symbol color depth	Limited color
Background color depth	None
Framing	Parallel plot Ending
Layout	Fragmented, Unemphasized

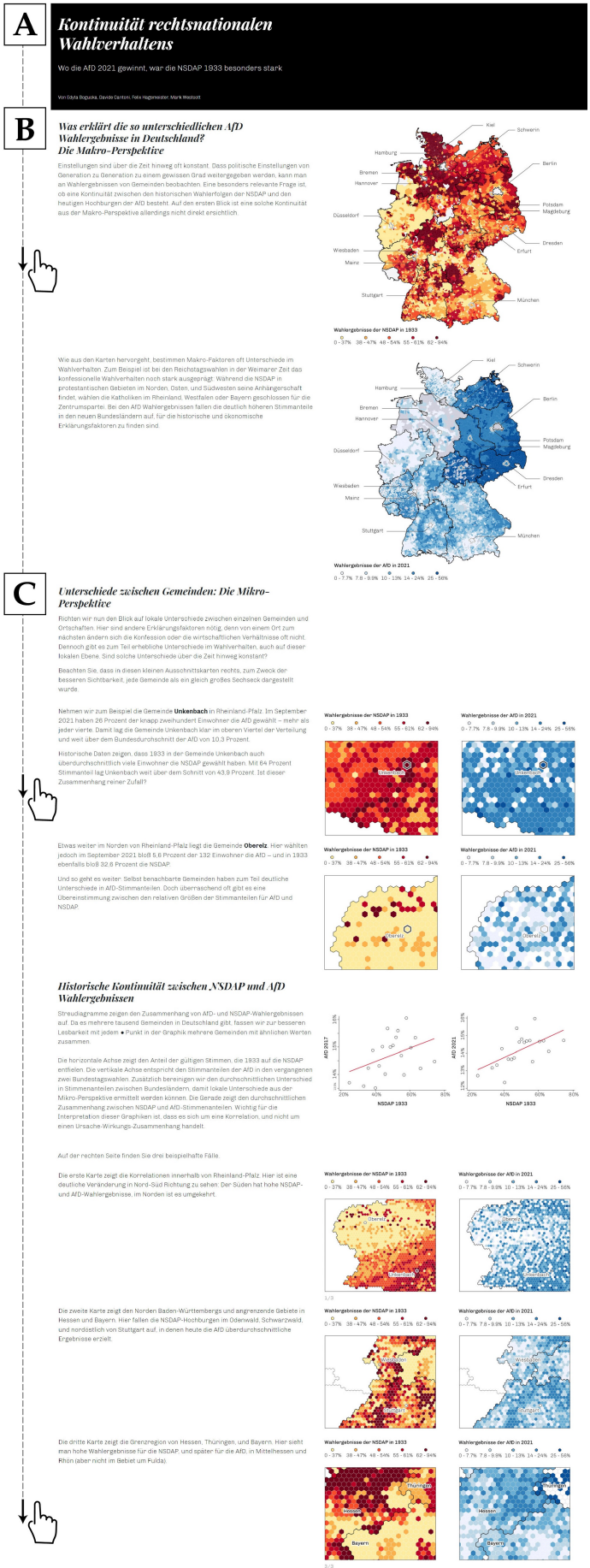


Figure 6.7: The plotline of the story on political persistence – a first part.

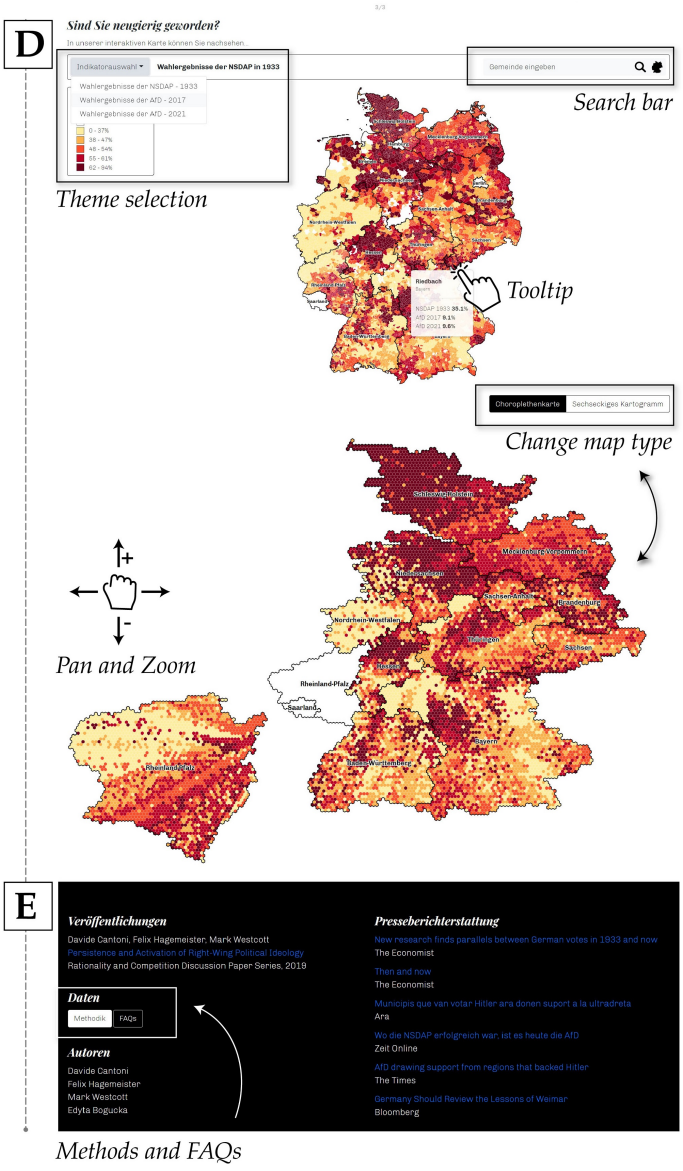


Figure 6.8: The plotline of the story on political persistence – a second part.

6.2 Case study 2: Cultural maps

Cultural maps were created as a part of the 3-month data science research internship at the Social Dynamics Team of Nokia Bell Labs. The internship took place between 1 June - 31 August 2019 in Cambridge, UK.

The researchers from the group found that streets are not only spatial indicators, but they also mirror a city's social, cultural and political values. Therefore the brief for the story was to create interactive map experience supporting the emergence of the *streetonomics* – a new way of quantifying a city's culture using street names (Bancilhon et al. 2021).

The story is publicly available under the following link: www.social-dynamics.net/streetonomics.

The results of the research were presented in the scientific community during the research seminar series "The Triumph of the City" (2021) at the Centre for Urban Science and Progress (CUSP) London – a joint initiative of King's College London and the University of Warwick. The research was also covered in two complementary researchpapers – one methods-oriented (Bancilhon et al. 2021) and one visualization-oriented (Bogucka, Constantinides, et al. 2020). Finally, the story was longlisted in the "Information is Beautiful Awards" competition in the "Places, Spaces and Environment" category (2022).

6.2.1 Data

The researchers combined heterogeneous open data sources about the individuals streets were named after to study how a city's cultural values changed through space and time. The exact process behind data processing was explained in details in the methodological paper. The final dataset included 4932 streets from four cities: Paris, Vienna, New York, and London. These cities were selected as case studies, as they culturally shaped the Western world in the 20th century. The attributes for each street included the street name, city, district and denomination date. The street was also connected to its honoree through additional information on their name, gender, occupation, country of origin and dates of birth and death, as well as link to their Wikipedia page and image.

6.2.2 Needs assessment

Together with researchers we grouped their findings into four aspects. First, they found that street names tended to be gender-biased against women despite recent efforts in mitigating such biases. Second, they found that street names tended to speak to a distant past. The streets of the three European capitals were mostly named after people who lived in the 19th century, but New York's naming was more present-oriented. Third, they showed that street names celebrated specific professions consistently over the centuries. Streetscapes in Paris and Vienna have always been dominated by artists or writers, London celebrated royals, while in New York, most of the streets were named after impactful people who worked in business. Fourth, they finally found that a city's street names did not always point to the city's national history. For instance, Vienna had half its streets named after foreigners.

The aim of the story was to engage broad public into a discussion on street naming patterns by stimulating own discoveries on the four aspects from the paper. The main cartographic challenge was how to visually convey such complex and intangible measures such as gender bias, city's global focus or temporal longing. Based on the requirement analysis, it became clear that this story had multiple *Characters*: unique historical personas behind each street and unique cities, that diverged in their commemorating practices.

6.2.3 Prototyping cultural maps

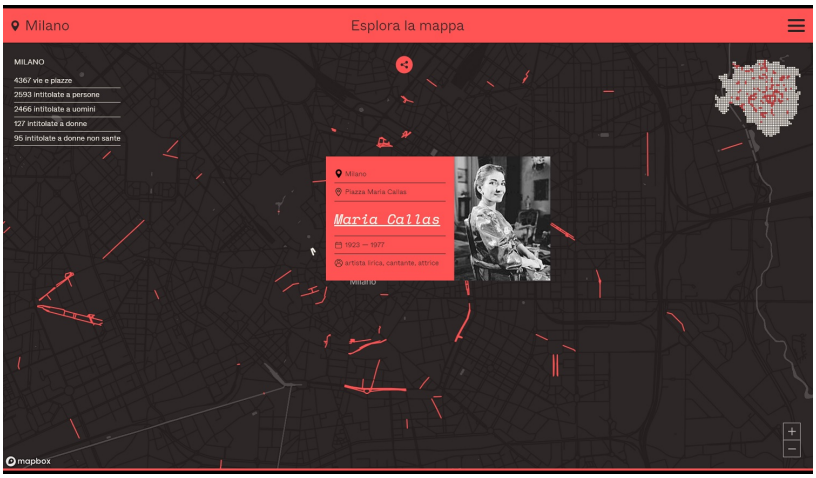
Existing approaches to mapping street name patterns

When searched for street names stories in news media, they utilized the *Longform Infographics* pattern connected with scroll-triggered interactions. The narrative flow of these stories focused on de-composing and explaining street names patterns theme-by-theme. On the other hand, two stories followed the *Drill down* narrative structure. For instance, the story map on female honorees in Italy started with the national patterns and the users could consequently narrow it down to the specific city and local streets (Figure 6.9a). In these exemplary stories interactive maps were framed either as a *Visual argument* or as the *Ending frame* allowing readers to explore the underlying dataset. The attention of the readers was mostly achieved through a *Propagandist* rhetorical map style with highly contrasted background map and vibrant symbol colors. Other projects color-coded the street segments based on the attributes of the street name, such as honoree's gender, occupation or mother language (Figure 6.9b).

Driven by the ambition of creating a story map that differs from these prevalent storytelling approaches, I defined a number of design constraints (Table 6.2). First, I wanted to present the interactive map earlier in the story flow to spark the discussions on the patterns outside of the ones mentioned in the methodological paper. Second, I wanted to visually show that seemingly unconnected streets form commemorative landscapes to be discovered. Thirdly, I needed to implement a versatile design approach, since the prototyping started with datasets available for Vienna and Paris, while New York and London were to be added in the future project iteration.

Table 6.2: Variables and codes used in the cultural maps design.

Variable	Code
Story theme	Culture, Heritage
Genre	Dynamic Slideshows
Site layout	Single column Maps
Story elements	Matrix and grid
Story flow	Pagination
Type	Other
Symbol color depth	Full color
Background color depth	Monochrome Dark
Framing	Container Ending
Layout	Fragmented, Emphasized



(a) Map of streets named after females in Milan (Comai et al. 2021).

(b) Map of linguistic origins of street names in Singapore (Pazos 2019).

Figure 6.9: Cartographic approaches for mapping street name patterns.

Selection of visual rhetorical figure

To find the right visual figure for connectedness, I tested two artistic approaches. The first one were typographic maps, that displayed street names as urban texts to be both viewed and read. Yet, the initial prototypes created in Mapbox GL JS were not visually pleasing and analytically relevant. The placement of street labels along the line geometry varied greatly between the cities. For instance, Rue Verdi in Paris was nicely aligned between streets crossing, while the labels for Johann-Nepomuk-Berger-Platz in Vienna were cropped in half length, thus unreadable. Therefore I resorted to the second visual figure of impressionistic origin – *Accumulation* through pointilism (Figure 6.10).

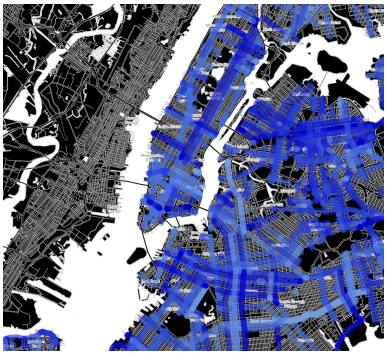
This painting technique is based on applying paint on canvas with point-like brushstrokes. When viewed en face, the strokes seem to be disconnected, but when viewed from a distance, they start blending into comprehensible spatial patterns. I implemented pointilism as the mixture of symbol exaggerations for three scales: a city, a district and a street level. At the city level, streets were shown as overlapping points on a map resulting in a color-full and painting-like view of thematic clusters. At the district level, streets were presented with half-opaque, slightly exaggerated lines. Finally, in the largest scale, symbols represent the exact spatial dimension of the street geometry, without further visual exaggerations.

I decided to design the experience in the *Propagandist* rhetorical map style, using the dark mode and accumulation of streets in bright and vibrant colors. For each theme I created a separate *Full color* palette. To depict gender bias, I used purples and greens suggested by the data visualization community (Muth 2018), instead of the stereotypical pink and blue shades (Figure 6.11a). For past versus future orientation I created a multi-hue sequential color scheme where the oldest streets were marked in yellow and the newest ones in blue (Figure 6.11b). Since the same scheme was applied to all cities, I needed to ensure that the color stops in the scheme will highlight unique development phases of each city.

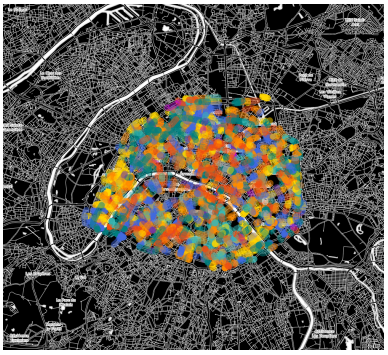
Figure 6.10: The Ruins at Grimaud, Saint-Tropez – pointilist painting by Signac 1899.

By following such approach, each city was getting it's distinct color based on the most frequent denomination dates, e.g. London was yellow and New York was blue. To depict occupations, I manually grouped them into similar clusters and gave one dominant color for the cluster (Figure 6.11c). For instance, greens were associated with social activists and scientists, while reds with royals and politicians. The colors for country of origin resemble on some colors from the respective countries' flags (Figure 6.11d).

(a) Gender bias in Vienna. Streets named after female are marked in purple.



(b) Historical longing of the city - most of the streets in new your was named after 2000.



(c) The variety of occupations in Paris.

(d) Street names honorees in London tend to originate from England, Ireland and Scotland.

Figure 6.11: Color coding for four street map themes.

Narrative flow

The flow was based on six *Frames* (Figure 6.12) placed along the three-arc narrative continuum of set-up, conflict and resolution (Roth 2021) :

The setup was introduced in the first two frames. The story cover displayed a *micro-animation* that delayed the reveal of the main topic. The second frame contained a verbal promise of a an unusual neighborhood walk.

The conflict was introduced in the third frame as the description of main challenges for using street names as proxies for culture.

The resolution came with cultural maps that show the cultural patterns and encourage urban data exploration. Last two frames contain a map gallery with all street patterns and authors note.

The control over the plot flow was achieved with the *Pagination* buttons on the left side of the interface. The design of the story was adjusted to mobile devices.

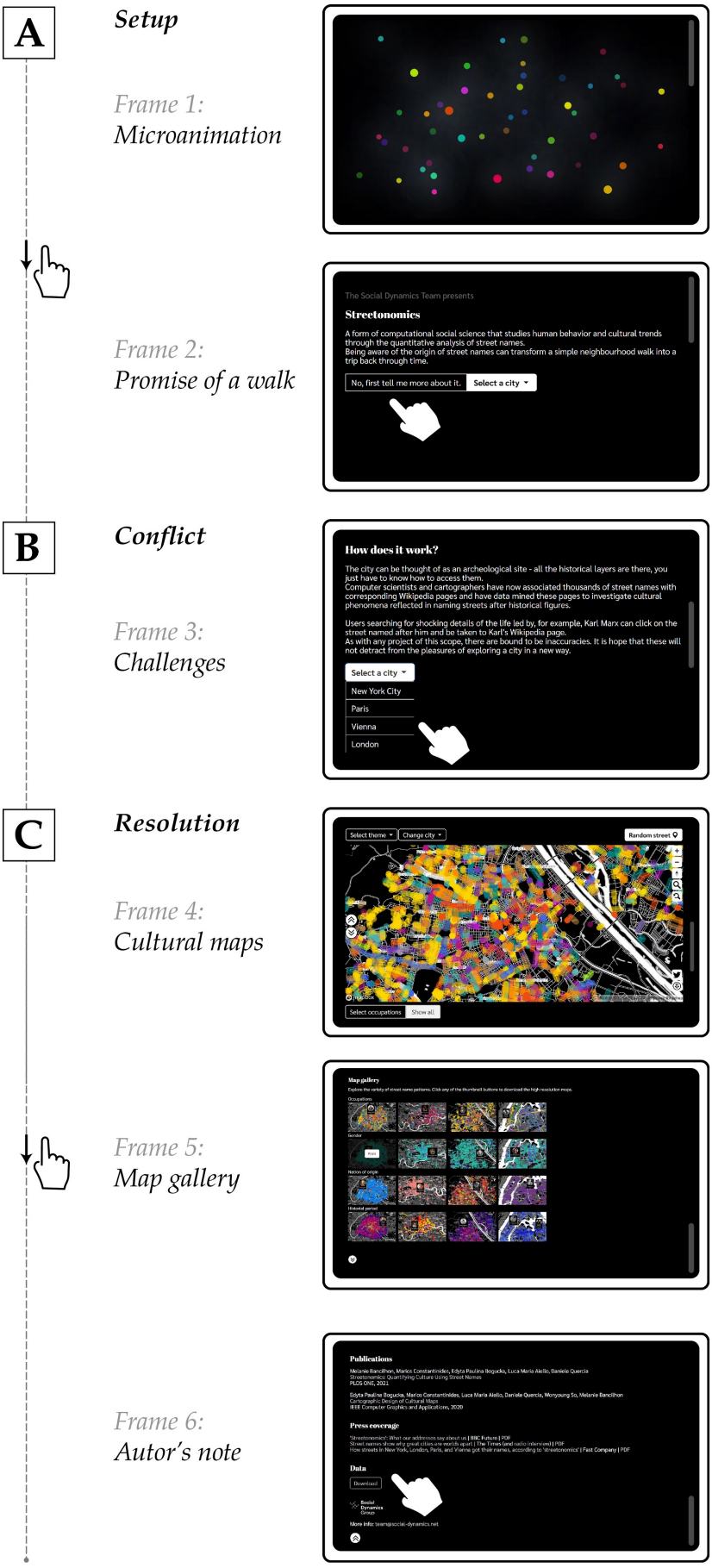


Figure 6.12: The plotline for the story on street name patterns following the three-act spatial narrative (Roth 2021).

Map interactions

Single map interactions (Roth 2013) were grouped into three functional tabs in the story interface (Figure 6.13):

Map controllers (M) allowed for transitions between the general and local views of data. Basic manipulations of map extent were achieved with manual zoom and pan (M1), rotation (M2) and zooming to a specific georeferenced address (M3).

Data selectors (D) acted as filters to explore data clusters. By clicking at dropdown D1 one could change the map theme and with D2 a city of interest. The visibility of different occupational categories was switched on and off with choice chips (D3). Finally, one could explore the temporal clusters with the denomination slider (D4).

Engagement triggers (E) encouraged serendipitous discoveries and story re-telling. Once the reader clicked on the color-coded street segment, the personal card of the honoree was displayed (E1). By further clicking on the honoree's photo or name, the browser opened in the new window the associated Wikipedia page. Single streets were also obtainable with a "Random street" button that zoomed to a randomly selected street and automatically displayed a card of the honoree (E2). After using map controllers and data selectors, users could download the resulting view of the map (E3) and share it on social media (E4).

The above-mentioned map interactions could have been potentially combined into multiple data exploration scenarios. The visualization-oriented paper (Bogucka, Constantinides, et al. 2020) shows how to chain them to create visual arguments supporting the numerically-devised statistics.

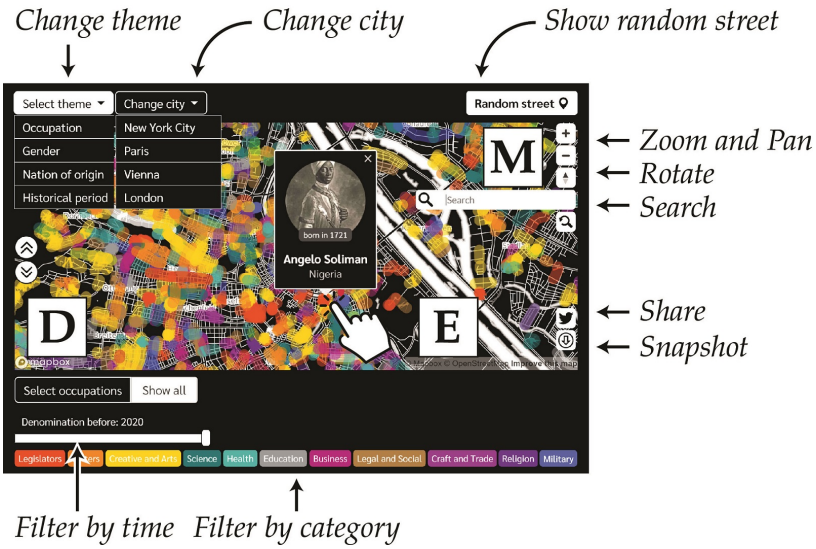


Figure 6.13: Functionalities of the interface for story pattern discovery (Roth 2013).

6.2.4 Dissemination and story feedback

The methodological paper (Bancilhon et al. 2021) was published on 30th June 2021. The dissemination package for the project included the textual summary of the main findings and three types of maps: choropleth maps from the methodological paper, a graphic with pointillist maps of top three celebrated occupations in each city and link to the full story (Figure 6.14).

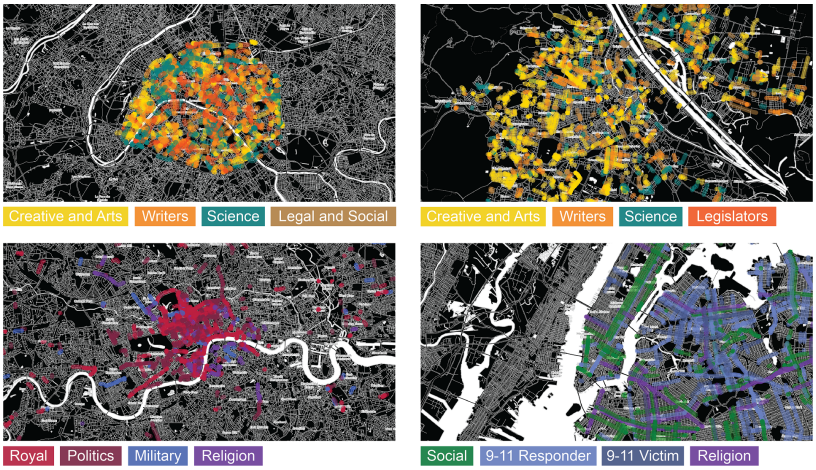


Figure 6.14: Small multiples used in the dissemination package.

The results of the research were interesting for local international journalists, since the research was framed as a comparison between the four cities. Within one month between 30th June 2021 and 28th July 2021, Streetonomics got covered by 28 online, print and radio newsrooms in eight languages, including Le Figaro, The Times, BBC Future and El País. The sections below summarize how newsrooms reproduced the maps from the story:

The Fast Company used three maps to report on the research findings. They started their story with a map of occupations celebrated in New York, then referenced the graphic with top three occupations in each city and closed the story with a screenshot of map card for Jeffrey Ross Hyman.

The BBC Future also used three maps in their coverage, but placed them in the middle of the story as visual arguments for gender bias and national focus. Journalists used the story to extract two maps for their article, specifically, to compare spatial distributions of male and female street names in Paris and London. They also included the choropleth map with shares of the streets named after foreigners in four cities.

The Science Today based in Russia featured a visual teaser with streets names in central Paris color-coded by occupations.

ORF The national public broadcaster from Austria, linked to the visual story in the articles announcing the radio interviews and during the interview.

Deutschlandfunk The public-broadcasting radio from Germany recorded a walk through New York which was accompanied with our audio-comments on the methodology and map functionalities. The journalist framed cultural maps as a tool to compare data patterns (*"With interactive online city map everyone can explore patterns in the*

naming of streets. Color coding makes it easy to see at a glance where the streets have been named after women or people from other countries. The display by country of origin makes it easy to see a colourful tapestry in Vienna.") and discover honorees' biographies (*"A click on a street here in the interactive map brings up a small infobox with honoree's photo and a Wikipedia link."*).

The Google Maps Mania blog featured cultural maps with the image of New York and map card for Langston Hughes. The same blog included Streetonomics on the subjective list of the 50 Best Maps of the Year 2021.

The cultural maps went viral on social media. Twitter users shared links to the project page and re-tweeted the paper summary published by the journal. The images accompanying these tweets mostly repeated the maps from the dissemination package. One newsroom re-created the top three occupations graphic as a GIF animation. There were three reactions that specifically commented on map design. User 1 opened the story in the mobile view and filtered the streets in Vienna to show Business and Science spots: (*Awesome site! This screenshot shows which streets in Vienna are named after science vs. business!*, Figure 6.15). User 2 wondered if the story will be extended with other maps (*This is really great. Will you do more cities?*). Finally, User 3 *A really interesting way of gaining a picture of the patchwork of a city's past – I found the London stuff particularly interesting, but all cities were interesting given their international and mercantile past.*

Figure 6.15: Re-telling of the story – user's map show Viennese streets named after businessmen and scientists.

6.2.5 Storytelling insights gained

Design with incomplete data

When working with the dataset involving humans behind the streets, we paid particular attention to data curation. Although the automatic match of street geometries with their honorees and respective Wikipedia pages was successful, we still manually checked every single entry. Very often the algorithm assigned to the honorees the very first image it found on their page, such as first page of their most famous work or a photo of a headstone. In such cases we checked all available language versions of Wikipedia to find the best personal depiction for the honoree. On the other hand, not all honorees had their Wikipedia pages and images. In such cases we used the silhouette placeholders and disabled the click interactions with honoree's image and name. Moreover, to make the user press the "Random street" button, we restricted it to randomly zoom only to these cards where both Wikipedia links and images were available.

Transferable storytelling insights

With the share-ability and virality in mind, I made two design choices that were not visible at first glance. First, I set the default starting view of the cultural maps to the thematic layer of occupations. This color scheme resulted in the map-like images that were the most similar to the original pointillist paintings. This proved to be a right choice, since most of the newsrooms used this thematic layer in their articles. None of the outputs re-used the origin maps of honorees and temporal views. Second, for each theme and city I created a pre-defined tweet text and a card image. Altogether I made sixteen different cards for each exploration scenario. For instance, users who explored the gender imbalance in Paris, after clicking the share button, would post on Twitter the street map of Paris with green and purple shades (Figure 6.16). The created visual language of cultural maps was particularly visible in online search, e.g., when browsing for the new term *streetonomics* in Google Image Search (Figure 6.17).

Figure 6.16: Exemplary Twitter card showing gender bias in Paris.

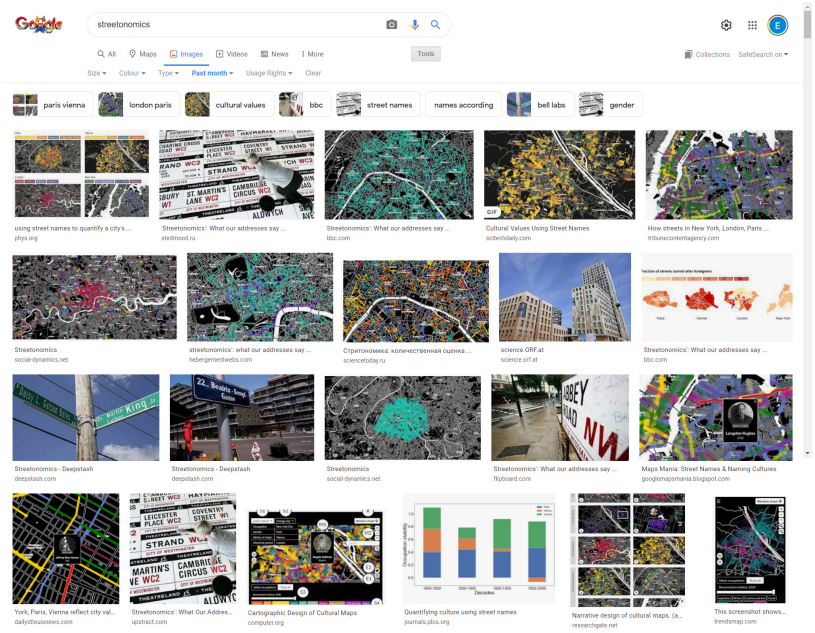


Figure 6.17: Results of the Google Image Search results for streetonomics.

6.3 Case study 3: Urban vitality maps

Urban vitality maps were created as a part of the research collaboration with the Social Dynamics Team of Nokia Bell Labs. The collaboration took place between August 2021 - August 2022. Researchers from the group developed a state-of-the-art deep-learning framework to predict urban vitality scores from one source: Sentinel-2 satellite images (Šćepanović et al. 2021). They tested the approach on six Italian cities (Bologna, Florence, Milan, Palermo, Rome and Turin), and found out that their model could explain on average 55% of the urban vitality variance.

The story is publicly available under the following link: www.social-dynamics.net/vitality.

The results of the research were presented in the scientific community during the 24th ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW 2021) and International Future Lab AI4EO Symposium (2022). Finally, the story was also shortlisted in the "Information is Beautiful Awards" competition in the "Places, Spaces and Environment" category (2022).

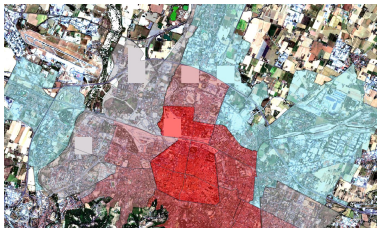
6.3.1 Data

The data inputs for the story were original satellite rasters and choropleth vitality maps. For each city, the researchers downloaded the earliest possible satellite image from the Sentinel-2 mission. The three spectral bands of the image (B4, B3, B2) were merged into a geo-referenced, true color composite raster. This raster was then cropped twice: first, to the city boundaries, second, into 8,400 imagelets – small images 64 × 64 pixels each (Figure 6.18a). Using a deep-learning framework, the researchers extracted urban features from the imagelets, and combined them with vector data from Open Street Map and mobile phone data from Telecom Italia. The framework produced one vitality score for each city district, that was then visualized on the choropleth maps (Figure 6.18b).

6.3.2 Needs assessment

Urban vitality is a crucial factor describing the well-being of the city. This complex concept combines multiple metrics (e.g., human activity, urban movements, building structures) and is therefore hard to understand by non-expert audience. The prevalent visualizations explaining vitality did not consider designing approachable interfaces for general audience. Instead, they focused on developing complicated visual analytic systems for urban planners and decision makers (Zeng and Ye 2018).

(a) Exemplary set of imagelets for Bologna.



(b) Choropleth map of vitality levels in Bologna.

Figure 6.18: Input data for the story – the case study of Bologna.

I wanted to tackle this problem by developing a visualization which simplifies multiple vitality metrics to one visual representation. Yet, the complexity of topic was very high, as the research covered multiple cities and the deep-learning framework convoluted several data processing steps.

One of the research findings was that, in general, the city centers were more vital than their outskirts. This was visible by looking at the choropleth maps placed side-by-side, but it did not shed a light on how did the city-specific urban forms contribute to this variability. Therefore I decided to unfold the research in the *Longform Infographics*, that would incrementally build readers understanding, starting from how urban forms are depicted on satellite images, through the algorithmic image processing to presenting the final vitality maps. I also wanted to achieve the synergy effect by extending the existing choropleth maps with imagelet references.

6.3.3 Prototyping urban vitality maps

Unlike with previous projects, I started the story design from formulating the key steps of the research and then designed visual encodings to support the key story findings (Table 6.3). I divided the story and its interface into four *Frames* with color swatches, framework explanations, DNA stripes (vitality continuums) and interactive dot grid maps (Figure 6.19).

Table 6.3: Variables and codes used in the urban vitality maps design.

Variable	Code
Story theme	Science, Urban, Environmental
Genre	Longform Infographics
Site layout	Single column
Story elements	Maps Satellite images Matrix and grid Bar chart
Story flow	Scroll
Type	Proportional symbol
Symbol color depth	Full color
Background color depth	Monochrome Dark
Framing	Argument Ending
Layout	Fragmented, Emphasized

Color swatches

The first *Frame* explained on the example of roofs how high- and low vitality spaces were depicted on satellite imagelets (Figure 6.19B). Different roofs were presented on twelve swatches composed by merging the average imagelet color with the underlying imagelet source. The presented swatches indicated urban activity by presenting roof shapes, structures and colors in the residential (Figure 6.20a) and industrial areas (Figure 6.20b). The average color of each imagelet was calculated using the K-means clustering method.

Framework explanations

In the next *Frame* (Figure 6.19C) I explained the principles behind the deep-learning framework by revealing through scroll-based interactions a set of static images of Bologna (Figure 6.21). The first two images showed how a satellite raster was cropped to 620 imagelets. The next two *Frames* highlighted where the low and high vitality imagelets were to be found in Bologna. The fifth frame presented users with imagelets depicting the city center of Bologna. The accompanying text explained how the model combined imagelets with mobile data. The framework explanation was finished with a microinteraction. After clicking a button, users could see how the previously highlighted imagelets are sorted into a DNA-like continuum based on their vitality score. This familiarized users with the following *Frame*.

DNA stripes (vitality continuums)

The comparison *Frame* showed colorful DNA's of six Italian cities and allowed for interactive exploration of connections between the vitality levels, colors and city features (Figure 6.19D).

The first user interaction was dissecting the DNA stripe by a coverage category (Figure 6.22). Once user clicked on the associated button, the category was highlighted in the DNA stripe. The position of the coverage category in the DNA sequence was dependent on the unique characteristic of the city. For instance, the urban forest Prati di Caprara in Bologna was much more vital than peripheral forests in Torino. The second user interaction was hovering over any DNA section. When performed, users were shown with the boundaries of the section and the tooltip displayed the coverage name and exemplary imagelet.

I generated the vitality DNA stripes separately for each city. The process involved several image processing techniques together with the color frequency analysis (Figure 6.23). The process started with coming back to the original choropleth maps of urban vitality. On these maps each city district was assigned to a vitality class, ranging from 1 (low vitality) to 5 (high vitality). I compared then the classes on the map against the underlying satellite image. The comparison script iterated over every 25th pixel of the satellite image in order to fetch the color of this pixel and its associated vitality class.

In the next step I grouped the obtained pixel samples into color clusters. The color cluster corresponded to a certain land cover category, for instance, red pixels in Florence were associated with roofs in residential areas. I started from re-calculating the pixel colors from the RGB scale (screen-based, satellite-based) to the CIELAB color space (human perceived). Using the CIELAB scale and the cosine K-means method, I calculated between 4-7 color clusters for each city. Each city had its own number of clusters that worked best, for instance for Bologna we were able to distinguish six clusters (land cover categories) and for Palermo only four. For each color cluster I calculated its average vitality value and we sorted the colors in the cluster based on their hue component. I placed then the clusters in the color bar based on their average vitality levels - from the lowest average to the highest average.

The initial sorting of pixel samples within cluster was based on the hue. Yet, it did not produce visually pleasing gradients, as there was too high chroma jump between the clusters. To generate smooth gradients within and between clusters, I calculated the five most dominant colors in each color cluster using the K-means clustering method. I then made the linear gradient between these color stops, keeping in mind the right placement of stops to convey the share of each land cover class within a city.

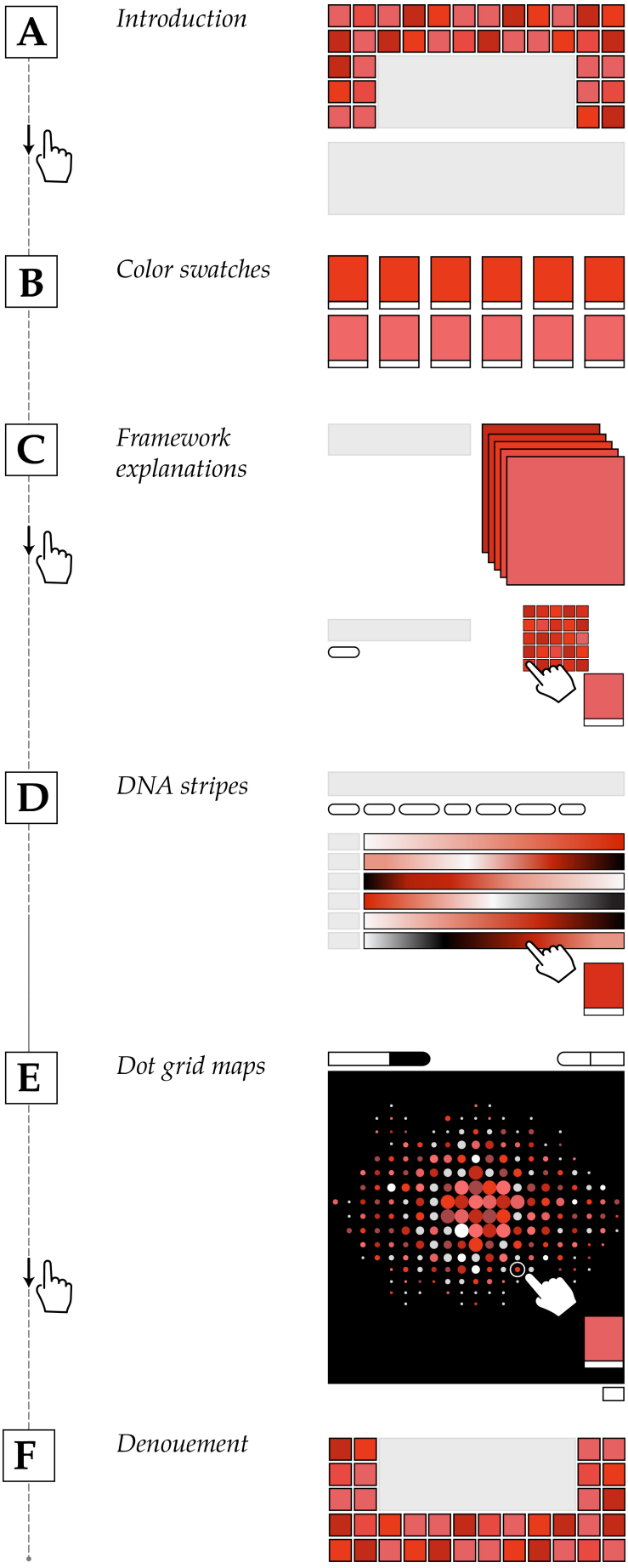
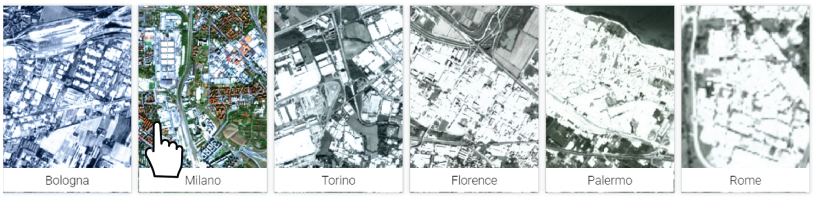


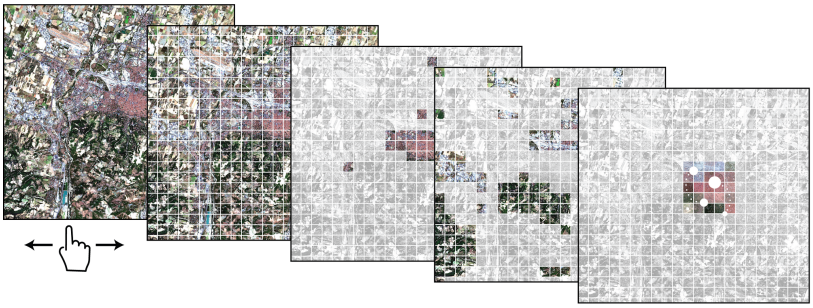
Figure 6.19: The storyline for the visualization.

(a) Roofs of residential areas.

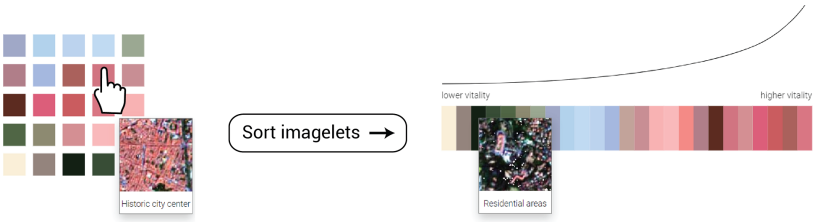


(b) Roofs of industrial areas.

Figure 6.20: Twelve swatches overlay satellite imagelets and their average colors.



(a) Slideshow with image processing steps.



(b) Sorting imagelets to vitality continuum.

Figure 6.21: Explanations behind the deep learning framework for satellite image processing.

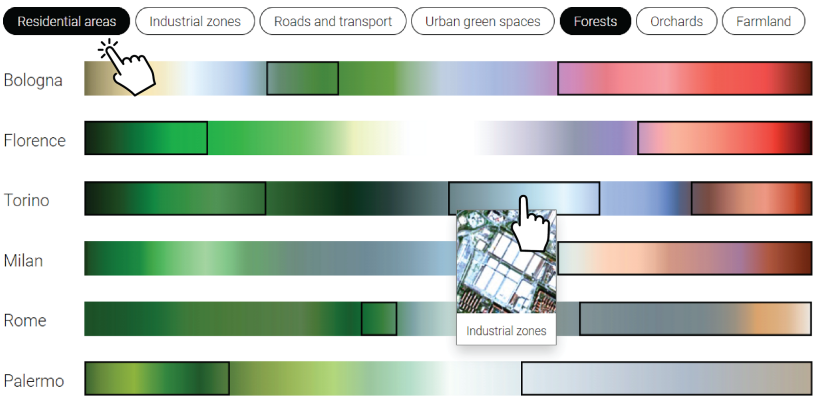


Figure 6.22: Vitality DNAs.

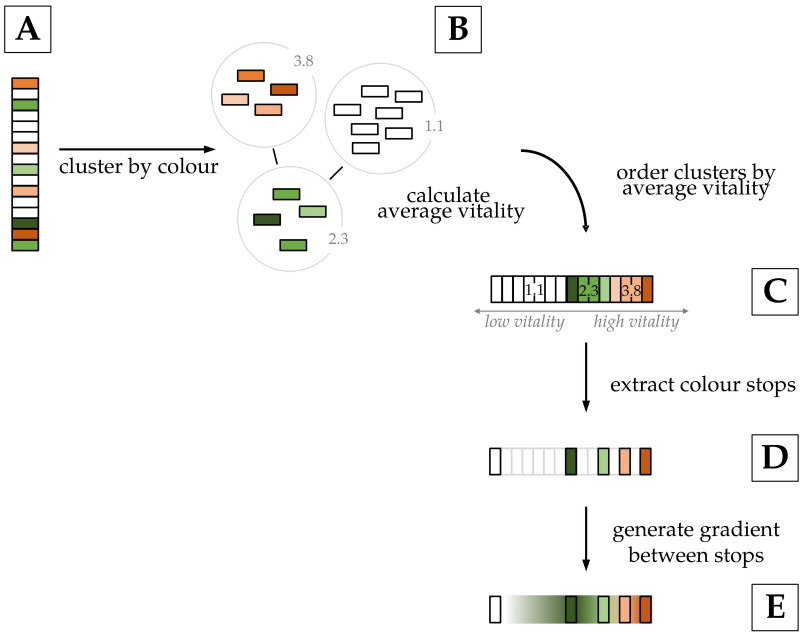


Figure 6.23: Process of generating the vitality DNA from pixel colors.

Interactive dot grid maps

Once the readers gained the understanding of most vital colors and structures in the cites, I invited them to explore the dataset in detail. I decided to replace the initial choropleth maps with dot grid maps (Figure 6.19E). Such replacement possibility was suggested already in 1967 by Jacques Bertin, but there were three main reasons why we used this approach. First, displaying dots in the regular grid was visually analogous to splitting satellite image into imagelets. Second, I could create bivariate dot symbols with visual variable of color encoding the average imagelet color and the size variable for vitality score. Third, I could make our dots more interactive than districts polygons.

Users could interact with dots using two view modes. The first one was to show dots in their original geographical position (Figure 6.24), and the second was to sort the dots in the hue grid (Figure 6.25). In both view modes users could hover over the dot to see the associated imagelet and vitality label. Finally, dot grid map for each city was also accessible in full screen mode.

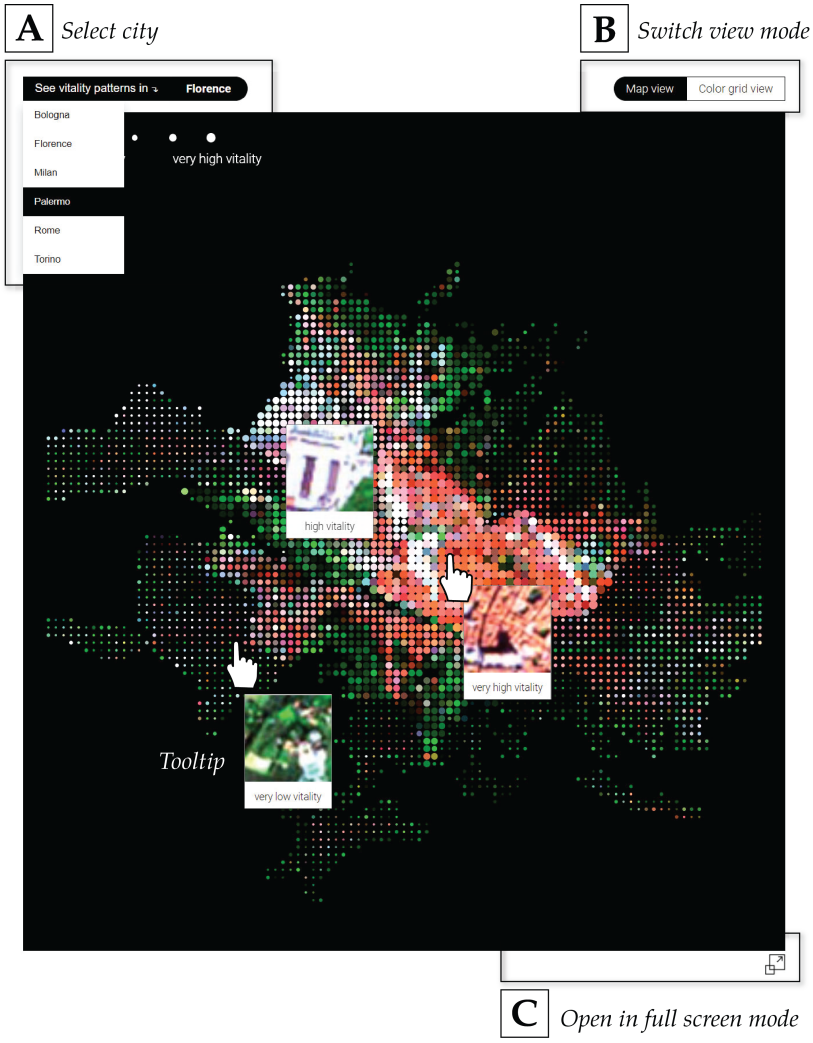


Figure 6.24: User interactions for the first dot view – a map.

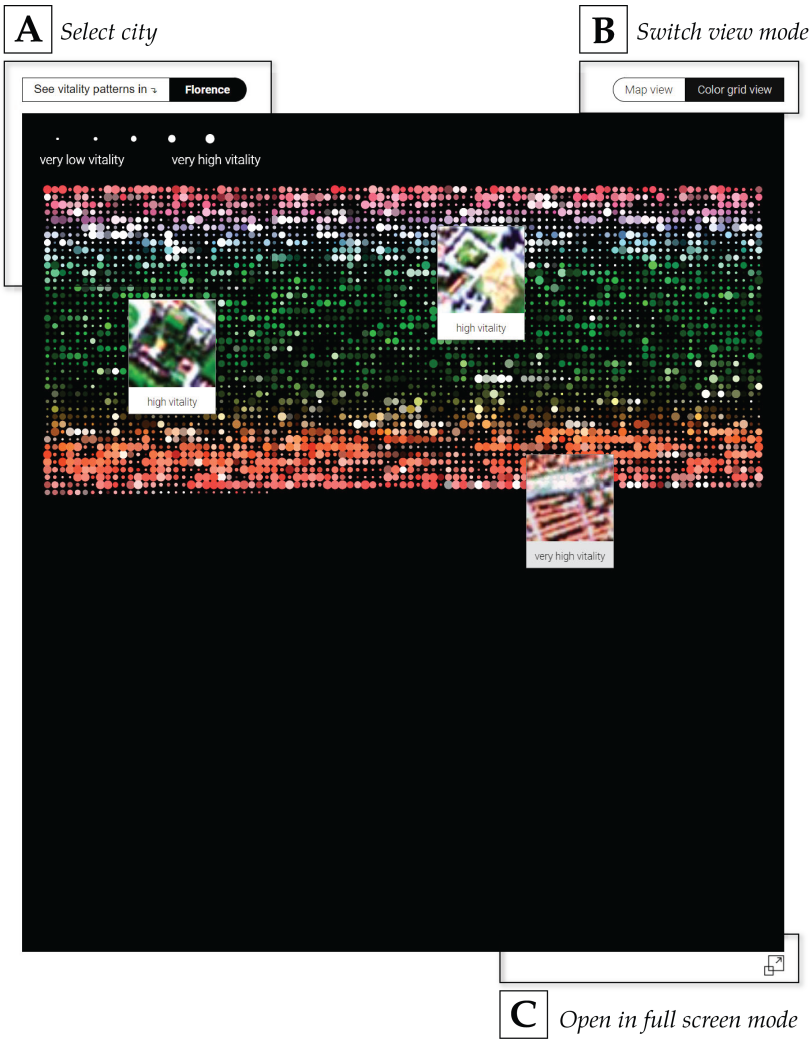


Figure 6.25: User interactions for the second dot view – a grid.

6.3.4 Storytelling insights gained

Design for yourself

What was different about this project, was the non-typical format of input data. They were no standard points, lines or polygons, but raster-based satellite images and choropleth maps instead. In fact, they could serve as primary data sources for designing various map-driven charts. In other words, it was an invitation to expand the design toolbox and create new forms of visualizations without using the "standard" cartographic software such as QGIS or Adobe Illustrator. Instead, I used two JavaScript libraries – p5.js for creative coding and D3.js for data-driven visualizations. This allowed for generating multiple design variations by changing just one parameter in the code, e.g., increasing dot density. The cartographic design of interactive maps does not finish when the map is exported and embedded in the website. Map appearance can be also adjusted with the browser properties. In the case of this projects, the original imagelets were of low contrast. Editing the 8 400 imagelets as single image files would be very time consuming. Instead, the story relied on the original satellite images and I used the Cascading Style Sheets (CSS) filter to raise the image saturation and contrast on the fly.

Design for delight

The research was not covered by any newsroom during the paper dissemination period, yet we received two comments on social media that informed this insight. The first user expressed their preference for DNA stripes: (*Beautiful work! I personally appreciate the color ramps that characterize different regions.*). The second user suggested the new direction for the mapping: *Beautiful! Makes me think, it will be interesting to see a similar approach used in parts of the world where vibrancy and city form is a bit more ambiguous and to see what readings emerge from that*.

As both users included beauty in their experience descriptions, I reflected on the storytelling process from the perspective of data delight. The story shows six unique characters – Italian cities – that had their local characteristics of colors and urban structures. As textual explanations in the essay were long, I did not want to lose users' attention before they see the final maps. Therefore in this project I ensured that every narrative section contained some small, micro-interactions. For instance, in the first section once the user hovered over a color swatch, the underlying imagelet was revealed. Similarly, small tooltips were implemented in each section to encourage small data discoveries and "staying on the path" of the story. As such, user engagement can be considered as one of the proxies for story success.

6.4 Case study 4: Emotional maps

Emotional maps were created as a part of blue sky research during a month-long workshop with community of artists, interaction designers, data scientists and educators. The goal of the "Autonomous Generative Spirit" workshop was to prototype new forms of map-based stories using generative algorithms for visual synthesis. The workshop took place between 6 and 31 August 2018 in Berlin and it was concluded with the public exhibition of the created stories. The results of the research were also presented in the scientific community during the International Cartographic Conference in Tokyo (Bogucka and Meng 2019), Social Dynamics Seminar Series (2019), Maptime Berlin (2019), and CartoHack by the German Cartographic Society (2022).

Emotional maps are publicly available under the following link: www.edytabogucka.gitlab.io/page/game.

6.4.1 Algorithm and data

Neural style transfer is an image synthesis technique that generates a new stylized image based on two inputs – a style input (such as artwork) and content input (such as photograph or map). In the first step the algorithm uses Convolutional Neural Networks (CNNs) to extract and separate the statistics of both images. In the second step, optimization techniques are used to generate the third image that maximizes both the style and content statistics of input images (Bogucka and Meng 2019).

Unlike the scientific practice of training neural networks with very big datasets, artistic experiments with style transfer could involve small but well curated set of data. The starting point for this project was to collect multiple pairs of inputs for style and content components. The style components consisted of multiple personal paintings. I asked the participants of the workshop to reflect on their current emotional states and express them through watercolor paintings. Then I digitized resulting paintings and cropped the scans into square aspect ratio. The second content components were designed in Mapbox Studio as plain basemaps without any accompanying labels. The basemaps presented the most distinguishable urban features of Berlin, such as roads, buildings and land use types. In the next step both types of inputs were merged together (Figure 6.26) using the neural style transfer implementation by Johnson (2015). Paintings and map samples had an equal contribution in the generated images, as both influence weights were set to 0.5.

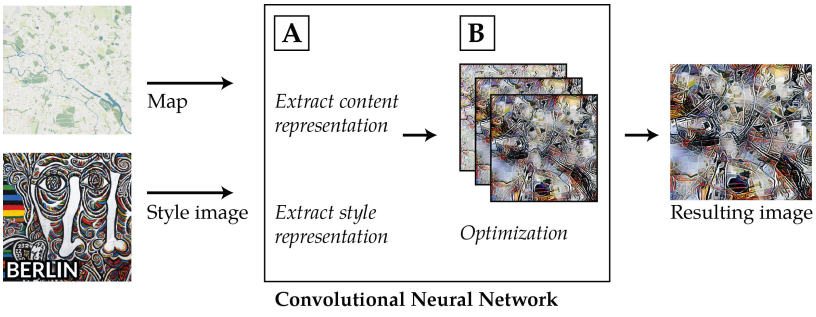


Figure 6.26: Combining textures and basemaps into emotional maps.

6.4.2 Needs assessment and prototyping

The goal of the story was to familiarize broad public with the neural style transfer by encouraging them to de-code the internal logic of the algorithm. As the story was to be presented in the physical exhibition space at the end of the workshop, its narrative needed to be engaging and thought-provoking, yet very short and not overwhelming with technical explanations of algorithms. To do so, I decided to experiment with the gamified storytelling ((Table 6.4, Chou 2017) and I created Style to Tile – a memory-like interactive experience. The goal of this card match game was to find pairs of human-made painting and machine-generated map.

The story consisted of two *Frames* (Figure 6.27). The first *Frame* explained in plain English the goal of the game and presented the workflow of the algorithm using three images - map input, artwork input and the generated map-like image (Figure 6.27A). This *Frame* was describing the mission of the experience and familiarized visitors with the possible types of generated images. Then visitors could choose between three difficulty modes – easy (6 pairs to be discovered), medium (10 pairs) and hard (15 pairs). After the mode selection, the second screen was enabled that displayed all *Cards* turned face down (Figure 6.27B). The visitors could start the round by selecting two *Cards* and flipping them face up. If the images contained the matching pair of the artwork and the synthesized image, then the visitor won the par. If the images did not match, the *Cards* were turned face down. As the artworks differed in their styles, it helped to maintain visitors curiosity for the upcoming tasks after collecting the first *Card* pair. The visitor could continue playing in single-player mode or could pass the game to the next visitor. The visitors were following the plot until all image pairs were discovered.

Table 6.4: Variables and codes used in the emotional maps design.

Variable	Code
Story theme	Culture, Heritage
Genre	Other
Site layout	Grid of cards
Story elements	Maps Satellite images Matrix and grid
Story flow	Entry points
Type	Other
Symbol color depth	Full color
Background color depth	Multichrome
Framing	Teaser Parallel plot
Layout	Fragmented, Emphasized

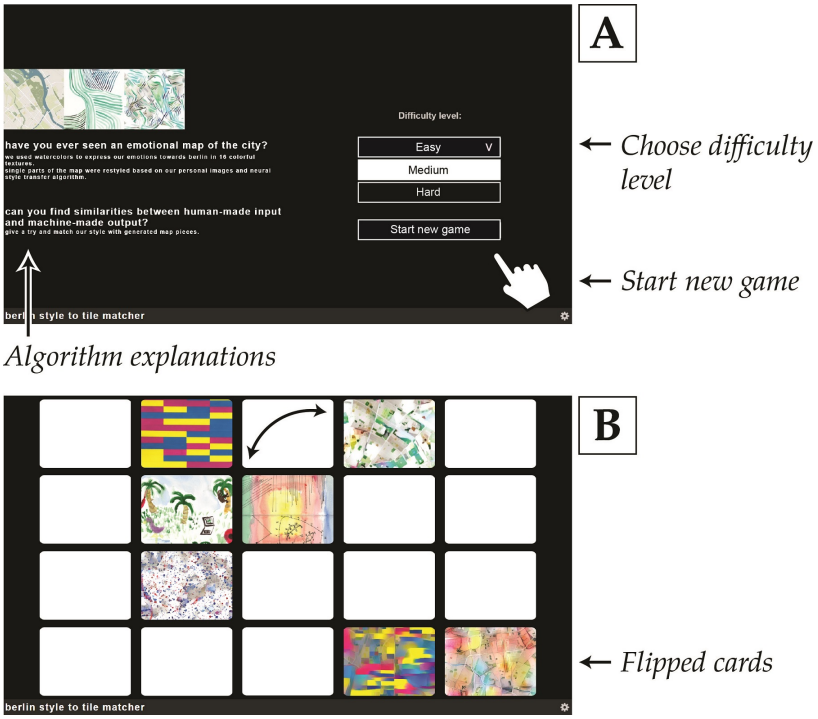


Figure 6.27: User interactions in the emotional city game.

6.4.3 Dissemination and story feedback

The story was exhibited during the final show at School of Machines, Making and Make Believe in Berlin (Figure 6.28). The reactions to the game were captured in person directly after the interaction session and could be divided into two thematic groups - **manipulation** and **personalization**. Visitors considered the game visually attractive and evocative. They were able to recognize the map-like qualities in the synthesized images, but they could not name what specific image manipulating techniques were used by neural style transfer (Visitor 1: *This was like map view from satellite, but with different colors*, Visitor 2: *Were these aerials of a town photoshopped with pastel colors?*). For the personalization theme, visitors expressed their wishes to create similar maps by exchanging the types of artwork. Visitor 3 mentioned that she *was moving between cities three times* and would like to *celebrate these transitions with maps of her favorite murals in each city*. Another visitor added, that he *moved out from Munich, but this is a city where my son was growing. I would like to transfer his first drawing on Munich's map*.

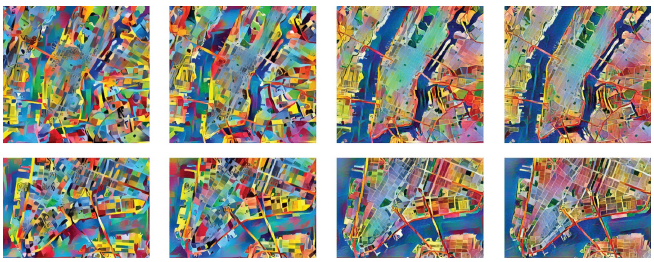
Figure 6.28: Visitor playing the game during the exhibition.

6.4.4 Transferable storytelling insights

The generated images were not "correct" in terms of cartographic standards. Their main drawbacks included the lack of consistent symbology, erosion of geographical objects or contrary, their visual exaggeration. The obtained "designs" were very subjective to the input data, and as such, hardly reproducible – for instance, different crop extent of style input would result in different image statistics and would be propagated to the generated image (Figure 6.29).

However, there are two directions in which algorithms and games can support visual storytelling. First, synthesized images can serve as visual teasers for the story. Due to their unique characteristics, the exhibition visitors connected them with knowledge emotions of interest and surprise. Majority of the generated maps (85%) evoked neither fear nor anger, and was perceived as slightly trustful (59%) and trustful (35%) (Bogucka and Meng 2019). This positive attention gain can be used later in the story to explain the story topic with more conventional data representations. One can also think of pairing two maps - "typical" and neurally-adjusted to make stories more memorable and relatable.

(a) Different crop extent of content. input



(b) Varying map designs for two extents of input content.

Figure 6.29: The instability of design with neural style transfer.

Second, such map-based images are examples of personal, yet incomprehensible visualizations. At first glance they look like artistic maps, yet the input style might be only understandable and meaningful for the single user. As the new methods of human-computer interactions emerge, the style transfer models can be embedded in web browsers as tools to re-tell or re-design the story in the personally-appealing style.

Design for playfulness

The intersection between data visualization, gamification, simulation and education is of a particular interest for Explainable AI domain (XAI). The game-like experiences or virtual sandboxes could be much more than just new forms of storytelling. For instance, in a scenario of raising awareness on how the machine learning algorithm work, they can help make sense of complex topics by allowing users to engage with the data in the rehearsal and trial environment. The story readers could use the sample of real data or upload own data to understand the implications of this algorithm for personal case studies.

6.5 Summary of transferable storytelling insights

The created portfolio demonstrates that it is possible to achieve a synergetic effect between cartography and journalism. The eight design prompts for fostering cross-disciplinary practices in map-based storytelling can be therefore summarized as:

1. Design with domain experts.
2. Design for multiple audiences.
3. Design and re-design.
4. Design with incomplete data.
5. Design for re-telling.
6. Design for yourself.
7. Design for delight.
8. Design for playfulness.

Discussion and implications

7 Discussion

7.1 Design trends

There seem to be a huge gap between what could be achieved in terms of cartographic design of stories and what was prevalent in the collected data sample. The analysis revealed three main trends of data-driven visual stories:

Templatization – the analysis showed that great single examples of story maps are rather design outliers. In the mainstream storytelling we observe the effect opposite to hybridization. We frame it as the templatization - an omnipresence of generic, content agnostic map designs with interchangeable data. Lonform Infographics and Static News Maps used to be the most common story genres (Roth 2021). As showed in the analysis, Longform Infographics still remain most popular, but technological advances have made the Multimedia Visual Experiences the second most popular genre (31%). In comparison to historical newspapers featuring full-spread maps (Figure 7.1), online maps became layout-less. Instead of being the key component of the story, they float between pieces of text in vaguely defined frames (Figure 7.2). In previous decades, maps were predominantly used to present violent events and political affairs (Mode 2017, Schulten 2015). In the last years the emphasis has been switched to science, society and culture.

Visual blandness – templatization also leads to the *grey zones* of similar looking maps, with limited possibilities of visual apperception and building knowledge in relation to previous map designs. Moreover, it became more difficult to grasp what is the visual rhetoric of modern maps. The most dominant are authoritative and understated styles, that can barely be distinguished. Even the propaganda maps became less prevalent and powerful, narrowing down their key characteristics to dark backgrounds and contrasting symbols. The use of contrast was however more visible in understated maps, especially to refresh the "classical" thematic maps such as choropleth maps. Over time, these prevalent "vivid maps" became less appealing. Due to their generality, one can barely recall what the actual topics were behind their colorful patterns.

Rareness of map-driven interactive experiences tailored to map content – the preliminary study on GIS-driven story maps (Zuo et al. 2019) highlighted the need of presenting multiple maps in order to create a plotline of the story. The vast majority of the stories created with ESRI Story Map templates used at least one map to unfold the story (82%). On the contrary, the analysis of journalistic stories showed that only 55% of them use more than one map to unfold. ESRI Story Maps and journalistic maps also noted a similar dynamic of abandoning certain functionalities. The interactions that used to be present, but are not popular now are map overlays (6 stories in 2019 vs. 2 maps in the analyzed sample) and data filters (3 stories in 2019 vs. 10 stories in the analyzed sample).

Maps used in the visual stories were treated as static visual arguments used to convince readers. Therefore there were nearly no possibilities for readers to customize even a simple map, such as re-expressing the map type or changing the color scheme behind the map. The interactive unfolding of the story was limited to scrolling and looking on the inactive images. There was also no need to come back to the story after one read, as no new content was added. The only stories that were regularly updated were the COVID-19 trackers. One could wonder if such compilations will disappear due to their negative connotations, or opposite, they will be kept to narrate other indicator-related topics such as progress in achieving sustainable development goals. With the increasing capabilities of web browsers, human-map interactions could be more complex and may make use of other inputs, such as voice or gestures.

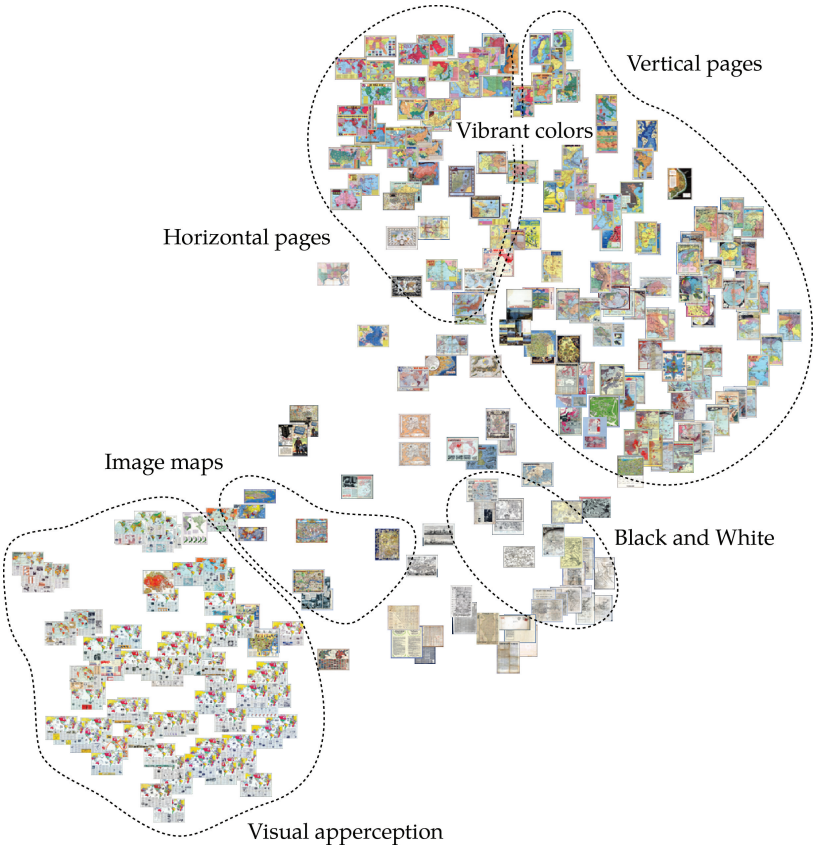


Figure 7.1: Design space of paper-based newspaper maps published between 1920 — 1950. Source: David Rumsey Map Collection.

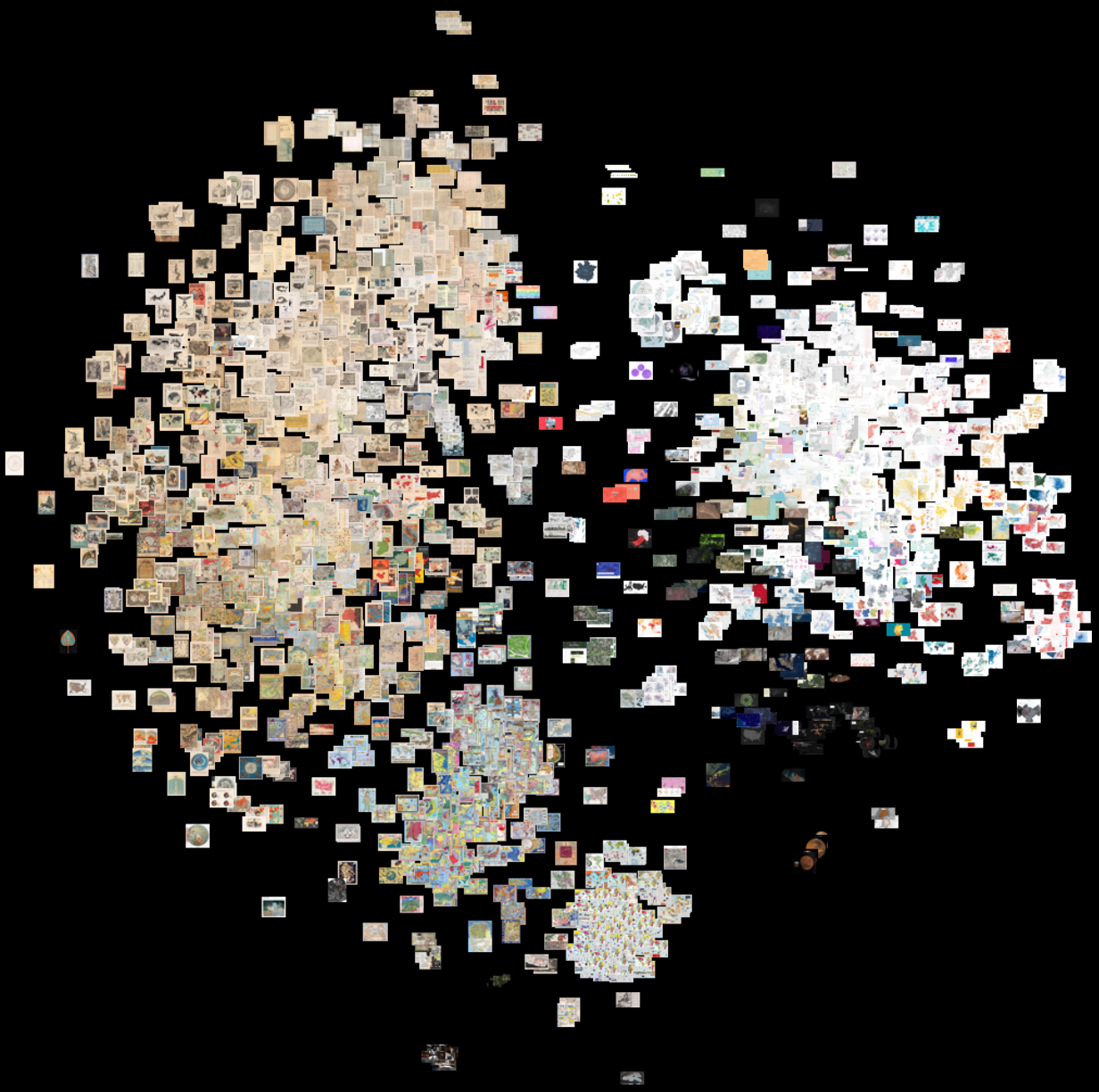


Figure 7.2: The design space of all maps from the visual archive.

7.2 Design opportunities

The analysis prompts a number of improvement strategies. Needless to say, not all stories can be summarized as template-based stitches of text pieces and maps. After reading all map stories, it became visible that stories that include multiple maps have some underlying philosophy on sequencing them to unfold the story content. These recurring strategies were firstly annotated and then grouped during the open sorting procedure into a narrative card deck (Bach et al. 2018). Finally, it was possible to distinguish fourteen map-based unfolding strategies for three types of story plots: main plots, parallel plots and sub-plots (Figure 7.3).

7.2.1 Strategies for main plots

Scale transformations – the unfolding of the story relies on changing the scale of the map. The **zoomytelling** is based on adjusting the narrative distance between the audience, zoom levels and dataset details. An exemplary story may start from a single data point, e.g., a tree. In the subsequent story frames the map scales are successively reduced to local, regional, national or global, e.g., by presenting a local forest, all forests in the country to conclude with global forest view. An opposite direction of the narration can also be set – starting from global overviews and narrowing down to their local meanings. In similar way, the **follow-the-path** technique allows to adjust the map scale while following the phenomena that is linear in its nature, e.g., the location of underground lines or flow of the rivers.

Visual teaser – the story starts with a captivating map, temporal map series or a map sequence that is then decomposed into single story frames.

The **temporal snippets** and **temporal clusters** techniques start a story with an animated map sequence. As the story progresses, audience sees the timestamps or time clusters repeated from the teaser content. Similarly, the **spatial drilldown** presents one big map in the teaser, which is then chopped up into self-sustaining pieces that explain or highlight interesting data patterns. Another variant consists in the unfolding of multivariate mapping using archetypal map legend as the ordering dimension. The following text modules describe then the interesting combinations between these variables (J. Nelson 2020).

Unfold matrix follows an opposite logic. The story teaser contains a mash-up of self-sustaining pieces that have some intrinsic order, e.g., small multiples showing the share of parks in five biggest cities in Germany. The multiples are then explained in the story text one after another, e.g., by starting from the cities with the smallest shares of parks to end up with the cities with the highest ratio.

Circular return contains the map in the teaser and repeats the same map at the end of the story. The second repetition re-frames the initial map use context, e.g., with an extra question or new interactions to let user play with the data and reinforce the key message of the first map.

Personal journey techniques are based on the personification strategies. These include **gamification**, where user is asked several questions and the answer is delivered as a personalized map. On the one hand, this approach might also put a single user in the context of other story readers, e.g., by presenting how many people received similar looking maps. On the other hand, user reactions to the story can be used to update the story content. In the **persona-driven** scenario we choose a character whose journey we want to follow. The persona can be a real person or a stereotypical summary of character traits. Finally, the **location-tailored** story displays different story content based on the location of the user. The idea behind is to make data relatable to the personal context before showing the global topics. For instance, a story about global warming can start with a local view of the number of hot days in user's city and end up with global statistics.

7.2.2 Strategies for parallel plots

Parallel plots present equally important, yet separate narratives of story character. These are mostly based on visual comparisons. The **persona-based** comparison displays maps and spatial developments of two different characters. For instance, we may visually accompany their journey through the day to see where they are and what they do at the same time. The **space-based** comparisons present how the same phenomenon develops differently in different places or how different starting conditions end up with the same effect. Finally, **visual overlay** blends maps that share some common characteristics, e.g., show the same city but in two different time periods.

7.2.3 Strategies for subplots

The **subplots** introduce **supporting characters**, reveal new information about the story space and intensify the conflict in the main plot. In the analyzed sample subplots were introduced through breaking the linearity of the layout. This can be achieved by **changing the layout** from horizontal to vertical (z-shaped story patterns) or by coupling the story with a stand-alone, aiding **dashboard** that drags users out of the story flow. Such complementary dashboard allows for the exploratory data discovery and contains functionalities to bring users back to main story with the newly gained knowledge in mind.

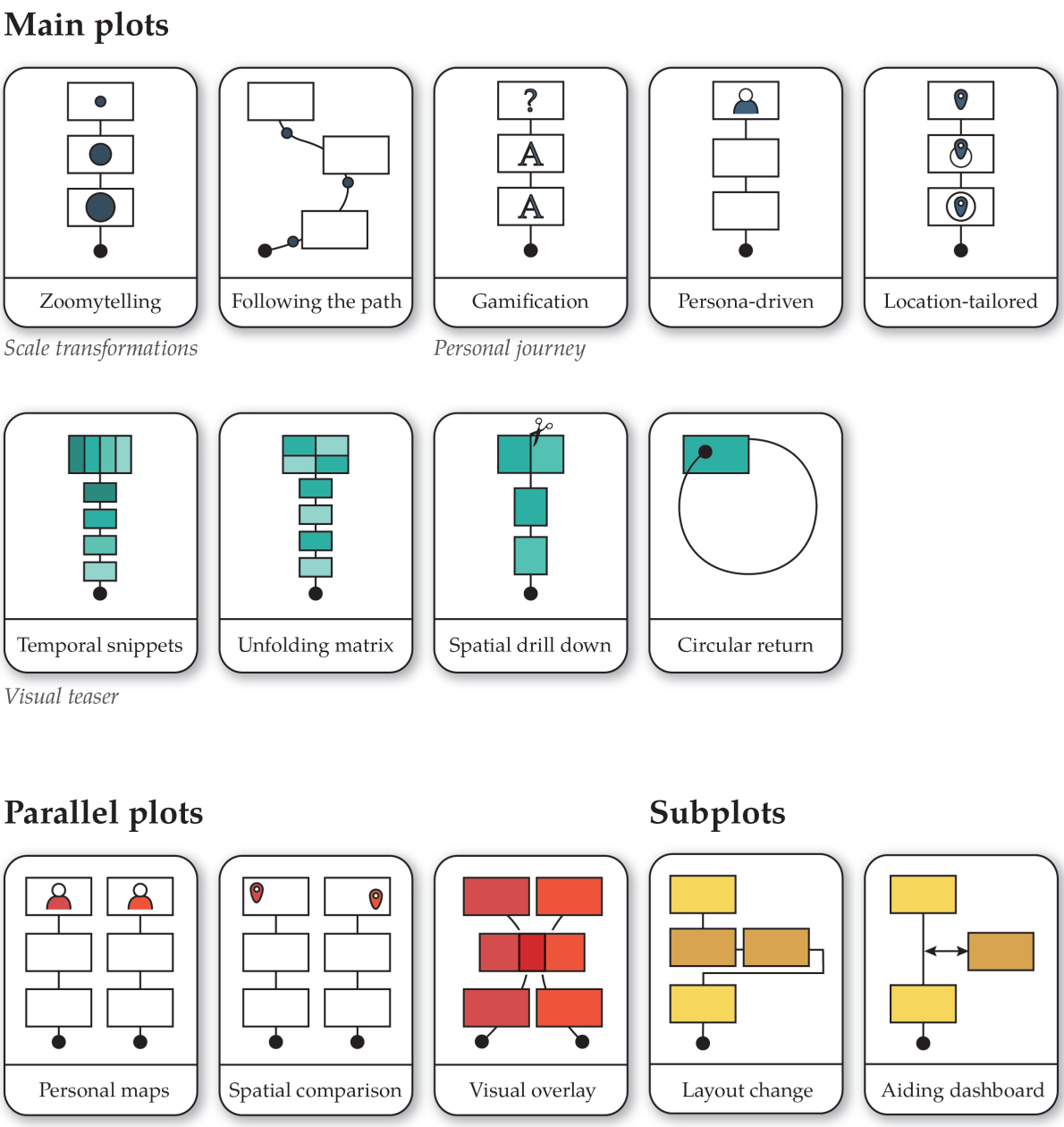


Figure 7.3: Stack of narrative cards for main plots, parallel plots and subplots.

7.2.4 Strategies for cartographic UX writing

The linearity of map-based stories is so far mostly driven by text rather than visuals. Two strategies may help prevent the spread of layoutless map-based stories. The one is to find ways to strengthen the visual affordances of the story flow. The other and more feasible strategy is to strengthen the already existing connections between map content and text. Such small links can be achieved with micronarratives. Micronarratives are "standalone items that tell a specific part of the narrator's expressed narrative" (*Changing narratives* 2021). Their key characteristics are the stand-alone semantic meaning, re-usability and combinability. In the analyzed sample, there were three forms of such micronarratives:

Map tooltips and pop-ups – their preliminary function is to deliver additional data to complement the content of the map (Gaigg 2021). Engaging with a map within a story map should be a rewarding experience. Clicking or hovering on the data point is an extra user effort, therefore designers should ensure that pop-ups will not show empty data states or display raw data in the automatized, framework-dependent style. Instead, tooltips and pop-ups should be understood as small mediators between a map, unique data points and the story text.

Swoopy arrows – map annotations that directly point to the most interesting parts of the map, e.g., clusters of extreme values. They might be used to indicate the hierarchy of findings from the data-rich maps and to encourage audience to "mentally draw" own paths to personally relevant patterns.

Embedding map legends in story text – traditional mapping approaches place map legend as close to the map as possible. However, the scroll-driven storytelling tend to organize the story around small excerpts of map legend and map content. This includes embedding small maps or map legend directly into the story text, thus providing users with integral information chunks.

Modes of personalization Although we are seeing the emergence of audience-centric modular journalism, traditional newsroom outputs have only demonstrated very limited possibilities for story personalization. Two types of such efforts were revealed in the analyzed maps. The first one was shortening the narrative distance between storyteller and user. This was achieved by making the storyteller one of the characters of the story, e.g., through visual pun (Figure 7.4a). The second effort was to shorten the distance between the user and story content. As discussed in the "personal journey" card stack, this might include gamification, character-driven stories and location tailoring. Stories can also make use of the concepts that are already familiar to the audience to make spatial comparisons (Figure 7.4b).

(a) Visual pun – introducing story authors through a set of stylized portraits (Aranz and Hernandez 2018).

(b) Visual comparison – the smoke plumes during the Australian bush fires reached the altitude of 16km. Fragment of the visual story by Robles, Long, and Ibrahim (2020).

Figure 7.4: Two modes of story personalization.

8 Statement of impact

8.1 Outcomes and research findings

This thesis aimed at (1) exploring the development of map-based storytelling in the data-driven era and (2) contributing to the intersecting design practices of cartographers and journalists.

Cartographic storytelling is driven by contributions from an eclectic set of domains. From a theoretical perspective, this thesis reviews the storytelling concepts present in cartography, journalism, literature, fine art, data visualization, and computer science. It summarizes them in a form of a codebook, that includes the definitions for two levels of detail: a story and a map. Moreover, the thesis contains a proof of concept for chaining in a novel way multiple data-driven and image-driven research methods from cartography, data science and cultural analytics. Journalists can use the created framework to check what digital visual traces they have left on the internet and to what extent they follow the mission of their newsrooms. The framework is also applicable for other cartography researchers who work with image collections.

From a design perspective, the annotated portfolio contributes with eight prompts for map-based storytelling that address the rhetorical relationships between narrator, story map, and map users. Narrators are encouraged to design with domain experts but also for themselves. When considering data-driven stories, they should embrace the incompleteness of data, be flexible for re-design as well as re-telling. Finally, keeping in mind multiple story audiences, story maps can be designed as delightful and playful objects.

8.2 Limitations

This work has two main limitations, related to the fact that pure data-driven methods were not enough to capture the essence of map-based storytelling.

Creating a visual archive
The data collection step revealed that it is very challenging to conceptualize and store story states. To some extent, this thesis narrowed down the complexity of the full story to one primary map. From the practical point of view, it was very challenging to actually store the full plot of the story. The initial trials were concerned with exporting the story content to PDF, but the resulting file layouts were different from the story layouts. One solution would be to screenshot and merge the full extent of the story, as it was done in the annotated portfolio. Such narrative stripes can then be used as an input for automatic tagging and visual dimensionality reduction.

The second limitation came with obtaining permissions from all copyright holders. While it was possible to present miniature maps in the metaimages, single story designs need permissions for public dissemination. Therefore this thesis is limited to providing the generalized descriptions of journalistic maps, while the detailed descriptions are introduced on the example of own works.

Data analysis

The analytical part of this thesis revealed that pure data-driven approaches were not enough to fully theorize the design space of story maps. The number of collected maps was similar to those reported in other quantitative content analyses, but it appeared not sufficient for two analytical purposes. First, the correspondence analysis revealed several feasible associations, but it was not possible to test them for their statistical validity. Second, the collected data were also not sufficient to reach a high explainability of the total variance. Categories derived for visual stories explained 30% of the total variance, and categories derived for maps explained 40% of the total variance. This means that the manually labelled data were difficult to project to linear scales with the MFA. The theoretical model captures to a limited degree some properties of the map-based stories, and it should not be used to make any further data predictions.

The polysemous nature of data indicates that there might be some multiple non-linear relationships between the analyzed variables. In order to re-do the analysis, one need to re-consider the set of categories and variables that might be related to storytelling. The second step would be to find more representative stories. The sample search should not be driven anymore by the initial choice of the newsrooms. Instead, the search should follow the data density principle. The hardest point for the analytical framework was to pass the fourth contingency table assumption: the expected cell frequencies must be larger than 1 and less than 20% of all cells should have cell frequencies smaller than 5. This assumption must be met for all combinations of two variables. In practical terms, if we take the combination of two variables with 5 codes each, we need to collect minimum 1 story per code combination and ensure that maximum 4 code combinations will have less than five stories. In this sense, the data spread of 215 stories was not equally sufficient for all code combinations.

8.3 Research agenda

Data-driven map-based stories are popular in practice, but little explored in theory. There is a long way to go, therefore the upcoming research tasks can be considered in three time perspectives – present, near future and long-term future. For the time being, cartographers can continue to look for added value in the already existing hybrid forms of storytelling. The emerging trends here are stories woven around 3D-models and story systems that organize broad knowledge through a set of interconnected sub-stories.

Research for the near future may address the supporting functions of text in cartographic design. The three research sub-directions here are the cartographic UX writing, text tagging and visual ethics. UX writing refers to all texts that accompany the interface of interactive stories. Currently such texts can be found in map tooltips, map pop-ups, swoopy arrows and map legends embedded in the story text. Yet, the concept of micronarratives opens up the possibilities to search for other ways of combining text and map content into snippets supporting and enriching the main story. Although automatic tagging might not be perfect, the use of AI in this domain will continue to grow. Only recently the Machines Reading Maps initiative announced that they will scan text in 60,000 maps from the georeferenced David Rumsey Map Collection. This opens up a great possibility to see and search for historical images through the text-based networks. The methods presented in this thesis offer the new ways of cartographic interpretations for the currently disseminated maps.

While analyzing the stories it could be observed that data experiences are only accessible for the non-disabled users. From the perspective of map-based storytelling, design is a mediator to the story content. From the perspective of Web Content Accessibility Guidelines, maps, graphs, illustrations and charts are referred as complex images that require two-part textural descriptions. "The first part is the short description to identify the image and, where appropriate, indicate the location of the long description. The second part is the long description – a textual representation of the essential information conveyed by the image" (Guidelines 2019). The role of the cartographer would be then not only to ensure the visual accessibility of the story through right levels of contrast. The next step would be to design data descriptions reveal the essence and meaning of the map for the particular story.

The long-term research direction is to adapt knowledge graphs as part of story creation.The initial function of stories is to store and spread knowledge. The information model behind the story can be therefore expressed as a knowledge graph – network of characters, objects, events and situations. While we believe that the role of cartographer is to pack the story into design, future developments can shift this responsibility in the direction of enabling spatial knowledge acquisition. In fact, the process of story creation would then rely then on sub-ontologies – reusable, self-containing and logical parts of the main ontology. Such process is already being initiated by the modular journalism, that combines update-able story chunks derived from the knowledge graph. This new form of on-the-fly storytelling could include further personalization possibilities, such as ad-hoc topic suggestions and design adjustments.

Appendices

A

Codebook for Quantitative Content Analysis

A.1 Categories, variables and codes for primary unit of a story

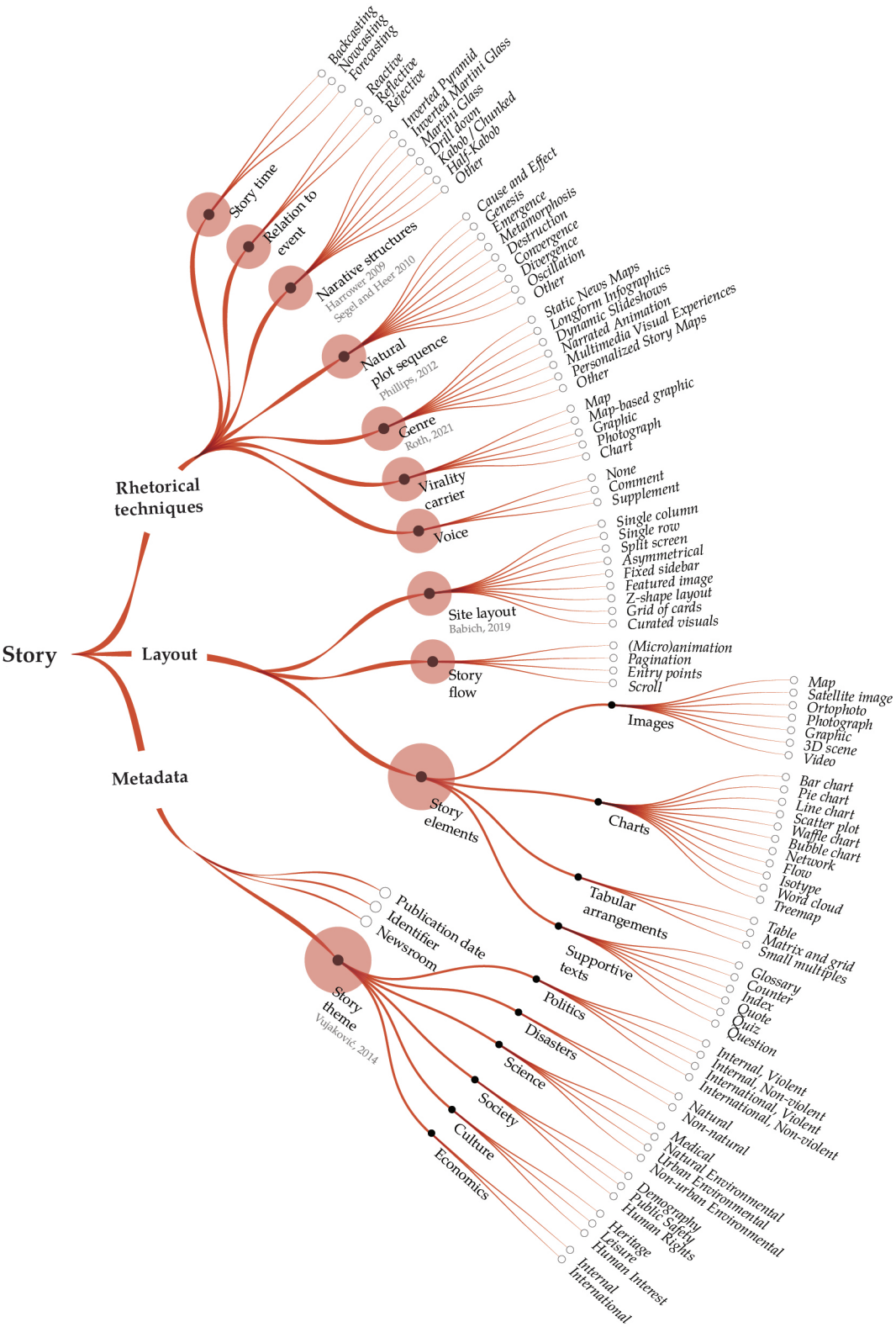


Figure A.1: Categories, variables and codes for primary unit of a story.

Table A.1: Category: Metadata.

Variable	Code	Code definition
Identifier	NYT-001	Combination of newsroom code and number
Publication Date	DD/MM/YYYY	Date, month and year uf publication
Newsroom	NYT	The New York Times
	ZO	Zeit Online
	KO	The Kontinentalist
	PU	The Pudding
	SCMP	South China Morning Post
Theme (Vujaković 2014)	Politics: Internal, Non-violent	Government, legislation, electoral, parties, nonviolent protest or strikes
	Politics: Internal, Violent	Riots, terrorism, civil conflicts, wars, secession movements, coupes
	Politics: International, Non-violent	International relations, negotiations, agreements (non-trade)
	Politics: International, Violent	Military conflicts, wars, defence issues, territorial or resource disputes
	Science: Medical	Public health, epidemiology, disease prevention, medical interventions, medical research
	Science: Natural Environmental	Environmental problems, impacts, pollution
	Science: Urban Environmental	Transportation, development and planning, civil engineering
	Science: Non-urban Environmental	Land use, land management, cultivation, forestry
	Disasters and Accidents: Natural	Large-scale, nature-related events disasters: earthquakes, floods, epidemics
	Disasters and Accidents: Non-natural	Accidents, explosions, fires, industrial disasters
	Society: Demography	Demography, social trends, housing, employment, education
	Society: Public Safety	Crime, courts, jurisdiction, police, missing people
	Society: Human Rights	Social disasters (famine, refugees), violations, equality
	Culture: Heritage	History and archaeology, heritage, arts, media
	Culture: Leisure	Travel, tourism, recreation and sport
	Culture: Human interest	Religion, royals, non-political scandals
	Economics: Internal	Micro-economics, business, finance, industry
	Economics: International	Macro-economics, trade agreements, international monetary issues, aid and economic development

Table A.2: Category: Rhetorical techniques.

Variable	Code	Code definition
Story time	Backcasting	Narrating past states
	Nowcasting	Narrating very recent past states, present states or the states in the very near future
	Forecasting	Predicting or speculating about future states
Relation to event	Reactive	Immediate reaction to the events including call to actions
	Reflective	Descriptive reflection or analysis of events
	Rejective	Events are not stressed, not recognizable, or seemingly hidden in the story content
Narrative structures (Segel and Heer 2010) (Harrower 2010)	Inverted Pyramid	Story is narrated from its most important takeaway to the least important information. Story content is divided into summary, supporting details and background information.
	Inverted Martini Glass	Story is narrated from its most important takeaway through a series of chronologically ordered events
	Drill down	Story introduces a general theme to be explored by a reader through backstories and additional details
	Kabob / Chunked	Story begins and ends with an anecdote, separated with information on *where*, *when*, *what*, *who*, *how*, *why*
	Half-Kabob	Similar to Kabob structure. The story contains begins with an anecdote, but ends with other written element, such as factoid, question to the audience or call to action.
	Martini Glass	Story consists of two parts. The introductory visualizations present author's findings and the following interactive visualizations encourage reader's data exploration
	Other	Novel story structure that can not be classified as one from the above-mentioned structures
Natural plot sequence (Phillips 2012)	Cause and Effect	Description of input conditions and their outcomes
	Genesis	Description of creation or development of phenomena
	Emergence	Explanation of emerging properties of phenomena
	Metamorphosis	Reorganization, rearrangement, or modification of phenomena
	Destruction	Loss, disappearance, or degradation of specific features
	Convergence	Development and evolution along convergent paths towards similar outcome
	Divergence	Development and evolution along divergent paths towards different outcomes
	Oscillation	Description of cyclical or recurring transitions

Table A.3: Category: Rhetorical techniques – continuation.

Variable	Code	Code definition
Genre (Roth 2021)	Static News Maps	Static story content is partitioned into frames and annotated with directions of reading
	Longform Infographics	Story content is organized in vertical containers and revealed on reader's scrolling
	Dynamic Slideshows	Series of slides or visual panels of consistent size and format
	Narrated Animation	Story progression is dependent on the digital display time
	Multimedia Visual Experiences	Multimedia-rich story with hyperlinks and anchor tags
	Personalized Story Maps	Georeferenced entry points for interactive access to full story content
	Compilations	Unfolding events in near real-time or major updates to the design
	Other	Genre combinations, novel designs different from other genres
Voice	None	No possibility to share, comment or contribute to story content
	Comment	Possibility to comment and (or) share story in social media
	Supplement	Possibility to share, comment and contribute to story content
Virality carrier	Map Map-based graphic Graphic Photograph Chart	Type of the image stored as Twitter Card content

Table A.4: Category: Layout.

Variable	Code	Code definition
Site layout (Babich 2019)	Single column	Story content is presented in a single, vertical column.
	Single row	Story content is presented in a single, horizontal row
	Split screen	Story content is displayed in two vertical or horizontal containers of equal importance
	Asymmetrical	Story content is displayed in two vertical or horizontal containers that lack equality
	Fixed sidebar	Story content is displayed through stationary sidebar(s) and interactive container
	Featured image	Bold visual statement presented in one image
	Z-shaped	Story content is displayed in multiple vertical and horizontal containers
	Grid of cards	Story displayed in a set of multiple card-like containers with equal visual hierarchy
	Curated visuals	Set of unique, artistic, or memorable images crafted for the specific story
Flow	Scroll	Reader scrolls down to unfold story content
	Pagination	Story content is divided into a set of pages
	Entry points	Reader unveils story content by clicking on entry points, e.g., specific locations in the map
	(Micro)animation	Story unfolds automatically after clicking on the play button
Story elements (Zuo et al. 2019)	Map Satellite image Ortophoto Photograph Graphic 3D scene Video	Counts of the image-like elements
	Bar chart Pie chart Line chart Scatter plot Waffle chart Bubble chart Network Flow Isotype Word cloud Treemap	Counts of the chart-like elements
	Table Matrix and grid Small multiples	Counts of the tabular arrangements
	Glossary Counter Index Quote Quiz Question	Counts of the supportive texts

A.2 Categories, variables and codes for primary unit of a map

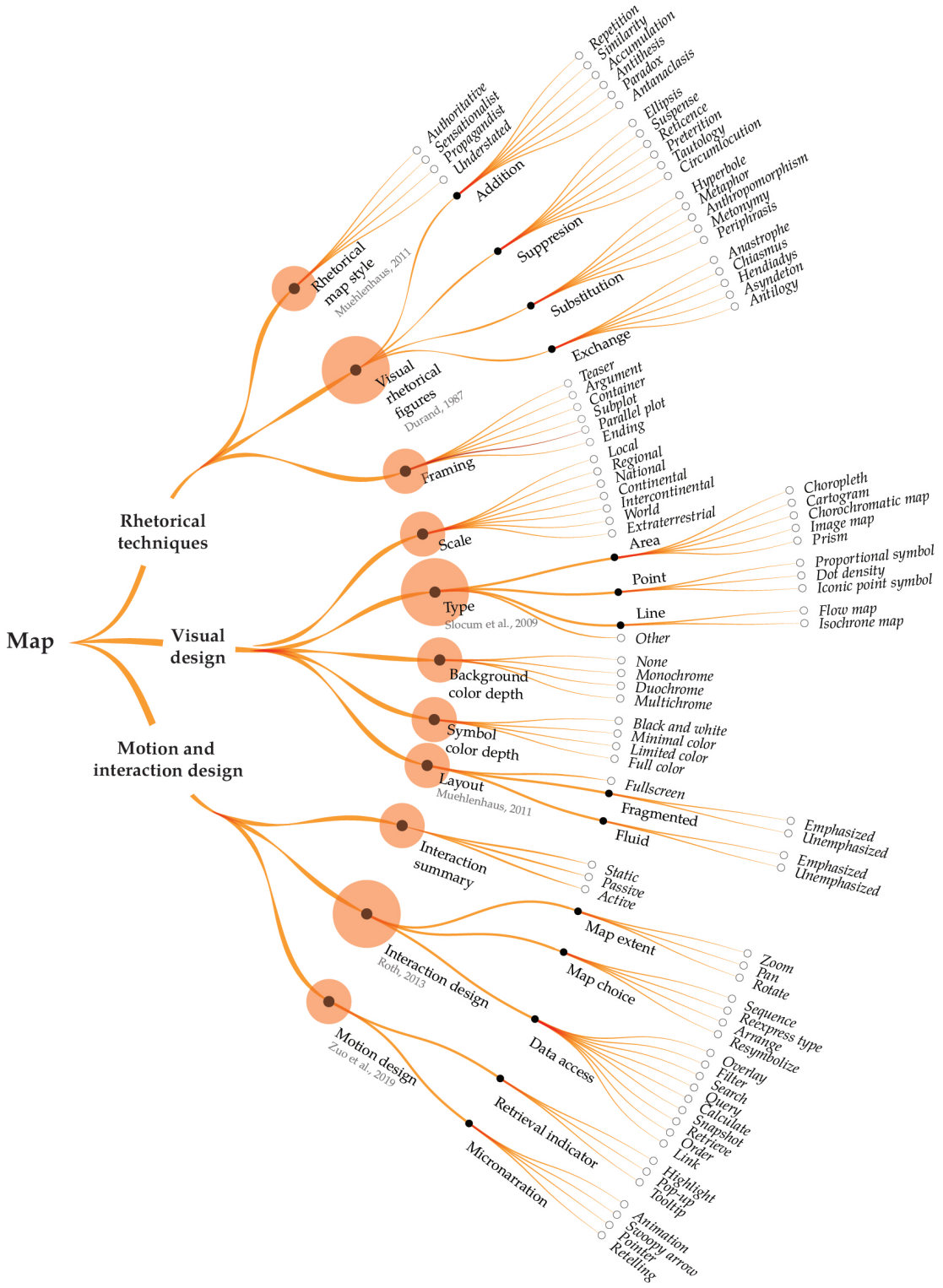


Figure A.2: Categories, variables and codes for primary unit of a map.

Table A.5: Category: Rhetorical techniques.

Variable	Code	Code definition
Rhetorical map style (Muehlenhaus 2011b)	Authoritative	Professional, scientific and accurate depictions for general reference or education
	Understated	Minimalistic depictions with conventional perspectives, geometric symbolizations, display data in concrete static states
	Propagandist	Highlight more than one theme at a time, contain cartographic embellishments, high levels of visual contrast and dynamic symbols
	Sensationalist	Dynamic representations with multiple illustrations, unique viewing perspectives, emotive icons and symbolizations
Framing	Teaser	Map is viewed at the beginning of the layout, e.g., to introduce the topic and grab reader's attention
	Argument	Map is integrated somewhere in the middle of the layout, e.g, to support the main points of the story
	Container	The map itself is the only component of the page, story content unfolds withing this frame based on reader's interaction
	Parallel plot	Map is accompanied with another maps to present two or more stories connected through common theme, place, or event
	Subplot	Supporting side map of secondary meaning unfolding outside of the main map
	Ending	Map is viewed at the end of the layout, e.g., as a visual summary of the topic or emotive call to action

Table A.6: Category: Rhetorical techniques – continuation.

Variable	Code	Code definition
Visual rhetorical figures (Durand 1987)	Repetition	Presents to the viewer identical elements multiple times
	Similarity	Juxtapose multiple elements sharing similar form (rhyme) or concept (comparison)
	Accumulation	Gives the impression of a great number, diversity and density
	Antithesis	Compares two opposite, competitive views
	Paradox	Opposite forms correspond to the same content
	Antanaclasis	Single element is repeated in two different meanings
	Ellipsis	Never showing the key element being discussed
	Suspense	Delays, holds back or reveals the element after presenting anther unrelated element
	Reticence	Contrasts two elements, but one of the elements is not displayed due to taboo, restrictions or prohibitions
	Preterition	Seemingly hides an element of the image or implies a secret while the element is accessible to the viewer
	Tautology	Repeats the same image several times with different meaning in each repetition
	Circumlocution	Connects missing element of the image with similar object
	Hyperbole	Qualitative or quantitative exaggeration
	Metaphor	Visual analogy between two elements and is based on similarity of their forms, content or associations
	Anthropomorphism	Assigns the qualities of a person or living forms to something that is not human or even alive
	Metonymy	Substitutes one element with another closely associated element
	Periphrasis	Captures a moving object in one or more images
	Anastrophe	Inversion of images with respect to the sequence expected by the viewer
	Chiasmus	Exchange between opposite elements
	Hendiadys	Similarity of form between two elements - abstract and concrete
	Asyndeton	Suppresing the conjunctions between elements
	Antilogy	Connects two opposite elements in one image

Table A.7: Category: Visual design.

Variable	Code	Code definition
Scale	Local	Extent of a street, neighbourhood, city, metropolitan area
	Regional	Extent of a region or regions withing a country
	National	Extent of a single country. The neighbouring countries are removed from the view or they remain, but map zoom and pan are deactivated
	Continental	Extent of several countries or regions within the continent
	Intercontinental	Extent of several countries or regions between two continents
	World	Extent of the entire globe
	Extraterrestrial	Extent of the entire planet or regions within the planet
Type (Slocum et al. 2008)	Choropleth	Administrative areas coloured, shaded or patterned by value
	Cartogram	Geographical areas scaled by value and coloured, shaded or patterned by other value
	Chorochromatic map	Regions coloured by value
	Image map	Regions coloured, shaded or patterned by value, overlaid on satellite image or ortophoto
	Prism	Geographical areas vertically scaled by value and coloured, shaded or patterned by other value
	Proportional symbol	Point symbols scaled by value
	Dot density	Point symbol density for value
	Iconic point symbol	Unique point icons for each value
	Flow map	Linear symbols coloured, shaded or patterned by value
	Isochrone map	Line symbols coloured, shaded or patterned by time
	Other	Novel designs different from other types
Layout (Muehlenhaus 2011b)	Fullscreen	The map is the main component of the page, non-map components are placed within map container
	Fragmented Emphasized	Map and non-map components are separated into frames delineated with bold visual elements, e.g., borders, outlines, backgrounds
	Fragmented Unemphasized	Map and non-map components are separated into frames, but their visual delineation is more subtle, e.g., by using the Gestalt principles
	Fluid Emphasized	Map and non-map components are placed in the same frames, re-scaled map is emphasized in optical center, e.g., map slightly exceeds the width of the text column
	Fluid Unemphasized	Map and non-map components are placed in the same frames, map ins not emphasized in the optical center and does not exceed the width of the text column

Table A.8: Category: Visual design – continuation.

Variable	Code	Code definition
Background color depth	None	Lack of map background
	Monochrome Grey	Map background in varying tones of grey, high lightness values
	Monochrome Light	Map background in varying tones of one non-grey colour, high lightness values
	Monochrome Dark	Map background in varying tones of one colour, low lightness values
	Duochrome	Map background in varying tones of two colours
	Multichrome	Map background in varying tones of multiple colours
Symbol color depth	Black and white	Map symbols in black, white or black and white
	Minimal color	Map symbols in one or two colors
	Limited color	Map symbols in three to five colors for sequential color schemes and three to seven colors for diverging color scheme
	Full color	Map symbols in more than five colors for sequential color schemes and more than seven colors for diverging color scheme

Table A.9: Category: Motion and interaction design.

Variable	Code	Code definition
Interaction summary	Static	Static maps without any interaction possibilities
	Passive	Partly interactive maps, the interaction is controlled by the system
	Active	Fully interactive maps, the interaction is controlled by the reader
Interaction design (Roth 2013)* (Zuo et al. 2019)	Zoom*	Change the scale and (or) resolution of the map
	Pan*	Change the geographic center of the map
	Rotate	Change map orientation
	Sequence*	Generate an ordered set of related maps
	Reexpress*	Change the displayed map type
	Arrange*	Manipulate map layout
	Resymbolize*	Adjust the design parameters of a map without changing its type
	Overlay*	Adjust the feature types included in the map
	Filter*	Display map features meeting some pre-defined requirements
	Search*	Identify a particular location or map feature of interest
	Query	Display map features meeting specific reader-defined requirements
	Calculate*	Derive new information about map features of interest
	Snapshot	Extract a generated map and store it locally for further use
	Retrieve*	Request specific details about data presented on the map
	Order	Change the visual hierarchy of the elements on the map
	Link views	Present multiple views of the same data, e.g., on the map and on the chart
Retrieval indicator (Zuo et al. 2019)	Highlight	Increase the visibility of the subset of data
	Pop-up	Display data attribute information on mouse click
	Tooltip	Display data attribute information on mouse hover
Micronarration (Zuo et al. 2019)	Swoopy arrow	Display textual annotation to the map content
	Pointer	Display graphical annotation to the map content
	Retelling	Share and comment current map view on a social media platform
	Animation	Transition between data designs or data states

B

List of analyzed map-based stories

B.1 Kontinentalist

Table B.1: Metadata: stories published by Kontinentalist.

Identifier	Story title	Source
KO-001	Wild Otters - Threatened and traded	https://kontinentalist.com/stories/otters-are-cute-but-endangered-and-trafficked-as-pets-in-asia
KO-002	Pasar: What makes Singapore's wet markets unique?	https://kontinentalist.com/stories/wet-markets-in-singapore-are-our-heritage-and-tradition
KO-003	Persons of the Forest: Sumatra's Endangered and Trafficked Orangutans	https://cdn-images.kontinentalist.com/static-html/sumatra-and-borneo-orangutans-endangered-by-deforestation-and-trafficking/index.html
KO-004	Exploring the lungs of Asia	https://kontinentalist.com/stories/forest-degradation-deforestation-and-conservation-in-asia
KO-005	The age of smart cities - How does Asia fare?	https://kontinentalist.com/stories/smart-cities-in-asia-offer-solutions-and-inequality
KO-006	Is foreign investment truly a force for good?	https://kontinentalist.com/stories/is-foreign-investment-sustainable-for-cambodia
KO-007	Singapore's historic sites of worship	https://kontinentalist.com/stories/singapore-religious-heritage-sites-history-and-conservation
KO-008	Inside the sacred Hajj pilgrimage	https://kontinentalist.com/stories/what-is-hajj-islam-pilgrimage-to-kaaba-mecca-2020
KO-009	A River Drained: Fish, Rice, and Food Security in the Mekong	https://cdn-images.kontinentalist.com/static-html/food-security-mekong-river-hydropower-dam-climate-change/index.html
KO-010	Born to fly - the life, journey, and trials of a migratory bird	https://kontinentalist.com/stories/spoon-billed-sandpiper-migratory-bird-conservation-yellow-sea-map
KO-011	Melting the Roof of the World	https://kontinentalist.com/stories/climate-change-is-melting-the-tibetan-plateau
KO-012	Panda diplomacy - Gifting pandas to further China's politics	https://kontinentalist.com/stories/panda-diplomacy-gifting-pandas-to-further-chinas-politics
KO-013	Shamans, nuns and judges - The lives of Asia's female religious leaders	https://kontinentalist.com/stories/shamans-nuns-and-judges-the-lives-of-asias-female-religious-leaders
KO-014	Singapore where got ghost? The Neighbourhood Ghost Watch	http://v1.kontinentalist.com.s3-website-ap-southeast-1.amazonaws.com/stories/singapore-where-got-ghost
KO-015	How Asian cultures approach death	https://kontinentalist.com/stories/how-asian-cultures-approach-death

Table B.2: Metadata: stories published by Kontinentalist – continuation.

Identifier	Story title	Source
KO-016	The truths of traditional medicine and wildlife	https://kontinentalist.com/stories/the-truths-of-traditional-medicine-and-wildlife
KO-017	Restoring a nation - Yuanmingyuan and China's journey to recover its lost art	https://kontinentalist.com/stories/restoring-a-nation-yuanmingyuan-and-chinas-journey-to-recover-its-lost-art
KO-018	Going Under: How sea level rise is threatening to sink major Asian cities	http://v1.kontinentalist.com.s3-website-ap-southeast-1.amazonaws.com/stories/going-under-how-sea-level-rise-is-threatening-to-sink-major-asian-cities/
KO-019	Murky waters - Where did your ornamental fish come from?	https://kontinentalist.com/stories/murky-waters-where-did-your-ornamental-fish-come-from
KO-020	Out of the blue - The colour that was desired by all	https://kontinentalist.com/stories/out-of-the-blue-the-colour-that-was-desired-by-all
KO-021	Pasir Gudang dumping - What happened and who is responsible?	https://kontinentalist.com/stories/pasir-gudang-dumping-what-happened-and-who-is-responsible
KO-022	Chinese Muslims in Indonesia	https://kontinentalist.com/stories/chinese-muslims-in-indonesia
KO-023	Transgender people in Asia	https://kontinentalist.com/stories/transgender-people-in-asia
KO-024	A siren song - Disappearing songbirds of Asia	https://kontinentalist.com/stories/a-siren-song-disappearing-songbirds-of-asia
KO-025	Weird beasts and where to find them	https://kontinentalist.com/stories/weird-beasts-and-where-to-find-them
KO-026	From gunpowder to ice cream - Asia got there first	https://kontinentalist.com/stories/from-gunpowder-to-ice-cream-asia-got-there-first
KO-027	Christmas in Asia	https://kontinentalist.com/stories/christmas-in-asia
KO-028	Sugar, spice, and everything not quite nice	https://kontinentalist.com/stories/sugar-trade-and-colonialism
KO-029	Understanding the Belt and Road	https://bri.kontinentalist.com
KO-030	The Science of Asia's Myths and Monsters	https://kontinentalist.com/stories/the-science-of-asias-myths-and-monsters
KO-031	Dam if you do, dam if you don't - Hydropower in the Mekong	https://kontinentalist.com/stories/dam-if-you-do-dam-if-you-dont-hydropower-in-the-mekong

B.2 The New York Times

Table B.3: Metadata: stories published by The New York Times.

Identifier	Story title	Source
NY-001	There's a New Definition of 'Normal' for Weather	https://www.nytimes.com/interactive/2021/05/12/climate/climate-change-weather-noaa.html
NY-002	Do You Live in a Political Bubble?	https://www.nytimes.com/interactive/2021/04/30/opinion/politics/bubble-politics.html
NY-003	Mapping New York City's Mayoral Campaign Money	https://www.nytimes.com/interactive/2021/05/22/nyregion/nyc-mayor-donors-map.html
NY-004	Which States Will Gain or Lose Seats in the Next Congress	https://www.nytimes.com/interactive/2021/04/26/us/politics/congress-house-seats-census.html
NY-005	How the Pandemic Did, and Didn't, Change Where Americans Move	https://www.nytimes.com/interactive/2021/04/19/upshot/how-the-pandemic-did-and-didnt-change-moves.html
NY-006	Incarcerated and Infected: How the Virus Tore Through the U.S. Prison System	https://www.nytimes.com/interactive/2021/04/10/us/covid-prison-outbreak.html
NY-007	Rise of Variants in Europe Shows How Dangerous the Virus Can Be	https://www.nytimes.com/interactive/2021/04/09/world/europe/europe-coronavirus-variants.html
NY-008	See Who Has Been Vaccinated So Far in New York City	https://www.nytimes.com/interactive/2021/03/26/nyregion/nyc-vaccination-rates-map.html
NY-009	A Close-Up Picture of Partisan Segregation, Among 180 Million Voters	https://www.nytimes.com/interactive/2021/03/17/upshot/partisan-segregation-maps.html
NY-010	Pandemic's Racial Disparities Persist in Vaccine Rollout	https://www.nytimes.com/interactive/2021/03/05/us/vaccine-racial-disparities.html
NY-011	In the Atlantic Ocean, Subtle Shifts Hint at Dramatic Dangers	https://www.nytimes.com/interactive/2021/03/02/climate/atlantic-ocean-climate-change.html
NY-012	Tracking Coronavirus Cases at U.S. Colleges and Universities	https://www.nytimes.com/interactive/2021/us/college-covid-tracker.html
NY-013	Mapping the Winter Storm's Impact	https://www.nytimes.com/interactive/2021/02/16/us/winter-storm-texas-power-outage-map.html
NY-014	U.S. Coronavirus Cases Are Down but Eclipse Spring and Summer Peaks	https://www.nytimes.com/interactive/2021/02/05/us/covid-peak-comparison.html
NY-015	An Extremely Detailed Map of the 2020 Election	https://www.nytimes.com/interactive/2021/upshot/2020-election-map.html
NY-016	Tracking Coronavirus Vaccinations Around the World	https://www.nytimes.com/interactive/2021/world/covid-vaccinations-tracker.html
NY-017	Every Country Has Its Own Climate Risks. What's Yours?	https://www.nytimes.com/interactive/2021/01/28/opinion/climate-change-risks-by-country.html
NY-018	What Are You Hoping For Over the Next Four Years?	https://www.nytimes.com/interactive/2021/01/20/opinion/joe-biden-inauguration-four-years.html
NY-019	See Where U.S. Intensive Care Units Are Filling Up	https://www.nytimes.com/interactive/2020/12/23/us/covid-rising-icu-capacity.html
NY-020	Who Gets to Breathe Clean Air in New Delhi?	https://www.nytimes.com/interactive/2020/12/17/world/asia/india-pollution-inequality.html
NY-021	Immigrant Neighborhoods Shifted Red as the Country Chose Blue	https://www.nytimes.com/interactive/2020/12/20/us/politics/election-hispanics-asians-voting.html
NY-022	Chinatown, Resilient and Proud	https://www.nytimes.com/interactive/2020/12/02/arts/design/chinatown-virtual-walk-tour.html
NY-023	Even in Defeat, Trump Found New Voters Across the U.S.	https://www.nytimes.com/interactive/2020/11/16/us/politics/election-turnout.html
NY-024	The Battlegrounds Within Battlegrounds	https://www.nytimes.com/interactive/2020/us/politics/battleground-state-polls.html

Table B.4: Metadata: stories published by The New York Times – continuation.

Identifier	Story title	Source
NY-025	Every Place Under Threat	https://www.nytimes.com/interactive/2020/10/02/opinion/amazon-under-threat.html
NY-026	The New Corporate Campus	https://www.nytimes.com/interactive/2020/10/12/style/faze-3d-house-tour.html
NY-027	The Two Americas Financing the Trump and Biden Campaigns	https://www.nytimes.com/interactive/2020/10/25/us/politics/trump-biden-campaign-donations.html
NY-028	The Worst Virus Outbreaks in the U.S. Are Now in Rural Areas	https://www.nytimes.com/interactive/2020/10/22/us/covid-rural-us.html
NY-029	U.S. Virus Cases Climb Toward a Third Peak	https://www.nytimes.com/interactive/2020/10/15/us/coronavirus-cases-us-surge.html
NY-030	The True Colors of America's Political Spectrum Are Gray and Green	https://www.nytimes.com/interactive/2020/09/02/upshot/america-political-spectrum.html
NY-031	Record Wildfires on the West Coast Are Capping a Disastrous Decade	https://www.nytimes.com/interactive/2020/09/24/climate/fires-worst-year-california-oregon-washington.html
NY-032	What We Know About Coronavirus Cases in K-12 Schools So Far	https://www.nytimes.com/interactive/2020/09/21/us/covid-schools.html
NY-033	How a Massive Bomb Came Together in Beirut's Port	https://www.nytimes.com/interactive/2020/09/09/world/middleeast/beirut-explosion.html
NY-034	How Decades of Racist Housing Policy Left Neighborhoods Sweltering	https://www.nytimes.com/interactive/2020/08/24/climate/racism-redlining-cities-global-warming.html
NY-035	Will You Have Enough Time to Vote by Mail in Your State?	https://www.nytimes.com/interactive/2020/08/31/us/politics/vote-by-mail-deadlines.html
NY-036	The Fullest Look Yet at the Racial Inequity of Coronavirus	https://www.nytimes.com/interactive/2020/07/05/us/coronavirus-latinos-african-americans-cdc-data.html
NY-037	I've Seen a Future Without Cars, and It's Amazing	https://www.nytimes.com/2020/07/09/opinion/sunday/ban-cars-manhattan-cities.html
NY-038	Black Lives Matter May Be the Largest Movement in U.S. History	https://www.nytimes.com/interactive/2020/07/03/us/george-floyd-protests-crowd-size.html
NY-039	How the Virus Won	https://www.nytimes.com/interactive/2020/us/coronavirus-spread.html
NY-040	Battle in the Himalayas	https://www.nytimes.com/interactive/2020/07/18/world/asia/china-india-border-conflict.html
NY-041	How Black Lives Matter Reached Every Corner of America	https://www.nytimes.com/interactive/2020/06/13/us/george-floyd-protests-cities-photos.html
NY-042	Minneapolis Police Use Force Against Black People at 7 Times the Rate of Whites	https://www.nytimes.com/interactive/2020/06/03/us/minneapolis-police-use-of-force.html
NY-043	The Richest Neighborhoods Emptied Out Most as Coronavirus Hit New York City	https://www.nytimes.com/interactive/2020/05/15/upshot/who-left-new-york-coronavirus.html
NY-044	There are 2,373 squirrels in Central Park. I know because I helped count them.	https://www.nytimes.com/interactive/2020/01/08/nyregion/central-park-squirrel-census.html
NY-045	A 3-D Tour of How the Senate Was Transformed for the Impeachment Trial	https://www.nytimes.com/interactive/2020/01/23/us/politics/impeachment-senate-chamber-diagram.html
NY-046	13,000 Missing Flights: The Global Consequences of the Coronavirus	https://www.nytimes.com/interactive/2020/02/21/business/coronavirus-airline-travel.html
NY-047	Where Americans Live Far From the Emergency Room	https://www.nytimes.com/interactive/2020/04/26/us/us-hospital-access-coronavirus.html
NY-048	How the Virus Got Out	https://www.nytimes.com/interactive/2020/03/22/world/coronavirus-spread.html

Table B.5: Metadata: stories published by The New York Times – continuation.

Identifier	Story title	Source
NY-049	See How the Coronavirus Death Toll Grew Across the U.S.	https://www.nytimes.com/interactive/2020/04/06/us/coronavirus-deaths-united-states.html
NY-050	The Great Flood of 2019: A Complete Picture of a Slow-Motion Disaster	https://www.nytimes.com/interactive/2019/09/11/us/midwest-flooding.html
NY-051	A Tidal Wave of Mud	https://www.nytimes.com/interactive/2019/02/09/world/americas/brazil-dam-collapse.html
NY-052	What Satellite Imagery Tells Us About the Amazon Rain Forest Fires	https://www.nytimes.com/interactive/2019/08/24/world/americas/amazon-rain-forest-fire-maps.html
NY-053	New York's Subway Map Like You've Never Seen It Before	https://www.nytimes.com/interactive/2019/12/02/nyregion/nyc-subway-map.html
NY-054	Cities Start to Question an American Ideal: A House With a Yard on Every Lot	https://www.nytimes.com/interactive/2019/06/18/upshot/cities-across-america-question-single-family-zoning.html
NY-055	Mapping the Whitney Biennial	https://www.nytimes.com/interactive/2019/07/05/arts/design/whitney-biennial-maps.html
NY-056	The British-Irish Dialect Quiz	https://www.nytimes.com/interactive/2019/02/15/upshot/british-irish-dialect-quiz.html
NY-057	Rising Seas Will Erase More Cities by 2050, New Research Shows	https://www.nytimes.com/interactive/2019/10/29/climate/coastal-cities-underwater.html
NY-058	A Closer Look at the Polar Vortex's Dangerously Cold Winds	https://www.nytimes.com/interactive/2019/01/30/science/polar-vortex-extreme-cold.html
NY-059	NASA's Opportunity Rover Dies on Mars	https://www.nytimes.com/interactive/2019/02/13/science/opportunity-rover-mars-map.html
NY-060	Augmented Reality: Explore NASA's InSight Mission on Mars	https://www.nytimes.com/interactive/2018/05/01/science/mars-nasa-insight-ar-3d-ul.html
NY-061	Where Glaciers Melt Away, Switzerland Sees Opportunity	https://www.nytimes.com/interactive/2019/04/17/climate/switzerland-glaciers-climate-change.html
NY-062	One nation, tracked	https://www.nytimes.com/interactive/2019/12/19/opinion/location-tracking-cell-phone.html
NY-063	Since When Have Trees Existed Only for Rich Americans?	https://www.nytimes.com/interactive/2021/06/30/opinion/environmental-inequity-trees-critical-infrastructure.html
NY-064	How maps reshape American Politics	https://www.nytimes.com/interactive/2021/11/07/us/politics/redistricting-maps-explained.html
NY-065	Where Should You Live?	https://www.nytimes.com/interactive/2021/11/23/opinion/sunday/best-places-live-usa-quiz.html
NY-066	A map of every building in America	https://www.nytimes.com/interactive/2018/10/12/us/map-of-every-building-in-the-united-states.html
NY-067	How the Midterms Made Us Feel: Afraid, Then Upset	https://www.nytimes.com/interactive/2018/11/05/opinion/election-midterms-2018-emotions.html
NY-068	95-Degree Days: How Extreme Heat Could Spread Across the World	https://www.nytimes.com/interactive/2017/06/22/climate/95-degree-day-maps.html
NY-069	How Connected Is Your Community to Everywhere Else in America?	https://www.nytimes.com/interactive/2018/09/19/upshot/facebook-county-friendships.html
NY-070	See Inside Typhoon Mangkhut in 3-D	https://www.nytimes.com/interactive/2018/09/15/world/asia/super-typhoon-mangkhut-ompong-storm.html
NY-071	How the Election Split France	https://www.nytimes.com/interactive/2017/04/23/world/europe/french-election-results-maps.html

B.3 The Pudding

Table B.6: Metadata: stories published by The Pudding.

Identifier	Story title	Source
PU-001	A People Map of the UK, where city names are replaced by their most Wikipedia'ed resident: people born in, lived in, or connected to a place	https://pudding.cool/2019/06/people-map-uk/
PU-002	A People Map of the US, where city names are replaced by their most Wikipedia'ed resident: people born in, lived in, or connected to a place	https://pudding.cool/2019/05/people-map/
PU-003	Music borders	https://pudding.cool/2018/06/music-map/?date=202106
PU-004	Mapping Gastronomic Borders in the US	https://pudding.cool/2018/02/restaurants/
PU-005	How far is too far? An analysis of driving times to abortion clinics in the US	https://pudding.cool/2017/09/clinics/
PU-006	The Shape of Slavery	https://pudding.cool/2017/01/shape-of-slavery/
PU-007	How is flooding affecting your community?	https://pudding.cool/projects/flooding/visuals/
PU-008	Where International Communities Cluster	https://pudding.cool/2020/01/diaspora/
PU-009	Men are from Chelsea, Women are from Park Slope	https://pudding.cool/2018/06/gayborhoods/
PU-010	Human Terrain - Visualizing the world's population in 3D	https://pudding.cool/2018/10/city_3d/
PU-011	The Geographic Divide of Oscar Films	https://pudding.cool/2017/02/oscars_so_-mapped/
PU-012	This project is about your geographic music bubble	https://pudding.cool/2021/04/music-bubble/
PU-013	A concise, travel-like-a-local guide to 74,762 attractions, according to 9,526,193 reviews	https://pudding.cool/2020/05/travel-local/
PU-014	Finding Forever Homes	https://pudding.cool/2019/10/shelters/
PU-015	Population Mountains	https://pudding.cool/2018/12/3d-cities-story/
PU-016	What Airport Traffic Tells Us About the World's Megacities	https://pudding.cool/2018/07/airports/
PU-017	A Tale of Two Cities	https://pudding.cool/2018/03/neighborhoods/
PU-018	Ye Olde Mad-Lib Pub Crawl Generator	https://pudding.cool/2019/10/pubs/
PU-019	Why Budapest, Warsaw, and Lithuania split themselves in two	https://pudding.cool/2019/04/eu-regions/
PU-020	Craft beer — so hot right now. But what city is the microbrew capital of the US?	https://pudding.cool/2017/04/beer/
PU-021	The Most Successful Labels in Hip Hop	https://pudding.cool/2017/03/labels/
PU-022	Limbo Lines: Dead Here, Alive There	https://pudding.cool/2018/02/death/
PU-023	How you play spades is how you play life	https://pudding.cool/2021/08/spades/

B.4 South China Morning Post

Table B.7: Metadata: stories published by South China Morning Post.

Identifier	Story title	Source
SC-001	Are we alone?	https://multimedia.scmp.com/culture/article/ufo/index.html
SC-002	'Made in China 2025': How Beijing is boosting its semiconductor industry	https://multimedia.scmp.com/news/china/article/2165504/china-2015-semiconductors/
SC-003	Why the world's flight paths are such a mess	https://multimedia.scmp.com/news/world/article/2165980/flight-paths/
SC-004	Betting big on biotech	https://multimedia.scmp.com/news/china/article/2167415/china-2025-biotech/
SC-005	The stones in the road for China's 2025 plan on electric vehicles	https://multimedia.scmp.com/news/china/article/2169344/china-2025-electric-vehicles/
SC-006	What is space junk and why is it a problem?	https://multimedia.scmp.com/news/world/article/2177933/space-debris/
SC-007	What is permafrost and why might it be the climate change time bomb?	https://multimedia.scmp.com/news/world/article/3000839/permafrost/
SC-008	Will Beijing weaponise its rare earth supply in the US-China trade war?	https://multimedia.scmp.com/infographics/news/china/article/3014968/rare-earth/index.html
SC-009	Do the world's best business locations also enjoy the most economic freedoms?	https://multimedia.scmp.com/business/article/3000851/doing-biz/index.html
SC-010	Australian fires: Understanding the intensity and global impact	https://multimedia.scmp.com/infographics/news/world/article/3046510/australian-fires/index.html
SC-011	The power of your passport	https://multimedia.scmp.com/culture/article/passportIndex/
SC-012	Getting to grips with North Korea in 15 graphics	https://multimedia.scmp.com/news/world/article/to-understand-North-Korea/
SC-013	Why Djibouti is home to China's first foreign military base	https://multimedia.scmp.com/news/china/article/2161807/china-djibouti-base/
SC-014	Narcos: the hidden drug highways linking Asia and Latin America	https://multimedia.scmp.com/week-asia/article/ 2174634/narcos-hidden-drug-trafficking/
SC-015	Brexit: how Britain voted	https://multimedia.scmp.com/news/world/article/3003593/brexit/index.html
SC-016	How every Boeing 737 MAX was grounded in five days	https://multimedia.scmp.com/news/world/article/3003901/boeing-737-grounded/index.html
SC-017	The China Ship: the beginning of modern globalisation	https://multimedia.scmp.com/culture/article/spanish-galleon/chapter_01.html
SC-018	Coronavirus cruise ship: stuck on board the quarantined Diamond Princess	https://multimedia.scmp.com/infographics/news/world/article/3050430/diamond-princess-japan-coronavirus/index.html
SC-019	Europe's coronavirus lockdown nightmare	https://multimedia.scmp.com/infographics/news/world/article/3077057/europe-coronavirus/index.html
SC-020	Coronavirus tests are the best way to contain the pandemic	https://multimedia.scmp.com/infographics/news/world/article/3083972/coronavirus-tests/index.html

Table B.8: Metadata: stories published by South China Morning Post – continuation.

Identifier	Story title	Source
SC-021	United States passes 100,000 coronavirus deaths	https://multimedia.scmp.com/infographics/news/world/article/3086433/us-covid19-100thousand-deaths/index.html
SC-022	India-China border clash explained	https://multimedia.scmp.com/infographics/news/world/article/3091480/China-India-border-dispute/index.html
SC-023	The slave trade	https://multimedia.scmp.com/infographics/news/world/article/3093101/african-slave-trade-history/index.html
SC-024	Who has the upper hand in the China-India border dispute?	https://multimedia.scmp.com/infographics/news/world/article/3109169/china-india-forces/index.html
SC-025	Architecture post-coronavirus	https://multimedia.scmp.com/infographics/news/world/article/3126723/architecture-post-coronavirus/index.html
SC-026	Cantonese performing art	https://multimedia.scmp.com/infographics/culture/article/3036661/cantonese-opera/index.html
SC-027	China's 400-year-old Wengding village consumed by flames	https://multimedia.scmp.com/infographics/news/china/article/3123696/wengding-village-fire/index.html
SC-028	The water pollution in China's rivers	https://multimedia.scmp.com/infographics/news/china/article/3093488/china-rivers-pollution/index.html
SC-029	How Shenzhen became China's Silicon Valley	https://multimedia.scmp.com/infographics/news/china/article/3100043/shenzhen-special-economic-zone/index.html
SC-030	The origins of Beijing's Forbidden City	https://multimedia.scmp.com/culture/article/forbidden-city/architecture/chapter_-01.html?src=follow-chapter
SC-031	How China is looking beyond borders	https://multimedia.scmp.com/news/china/article/3007692/belt-and-road/
SC-032	Ten signature dishes from around the world	https://multimedia.scmp.com/lifestyle/article/2178630/the-pleasure-of-food/
SC-033	China's radical new rules to recycle rubbish	https://multimedia.scmp.com/infographics/news/china/article/3038540/china-waste-sorting/index.html
SC-034	The rule of law: Hong Kong vs China	https://multimedia.scmp.com/infographics/news/world/article/3023351/rule-of-law/index.html?src=arcade
SC-035	How Hong Kong airport protests ended in chaos	https://multimedia.scmp.com/infographics/news/hong-kong/article/3022630/hong-kong-airport-protest/index.html?src=arcade

Table B.9: Metadata: stories published by South China Morning Post – continuation.

Identifier	Story title	Source
SC-036	Back to Wuhan, one year after world's first lockdown	https://multimedia.scmp.com/infographics/news/china/article/3118700/wuhan-one-year-after/index.html
SC-037	The labs where monsters live	https://multimedia.scmp.com/infographics/news/world/article/3101114/biosafety-laboratories/index.html
SC-038	Hong Kong district council elections: winners and losers	https://multimedia.scmp.com/infographics/news/hong-kong/article/3039600/hong-kong-district-council-elections-2019/index.html
SC-039	Hindenburg disaster: The end of the airship era	https://multimedia.scmp.com/news/ world/article/3008906/hindenburg/index.html
SC-040	Electrifying return of the Hong Kong Formula E	https://multimedia.scmp.com/sport/article/3001105/formula-e-hong-kong/index.html
SC-041	How big is the crazy rich Asian wealth gap?	https://multimedia.scmp.com/lifestyle/article/2163738/crazy-rich-asians/index.html
SC-042	Plugging China into Europe	https://multimedia.scmp.com/news/china/article/One-Belt-One-Road/europe.html
SC-043	How a new wave of Covid-19 spread through China	https://multimedia.scmp.com/infographics/news/china/article/3145723/china-new-wave/index.html
SC-044	Global warming: is time running out?	https://multimedia.scmp.com/infographics/news/world/article/3154110/global-warming/index.html

B.5 Die Zeit Online

Table B.10: Metadata: stories published by Die Zeit Online.

Identifier	Story title	Source
ZO-001	Wie die Medizin dem Geld folgt	https://www.zeit.de/wirtschaft/2014-04/arzt-facharzt-praxis-verteilung-berlin-hamburg-koeln-muenchen-interaktiv#stadtteile/einwohner/muenchen/frauenaerzte
ZO-002	Dürfen wir vorstellen: Die Freunde von Pegida	https://www.zeit.de/gesellschaft/zeitgeschehen/2015-02/wer-ist-pegida-facebook-daten
ZO-003	Ein gut bewachtes Massengrab	https://www.zeit.de/gesellschaft/zeitgeschehen/2015-04/mittelmeer-fluechtlinge-schiffsunglueck-sicherheit
ZO-004	Geld zieht Ärzte an	https://www.zeit.de/feature/gesundheit-arzt-privat-versicherung-praxis
ZO-005	Hier wohnen Deutschlands Asylbewerber	https://www.zeit.de/gesellschaft/zeitgeschehen/2015-08/fluechtlinge-verteilung-quote
ZO-006	Diese Keime töten	https://www.zeit.de/wissen/gesundheit/2014-11/multiresistente-keime-mrsa-antibiotika-massentierhaltung-keimkarte
ZO-007	Was Vorratsdaten über uns verraten	https://www.zeit.de/digital/datenschutz/2011-02/vorratsdaten-malte-spitz
ZO-008	Es brennt in Deutschland	https://www.zeit.de/politik/deutschland/2015-11/rechtsextremismus-fluechtlingsunterkuenfte-gewalt-gegen-fluechtlinge-justiz-taeter-urteile
ZO-009	Es brennt in Deutschland	https://www.zeit.de/politik/2016-04/fluechtlingsrouten-europa-mittelmeer
ZO-010	Milliarden, die die Welt braucht	https://www.zeit.de/politik/ausland/2016-05/humanitaere-hilfe-weltweit-grafik
ZO-011	Eine Nation pendelt	https://www.zeit.de/feature/pendeln-stau-arbeit-verkehr-wohnort-arbeitsweg-ballungsraeume
ZO-012	So haben die Briten abgestimmt	https://www.zeit.de/politik/ausland/2016-06/wahlergebnisse-grossbritannien-eu-referendum
ZO-013	Die tödlichste Fluchtroute der Welt	https://www.zeit.de/gesellschaft/zeitgeschehen/2016-08/mittelmeer-fluechtlingsroute-europa-afrika
ZO-014	Deutschlands neue Kinder	https://www.zeit.de/gesellschaft/2016-10/geburtenrate-deutschland-auslaendische-muetter-alter-bundeslaender
ZO-015	Fremde Freunde	https://www.zeit.de/feature/usa-amerikaner-gesellschaft-gruppierungen-wirtschaftssystem-grafiken

Table B.11: Metadata: stories published by Die Zeit Online – continuation.

Identifier	Story title	Source
ZO-016	Im Land der Alten	https://www.zeit.de/gesellschaft/2016-11/demografischer-wandel-deutschland-landkreise-bevoelkerung-durchschnittsalter
ZO-017	Richtig falsch	https://www.zeit.de/wissen/2016-11/wahlprognosen-umfragen-usa-praesidentschaftswahl-donald-trump
ZO-018	Die Waffenbürger	https://www.zeit.de/gesellschaft/zeitgeschehen/2016-12/migrantenschreck-waffen-waffenhandel-mario-roensch-kunden
ZO-019	Macron ist schwul, NOT!	https://www.zeit.de/politik/2017-02/fake-news-emanuel-macron-russland-rekonstruktion/komplettansicht
ZO-020	Treibstoff für den Syrienkrieg	https://www.zeit.de/politik/deutschland/2017-03/bundeswehr-flugbereitschaft-bundesregierung-tankfluege-syrien-krieg-daten
ZO-021	Weniger Helfer bedeuten mehr Tote	https://www.zeit.de/politik/ausland/2017-07/seenotrettung-mittelmeer-fluechtlinge-boote-ngos-marine/komplettansicht
ZO-022	Straßenbilder	https://www.zeit.de/feature/strassenverzeichnis-strassennamen-herkunft-deutschland-infografik
ZO-023	Wie oft gibt es Ihre Straße?	http://interactive.zeit.de/strassennamen/
ZO-024	Stadt, Land, Vorurteil	https://www.zeit.de/feature/deutsche-bevoelkerung-stadt-land-unterschiede-vorurteile
ZO-025	Merkel-Enttäuschte und Nichtwähler machen die AfD stark	https://www.zeit.de/politik/deutschland/2017-09/wahlverhalten-bundestagswahl-wahlbeteiligung-waehlerwanderung
ZO-026	Die WM auf einen Blick	https://www.zeit.de/sport/2018-06/fussball-wm-2018-grafiken
ZO-027	Das hält der Wald nicht aus	https://www.zeit.de/wissen/umwelt/2018-08/duerre-deutschland-hitze-klima-wald-forst/komplettansicht
ZO-028	Der Süden tankt teurer	https://www.zeit.de/wirtschaft/2018-12/benzinpreise-unterschiede-norddeutschland-sueddeutschland-tankstellen
ZO-029	Teurer geht immer	https://www.zeit.de/wirtschaft/2019-01/mietpreise-immobilienmarkt-staedte-deutschlandkarte
ZO-030	Wo Deutschland rast	https://www.zeit.de/mobilitaet/2019-02/autobahnen-geschwindigkeit-tempo-schnelligkeit-raser-verkehr#autobahn-daten-tomtom-3-tab

Table B.12: Metadata: stories published by Die Zeit Online – continuation.

Identifier	Story title	Source
ZO-031	Die Millionen, die gingen	https://www.zeit.de/politik/deutschland/2019-05/ost-west-wanderung-abwanderung-ostdeutschland-umzug
ZO-032	Wo unsere Freunde leben	https://www.zeit.de/gesellschaft/zeitgeschehen/2019-05/staedtepartnerschaften-befreundete-staedte-und-gemeinden
ZO-033	Europa von links nach rechts	https://www.zeit.de/politik/ausland/2019-05/parlamentswahlen-eu-laender-wahlergebnisse-europakarte
ZO-034	Gespaltenes Land	https://www.zeit.de/politik/deutschland/2019-05/wahlergebnisse-europawahl-hochburgen-daten
ZO-035	Die neuen Farben Europas	https://www.zeit.de/politik/ausland/2019-07/europawahl-gemeinden-eu-mitgliedsstaaten-ergebnisse-analyse
ZO-036	Europas Speckgürteleffekt	https://www.zeit.de/politik/ausland/2019-07/demografie-europa-bevoelkerung-entwicklung-wandel-karte
ZO-037	Rentenbescheid an die Costa del Sol	https://www.zeit.de/wirtschaft/2019-07/deutsche-rentenversicherung-zahlungen-deutsche-ausland
ZO-038	Grün ist die neue Hamburger Mitte	https://www.zeit.de/politik/deutschland/2020-02/buergerschaftswahl-hamburg-wahlergebnis-bezirke-waehler
ZO-039	Das obere Prozent	https://www.zeit.de/wirtschaft/2020-07/vermoegensverteilung-deutschland-diw-studie-ungleichheit
ZO-040	Wo Intensivbetten in Deutschland knapp sind	https://www.zeit.de/wissen/2020-04/coronavirus-intensivbetten-deutschland-auslastung-kapazitaeten-tagesaktuelle-karte
ZO-041	Wir haben die Parkposition erreicht	https://www.zeit.de/mobilitaet/2020-08/flugverkehr-flightradar24-flugbewegungen-coronavirus-anstieg-flugzahlen
ZO-042	187 Schicksale	https://www.zeit.de/gesellschaft/zeitgeschehen/2018-09/todesopfer-rechte-gewalt-karte-portraet
ZO-043	Viel zu warm hier	https://www.zeit.de/wissen/umwelt/2019-12/klimawandel-globale-erwaermung-warming-stripes-wohnort
ZO-044	Es brennt und brennt und brennt	https://www.zeit.de/wissen/umwelt/2020-01/australien-feuer-karte-braende-buschfeuer-flaechenbraende-duerre
ZO-045	In der Hitze der Ozeane	https://www.zeit.de/wissen/umwelt/2020-01/klimawandel-temperaturen-rekord-wassertemperatur-folgen-tierschutz-klimaschutz
ZO-046	Historisch trocken	https://www.zeit.de/wissen/umwelt/2020-04/klimawandel-duerresommer-deutschland-landwirtschaft-boeden/komplettansicht

C

Tabular statistics from story analysis

C.1 Story themes and subthemes

Table C.1: Main themes and subthemes of map-based stories between 2014 - 2021. Classification based on Vujaković (2014).

Story theme	Story subtheme	Nº	Share within stories	Share within theme
Science	Medical	27	13%	36%
	Natural Environmental	27	13%	36%
	Urban Environmental	14	7%	20%
	Non-urban Environmental	6	3%	8%
Politics	Internal, Non-Violent	22	10%	50%
	Internal, Violent	6	3%	14%
	International, Non-violent	9	4%	20%
	International, Violent	7	3%	16%
Cultural	Heritage	18	8%	49%
	Leisure	16	7%	43%
	Human Interest	3	1%	8%
Society	Demography	23	11%	64%
	Human Rights	10	5%	28%
	Public Safety	3	1%	8%
Disaster Events	Natural	9	4%	64%
	Non-natural	5	2%	36%
Economics	Global	5	2%	50%
	Local	5	2%	50%

C.2 Non-map elements in visual stories

Table C.2: Non-map elements in visual stories.

Function	Visual type	Nº	Share within stories
Images	Graphic	73	34%
	Photograph	62	29%
	Motion graphics	54	25%
	Satellite and Orthophotos	24	11%
	3D Scene	14	7%
Tabular arrangements	Small multiples	50	25%
	Table	37	17%
	Matrices and grids	17	8%
Charts	Bar chart	95	44%
	Line chart	63	29%
	Scatter plot	24	11%
	Bubble chart	15	7%
	Treemap	11	5%
	Waffle chart	10	5%
	Isotype chart	7	3%
	Pie chart	6	3%
	Network	5	2%
	Flow	4	2%
	Word cloud	1	0%
Supportive texts	Counter	67	31%
	Glossary, Index	23	11%
	Quiz, Question	11	5%
	Quote	4	2%

C.3 Motion and interaction design

Table C.3: Prevalent and rare map interactions, micronarrations and motion elements. Classification based on Roth (2013) and Zuo et al. (2019).

Function	Interaction	Nº	Share within stories
Map extent	Pan	64	30%
	Zoom	59	27%
	Rotate	6	3%
Map choice	Sequence	36	17%
	Time slider	9	4%
	Re-express type	11	5%
	Arrange	2	1%
	Resymbolize	0	0%
Map as interface – access to data	Retrieve	69	32%
	Search	20	9%
	Link	17	8%
	Filter	10	5%
	Overlay	2	1%
	Snapshot	2	1%
	Calculate	0	0%
Retrieval indicator	Highlight	61	28%
	Tooltip	45	21%
	Pop-up	32	15%
Micronarration	Swoopy arrow	35	16%
	Pointer	21	10%
	Retelling	4	2%
	Animation	109	51%

Bibliography

Research articles

References in citation order.

[1] Luca Maria Aiello, Rossano Schifanella, Daniele Quercia, and Francesco Aletta. 'Chatty maps: constructing sound maps of urban areas from social media data'. In: *Royal Society Open Science* 3.3 (Mar. 2016), p. 150690. DOI: 10.1098/rsos.150690 (cited on page 8).

[7] William George Victor Balchin. 'Media Map Watch: a report'. In: *Geography* 70.4 (1985), pp. 339–343 (cited on page 2).

[8] Melanie Bancilhon, Marios Constantinides, Edyta P. Bogucka, Luca Maria Aiello, and Daniele Quercia. 'Streetonomics: Quantifying culture using street names'. In: *PLOS ONE* 16.6 (June 2021), pp. 1–16. DOI: 10.1371/journal.pone.0252869 (cited on pages 89, 96).

[11] Sarah Bell. 'Map Icon Design'. In: *The Geographic Information Science and Technology Body of Knowledge* (2020). Ed. by John P. Wilson. DOI: 10.22224/gistbok/2020.1.6 (cited on page 25).

[16] Edyta P. Bogucka, Marios Constantinides, Luca Maria Aiello, Daniele Quercia, Wonyoung So, and Melanie Bancilhon. 'Cartographic Design of Cultural Maps'. In: *IEEE Computer Graphics and Applications* 40.06 (Nov. 2020), pp. 12–20. DOI: 10.1109/MCG.2020.3026596 (cited on pages 89, 95).

[17] Edyta P. Bogucka and Liqiu Meng. 'Projecting emotions from artworks to maps using neural style transfer'. In: *Proceedings of the ICA* 2 (July 2019), pp. 1–8. DOI: 10.5194/ica-proc-2-9-2019 (cited on pages 110, 112).

[18] Edyta P. Bogucka and Liqiu Meng. 'Quantitative Content Analysis of Maps on Twitter using network visualization and pre-trained machine learning models'. In: *Abstracts of the ICA* 3 (2021), p. 33. DOI: 10.5194/ica-abs-3-33-2021 (cited on page 37).

[20] Nigel Bond and John Falk. 'Tourism and identity-related motivations: why am I here (and not there)?' In: *International Journal of Tourism Research* 15.5 (Apr. 2012), pp. 430–442. DOI: 10.1002/jtr.1886 (cited on page 27).

[23] Chris Brennan-Horley, Susan Luckman, Chris Gibson, and Julie Willoughby-Smith. 'GIS, Ethnography, and Cultural Research: Putting Maps Back into Ethnographic Mapping'. In: *The Information Society* 26.2 (2010), pp. 92–103. DOI: 10.1080/01972240903562712 (cited on page 8).

[26] Davide Cantoni, Felix Hagemeister, and Mark Westcott. 'Persistence and Activation of Right-Wing Political Ideology'. In: 143 (Feb. 2019) (cited on pages 80, 83, 84).

[27] Sébastien Caquard and William Cartwright. 'Narrative Cartography: From Mapping Stories to the Narrative of Maps and Mapping'. In: *The Cartographic Journal* 51.2 (2014), pp. 101–106. DOI: 10.1179/0008704114Z.000000000130 (cited on pages 30, 41).

[28] Sébastien Caquard, Daniel Naud, and Rodolphe Gonzalès. 'Esquisses géographiques des récits cinématographiques Canadiens contemporains'. In: *The Canadian Geographer / Le Géographe canadien* 56.4 (Sept. 2012), pp. 508–530. DOI: 10.1111/j.1541-0064.2012.00443.x (cited on page 8).

[31] Siming Chen, Jie Li, Gennady Andrienko, Natalia Andrienko, Yun Wang, Phong H. Nguyen, and Cagatay Turkay. 'Supporting Story Synthesis: Bridging the Gap between Visual Analytics and Storytelling'. In: *IEEE Transactions on Visualization and Computer Graphics* 26.7 (2020), pp. 2499–2516. DOI: 10.1109/TVCG.2018.2889054 (cited on page 8).

[36] Neil Cohn. 'Visual Narrative Structure'. In: *Cognitive Science* 37.3 (2013), pp. 413–452. DOI: https://doi.org/10.1111/cogs.12016 (cited on page 7).

[37] Neil Cohn. 'Visual narrative comprehension: Universal or not?' In: *Psychonomic Bulletin Review* 27.2 (Dec. 2019), pp. 266–285. DOI: 10.3758/s13423-019-01670-1 (cited on page 7).

[42] John W. Delicath and Kevin Michael DeLuca. 'Image events, the public sphere, and argumentative practice: The case of radical environmental groups'. In: *Argumentation* 17.3 (2003), pp. 315–333. DOI: 10.1023/a:1025179019397 (cited on page 19).

[43] Damien Demaj and Kenneth Field. 'Reasserting Design Relevance in Cartography: Some Examples'. In: *The Cartographic Journal* 49.1 (2012), pp. 77–93. DOI: 10.1179/0008704112Z.00000000012 (cited on pages 8, 41).

[44] Mark Denil. 'Storied Maps'. In: *Cartographic Perspectives* 84 (Jan. 2017), pp. 5–22. DOI: 10.14714/cp84.1374 (cited on pages 20, 28, 32).

[50] Dennis Edler, Julian Keil, and Frank Dickmann. 'Varianten interaktiver Karten in Video- und Computerspielen — eine Übersicht'. In: *KN - Journal of Cartography and Geographic Information* 68.2 (Mar. 2018), pp. 57–65. DOI: 10.1007/bf03544525 (cited on page 8).

[57] Carolyn S. Fish. 'Cartographic content analysis of compelling climate change communication'. In: *Cartography and Geographic Information Science* 47.6 (2020), pp. 492–507. DOI: 10.1080/15230406.2020.1774421 (cited on pages 2, 8, 35, 36, 47).

[64] William Gaver and John Bowers. 'Annotated Portfolios'. In: *Interactions* 19.4 (July 2012), pp. 40–49. DOI: 10.1145/2212877.2212889 (cited on page 41).

[65] Patricia Gilmartin. 'The design of journalistic maps. Purposes, parameters and prospects.' In: *Cartographica: The International Journal for Geographic Information and Geovisualization* 22.4 (1985), pp. 1–18. DOI: 10.3138/4n0w-35p7-w416-9341 (cited on pages 1, 2).

[67] David R. Green. 'Journalistic Cartography: Good or Bad? A Debatable Point'. In: *The Cartographic Journal* 36.2 (1999), pp. 141–153. DOI: 10.1179/caj.1999.36.2.141 (cited on pages 2, 44).

[70] Amy L. Griffin, Anthony C. Robinson, and Robert E. Roth. 'Envisioning the future of cartographic research'. In: *International Journal of Cartography* 3.sup1 (2017), pp. 1–8. DOI: 10.1080/23729333.2017.1316466 (cited on page 41).

[72] John Brian Harley. 'Cartography, Ethics and Social Theory'. In: *Cartographica: The International Journal for Geographic Information and Geovisualization* 27.2 (1990), pp. 1–23. DOI: 10.3138/C211-1512-0603-XJ14 (cited on pages 27, 29).

[80] Nadav Hochman and Raz Schwartz. 'Visualizing Instagram: Tracing Cultural Visual Rhythms'. In: *Proceedings of the International AAAI Conference on Web and Social Media* 6.4 (Aug. 2021), pp. 6–9. DOI: 10.1609/icwsm.v6i4.14361 (cited on page 37).

[84] Cristina M. Iosifescu Enescu, Jacques Montangero, and Lorenz Hurni. 'Toward Dream Cartography: Mapping Dream Space and Content'. In: *Cartographica: The International Journal for Geographic Information and Geovisualization* 50.4 (Dec. 2015), pp. 224–237. DOI: 10.3138/cart.50.4.3137 (cited on page 8).

[89] Alexander Kent. 'Trust Me, I'm a Cartographer: Post-truth and the Problem of Acritical Cartography'. In: *The Cartographic Journal* 54.3 (2017), pp. 193–195. DOI: 10.1080/00087041.2017.1376489 (cited on pages 29, 30, 41).

[91] Bongshin Lee, Kate Isaacs, Danielle Albers Szafir, G. Elisabeta Marai, Cagatay Turkay, Melanie Tory, Sheelagh Carpendale, and Alex Endert. 'Broadening Intellectual Diversity in Visualization Research Papers'. In: *IEEE Computer Graphics and Applications* 39.4 (2019), pp. 78–85. DOI: 10.1109/MCG.2019.2914844 (cited on page 41).

[101] Katherine McLean. 'Smellmap: Amsterdam — olfactory art and smell visualization'. In: *Leonardo* 50.1 (2017), pp. 92–93 (cited on page 8).

[103] Franz-Benjamin Mocnik and David Fairbairn. 'Maps Telling Stories?' In: *The Cartographic Journal* 55.1 (2018), pp. 36–57. DOI: 10.1080/00087041.2017.1304498 (cited on page 8).

[104] Paul J. Mode. '"Not Maps At All" – What Is Persuasive Cartography? And Why Does It Matter?' In: *The Portolan. Journal of the Washington Map Society* 100 (2017), pp. 8–26 (cited on pages 1, 8, 20, 115).

[106] Antoni B. Moore, Mariusz Nowostawski, Christopher Frantz, and Christina Hulbe. 'Comic Strip Narratives in Time Geography'. In: *ISPRS International Journal of Geo-Information* 7.7 (2018). DOI: 10.3390/ijgi7070245 (cited on page 8).

[107] Ian Muehlenhaus. 'Another Goode Method: How to Use Quantitative Content Analysis to Study Variation in Thematic Map Design'. In: 69 (2011), pp. 7–30. DOI: 10.14714/cp69.28 (cited on pages 22, 35, 36, 44, 47).

[108] Ian Muehlenhaus. 'Genealogy That Counts: Using Content Analysis to Explore the Evolution of Persuasive Cartography'. In: 46.1 (Mar. 2011), pp. 28–40. DOI: 10.3138/carto.46.1.28 (cited on pages 22, 133, 135).

[109] Ian Muehlenhaus. 'The design and composition of persuasive maps'. In: *Cartography and Geographic Information Science* 40.5 (2013), pp. 401–414. DOI: 10.1080/15230406.2013.783450 (cited on pages 1, 22, 35).

[119] John Nelson. 'Multivariate Mapping'. In: *Geographic Information Science & Technology Body of Knowledge* 2020.Q1 (2020). DOI: 10.22224/gistbok/2020.1.5 (cited on page 118).

[120] Sabine Niederer and Gabriele Colombo. 'Visual Methodologies for Networked Images: Designing Visualizations for Collaborative Research, Cross-platform Analysis, and Public Participation'. In: 14 (Feb. 2019), pp. 40–67. DOI: 10.7764/disena.14.40-67 (cited on pages 35–38).

[123] Heather O'Brien and Paul Cairns. 'An empirical evaluation of the User Engagement Scale (UES) in online news environments'. In: *Information Processing & Management* 51.4 (2015), pp. 413–427. DOI: https://doi.org/10.1016/j.ipm.2015.03.003 (cited on page 28).

[124] Heather L. O´Brien, Paul Cairns, and Mark Hall. 'A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form'. In: *International Journal of Human-Computer Studies* 112 (2018), pp. 28–39. DOI: https://doi.org/10.1016/j.ijhcs.2018.01.004 (cited on page 28).

[132] Jonathan Phillips. 'Storytelling in Earth Sciences: The eight basic plots'. In: *Earth-Science Reviews* 115.3 (2012), pp. 153–162. DOI: https://doi.org/10.1016/j.earscirev.2012.09.005 (cited on pages 10, 13, 14, 56, 129).

[135] Andrew J. Reagan, Lewis Mitchell, Dilan Kiley, Christopher M. Danforth, and Peter Sheridan Dodds. 'The emotional arcs of stories are dominated by six basic shapes'. In: *EPJ Data Science* 5.1 (Nov. 2016). DOI: 10.1140/epjds/s13688-016-0093-1 (cited on pages 13, 14).

[137] Anthony C. Robinson. 'Elements of viral cartography'. In: *Cartography and Geographic Information Science* 46.4 (2019), pp. 293–310. DOI: 10.1080/15230406.2018.1484304 (cited on pages 2, 36, 37, 44).

[138] Anthony C. Robinson, Urška Demšar, Antoni B. Moore, Aileen Buckley, Bin Jiang, Kenneth Field, Menno-Jan Kraak, Silvana P. Camboim, and Claudia R. Sluter. 'Geospatial big data and cartography: research challenges and opportunities for making maps that matter'. In: *International Journal of Cartography* 3.sup1 (2017), pp. 32–60. DOI: 10.1080/23729333.2016.1278151 (cited on page 7).

[139] Anthony C. Robinson and Jonathan K. Nelson. 'Evaluating Maps in a Massive Open Online Course'. In: 80 (Oct. 2015), pp. 6–17. DOI: 10.14714/cp80.1299 (cited on page 36).

[142] Robert E. Roth. 'An Empirically-Derived Taxonomy of Interaction Primitives for Interactive Cartography and Geovisualization'. In: *IEEE Transactions on Visualization and Computer Graphics* 19 (2013), pp. 2356–2365 (cited on pages 16, 95, 137, 152).

[143] Robert E. Roth. 'How do user-centered design studies contribute to cartography?' In: *Geografie* 124.2 (2019), pp. 133–161. DOI: 10.37040/geografie2019124020133 (cited on pages 41, 79).

[144] Robert E. Roth. 'Cartographic Design as Visual Storytelling: Synthesis and Review of Map-Based Narratives, Genres, and Tropes'. In: *The Cartographic Journal* 58.1 (2021), pp. 83–114. DOI: 10.1080/00087041.2019.1633103 (cited on pages 7, 8, 11, 13, 14, 16, 17, 20, 27, 30, 93, 94, 115, 130).

[147] Sanja Šćepanović, Sagar Joglekar, Stephen Law, and Daniele Quercia. 'Jane Jacobs in the Sky: Predicting Urban Vitality with Open Satellite Data'. In: *Proc. ACM Hum.-Comput. Interact.* 5.CSCW1 (2021). DOI: 10.1145/3449257 (cited on page 99).

[151] Edward Segel and Jeffrey Heer. 'Narrative Visualization: Telling Stories with Data'. In: *IEEE Transactions on Visualization and Computer Graphics* 16.6 (Nov. 2010), pp. 1139–1148. DOI: 10.1109/tvcg.2010.179 (cited on pages 13, 16, 30, 129).

[152] Jerry Shannon and Kyle E. Walker. 'Ventures into Viral Cartography: Waffle House, Educational Attainment, and the Social Life of Maps'. In: *The Professional Geographer* 72.1 (2020), pp. 66–77. DOI: 10.1080/00330124.2019.1653774 (cited on pages 2, 32, 41).

[157] André Skupin and Sara Fabrikant. 'Spatialization Methods: A Cartographic Research Agenda for Non-geographic Information Visualization'. In: *Cartography and Geographic Information Science - CARTOGR GEOGR INF SCI* 30 (Apr. 2003). DOI: 10.1559/152304003100011081 (cited on page 25).

[159] Wonyoung So, Edyta P. Bogucka, Sanja Šćepanović, Sagar Joglekar, Ke Zhou, and Daniele Quercia. 'Humane Visual AI: Telling the Stories Behind a Medical Condition'. In: *IEEE Transactions on Visualization and Computer Graphics* 27.2 (2021), pp. 678–688. DOI: 10.1109/TVCG.2020.3030391 (cited on page 16).

[163] Matthias Thöny, Raimund Schnürer, René Sieber, Lorenz Hurni, and Renato Pajarola. 'Storytelling in Interactive 3D Geographic Visualization Systems'. In: *ISPRS International Journal of Geo-Information* 7.3 (2018). DOI: 10.3390/ijgi7030123 (cited on page 11).

[165] Chao Tong, Richard Roberts, Rita Borgo, Sean Walton, Robert S. Laramee, Kodzo Wegba, Aidong Lu, Yun Wang, Huamin Qu, Qiong Luo, and Xiaojuan Ma. 'Storytelling and Visualization: An Extended Survey'. In: *Information* 9.3 (2018). DOI: 10.3390/info9030065 (cited on page 7).

[167] Judith A. Tyner. 'Persuasive cartography'. In: *Journal of Geography* 81.4 (1982), pp. 140–144. DOI: 10.1080/00221348208980868 (cited on page 1).

[172] Peter Vujaković. 'Comic cartography: maps in cartoons'. In: *Geographical Magazine* 62.6 (1990), pp. 22–26 (cited on page 8).

[173] Peter Vujaković. 'The State as a 'Power Container': The Role of News Media Cartography in Contemporary Geopolitical Discourse'. In: *The Cartographic Journal* 51.1 (2014), pp. 11–24. DOI: 10.1179/1743277413Y.0000000043 (cited on pages 20, 128, 150).

[174] Rick Walker, Llyrap Cenydd, Serban Pop, Helen C. Miles, Chris J. Hughes, William J. Teahan, and Jonathan C. Roberts. 'Storyboarding for visual analytics'. In: *Information Visualization* 14.1 (May 2013), pp. 27–50. DOI: 10.1177/1473871613487089 (cited on page 11).

[177] Florian Windhager, Paolo Federico, Gunther Schreder, Katrin Glinka, Marian Dörk, Silvia Miksch, and Eva Mayr. 'Visualization of Cultural Heritage Collection Data: State of the Art and Future Challenges'. In: *IEEE Transactions on Visualization and Computer Graphics* 25.6 (June 2019), pp. 2311–2330. DOI: 10.1109/tvcg.2018.2830759 (cited on pages 38, 39).

[178] Jo Wood, Alexander Kachkaev, and Jason Dykes. 'Design Exposition with Literate Visualization'. In: *IEEE Transactions on Visualization and Computer Graphics* 25.1 (2019), pp. 759–768. DOI: 10.1109/TVCG.2018.2864836 (cited on pages 30, 41).

[179] Nai Yang, Alan M. MacEachren, and Emily Domanico. 'Utility and usability of intrinsic tag maps'. In: *Cartography and Geographic Information Science* 47.4 (2020), pp. 291–304. DOI: 10.1080/15230406.2020.1732835 (cited on page 8).

[181] Ye Yuan, Judy Major-Girardin, and Steven Brown. 'Storytelling Is Intrinsically Mentalistic: A Functional Magnetic Resonance Imaging Study of Narrative Production across Modalities'. In: *Journal of Cognitive Neuroscience* 30.9 (Sept. 2018), pp. 1298–1314. DOI: 10.1162/jocn_a_01294 (cited on pages 10, 28).

[182] Wei Zeng and Yu Ye. 'VitalVizor: A Visual Analytics System for Studying Urban Vitality'. In: *IEEE Computer Graphics and Applications* 38.5 (2018), pp. 38–53. DOI: 10.1109/MCG.2018.053491730 (cited on page 99).

Books

[22] Nadieh Bremer and Shirley Wu. *Data Sketches*. AK Peters Visualization Series. London, England: CRC Press, Feb. 2021 (cited on page 41).

[29] Michel de Certeau. *Practice of Everyday Life*. University of California, 1980 (cited on pages 1, 7).

[33] Yu-Kai Chou. *Actionable Gamification - Beyond Points, Badges, and Leaderboards*. Milpitas, USA: Octalysis Media, Apr. 1, 2017 (cited on page 111).

[40] Catherine D'Ignazio and Lauren F. Klein. *Data Feminism*. The MIT Press, 2020 (cited on page 30).

[45] Borden D. Dent, Jeff Torguson, and Thomas W. Hodler. *Cartography: Thematic Map Design*. New York: McGraw-Hill, 2009, pp. 19–20 (cited on page 29).

[46] Allan deSouza. *How Art Can Be Thought: A Handbook for Change*. Duke University Press Books, 2018 (cited on page 7).

[47] Ansen Dibell. *Plot. Elements of Fiction Writing*. Writer's Digest Books, 1999, p. 5 (cited on page 7).

[55] John H. Falk. *Identity and the Museum Visitor Experience*. Routledge, 2012 (cited on page 27).

[59] Brian Jeffrey Fogg. *Persuasive Technology: Using Computers to Change What We Think and Do*. Morgan Kaufmann, 2003 (cited on pages 20, 31).

[62] Mike Gasher. *Maps of the news: Journalism as a practice of cartography*. Stuttgart, Germany: Franz Steiner Verlag, 2021 (cited on pages 1, 2, 29).

[66] Jonathan Gray, Lucy Chambers, Liliana Bounegru, and Wilfried Ruetten. *Data Journalism Handbook*. en. Sebastopol, CA: O'Reilly Media, 2012 (cited on page 2).

[68] Saul Greenberg, Sheelagh Carpendale, Nicolai Marquardt, and Bill Buxton. *Sketching User Experiences: The Workbook*. Elsevier, 2012 (cited on page 41).

[74] Tim Harrower. *Inside Reporting: A Practical Guide to the Craft of Journalism*. English. Paperback. McGraw Hill India, 2010 (cited on pages 34, 44, 129).

[75] Hannah B. Harvey. *The Art of Storytelling: From Parents to Professionals*. Chantilly, Virginia: The Great Courses, 2015 (cited on page 6).

[79] David Herzog. *Mapping the news*. Redlands, USA: Environmental Systems Research Institute, 2003 (cited on page 2).

[83] Peter Hühn, John Pier, Wolf Schmid, and Jörg Schönert, eds. *Handbook of Narratology*. Walter de Gruyter, Jan. 2009 (cited on page 27).

[94] Giorgia Lupi and Stefanie Posavec. *Dear Data*. Princeton Architectural Press, Sept. 2016 (cited on page 41).

[95] Ellen Lupton. *Design Is Storytelling*. Thames and Hudson, 2017 (cited on pages 11, 13, 31).

[97] Lev Manovich. *Cultural Analytics*. The MIT Press, 2020 (cited on pages 35–38).

[98] Massimo Mariani. *What Images Really Tell Us. Visual Rhetoric in Art, Graphic Design, and Advertisement*. Hoaki, 2019 (cited on pages 8, 10, 11, 17, 24, 25, 27).

[99] Todd May. *A Significant Life: Human Meaning in a Silent Universe*. Chicago: Unversity of Chicago Press, 2015 (cited on page 27).

[105] Mark Monmonier. *The History of Cartography, Volume 6: Cartography in the Twentieth Century*. Chicago: University of Chicago Press, 2015.

[121] Christian Nold. *Emotional Cartography: Technologies Of The Self*. Christian Nold, 2009 (cited on page 8).

[129] Luc Pauwels and Dawn Mannay, eds. *The SAGE Handbook of Visual Research Methods*. London, UK: SAGE Publications Ltd, 2020 (cited on page 35).

[134] Whitney Quesenbery and Kevin Brooks. *Storytelling for User Experience: Crafting Stories for Better Design*. Rosenfeld Media, 2010 (cited on page 10).

[136] Nathalie Henry Riche, Christophe Hurter, Nicholas Diakopoulos, and Sheelagh Carpendale, eds. *Data-Driven Storytelling*. AK Peters Visualization Series. London, England: CRC Press, 2018 (cited on page 2).

[158] Terry A. Slocum, Robert B. McMaster, Fritz C. Kessler, and Hugh H. Howard. *Thematic Cartography and Geovisualization, 3rd Edition*. English. Hardcover. Pearson, Apr. 14, 2008, p. 576 (cited on page 135).

[164] Paweł Tkaczyk. *Narratologia*. Warsaw: Wydawnictwo Naukowe PWN, 2017 (cited on pages 7, 11, 19, 27, 28).

[175] Jerry Weissman. *Presenting to Win: The Art of Telling Your Story*. Financial Times Prentice Hall, 2008 (cited on pages 13, 14, 17, 27).

[180] Daniel Yates, David Moore, and George McCabe. *The practice of Statistics*. New York, USA: W.H. Freeman, 1999, p. 734 (cited on page 49).

Book chapters

[6] Benjamin Bach, Moritz Stefaner, Jeremy Boy, Steven Drucker, Lyn Bartram, Jo Wood, Paolo Ciuccarelli, Yuri Engelhardt, Ulrike Köppen, and Barbara Tversky. 'Narrative Design Patterns for Data-Driven Storytelling'. In: *Data-Driven Storytelling*. Ed. by Nathalie Henry Riche, Christophe Hurter, Nicholas Diakopoulos, and Sheelagh Carpendale. AK Peters Visualization Series. London, England: CRC Press, 2018, pp. 107–133 (cited on pages 23, 118).

[10] Philip Bell. 'Content analysis of visual images'. In: *The Handbook of Visual Analysis*. Ed. by Theo Van Leeuwen and Carey Jewitt. London, UK: SAGE Publications Ltd, 2000, pp. 10–34 (cited on pages 44, 48).

[34] Andrew Clark. 'Visual Ethics Beyond the Crossroads'. In: *The SAGE Handbook of Visual Research Methods*. Ed. by Luc Pauwels and Dawn Mannay. London, UK: SAGE Publications Ltd, 2020, pp. 682–694 (cited on page 29).

[35] Paul Cobley. 'Narratology'. In: *The John's Hopkins Guide to Literary Theory and Criticism*. Ed. by Michael Groden, Martin Kreiswirth, and Imre Szeman. Baltimore: The Johns Hopkins University Press, 2005, pp. 677–683 (cited on page 27).

[39] Donna J. Cox. 'Metaphoric mappings: The art of visualization'. In: *Aesthetic Computing*. Ed. by Paul A. Fishwick. Cambridge, Massachusetts: The MIT Press, 2006, pp. 89–114 (cited on page 25).

[49] Jacques Durand. 'Rhetorical Figures in the Advertising Image'. In: *Marketing and Semiotics: New Directions in the Study of Signs for Sale*. Ed. by Jean Umiker-Sebeok. New York, New York, USA: De Gruyter, 1987, pp. 295–318 (cited on pages 19, 22, 24, 44, 134).

[69] Laurie Gries. 'Advances in Visual Rhetorical Analysis'. In: *The SAGE Handbook of Visual Research Methods*. Ed. by Luc Pauwels and Dawn Mannay. London, UK: SAGE Publications Ltd, 2020, pp. 381–396 (cited on pages 19, 20, 34, 35, 37).

[73] John Brian Harley. 'Deconstructing the Map'. In: *Classics in Cartography*. John Wiley and Sons, Ltd, 2011. Chap. 16, pp. 271–294. DOI: https://doi.org/10.1002/9780470669488.ch16 (cited on pages 20, 22, 28, 29).

[81] Haosheng Huang and Georg Gartner. 'A Technical Survey on Decluttering of Icons in Online Map-Based Mashups'. In: *Online Maps with APIs and WebServices*. Ed. by Michael P. Peterson. Berlin, Heidelberg: Springer Berlin Heidelberg, Feb. 2012, pp. 157–175. DOI: 10.1007/978-3-642-27485-5_11 (cited on page 22).

[93] Mirko Lorenz. 'Status and Outlook for data-driven journalism'. In: *Data-driven journalism: What is there to learn?* Ed. by Howard Hudson. European Journalism Center EJC, 2010, p. 13 (cited on page 2).

[128] Katy Parry. 'Quantitative Content Analysis of the Visual'. In: *The SAGE Handbook of Visual Research Methods*. Ed. by Luc Pauwels and Dawn Mannay. London, UK: SAGE Publications Ltd, 2020, pp. 353–366 (cited on page 44).

[131] James Phelan. 'Narrative Ethics'. In: *Handbook of Narratology*. Ed. by Peter Hühn, Jan Christoph Meister, John Pier, and Wolf Schmid. De Gruyter Handbook. Berlin, Germany: De Gruyter, 2014, pp. 531–546 (cited on page 29).

[145] Robert E. Roth, Chloë Quinn, and David Hart. 'The Competitive Analysis Method for Evaluating Water Level Visualization Tools'. In: *Modern Trends in Cartography: Selected Papers of CARTOCON 2014*. Ed. by Jan Brus, Alena Vondrakova, and Vit Vozenilek. Lecture Notes in Geoinformation and Cartography. Cham, Switzerland: Springer International Publishing, 2015, pp. 241–256. DOI: 10.1007/978-3-319-07926-4_19 (cited on page 35).

[149] Susan Schulten. 'Journalistic Cartography'. In: Mark Monmonier. *The History of Cartography, Volume 6: Cartography in the Twentieth Century*. Chicago: University of Chicago Press, 2015, pp. 706–717 (cited on pages 1, 115).

[168] Judith A. Tyner. 'Persuasive Cartography'. In: Mark Monmonier. *The History of Cartography, Volume 6: Cartography in the Twentieth Century*. Chicago: University of Chicago Press, 2015, pp. 1087–1095 (cited on page 20).

Conference proceedings

[19] Nina Bonassi and René Sieber. 'Storytelling in Atlases – the intrinsic way'. In: *Proceedings of the 28th International Cartographic Conference ICC 2017*. 2017 (cited on page 8).

[63] William Gaver. 'What Should We Expect from Research through Design?' In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '12. Austin, Texas, USA: Association for Computing Machinery, 2012, pp. 937–946. DOI: 10.1145/2207676.2208538 (cited on page 40).

[78] Richard Herriott. 'What kind of research is research through design?' In: *Proceedings of the 2019 IASDR Conference on Design Revolutions*. IASDR '21. Manchester, United Kingdom: International Association of Societies of Design Research, 2019 (cited on page 40).

[87] Tobias Kauer, Marian Dörk, Arran L. Ridley, and Benjamin Bach. 'The Public Life of Data: Investigating Reactions to Visualizations on Reddit'. In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. CHI '21. Yokohama, Japan: Association for Computing Machinery, 2021. DOI: 10.1145/3411764.3445720 (cited on page 32).

[92] Crystal Lee, Tanya Yang, Gabrielle D. Inchoco, Graham M. Jones, and Arvind Satyanarayan. 'Viral Visualizations: How Coronavirus Skeptics Use Orthodox Data Practices to Promote Unorthodox Science Online'. In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. CHI '21. Yokohama, Japan: Association for Computing Machinery, 2021. DOI: 10.1145/3411764.3445211 (cited on page 32).

[96] Narges Mahyar, Sung-Hee Kim, and Bum Chul Kwon. 'Towards a Taxonomy for Evaluating User Engagement in Information Visualization'. In: *Personal Visualization : Exploring Data in Everyday Life : An IEEE VIS 2015 Workshop*. 2015 (cited on page 28).

[133] Barbara Piatti, Anne-Kathrin Reuschel, and Lorenz Hurni. 'A Literary Atlas of Europe - Analysing the Geography of Fiction with Interactive Mapping and Visualisation Tools'. In: *Proceedings of the 25th International Cartographic Conference ICC 2011*. 2011 (cited on page 8).

[153] Ben Shneiderman. 'The eyes have it: a task by data type taxonomy for information visualizations'. In: *Proceedings 1996 IEEE Symposium on Visual Languages*. 1996, pp. 336–343. DOI: 10.1109/VL.1996.545307 (cited on page 39).

[183] Chenyu Zuo, Linfang Ding, Edyta P. Bogucka, and Liqiu Meng. 'Map-based Dashboards versus Storytelling Maps'. In: *Adjunct Proceedings of the 15th International Conference on Location Based Services (LBS 2019)*. Vienna, Austria: Research Group Cartography, Vienna University of Technology, 2019. DOI: 10.34726/LBS2019 (cited on pages 31, 35, 36, 44, 46, 115, 131, 137, 152).

Online resources

[5] Nick Babich. *Top Website Layouts That Never Grow Old*. (visited: 2022-02-02). 2019. URL: https://xd.adobe.com/ideas/principles/web-design/11-website-layouts-that-made-content-shine-in-2019/ (cited on pages 44, 131).

[9] Bayerischer Rundfunk. *Ethics of Artificial Intelligence. Our AI Ethics Guidelines*. (visited: 2022-03-02). 2020. URL: https://www.br.de/extra/ai-automation-lab-english/ai-ethics100.html (cited on page 30).

[21] Paul Bradshaw. *The inverted pyramid of data journalism*. (visited: 2022-02-22). 2011. URL: https://onlinejournalismblog.com/2011/07/07/the-inverted-pyramid-of-data-journalism/ (cited on page 8).

[24] Harry Brignull. *Dark Patterns*. (visited: 2022-02-02). 2022. URL: https://www.darkpatterns.org/types-of-dark-pattern (cited on page 31).

[30] *Changing narratives*. (visited: 2021-06-21). 2021. URL: https://narrativelead.com/tag/changing-narratives/ (cited on page 121).

[48] Stephen K. Doig, James Savage, Dan Clifford, Jacquee Petchel, Jeff Leen, Lisa Getter, Tim Chapman, Luis Feldstein Soto, Don Finefrock, Patterson Clark, Al Diaz, Claudia Liautaud, Daryl Kanneberg, Erica Johnston, John Pancake, Bob Gilley, and Paul Mull. *What went wrong. Special Report. The Miami Herald*. (visited: 2022-02-02). 1992. URL: https://www.flickr.com/photos/juggernautco/albums/72157607210036175 (cited on page 2).

[60] Michael Gaigg. *Map UI patterns. Info-Popup*. (visited: 2021-08-21). 2021. URL: https://www.mapuipatterns.com/info-popup/ (cited on page 121).

[71] Web Content Accessibility Guidelines. *Complex Images*. (visited: 2021-08-21). 2019. URL: https://www.w3.org/WAI/tutorials/images/complex/ (cited on page 124).

[76] Marc Hassenzahl, Michael Burmester, and Franz Koller. *AttrakDiff*. (visited: 2022-02-02). 2022. URL: http://attrakdiff.de/index-en.html (cited on page 28).

[82] William Huber, Tara Zepel, and Lev Manovich. *Analyzing the Visual Strategies in the Science and Popular Science Magazines, 1872-2007*. (visited: 2022-03-02). 2010. URL: http://lab.culturalanalytics.info/2010/11/science-and-popular-science-magazines_23.html (cited on page 37).

[86] Justin Johnson. *A Neural Algorithm of Artistic Style*. (visited: 2022-02-22). 2015. URL: https://github.com/jcjohnson/neural-style (cited on page 110).

[88] Rudo Kemper, Antonio Peluso, and Isabella Roldan Usesche. *Mapping and recording place-based oral histories: a methodology*. (visited: 2022-02-22). 2019. URL: https://www.amazonteam.org/wp-content/uploads/2019/06/ACT_OralHistories_Guide_2019_ENGLISH-draft.pdf (cited on page 8).

[90] Marcela Kunova. *Modular journalism: what you need to know about this new approach to storytelling*. (visited: 2022-02-22). 2022. URL: https://www.journalism.co.uk/news/modular-journalism-what-you-need-to-know-about-this-new-approach-to-storytelling/s2/a905486/ (cited on page 34).

[102] Microsoft Canada. *Attention spans. Consumer Insights*. 2015. URL: https://dl.motamem.org/microsoft-attention-spans-research-report.pdf (cited on page 28).

[110] Lisa Charlotte Muth. *An alternative to pink and blue: Colors for gender data*. (visited: 2022-03-02). 2018. URL: https://blog.datawrapper.de/gendercolor/ (cited on page 92).

[113] N.N. *The Atlas of Design – a gallery of beautiful and inspiring maps from around the world*. (visited: 2022-03-02). 2012. URL: https://atlasofdesign.org/ (cited on page 41).

[127] Oxford English Dictionary. *Apperception*. 2022. URL: https://www.lexico.com/en/definition/apperception (cited on page 27).

[146] David Rumsey. *More Than Digital Copies: Maps That Interpret Maps*. (visited: 2022-02-22). 2022. URL: https://www.davidrumsey.com/blog/2022/1/25/more-than-digital-copies-maps-that-interpret-maps (cited on pages 38, 39).

[150] Jonathan Schwabish. *4 Observations on Animating Your Data Visualizations*. (visited: 2022-02-22). 2019. URL: https://medium.com/@urban_institute/4-observations-on-animating-your-data-visualizations (cited on page 16).

[161] The Open Data Institute. *The Data Ethics Canvas*. (visited: 2022-03-02). 2021. URL: https://theodi.org/article/the-data-ethics-canvas-2021/ (cited on page 30).

[162] Amber Thomas. *Continue, Pivot or Put it Down. The Pudding's process to go from idea to data story*. (visited: 2022-03-02). 2020. URL: https://pudding.cool/process/pivot-continue-down/ (cited on pages 31, 32).

Featured map-based stories

[12] Paul Blickle, Elena Erdmann, Flavio Gortana, Maria Mast, Julian Stahnke, and Julius Tröger. *Viel zu warm hier*. URL: https://www.zeit.de/wissen/umwelt/2019-12/klimawandel-globale-erwaermung-warming-stripes-wohnort. [Online; accessed March 07, 2022]. Dec. 2019 (cited on page 58).

[14] Paul Blickle, Karsten Polke-Majewski, Julian Stahnke, and Venohr Sascha. *Geld zieht Ärzte an*. URL: https://www.zeit.de/feature/gesundheit-arzt-privat-versicherung-praxis. [Online; accessed March 07, 2022]. July 2015 (cited on page 58).

[15] Ilia Blinderman. *A concise, travel-like-a-local guide to 74,762 attractions, according to 9,526,193 reviews*. URL: https://pudding.cool/2020/05/travel-local/. [Online; accessed March 07, 2022]. May 2020 (cited on page 58).

[32] Gwyneth Cheng. *Wild Otters – Threatened and traded*. URL: https://kontinentalist.com/stories/otters-are-cute-but-endangered-and-trafficked-as-pets-in-asia. [Online; accessed March 07, 2022]. June 2021 (cited on page 58).

[41] Matt Daniels, Ilia Blinderman, and Russell Samora. *The Geographic Divide of Oscar Films*. URL: https://pudding.cool/2017/02/oscars_so_mapped/. [Online; accessed March 07, 2022]. Feb. 2017 (cited on page 58).

[51] Annick Ehmann, Linda Fischer, Flavio Gortana, and Julius Tröger. *Historisch trocken*. URL: https://www.zeit.de/wissen/umwelt/2020-04/klimawandel-duerresommer-deutschland-landwirtschaft-boeden/komplettansicht. [Online; accessed March 07, 2022]. Apr. 2020 (cited on page 58).

[52] Annick Ehmann, Flavio Gortana, Maria Mast, Julian Stahnke, and Julius Tröger. *In der Hitze der Ozeane*. URL: https://www.zeit.de/wissen/umwelt/2020-01/klimawandel-temperaturen-rekord-wassertemperatur-folgen-tierschutz-klimaschutz. [Online; accessed March 07, 2022]. Feb. 2020 (cited on page 58).

[118] N.N. *This project is about your geographic music bubble*. URL: https://pudding.cool/2021/04/music-bubble/. [Online; accessed March 07, 2022]. Apr. 2021 (cited on page 58).

[140] Pablo Robles, Darren Long, and Yaser Ibrahim. *Australian fires: Understanding the intensity and global impact*. URL: https://multimedia.scmp.com/infographics/news/world/article/3046510/australian-fires/index.html. [Online; accessed March 07, 2022]. Jan. 2020 (cited on page 121).

Maps

[2] Gregor Aisch, Matthew Bloch, Kenan Davis, Stephen Farrell, Troy Griggs, Rich Harris, and Adam Pearce. *How Britain Voted*. [Online; accessed March 07, 2022]. 2017. URL: https://www.nytimes.com/interactive/2017/06/08/world/europe/british-general-election-results-analysis.html (cited on page 81).

[3] Adolfo Aranz and Marco Hernandez. *The discovery of the roundtrip and the beginning of globalisation*. [Online; accessed March 07, 2022]. 2018. URL: https://multimedia.scmp.com/culture/article/spanish-galleon/chapter_01.html (cited on page 121).

[4] Azofi. *Book of the Images of the Fixed Stars*. [Online; accessed October 22, 2021]. 15th century. URL: https://www.metmuseum.org/art/collection/search/446297 (cited on page 15).

[13] Paul Blickle, Elena Erdmann, Fravio Gortana, Maria Mast, and Julius Stahnke Julian und Tröger. *Viel zu warm hier*. [Online; accessed September 10, 2021]. 2019. URL: https://www.zeit.de/wissen/umwelt/2019-12/klimawandel-globale-erwaermung-warming-stripes-wohnort (cited on page 23).

[25] Elmer Simms Campbell. *A night-club map of Harlem*. [Online; accessed March 10, 2021]. 1933. URL: https://www.loc.gov/item/2016585261/ (cited on page 12).

[38] Giorgio Comai, Alice Corona, Lorenzo Ferrari, Ornaldo Gjergji, and Chiara Sighele. *Perché la toponomastica riguarda ognuno di noi*. [Online; accessed November 20, 2021]. 2021. URL: https://mappingdiversity.eu/ (cited on page 91).

[53] Paul Ehrlich. *Topografische Karte 1:25,000, 1269 Aletschgletscher*. [Online; accessed December 15, 2019]. 2013. URL: https://www.palestine-studies.org/en/node/198349 (cited on page 24).

[54] Erik Escoffier, Juan Carlos Alonso, and Jose Angel Parreño. *OpenStreetMap Haiku*. [Online; accessed March 06, 2022]. 2019. URL: https://satellitestud.io/osm-haiku/app (cited on page 9).

[56] Jason Farago. *A Picture of Change for a World in Constant Motion*. [Online; accessed September 24, 2020]. 2020. URL: https://www.nytimes.com/interactive/2020/08/07/arts/design/hokusai-fuji.html (cited on page 9).

[58] Lella Secor Florence. *Altitude and Vegetation, United States*. [Online; accessed October 22, 2017]. 1943. URL: https://eagereyes.org/isotope-books/isotype-book-florence-only-an-ocean-between (cited on page 15).

[61] J.T. Gardner. *Yosemite Valley*. [Online; accessed March 07, 2022]. 1868. URL: https://davidrumsey.georeferencer.com/maps/e6741461-f798-5137-8f39-d0a9624c6f44/ (cited on page 39).

[77] Anthony Hearsey. *Australia is burning. A 3D visualization*. [Online; accessed March 07, 2022]. 2020. URL: https://anthonyhearsey.com/australia-is-burning-a-3d-visualisation (cited on page 26).

[85] Andreu Jerez. *Municipis que van votar Hitler ara donen suport a la ultradreta*. [Online; accessed March 07, 2022]. 2019. URL: http://www.davidecantoni.net/press/Ara_20190310_19.pdf (cited on page 85).

[100] Stuart McArthur. *McArthur's Universal Corrective Map of the World*. [Online; accessed March 07, 2022]. 1979. URL: https://mapdesign.icaci.org/2014/02/mapcarte-38365-mcarthurs-universal-corrective-map-of-the-world-stuart-mcarthur-1979/ (cited on page 24).

[111] N.N. *Atlas administratif de la ville de Paris*. [Online; accessed March 07, 2022]. 1868. URL: https://www.davidrumsey.com/blog/2022/1/25/more-than-digital-copies-maps-that-interpret-maps (cited on page 39).

[112] N.N. *Topografische Karte 1:200.000*. [Own photograph from the exhibition: Navigating Berlin. Perspectives on Cartography. Representation & Absence; made February 08, 2020]. 1988 (cited on page 24).

[114] N.N. *EU Referendum Results 2016 vs. Mad Cow Disease Outbreak Areas 1992*. [Online; accessed March 07, 2022]. 2016. URL: https://www.facebook.com/TerribleMaps/photos/a.1702342333343482/1762318730679175 (cited on page 24).

[115] N.N. *Fridays for Future. Map of Actions*. [Online; accessed September 10, 2019]. 2019. URL: https://fridaysforfuture.org/action-map/map/ (cited on page 23).

[116] N.N. *New research finds parallels between German votes in 1933 and now*. [Online; accessed March 07, 2022]. 2019. URL: https://www.economist.com/graphic-detail/2019/03/16/new-research-finds-parallels-between-german-votes-in-1933-and-now (cited on page 85).

[117] N.N. *If Land & Sea Were Inverted*. [Online; accessed March 07, 2022]. 2021. URL: https://www.reddit.com/r/MapPorn/comments/nc2vke/if_land_sea_were_inverted/ (cited on page 24).

[122] Jean Baptiste Nolin. *Historic Map : Le Globe Terrestre Represente En Deux Plans-Hemispheres et en Diverses Autres Figures*. [Online; accessed March 07, 2022]. 1742. URL: https://www.historicpictoric.com/products/historic-map-le-globe-terrestre-represente-en-deux (cited on page 26).

[125] John Ogilby. *The Road from Whitby to Durham. Durham to Tinmouth*. [Online; accessed October 22, 2021]. 1675. URL: https://searchworks.stanford.edu/view/kq067ff9858 (cited on page 16).

[126] OSM Contributors. *Open Street Map*. [Online; accessed March 07, 2022]. 2022. URL: https://davidrumsey.georeferencer.com/compare#35052276697 (cited on page 39).

[130] Rebecca Pazos. *On a little street in Singapore... A road map of history, culture and society*. [Online; accessed November 20, 2021]. 2019. URL: https://graphics.straitstimes.com/STI/STIMEDIA/Interactives/2019/06/singapore-street-names/index.html (cited on page 91).

[141] Dan Rosenheck and James Fransham. *Too close to call*. [Online; accessed March 07, 2022]. 2018. URL: https://blueprintnewsonline.com/5406/news/whats-on-the-ballot-a-moco-student-guide-to-the-2018-midterms/ (cited on page 81).

[148] Paula Scher. *Maps*. [Online; accessed May 10, 2020]. 2011. URL: https://www.printmag.com/designer-interviews/paula-scher-maps/ (cited on page 9).

[155] Paul Signac. *The Ruins at Grimaud, Saint-Tropez*. [Online; accessed November 20, 2021]. 1899. URL: https://artsandculture.google.com/asset/the-ruins-at-grimaud-saint-tropez-signac-paul/NgGriKxfqF_K3w (cited on page 92).

[156] T.-B. Sirén. *N.N.* [Online; accessed March 07, 2022]. 1967. URL: https://hs.mediadelivery.fi/img/1920/fb16969e20b744a3906dbfa18a865d76.jpg (cited on page 19).

[160] Famiano Strada. *Leo Belgicus. Novus XVII. Inferioris Germaniæ Provinciarum*. [Online; accessed March 07, 2022]. 1648. URL: https://digital.library.cornell.edu/catalog/ss:3293726 (cited on page 26).

[166] Walter Trier. *Karte von Europe im Jahre 1914*. [Online; accessed May 15, 2021]. 1914. URL: http://www.worldwar1.com/roads/jpg/roads_satiremaps.jpg (cited on page 24).

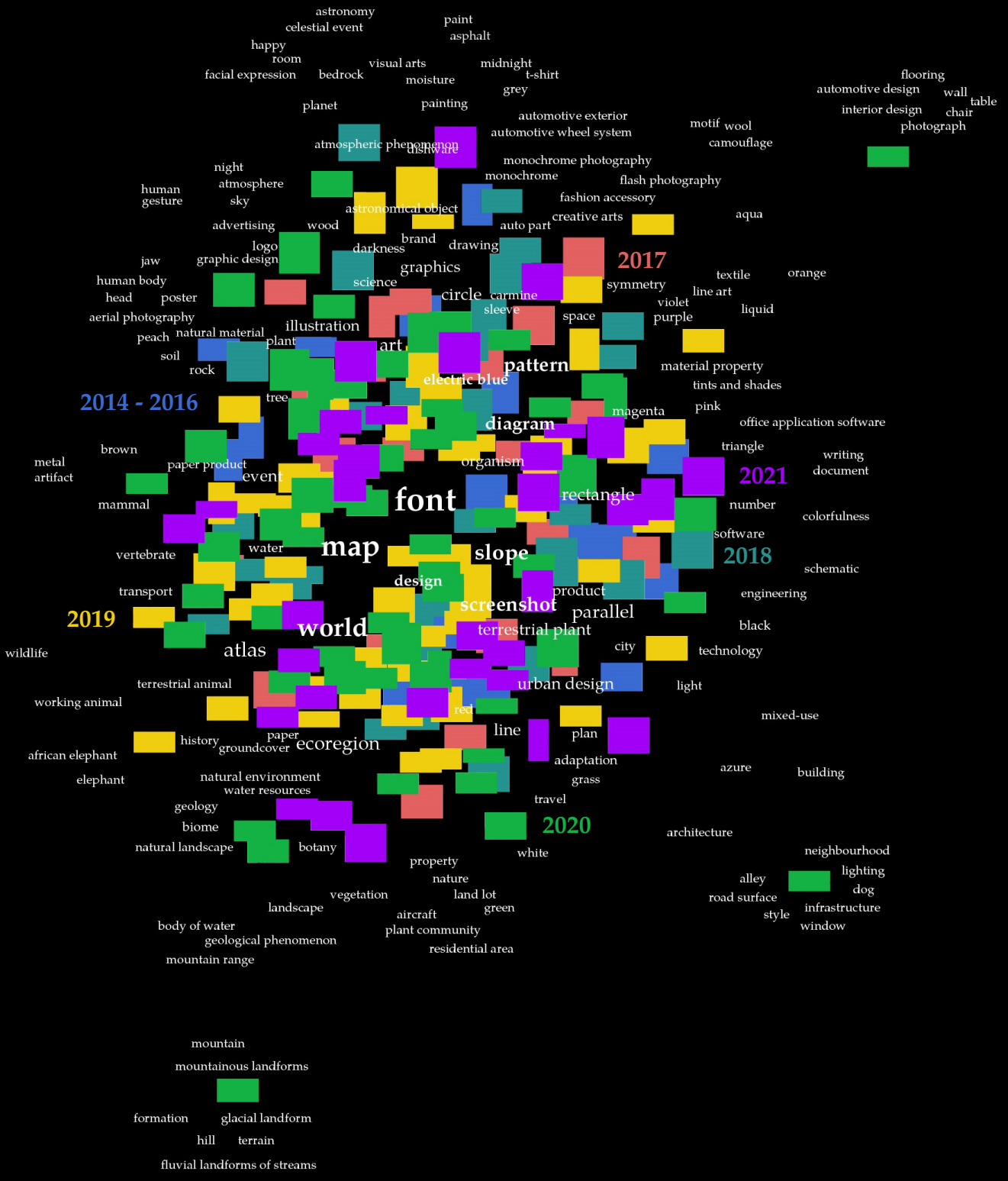
[169] U.S. Geological Survey. *Yosemite, Calif*. [Online; accessed March 07, 2022]. 1906. URL: https://davidrumsey.georeferencer.com/maps/5614f2b5-4785-536c-a4aa-89b69cd0aa69/ (cited on page 39).

[170] Kryštof Vetter. *Mapa Bohemiae Rosa*. [Online; accessed March 07, 2022]. 1668. URL: https://centrici.hypotheses.org/871 (cited on page 26).

[171] Fernanda Viégas and Martin Wattenberg. *Wind map*. [Online; accessed March 07, 2022]. 2012. URL: http://hint.fm/wind/ (cited on page 26).

[176] G.M. Wheeler. *Topographical Map Of The Yosemite Valley And Vicinity. Preliminary Edition.* [Online; accessed March 07, 2022]. 1876. URL: https://davidrumsey.georeferencer.com/maps/94ed996d-0d8f-58ed-9f7f-f71b82235fde/ (cited on page 39).

Alphabetical index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celestial event
paint
asphalt
happy
room
facial expression
bedrock
visual arts
moisture
midnight
t-shirt
grey
flooring
automotive design
wall
table
interior design
chair
photograph
planet
painting
automotive exterior
automotive wheel system
motif
wool
camouflage
atmospheric phenomenon
dishware
monochrome photography
monochrome
flash photography
night
atmosphere
human gesture
sky
fashion accessory
astronomical object
creative arts
aqua
advertising
wood
auto part
brand
drawing
logo
darkness
graphic design
2017
jaw
graphics
textile
orange
human body
science
symmetry
head
poster
circle
carmine
line art
violet
aerial photography
sleeve
space
purple
liquid
illustration
peach
natural material
plant
art
soil
pattern
material property
rock
electric blue
tints and shades
2014 - 2016
tree
magenta
pink
diagram
office application software
brown
triangle
writing
metal artifact
paper product
organism
document
event
2021
font
rectangle
mammal
number
colorfulness
software
vertebrate
water
map
slope
2018
schematic
design
transport
product
engineering
screenshot
2019
parallel
world
terrestrial plant
black
wildlife
atlas
city
technology
terrestrial animal
urban design
light
working animal
red
mixed-use
line
plan
paper
history
groundcover
ecoregion
adaptation
azure
building
african elephant
natural environment
grass
elephant
water resources
travel
geology
2020
biome
architecture
natural landscape
botany
white
neighbourhood
property
lighting
nature
alley
vegetation
land lot
dog
road surface
landscape
green
infrastructure
aircraft
style
body of water
plant community
window
geological phenomenon
residential area
mountain range
mountain
mountainous landforms
formation
glacial landform
hill
terrain
fluvial landforms of streams