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**Navigating Pictorial Maps
with Attention Guiding and
Narrative Techniques**

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Navigating Pictorial Maps with Attention Guiding and Narrative Techniques

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Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled:
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Literal or analogous citations are clearly marked as such.

Munich, 21.10.2020

Shah Taj

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Abstract

The absence of visual or narrative guidance in a busy pictorial map can leave map users disoriented. Interaction and guidance to support navigation is the state of art in digital maps. This research focuses on finding attention guiding and narrative techniques suitable for pictorial maps, existing in web applications and literature and choose the suitable ones for evaluation over a pictorial map. Opacity mask, numbering, and geometric boundaries are chosen to be evaluated/assessed for this study.

These attention guiding and narrative techniques are implemented in a specifically developed web-based prototype. The three attention guiding techniques are integrated as layers overlaid on a pictorial base map. These techniques are subject to a quantitative and qualitative user evaluation study. The respondents explore the prototype and register their user experience. Two fundamental questions under evaluation are 1) the comparison of a pictorial base map against a pictorial map with attention guidance 2) the comparison of the three attention guiding techniques among themselves. The research concludes by establishing that users prefer a pictorial map with attention guidance and the preferred attention guiding technique is Opacity Mask.

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1. Introduction

This chapter introduces the perspectives on pictorial maps, the objectives, and questions of the research and the motivation for it. As a cartographic-centered study, the subject under consideration is a map. To understand the topic and scope of this thesis, let us first observe what a map is.

“The projection and materialization of a mental schema on a medium. The materialization of an abstract intellectual order extracted from the empirical universe”
(Jacob & Jacob, 2006, as cited in Denil, 2016)

And what is a map supposed to do?

“A rhetorical entity that must be useful, usable and persuasive.”
(Denil, 2003, as cited in Denil, 2016)

The two definitions point out the identity and the purpose of a map. Denil (2016) has identified a map as a rhetorical entity; this could be because it reflects what already exists in the world or our minds, as pointed out by Jacob & Jacob (2006). And like a lot of things, while its purpose is to be useful, it is also supposed to be persuasive and convince the reader of the information or narrative it conveys.

Maps have some established genres through which most audiences identify it; such as *Topographic, Thematic, and Navigation* maps. There are also some new forms of maps that are evolving with the introduction of new technology. One direction develops with the digitalization of maps and introduced interactions that formed digital maps, 3D maps, web maps, and similar. Another with the advent of narrative visualization in maps, turning them into storytelling maps and pictorial maps. A third direction came with the development in remote sensing, creating image maps.

Among the new forms, some have been researched while some have yet to be explored in detail. And as it might seem that all these forms are new, it could come as a surprise that pictorial maps go back as far as the beginning of cartography.

1.1. Pictorial maps in historical perspective

Humans have been making maps since ancient times with any available resources to establish and explain the geography around them. Since previously most maps were handmade, the object representations were more artistic in nature. A very good example of this is the Babylonian map of the world on a clay tablet, made in around 600 B.C. (Figure 1-1, left). The Babylonians managed to mark their surrounding cities and river Euphrates to depict geography according to their understanding.

Another example of an ancient map is the work of Moroccan cartographer Muhammad Al-Idrisi (Figure 1-1, right). The map is hand-drawn, putting south on the top, with blue color representing the ocean and hand-drawn peaks representing mountains. It clearly has pictorial elements and labels in Arabic to identify the

locations. Similarly, the historical map of East Asia (Figure 1-2), is entirely pictorial, whereas, the portolan chart from Europe contains several pictorial elements, such as flags, buildings, mountains, and rivers to name a few (Figure 1-3). These examples prove that the maps created in ancient times were mostly pictorial or had pictorial elements in them to show themes and culture. In the past, most T-O maps (*Orbis Terrarum*) were pictorial maps that told the religious history of an area.



Figure 1-1: Oldest pictorial representations on the map: (left) the World Map on the Babylonian Clay Tablet, around 600 B.C (Tablet | British Museum, n.d.); (right) the World Map by Moroccan Cartographer Muhammad Al-Idrisi, made in 1154 (Idrisi, 1154)



Figure 1-2: Pictorial maps of Aihun, Russia, Taiwan, and Mongolia created between 1697 –1722. (Aihun, Luosha, Taiwan, Nei Menggu tu., 1697)



Figure 1-3: Chart of the world from the Cape Verde Islands to the Red Sea. It depicts, Atlas Mountains, Alps, and a few rivers including the Danube and the Guadalquivir, and a church marking Rome. (Portolan Chart Attributed to Angelino Dulcert | British Library - Picturing Places, n.d.)

1.2. Understanding a modern pictorial map

Presently several terms are used interchangeably to describe the cartographic products with image-like content, among them “pictorial maps”, “image maps”, “map-related presentations” or “storytelling maps”. Pictorial maps were firstly defined by Naz (2005) as:

“... mental or thematic maps, where geography is distorted to reflect the reality in our minds rather than the world around us.”

However, a pictorial map is not the same as an image map, because an image map is, as defined by Murphy (2014):

A “visualization technique composed by remote sensing imagery and cartographic symbolization”.

These definitions draw a clear contrast between an image map and a pictorial map. In an image map, the geography can only be distorted by the distortion of the remote sensing imagery itself, possibly from the tilt or angle of the camera through which the image is captured. Pictorial maps imply deliberate (dis)placement of geographical elements.

A storytelling map goes beyond the purpose of displaying geographical features and helps to tell stories through the visual and narrative elements embedded in it. Pictorial maps are therefore referred to as storytelling maps because of their artistic visuals conveying information on the history, lifestyle, beliefs, and legacy of an area.

From the technical perspective, a pictorial map may be usually classified as a map-related presentation instead of a map. According to Meng (n.d.),

“A map-related presentation may share with maps certain similarity with regard to mapping contents and abstractions driven by map scale, target groups and/or purposes... may differ from maps in aspects like display dimensions, projections, symbolization styles and perception channels.” (Meng, n.d.)

However, this does not mean that they fail in their purpose of landmark identification and wayfinding.

Navigation is a process that helps people to reach one point from the other. In the real world, it can be through digital platforms and, obviously, maps. Navigating a pictorial map similarly means being able to move through the elements of the map. As in all navigation processes, it uses signs, cues, or other supporting elements to help through the process. Navigation through a pictorial map can be done with the use of attention guiding and narrative techniques. The attention guiding techniques guide the reader’s attention on the map, while the narrative techniques explain the narrative or information regarding the significant map elements.

Figure 1-4 shows the pictorial map of The Metropolitan Museum of Art (New York), which is made for children to familiarize them with the different parts of the museum. For this map, the indoor geography of the museum is distorted to squeeze everything in; however, it does provide a sense of orientation and placement of the artifacts in the museum. It might not be a geographically correct map but is nevertheless labeled as a map by the website. Observing this map in the light of referred map definitions, (Jacob & Jacob 2006, Denil 2016), this map fulfills the definition and the purpose of a map. Moreover, it fits the definition of a pictorial map by Naz (2005). Hence, this is a perfect example of a pictorial map.



Figure 1-4: Metkids - interactive pictorial map of a museum. (#MetKids Map, n.d.)

1.3. Motivation and Problem Statement

Misinterpretation of the map contents can lead to problematic perceptions. Likewise, lack of guidance through a busy map such as a pictorial map can leave the reader at a loss of information about it. When evaluated for pictorial maps, not all attention guiding techniques seemed to fit. Conclusively, *the problem is that there has not been much research on the use of these existing genres and techniques for the case of pictorial maps*. Hence, the motivation for this research is *to find narrative and attention guiding techniques that work well for pictorial maps in terms of perception and navigation*.

1.4. Research Objectives & Questions

1.4.1. Research Objectives

The main objective of this thesis is to derive a taxonomy and evaluate the effectiveness of attention guiding and narrative techniques for navigating pictorial maps. To reach this objective, the following intermediate steps need to be accomplished:

- a. Creation of a taxonomy of attention guiding techniques based on the existing literature and web-based applications review.
- b. Selection and implementation of chosen techniques in a web-based application prototype.
- c. Evaluation of the applied techniques through a user study and results analysis.

1.4.2. Research Questions

Sub-objective a: Creation of a taxonomy of attention guiding techniques based on the existing literature and web-based applications review.

Literature research

- 1) What are the groups of attention guiding and narrative techniques available in the literature?
- 2) Have any of these techniques been researched for Cartography?

Application-based research

- 3) What are the main groups of attention guiding techniques and narrative techniques available online?
- 4) Do these techniques exist in combinations or in isolation?

Sub-objective b: Selection of the techniques and their implementation in prototype development.

- 5) What attention guiding and narrative technique did I choose for this study and why?
- 6) What technologies are used in the development of the prototype?
- 7) How to design and deploy attention guiding techniques using visual encoding and interactions?

Sub-objective c: Evaluation of the applied techniques through user study and results analysis

- 8) Which method is employed for the evaluation of techniques?
- 9) Which technique performed better in the user study and on what grounds?
- 10) What are the differences observed between the baseline pictorial map and the attention guiding technique applied to it?

1.5. Target Research Innovation and Audience

The novelty of this work would be to evaluate the attention guiding techniques for pictorial maps. The work will be the only of its kind since navigating interactive pictorial maps is a relatively new domain. While there have been some studies on the conceptual framework for interactive cartographic storytelling (Cortés, 2018), there has not been so far any comparative evaluation of the attention guiding techniques for interactive pictorial maps.

This study will draw out the effectiveness of the techniques under investigation and their advantages over each other. The audience for whom it would be useful in the context of navigating through maps:

- Students and cartographers,
- Tourists,
- Oil and Gas Exploration Workers,
- Indoor Evacuation Planners.

The audience that does not necessarily use maps but pictures or a visual representation for which the attention guiding and narrative techniques would be useful:

- Storytellers,
- Specialists in heritage digitalization: for preservation and conveyance of the heritage site and belongings through a digital medium,
- Museum specialists for virtual navigation of the museum chambers and treasuries.

2. Literature Review

This chapter discusses the literature that has helped understand some basic concepts in the light of prior research, such as data visualization, storytelling, and cartographic design to name a few. The Literature review is further divided into two categories, both ordered chronologically:

1) Foundational Literature - the research that has been carried out to identify and categorize the genres and techniques for visualization and storytelling through maps. These studies have also helped in developing the taxonomy.

2) Supportive Literature - the research that is not directly applicable to pictorial maps but has helped in understanding some basic map, visualization, and design concepts and how they evolved.

Keywords: attention guiding, visualization, storytelling, narrative design, storytelling design, storytelling interface, visual guidance

2.1. Foundational Literature

Segel & Heer (2010) employed seven genres while analyzing visual storytelling through narrative visualization: magazine-style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation (Figure 2-1). These genres were based on applications of storytelling through data and had limitations in terms of their application for maps.

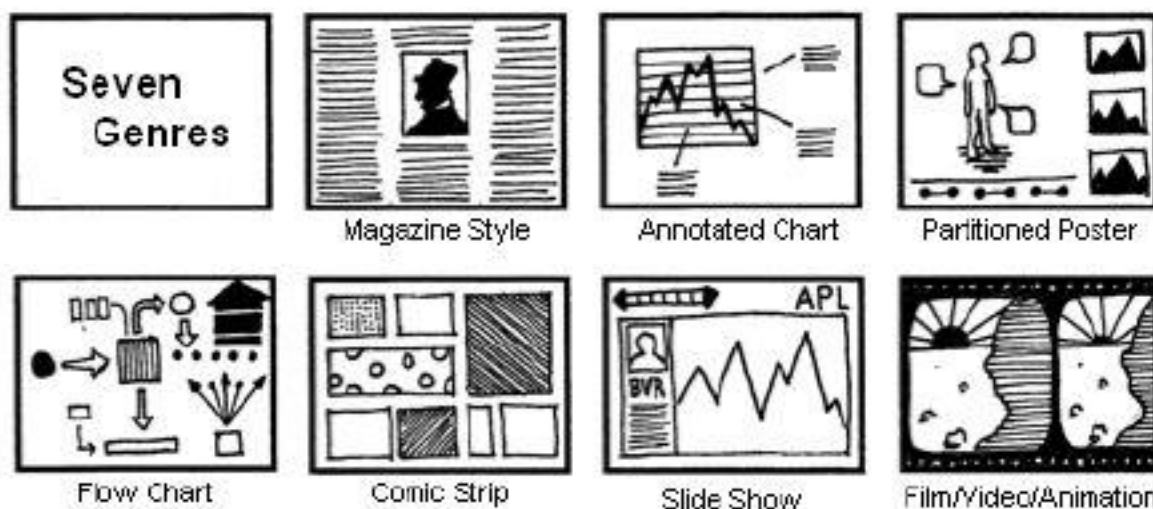


Figure 2-1: Visual Storytelling Genres by Segel & Heer (2010)

Roth (2020) has done a thorough review of techniques for approaching cartographic design as visual storytelling. He has reviewed 10 themes that make visual storytelling

different from the traditional perspective on cartographic design. He reviewed 3 ways to organize the design space for map-based visual storytelling: 1) narrative elements 2) visual storytelling genres 3) tropes. The narrative element defines how a story will move through the course of its phases in the narrative sense. The genres contain the ways a visual story can look or how one navigates through it (Figure 2-2). The tropes define the way texts, maps, images, or other media are used within the visual story. All the techniques within them are important and we will weigh the efficiency of their combinations on a pictorial map by applying a few of them in our prototype.

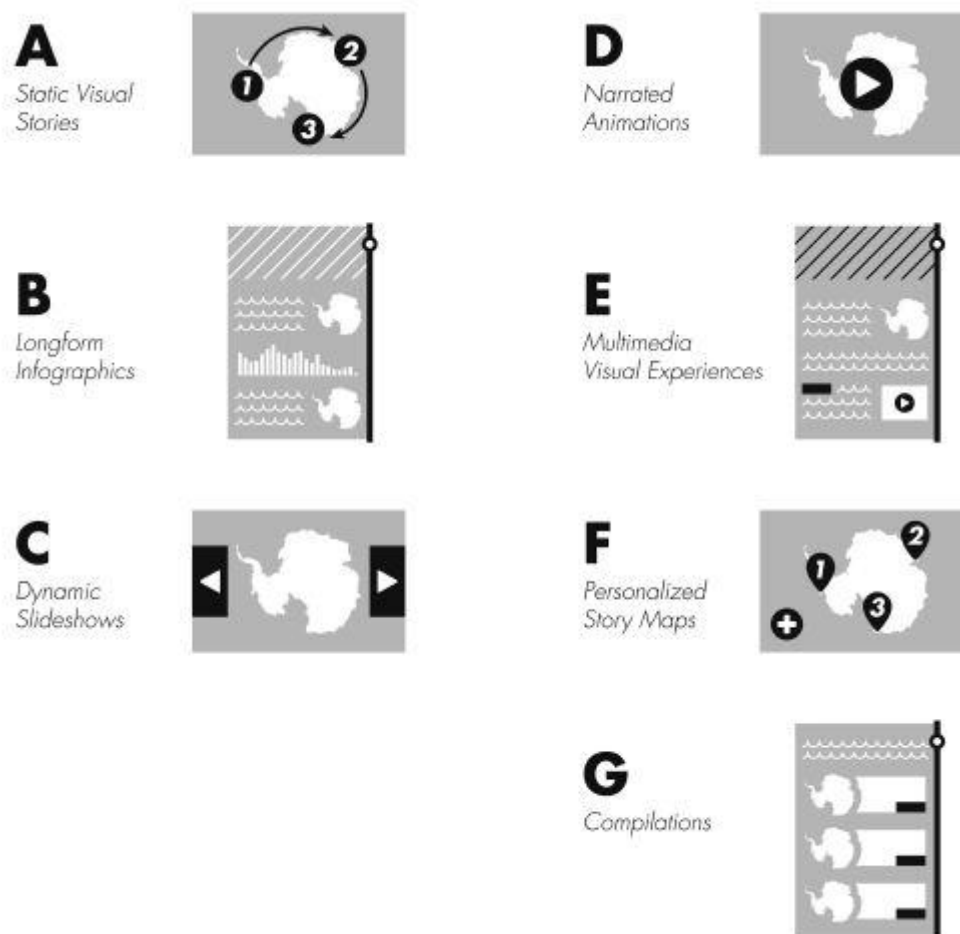


Figure 2-2: Robert Roth's (2020) Visual Storytelling Genres

Roth (2020) devised two main categories for attention guiding: 1) visual hierarchy (figure-ground) and 2) visual accenting. Roth's visual accenting methods are highlighting area or boundaries, leader lines, flow arrows, appended geometric frames, opacity masks, numbering, changes in map scale, variable levels of detail, and call-outs. The applications of these methods on map are shown in the Figure 2-3.

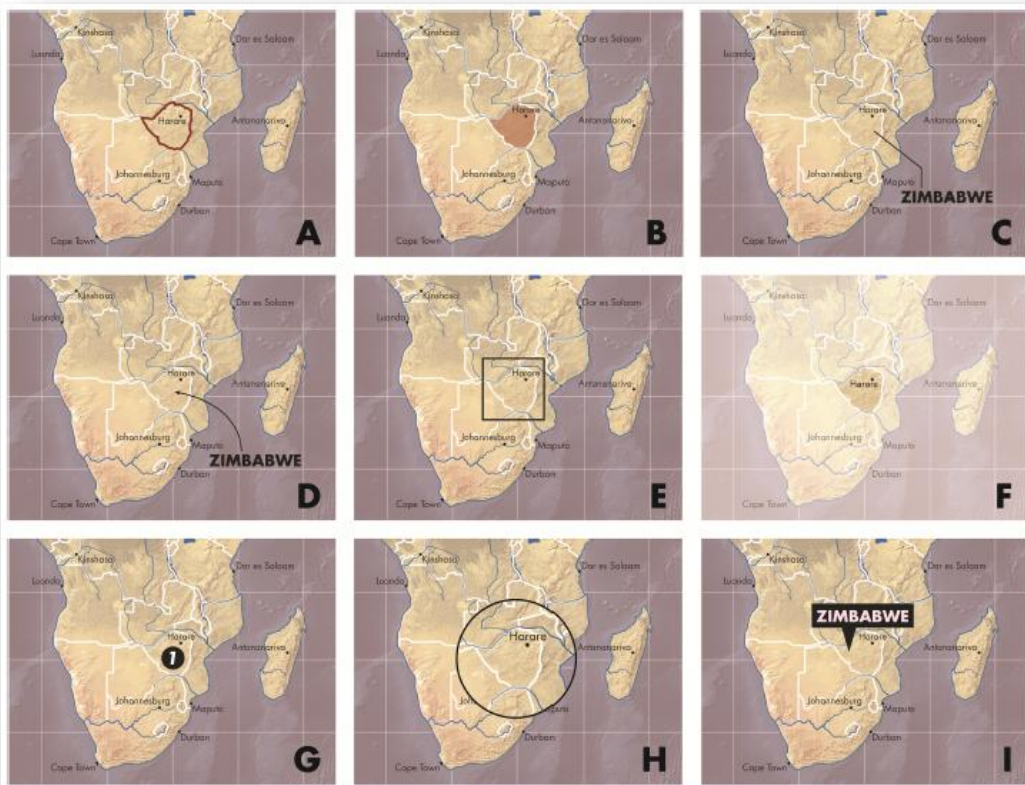


Figure 2-3: Visual Accenting Techniques by Robert Roth (2020)

Song (2017) has specifically researched map-based visual storytelling and used the three-act narrative for story creation. Song evaluated 2 genres and 2 focus attention techniques. She compared 'longform infographics' with 'dynamic slideshow' and finally decided that longform infographics have better results in retention and comprehension by users than dynamic slideshows. For 'focus attention' she compared *black leading lines* with *black color highlighting* and her results show that leading lines performed better. She urges researchers to explore more genres and tropes and study their effectiveness for visual storytelling.

The work done by Cortés (2018), 'A conceptual framework for interactive cartographic storytelling', has been a guide to understanding the genres and categories of map-based visualizations and the techniques applied to them. Cortes has done an extensive study on the visualization techniques available in the literature and devised a comprehensive framework of the classification and categorization of these techniques (Figure 2-3). He further tested their existence on the maps he chose for study and identified the most prominent genres and navigation techniques. His work helps in understanding the taxonomy of techniques and their identification in visualizations of maps and other applications.

Main Category	Subcategory (Number of individual techniques)	Total
Visual Narrative Tactics		
Main Design Alternatives	Conceptual Design (5), Input Type (4), Navigation Indicators/Controls (8)	17
Navigation Feedback and Transition Guidance	Editing (3), No subcategory (4)	7
Communication of Narrative and Information	No subcategories (21)	21
Emphasis	No subcategories (17)	17
Linking	No subcategories (6)	6
Interaction	Working Operators (14), Enabling Operators (5), Interaction Cues (3), Control Split (4), Other capabilities (5)	31
Rhetoric Devices		
Information Access Rhetoric	Metonymy (6), Omission (4)	10
Mapping Rhetoric	Visual metaphor (8), Obscuring (7), Redundancy (7)	22
Linguistic Rhetoric	Similarity (6), Individualization (11), Irony (2)	19
Provenance Rhetoric	Identification (2), Representing Uncertainty (5), Data Provenance (5)	12
Procedural Rhetoric	Anchoring (9)	9

Table 2-1: Cortes' (2018) Summary of Techniques

While the three-act narrative is used for visual storytelling, it must be noted that the pictorial map may or may not possess a story that can be defined in a three-act narrative. While it is still a debate, it is not yet clear whether we need narrative elements for our study. Similarly, for a static pictorial map like the one I intend to use, it is not necessary to be able to play with all genres since the purpose is to explore content that already exists on the map. The techniques that seem to best work on the pictorial maps are tropes for attention.

Table 2-2 shows a brief taxonomy of the Genres and Attention Guiding Tropes for visualization of data as well as maps that were found through this foundational literature.

Literature	Narrative	Genres	Attention Guiding Tropes
Segel and Heer (2010)		Magazine Style Annotated Chart Partitioned Poster Flow Chart Comic Strip Slide Show Film/Video/Animation	Close-Ups Feature Distinction Character Direction Motion Audio Zooming
Song (2017)	Three-act narrative	Longform Infographics vs. Dynamic Slideshows	Leader Lines vs. Color Highlighting
Cortes (2018)	Visual Narrative Techniques Textual: Intro text, labels, narrative text, annotations, captions, articles Media: video, images, sound, audio narration Graphics: Maps, animation, ribbons,	Static News Maps Longform Infographics Dynamic Slideshows Narrated Animations Personalized Story Maps Multimedia Visual Experiences	Emphasis <ul style="list-style-type: none"> • Highlighting • Call-outs • Annotation • Masking • Dynamic Panning • Dynamic Zooming • Animations

	arrows, static & interactive visualization		
Roth (2020)	Three-act narrative	Static Visual Stories Longform Infographics Dynamic Slideshows Narrated Animations Multimedia Visual Experiences Personalized Story Maps Compilations	Visual Hierarchy Visual Accenting: <ul style="list-style-type: none"> • Highlighting & visual variables • Annotation: leader lines, flow arrows, appended geometric frames, opacity masks, numbering, changes in map scale, variable levels of detail, call-outs, labeling clarifications • Dynamic: blinking/flickering, dynamic panning/ zooming, focus + context visualization

Table 2-2: Taxonomy of Narrative, Genres & Tropes for Data Visualization

2.2. Supportive Literature

Naz (2004) determined that a good way to keep the old pictorial maps alive in the new era would be to convert them into 3D Interactive Web maps. While explaining the history of pictorial maps briefly she explained that they have three types: Graphical, Statistical, and Metaphorical. She worked through a 3D software and her efforts resulted in the creation of 3D pictorial maps as webpages which were scalable, zoomable, and navigable maps. This helped in learning the definition of the pictorial map, different types of it, and in identifying that this research is focused only on the graphical pictorial map.

When mobile devices were not smart, Reilly et al. (2006) worked on marked-up maps that were made by combining paper maps with electronic information sources. The research used multiple maps that were marked at certain places with RFID (radio-frequency identification) tags and the handheld devices contained the information regarding those places. The result of this research shows that this method is useful for tourism and activities that required location information on the move. This was a time with no smartphones and hence this gap was filled with smartphones containing GPS.

The research by Wang and Ai (2006) has proposed a conceptual framework of adaptive visualization considering three main factors: 1) user's interactive map behavior 2) periphery conditions (surroundings where the map stays) 3) egocentric representation. Another important factor is the user category based on their knowledge and experience. While the research is 14 years old, it is still applicable today for adaptive electronic maps. These adaptive strategies are the principles on which digital dynamic maps are designed in the present. These strategies enhance the efficiency of an electronic map for information perception and hence would be useful to keep in mind while developing the prototype.

Swienty et al. (2006) carried out a study for the development, implementation, and evaluation of attention guiding visualization following human information processing and theories of relevance on maps of urban areas. For this, they propose using graphical variables based on perception and relevance-oriented design principles. These graphical variables were tested through vector features in the map, which are point, line, and polygon. The graphical variables were tested to guide the attention of viewers towards salient features on the map. The results show that 1) for point features, the value-size and saturation-size combination served the purpose best, 2) for linear features, color value and size help make them more noticeable, and 3) for areal features, value and size play an important role. However, the variables are to be tweaked carefully so as not to disturb the surrounding semi-important features. The findings of this research might help in the attention guiding of the pictorial map in the prototype as the author claims the work to be a substantial contribution to the enhancement of an exploration system's efficiency.

Hegarty et al., (2009) in the research, 'Naïve Cartography: How Intuitions about Display Configuration can hurt performance', shows that although students prefer enhanced displays, realism, and 3D maps, they affect the performance of the maps. Therefore, the display configurations are a delicate choice depending on the purpose of the final product and should be set accordingly for web maps.

Christian E. Murphy (2014) in his research of 'a concise image map design' has strived to emphasize the importance of a cohesive design for an image map including both the raster and the vector aspects of the image map in a way that they appear harmonious and enhance the legibility of the image map. He has discussed symbolizing the image objects to improve their appearance within the image map along with the vector labeling and symbolization. His work has also suggested a new definition of the image map as 'visualization technique composed by remote sensing imagery and cartographic symbolization' (Murphy, 2014). This work helped me understand the image map itself and the visualizations and effects that come into play when designing an image map.

Recently Microsoft carried out a study on intersection between visual perception and storytelling (Huang et al., 2016). The purpose of the study was to train the AI using human-like language to describe visuals, so that AI understands the visuals in a way human would. The research basically fed a designed dataset into the models to monitor their progress in understanding visual data and describing it in a more human-like manner. The dataset described as the 'sequential vision-to-language' dataset consisted of more than 84,000 unique photos divided into 20,211 sequences with both descriptive and story-like language phrases. Once the models were trained, they gave more subjective and human-like descriptions of the visuals. The research shows how storytelling is closely related to visual perception and how it is important to take the visual elements into account to portray a message.

Similarly, 'Map telling Stories' (Mocnik & Fairbairn, 2018) draws a comparison between the story-telling ability of text versus conventional maps and then demonstrates that

a modification of a map with the appropriate text structure can help maps tell stories in a better way. The idea of this map design is to gain insights into how maps can be used more effectively for telling stories. The map design ideas from this paper will help in the development of our own prototype.

Collectively, all these studies have given a very good insight into the topics relevant to this research and helped to form a basis for answering the first two research questions. However, to answer the next two research questions and finally fulfill the first objective of this study, an evaluation of the web-based map applications is carried out which is thoroughly explained in the next chapter.

look monochromatic, some are colorful. They portray different themes and narratives as well. Some look like images, some are purely illustrated and display art and some lie in between the two extremes.

3.2. Coding and Categorization

As the applications are different from each other in their themes, visual representation, and narrative, they were further coded and categorized for clarity. There are two criteria established for categorizing the map applications.

3.2.1. Criterion 1: Illustration

An initial idea for categorization of the applications was to identify maps according to their illustration capabilities i.e. pictorial and non-pictorial. This, however, was not as simple as there exists an assortment of maps that might not be labeled as pictorial maps but contain pictorial elements. Similarly, for non-pictorial maps, some were image maps and some were vector-based. That is why not all could be placed in the same category. To accommodate this, coding scale was developed that gave different scores to each type of map, as shown in Table 3-1.

X-Axis - Illustration						
Non-Pictorial						Pictorial
-3	-2	-1	0	1	2	3
Remote sensing imagery as background, supported with real images and videos of the landscape or area	Image background with one more element supporting realism	Vector map with images	Vector map with no pictorial elements	One of the three map elements (text, icon, background) is pictorial	Two of the three map elements (text, icons, background) are pictorial	All three elements (text, icon, background) are pictorial

Table 3-1: Coding for maps, representing the level of Illustration or realism.

This scale formed the X-Axis, Illustration, for assessing the maps. The positive side of the X-axis gives a score to applications, based on the number of pictorial elements in them. A map with a score of 3 is entirely pictorial. A map with a score of 2 has two pictorial elements of the map (text, icon, background) and a map with a score of 1, has one of the three elements (text, icon, background) represented as pictorial.

The negative side assesses the applications based on realistic elements embedded in it. Therefore, a map with score -3 will have remote sensing imagery as background, supported with further images or videos of the area, -2 will contain an image background and at least one element supporting realism, and -1 would be a vector map supported by images. A pure vector map would score 0. For instance, consider Figure 3-2 below; the map shown has all three elements, text (map labels), icons (map symbol), and background as pictorial, so it is scored a 3 on the X-Axis. A map with a score of -3 on X-Axis can be seen in the Appendix (Pg. 69).

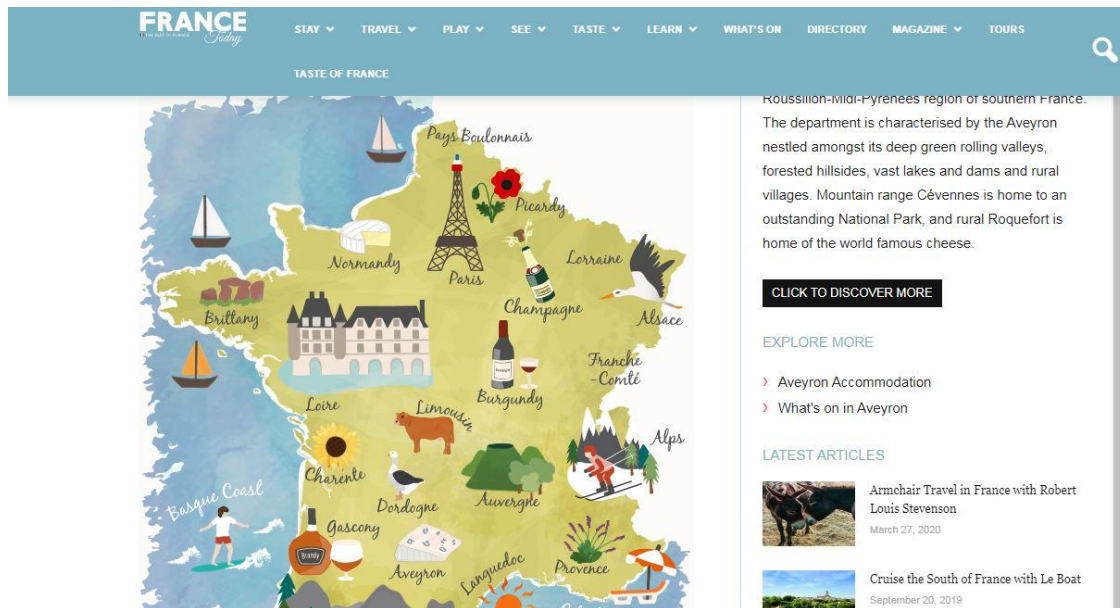


Figure 3-2: Screenshot of the Pictorial map of France. (“Interactive Map of France | French Cities, Regions & Departments,” n.d.)

3.2.2. Criterion 2: Freedom of Exploration

The second criterion is based on the freedom allowed by the application to the user for exploration. The scale for this criterion would range from an explanatory map to an exploratory map. While an exploratory map provides full freedom to the user to navigate and explore through the map, an explanatory map navigates the user through the map in a pre-defined animation or set of steps. But similar to the first criterion, the maps do not strictly lie in those two domains and have varying degrees of freedom for navigation and exploration (Table 3-2).

Y-Axis – Freedom of Exploration		
Exploratory	3	User is free to explore a map without any explanations imposed
	2	An initial introduction or pop up
	1	A full guide as an initial display before the map
	0	Choice given to either explore or follow the instructions/explanations
	-1	Sequence/structure to follow in the map
	-2	Narration through any media
Explanatory	-3	Fully guided story with narration and animation

Table 3-2: Coding for maps, representing degrees of Freedom for Exploration

This criterion formed the Y-axis, Freedom of Exploration. The positive side of the Y-axis indicates maps with little to no guidance and full freedom to explore the map and application. The negative side indicates a more controlled interface where the user has to follow a specific sequence of narration and has little to no exploration freedom, as the map is completely self-explanatory.

3.2.3. Result

Once all the maps were scored on both the X and Y axes, the points representing each sample were plotted on a graph to see the spread of the collection. (Figure 3-2)

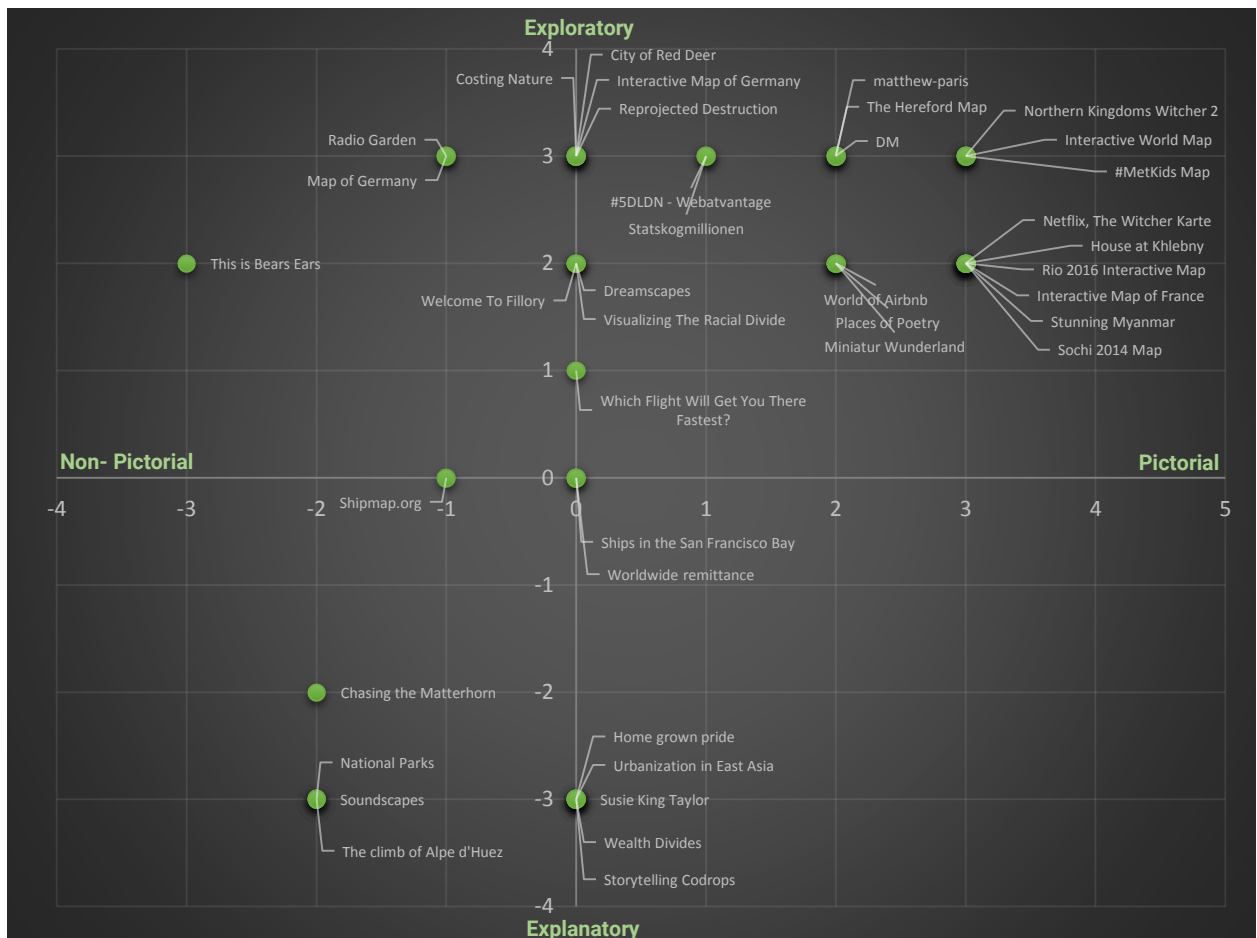


Figure 3-2: Spread of Map Applications according to their level of Illustration and degree of Freedom for Exploration.

Observing the map clusters, it is evident that most map applications lie in the positive X, Y quadrant which means that *more than half of the collected applications are partially or completely pictorial, and more than half of these applications give the user the freedom to explore them*. The individual scores of map applications for each axis are given in the table below to individually view the clusters in terms of both categories.

X-Axis	Scores	No. of Apps	Y-Axis	Score	No. of Apps
Pictorial	3	9	Exploratory	3	14
	2	6		2	13
	1	2		1	1
Vector	0	15	Freedom for both	0	3
	-1	3		-1	0
	-2	4		-2	1
	-3	1		-3	8
Non-Pictorial	-3	1	Explanatory	-3	8

Table 3-3: Number of map applications against each individual X and Y-axis scores

3.3. Recognizing Attention Guiding and Narrative Techniques

The collected maps were observed to have an assortment of attention guiding and narrative techniques described by Cortes (2018) and Roth (2020), as mentioned in Section 2.1 Foundational Literature. This task required observing each map application in detail and recognizing the techniques used for guiding the user's attention as well as the narrative techniques being used to give information. The collective techniques that were observed are as presented in Table 3-4.

Techniques marked in light grey are the techniques that were looked for but not found in the map applications. The ones in dark grey are the ones that appeared only once and are not included in the charts or graphs. Those in black are the techniques that

Attention Guiding Techniques	Narrative Techniques
highlighting	animation
visual variables	images
animation	intro text
markers	labels
dynamic flickering	accompanying articles
dynamic zooming	text
dynamic panning	textual narration
call outs	videos
opacity mask	sound
numbering	headlines
shadows	interactive
changes in map scale	visualization
variable levels of details	map
labeling clarifications	captions
dynamic blinking	legend
Leader lines	pop-ups
flow arrows	static visualization
appended geometric frames	audio narration
focus	
context visualization	
visual hierarchy	

Table 3-4: Attention Guiding and Narrative Techniques under consideration and observed in the map applications

were observed and found. After observation and noting them down for each map application, the results of the frequency of each technique were plotted in graphs to show which techniques appeared more and which less. This helps in identifying the most and the least used techniques and to reach a conclusion about which techniques to imply for our research.

3.3.1. Attention Guiding Techniques

The attention guiding techniques observed in each map application were recorded against it in an Excel sheet and afterward, a summary of the frequency of each technique was made by counting the sum of its mention. This resulted in a pie chart (Figure 3-3) showing the number of times a technique appeared in the observed map applications.

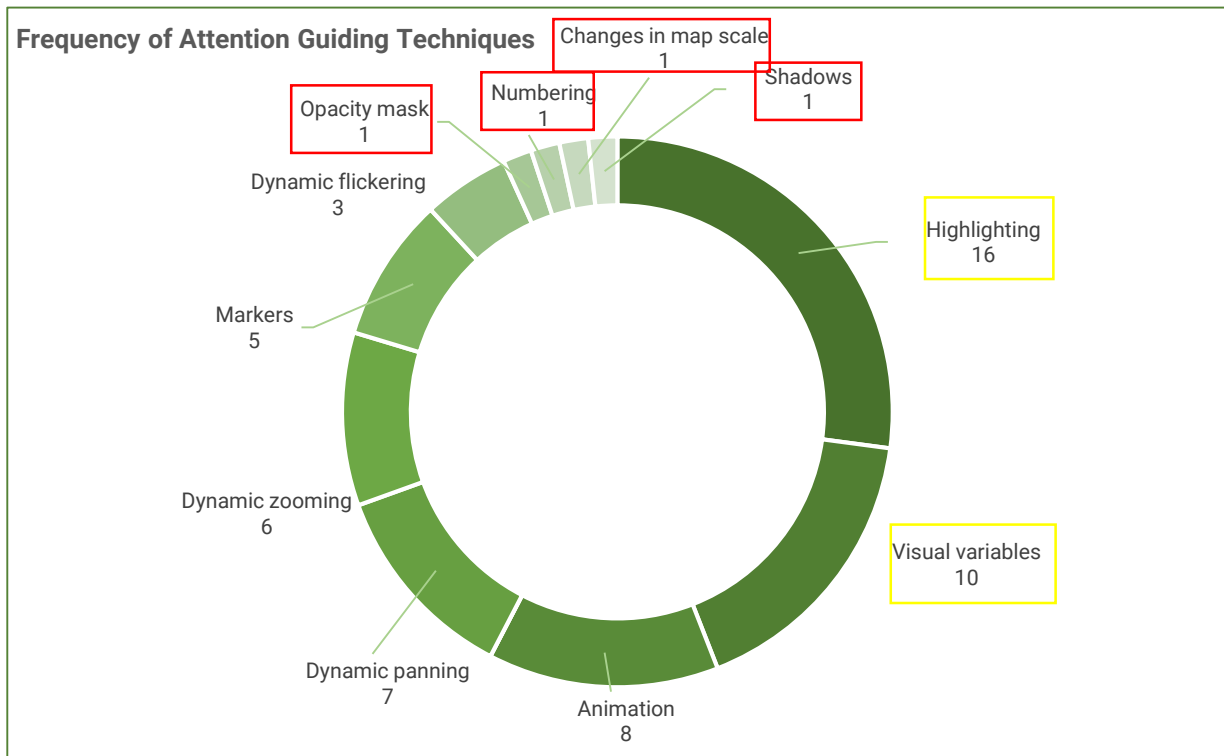


Figure 3-3: Frequency of Attention Guiding techniques in the map applications

The chart shows that the technique that occurs most frequently is *highlighting* and the second in line is *visual variables*. The techniques that appear only once are *opacity mask*, *numbering*, *changes in map scale*, and *shadows*. This information is of importance for deciding on which attention guiding technique to use for our study. The occurrence of attention guiding techniques either in combination or in isolation is also important. The attention guiding techniques appearing in each map application were

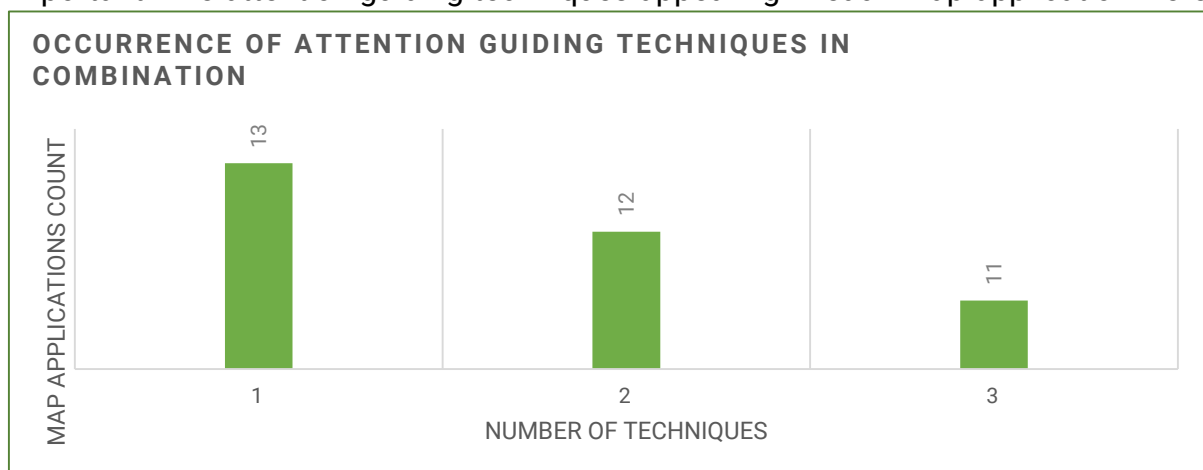


Figure 3-4: Occurrence of Attention Guiding Techniques solo and in combinations of 2 & 3

counted and the histogram (Figure 3-4) shows the number of applications with respectively 1, 2, and 3 techniques.

The histogram does not show much variation in the number of attention guiding techniques in each application. While 13 out of 40 map applications show only 1 technique, 12 shows 2 and 11 show 3, and about 4 show no attention guiding technique at all. This proves that *they exist both in isolation and in combination* depending on the map application and its purpose.

3.3.2. Narrative Techniques

The narrative techniques were observed and recorded the same way as attention guiding techniques; hence, observe the pie chart of the frequency of techniques (Figure 3-5).

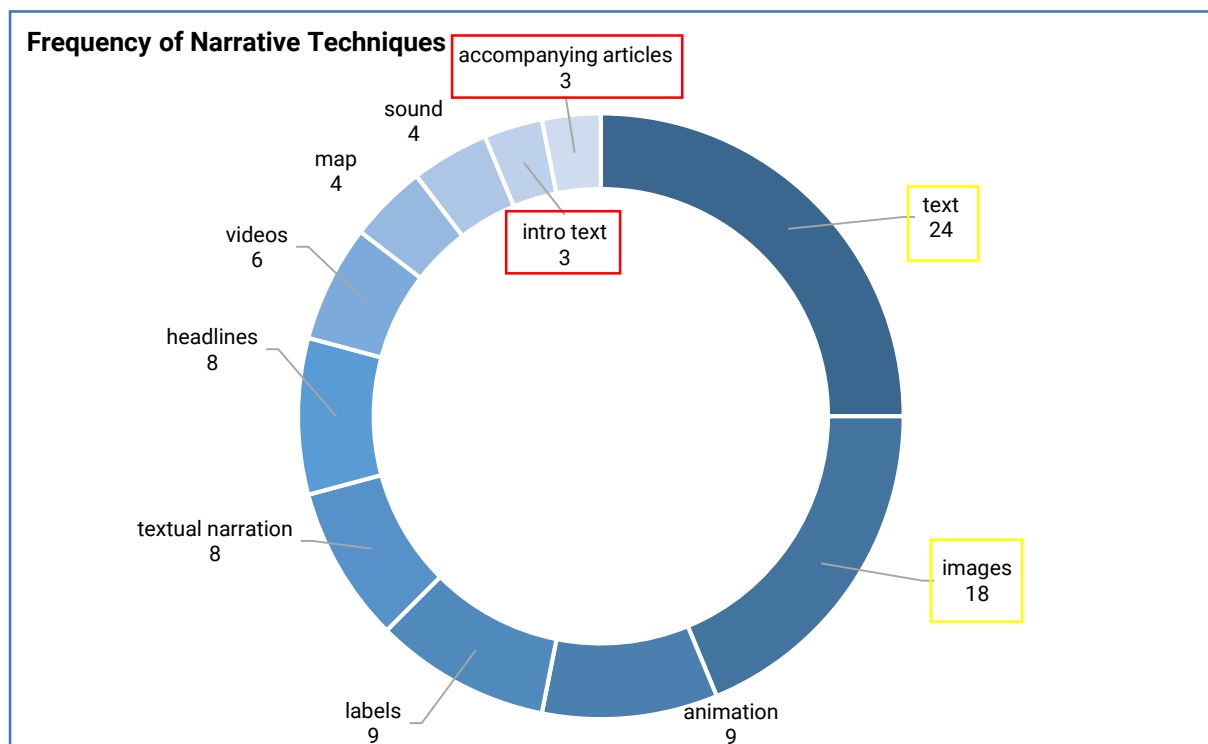


Figure 3-5: Frequency of Narrative Techniques in the map applications.

The chart of Narrative Techniques shows that the *most frequently occurring narrative techniques* that occur in map applications are *text*, appearing 24 times, and *images*, 18 times. Contrary, *introductory text* and *accompanying articles* are the *least occurring narrative techniques*, occurring in only 3 out of the 40 applications. Some narrative techniques appeared only once so they were not included in this chart for visual optimization. These techniques are *captions*, *legends*, *pop-ups*, *static visualization*, and *audio narration*. The narrative techniques have shown the *trend to exist mostly in combination* according to the Figure 3-6. Most map applications contain 2 or 3 narrative techniques consecutively and their occurrence can go up to 4 and 5.

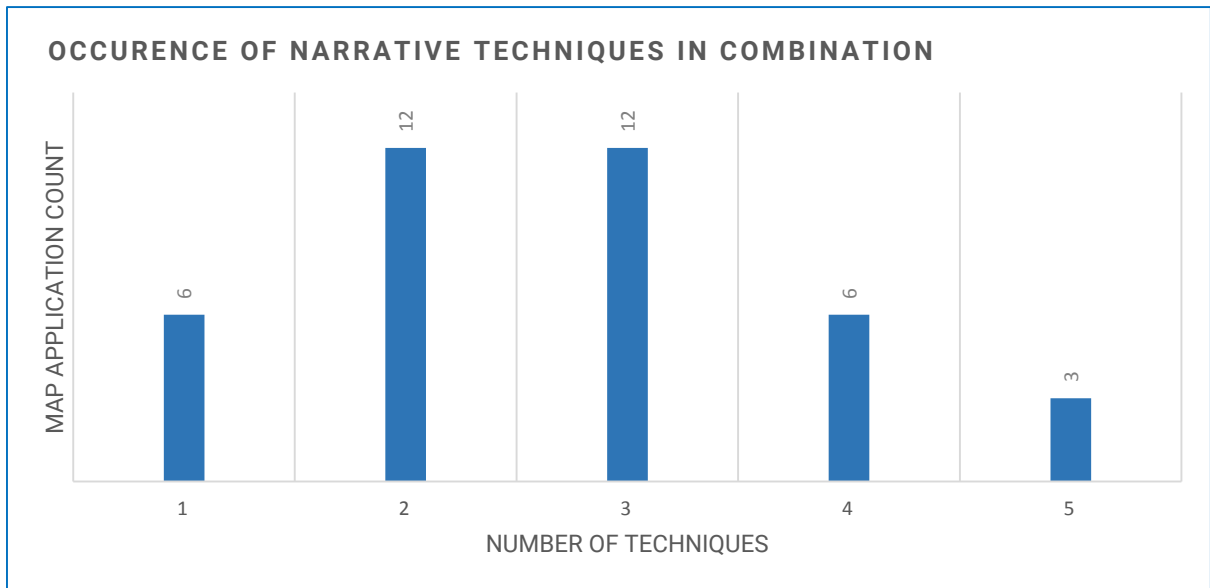


Figure 3-6: Occurrence of Narrative Techniques in combination in the map applications.

The outcomes from the derivation of taxonomy for map applications and the techniques within them have answered Research Questions 3 and 4 and will help to define the final methodological approach and techniques to be studied.

4. Methodology

This chapter contains the methodology for carrying out the remaining research. The flowchart below (Figure 4-1: Methodology Flowchart) describes the steps. The methodology is divided into 3 phases. The work in Chapters 2 and 3 constitutes Phase I. This Chapter covers Phase II and III.

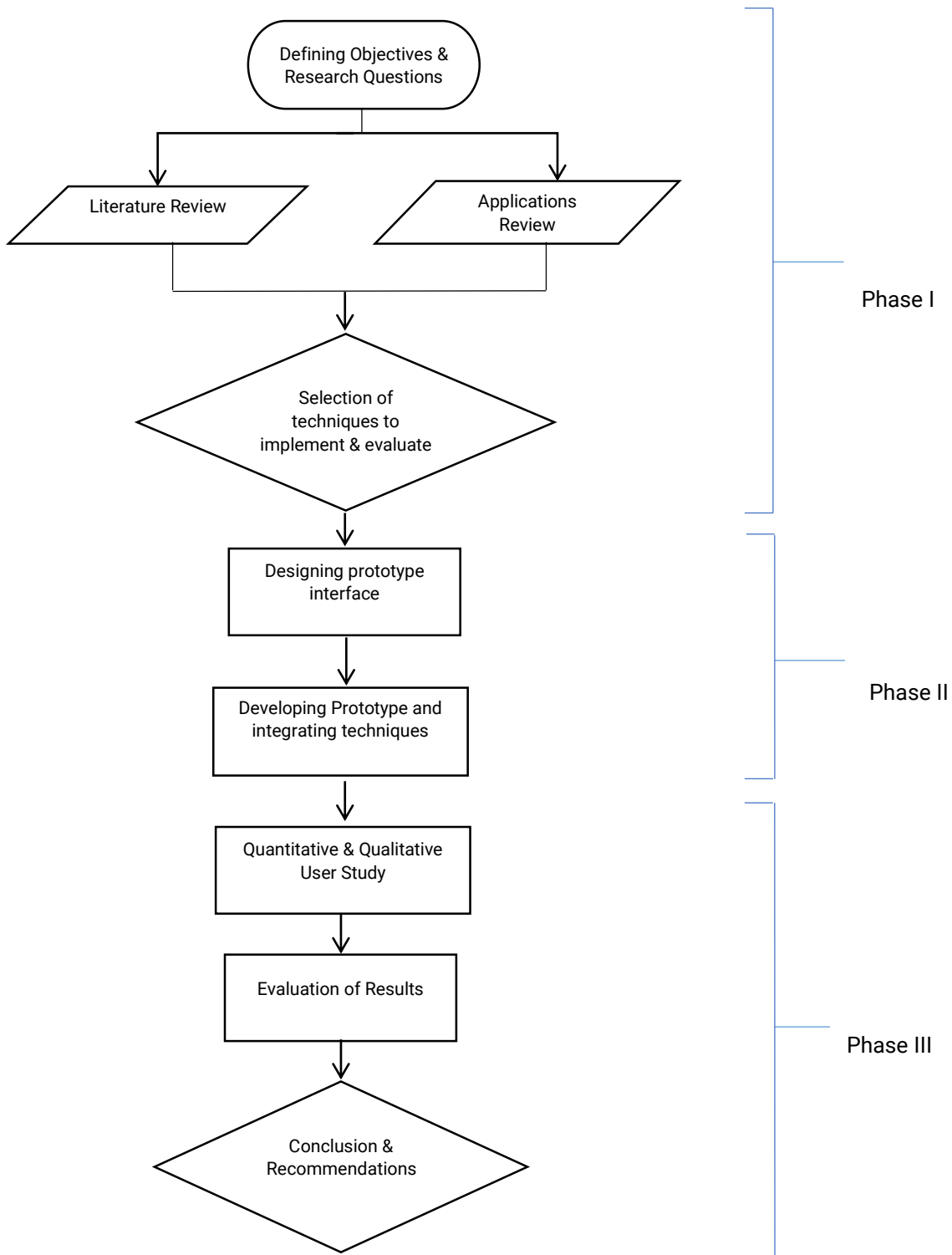


Figure 4-1: Methodology Flowchart

4.1. Phase I

The first phase of the research started with the literature review and reviewing the applications. The purpose was to find the attention guiding and narrative techniques that exist in both these areas and then to choose the techniques to be further researched. For this, we set the criteria to choose the techniques and eliminate them. The basic criteria are to choose the techniques that have not been researched before and that are suitable to be applied to a pictorial map. But before that, I also had to consider the genres of visual storytelling and identify if we would be using any of these in our research, as shown in Figure 2-2.

4.1.1. Choosing a case study map

The Map under consideration for this Prototype is the pictorial map of Prague for tourists (Figure 4-2). I bought as a hard copy, but it was also acquired digitally by contacting the publisher and asking for the permission to use it for this research. The map is a purely pictorial map depicting the Old Town and the Castle area, stretching down to cover some of the important buildings. It presents an oblique view of the city from a height.



Figure 4-2: Pictorial Map of Prague (ATP publishers, 2006).

4.1.2. Choosing Storytelling Genre for a Pictorial Map

While Roth’s (2020) genres are an excellent guide for designing storytelling maps, not all of them can be employed for narrative visualization or storytelling of a pictorial map. The reason for this is that a pictorial map is already rich in terms of illustrations and is a whole entity of its own.

Table 4-1 explains the genres under consideration and the reasons they can or cannot be incorporated in our prototype.

Considered Genres (Roth, 2020)	Suitable for Pictorial Map?	Reason
Longform Infographics	No	Already researched by Song(2017) for storytelling, but does not fit for the case of the pictorial map. The information will get lengthy and boring and will take the focus out of the map itself.
Dynamic Slideshow	No	Well-suited for stories but not for pictorial maps as it cannot be divided to be placed on slides.
Narrated Animations	No	The focus is on attention guiding while navigating pictorial maps, this genre does not allow navigation through the map, no freedom for exploration.
Multimedia Visual Animations	No	The media-heavy genre takes the attention away from the map, moves it towards the media and defeats the purpose of map exploration.
Compilation	No	More story-heavy and not map-focused.
Static Visual Stories	Yes	Perfect for displaying the whole pictorial map with a simple form of narrative applied.
Personalized Story Maps	Yes	Freedom to design as one deems fit.

Table 4-1: Suitability of Storytelling Genres for Pictorial Maps

Static Visual Stories and *Personalized Story Maps* are suitable for pictorial maps. The genre that is more probable to be used for most pictorial maps on the web is going to be *Personalized Story Maps* as it has room for customization.

4.1.3. Choosing Attention Guiding Techniques

Zihan Song (2017) conducted research evaluating the genres and tropes proposed by Roth (2020) for visual storytelling. She evaluated two visual accenting techniques: black leader lines and black color highlighting. For this reason, we out ruled these two techniques from our consideration. The table below gives the names of the techniques, the reasons to eliminate them and the reasoning behind finally chosen techniques.

The techniques chosen for the further research are *Geometric Boundaries*, *Numbering*, and *Opacity Mask* for the following reasons:

1. According to Figure 3-3, *Opacity Mask* and *Numbering* are two of the least frequently appearing techniques in the web-based map applications.
2. *Geometric Boundaries* follows a similar style as the *Opacity Mask*, highlighting an object from among the rest by demarcating a boundary around it.
3. *Numbering* follows a counting sequence and might navigate the reader through the map in a specified order.

Visual Accenting Technique as shown in Figure 2-3	Considered Techniques (Roth, 2020)	Decision if chosen	Reason
A	Boundary Highlighting	No	Song (2017) already researched it.
B	Color Highlighting (polygon fill)	No	Well suited for vector maps but not pictorial maps because of rich pictorial objects instead of empty polygons.
C	Leader Lines with Label	No	Song (2017) already researched it.
D	Flow Arrows with Label	No	Additional labels are too cluttered for a pictorial map.
E	Geometric Boundaries	Yes	Highlights the important objects while keeping the surrounding objects in view.
F	Opacity Mask	Yes	Brings out the object in consideration by dimming down the other information. Less present in the observed map applications.
G	Numbering	Yes	Helps to find important objects quickly and follows a sequence. Appeared less in the observed map applications.
H	Change in Scale	No	The variable scale might be confusing while zooming in and out of the map.
I	Call-outs	No	Contains labels which might make the map busier.

Table 4-2: Suitability of Visual Accenting Techniques for Pictorial Maps

Hence the visual accenting tropes chosen for attention guiding for this research are *Geometric Boundaries*, *Opacity Mask* and *Numbering*. These are further implemented on the pictorial map to observe how they appear with its busy background (Figure 4-3).

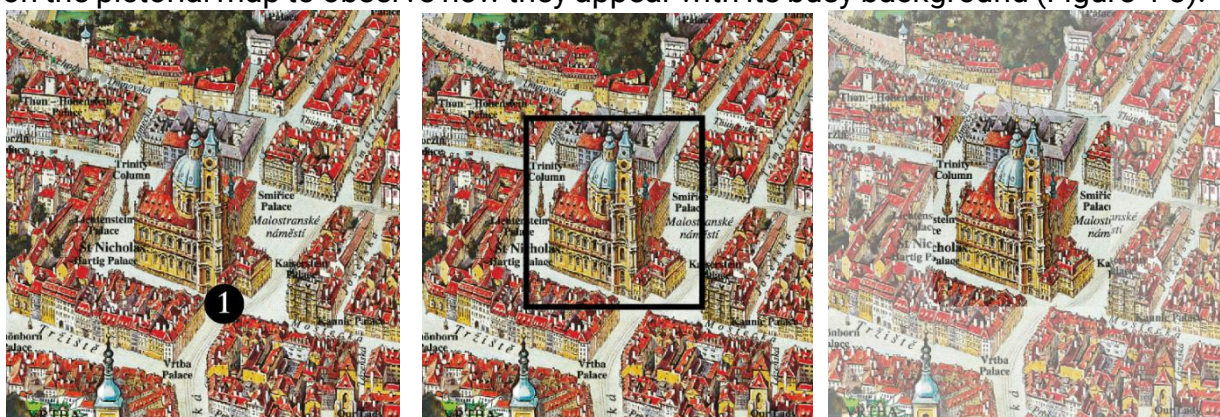


Figure 4-3: Numbering, Geometric Boundaries and Opacity Mask applied on the Prague Pictorial Map ()

4.1.4. Choosing Narrative Techniques

The initial criteria for choosing the techniques to apply have been 1) to choose those less or not researched, and 2) the ones fitting for pictorial maps. To keep within the scope and time frame for this research, I focused on evaluating the attention guiding techniques and decided to keep the narrative technique simple and familiar. I was choosing from the ones with the least engagement and intrigue for the reader.

As evident from Figure 3-5 the most frequently appearing Narrative Techniques are *text (textual narration) and images*. It was decided to use them in combination instead of using just one, as most narrative techniques appear in combination (Figure 3-6). Using only textual narration and images aims to give a familiar feel to the reader and helps them focus more on evaluating the attention guiding techniques instead of getting carried away in understanding the narration for the map.

4.2. Phase II

This phase describes briefly the methodology for developing a web-based prototype, integrating the chosen techniques in it and making it functional for further testing.

4.2.1. Interface Design

The development of the prototype begins with designing the user interface, deciding upon functionalities, and then beginning to code the web application. While there is a possibility of using technologies such as Bootstrap for the skeleton of website interface, creating original wireframes can also help in keeping an original design and building it from the ground up as per requirements. The initial prototype design sketch looked as follows on Figure 4-4

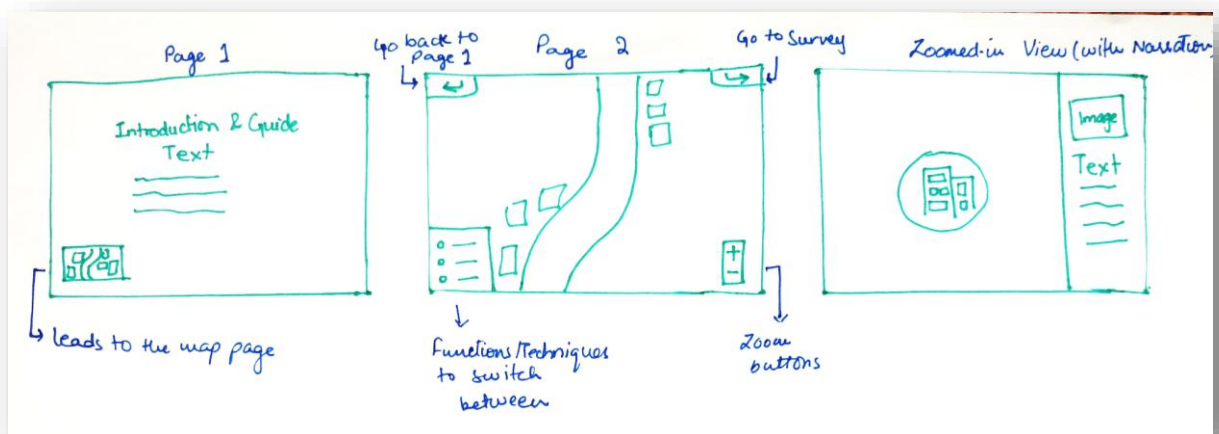


Figure 4-4: Initial Prototype Design

4.2.2. Identifying POIs and Narrative Information to add

The hard copy of the map has some pictures and detailed information regarding the important places in the city at the back of the map. The same places are considered as the points of Interest (POIs) for the prototype and the supporting images and information about these places are used as image and textual narration.

4.2.3. Developing the Prototype and Integrating the Techniques

The integration of techniques is not a separate process but is the backbone of the web application since it is supposed to work together with the attention guiding techniques. The scope of this phase is limited to a functional web application with the chosen attention guiding techniques applied to it. Complete implementation details are described in Chapter 5: Prototype Development.

4.3. Phase III

Phase III discusses the method of analysis for evaluation and the procedure for extracting the results from the evaluation. The study will draw comparisons in two ways:

- a. between a static web map and a map with some attention guiding technique applied to it,
- b. between two or more attention guiding techniques.

Further details on the evaluation design are presented in Chapter 6: User study.

4.3.1. Quantitative or Qualitative Analysis?

A user study is deemed as a good method for getting a response on how a new technique or product performs. Hence to evaluate the techniques from the user's perspective, it was decided to conduct a user study of the prototype. The study will combine both quantitative and qualitative approach combined into an online survey.

4.3.2. Independent or Dependent Sampling?

Since three attention guiding techniques need to be evaluated, the concern was whether to have different users evaluate different techniques or have all of them evaluate all three. Finally, the study is a comparative one between the three techniques, it would not be beneficial to conduct independent sampling because the responses would be only based on the only technique they experienced. So *dependent sampling* was chosen as the method.

4.3.3. What to measure?

All the qualitative and quantitative questions in the user study aim to measure the following factors regarding the user's interaction with the prototype and techniques:

- Understanding,
- Experience,
- Ability to Navigate,
- Preference.

4.3.4. Evaluation of Results:

As the results will be divided into two parts (qualitative and quantitative), the method of analysis for both was going to be different.

The qualitative responses will be coded according to the themes found in the responses and then the keywords found in each theme will be collected to find a trend in responses. One of the ways to represent qualitative response is through word clouds to see the most prominent words and possible user biases.

The quantitative responses will be stored in separate sheets and the percentages for each response will be calculated to see how many people had answered in favor or against something according to their experience (Figure 4-5). While quantitative responses seem to be easier to process, their presentation matters a lot so different visualization methods will be chosen to present different responses. The results of the study are described in Chapter 7: Results and analysis

The conclusions will be drawn by deeply analyzing the results according to dependent and independent responses and compelling evidence found in them. The recommendations, limitations of this study and the feedback of users for improvement is commented in Chapter 8: Conclusion and Discussion.

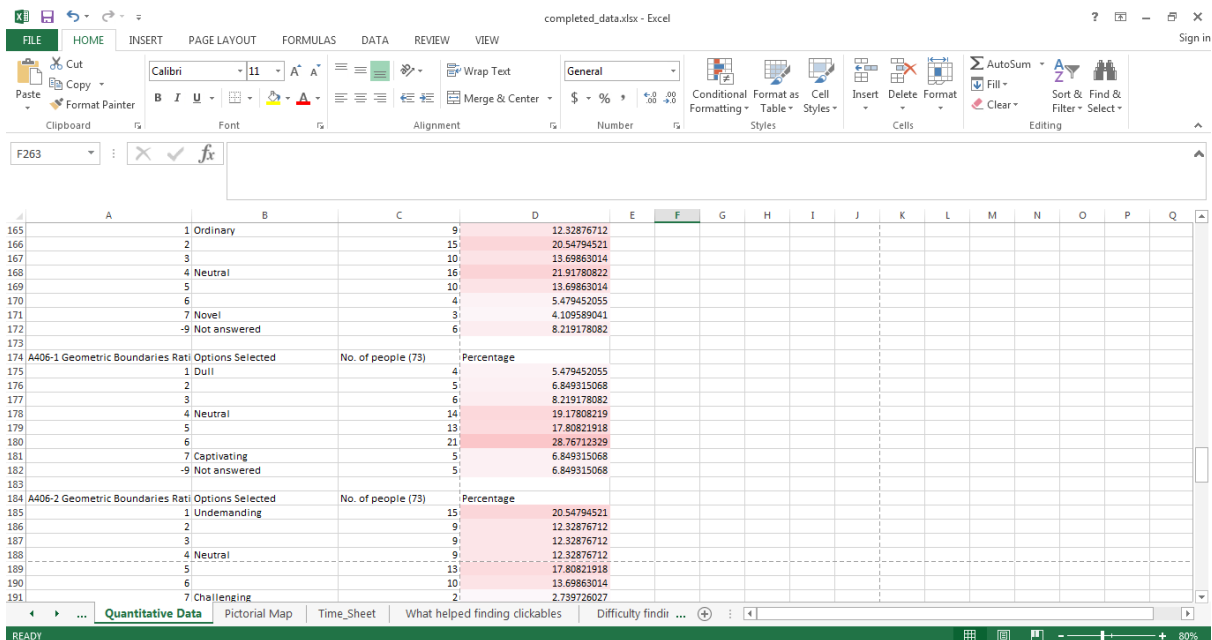


Figure 4-5: A look of the processed Quantitative Data from the Results

5. Prototype development

This chapter discusses in detail the purpose of the prototype, interface requirements, how and to what extent these requirements are met, the technologies at play, and the functions within the prototype.

5.1. Purpose

The purpose of the prototype is to apply the attention guiding and narrative techniques chosen over a pictorial map. The interface of the prototype should be interactive, so the user can navigate through the map, switch between techniques and experience the difference between them. Furthermore, the exploration of the prototype will form a part of the user study, so the prototype is a main product for carrying out this research.

5.2. Interface Requirements

The interface of the prototype is required to have a simple one-page design that focuses on the intended use. Considering the components of the prototype, the interface requirements are as follows:

1. A pictorial map is the base (background) of the website.
2. The prototype provides map zoom and pan functions to allow exploring the pictorial map.
3. The pictorial map is clickable at some points of interest (POIs).
4. Attention guiding techniques are applied individually onto POIs.
5. Each technique has its own layer (mode) that does not overlap with the other and it is easy to switch between the techniques.
6. The POIs have some information stored about them in the prototype that appears in the form of narration (text and image) upon clicking them.
7. The main page has a title.

5.3. Technologies used

The technologies used were chosen according to the requirements of this project and to keep the workflow seamless. They are as follows:

1. Framework: AngularJS, NodeJS

Angular JS is a web framework particularly suitable for developing web applications. It is open-source and based on JavaScript (JS). It takes away the trouble of developing a website with single-page HTML files. This makes it very convenient and easy to follow.

Node JS is an open-sourced back-end environment for running JS code outside the web browser. To work with Angular JS, it was necessary to have a Node JS environment in the system.

2. Languages: JavaScript, Typescript, HTML, CSS

All these languages are the backbone of developing a web application. JavaScript deals with the functionality of the code. Typescript creates .ts files within the AngularJS framework and supports HTML and CSS. HTML is responsible for holding the different components of the web application together, creating a skeleton for the program, whereas CSS takes care of the styling of elements in the web application.

3. Tools: Visual Studio Code, Notepad++

Notepad++ is to code what Microsoft Word is to text. It provides a platform to write, edit, and execute code. Visual Studio Code is a more tailored platform specifically designed for code editing. Both of these tools are open-source.

4. Sharing and Hosting: GitHub and Netlify

GitHub was used to create a repository for the project, so that developers can simultaneously work on the code and see each other's changes. The web application is hosted on Netlify to be available on the web. Netlify can connect with the repository in GitHub and automatically deploys the code pulled from GitHub onto the live web application

5.4. Requirements checklist

This section discusses in detail how each requirement of the prototype was fulfilled and what were the challenges faced in completing the task. Each heading refers to one of the seven requirements mentioned in Section 5.2.

1. A pictorial map is the base (background) of the website.

Firstly, the pictorial map chosen for this project was a tourist map that I bought from Prague in December 2019. The map seemed interesting to use for the purpose of this research. I have the hard copy which has the pictorial map as a front and a guide at the back. The guide shows the important places with pictures and textual information regarding them. Through a border grid guide it also points to the area where the place can be found. The map is named, 'Prague – a panoramic map of the city center and guide'. I contacted the publisher over email and asked for their permission to use the map for my research. Upon approval, they sent me a high-resolution digital copy of the pictorial map that I needed for the web application.

The digital copy was sourced in the code to make the map as the background of our web application. However, the size of the image was larger than the size of the screen and even after multiple attempts it was not possible to keep the full extent on the screen. Therefore, scroll bars were added to the HTML code to access the full extent of the map.

2. The prototype provides map zoom and pan functions to allow exploring the pictorial map

To enable readers to read the labels and see the map elements in detail, zoom in, and zoom out functions were included. The scale was designed to let the map zoom in by 3 times. Besides the zoom in and zoom out button, another button was added to refresh the map and bring it to the original zoom level. The colors of the button were kept a bright orange to make them stand out on the overall dark background above the map.

3. *The pictorial map is clickable at some points of interest (POIs).*

The task required to first point out the places that we will mark as points of interest (POIs). These places were chosen from the guide at the back of the map. This guide had more than a dozen places to point out, but we chose only 12 to be shown on the map.



Figure 5-1: Map guide of the Panoramic Prague Map

Locating each point correctly on the web map was a challenging task, because the screen is a 2D pixel space and to pinpoint a location, one needs to know its exact X and Y pixel coordinates. This began mostly by trial and error and once a location's pixel coordinates were established, the location of other places was figured out relative to the established ones.

Another addition to helping in finding the places to click was a micro-interaction. This micro-interaction is a change of cursor when it hovers over a clickable place. This tiny interaction is supposed to help in identifying the places to click when there is no attention guiding technique applied.

4. Attention guiding techniques reapplied individually onto POIs.

The attention guiding techniques had individual style and design requirements, so each technique was applied to all 12 POIs. The difficult part was to decide on the final design of the technique. In the case of the *Opacity Mask*, the question was regarding the level of transparency, the color of the mask, and the shape that will surround the important places. Since the map was colorful, it made sense to use a white mask with a transparency of 50%, but in the application, the level of transparency was too little as it hid the rest of the map. This was brought up to 80% after trial and error and observing what looked suitable. Additionally, the initial idea was to keep a round boundary for the visible locations; however, the map is a panorama and the buildings are oblique, so the boundaries were also made oblique to harmoniously fit with the orientation of buildings (Figure 5-2).

Likewise, the color and width of the Geometric Boundary was also a question. The color was decided to be black, keeping the numerous colors of the background map in mind. Black stands out against a busy background easily and serves well the purpose of attention guiding. The width of the Geometric Boundary had to be just wide enough to not get lost with the rest of the map, so it was given a solid 5-pixel boundary.

Finally, for Numbering, the numbers had to be visible on the busy background. A circle with a black color fill of 30x30 pixels had a white number in the center. These circles were placed close to the building they were pointing to. The size seems suitable to draw attention. The size and weight of the font are 18px and 2.0 respectively to make it easily legible.

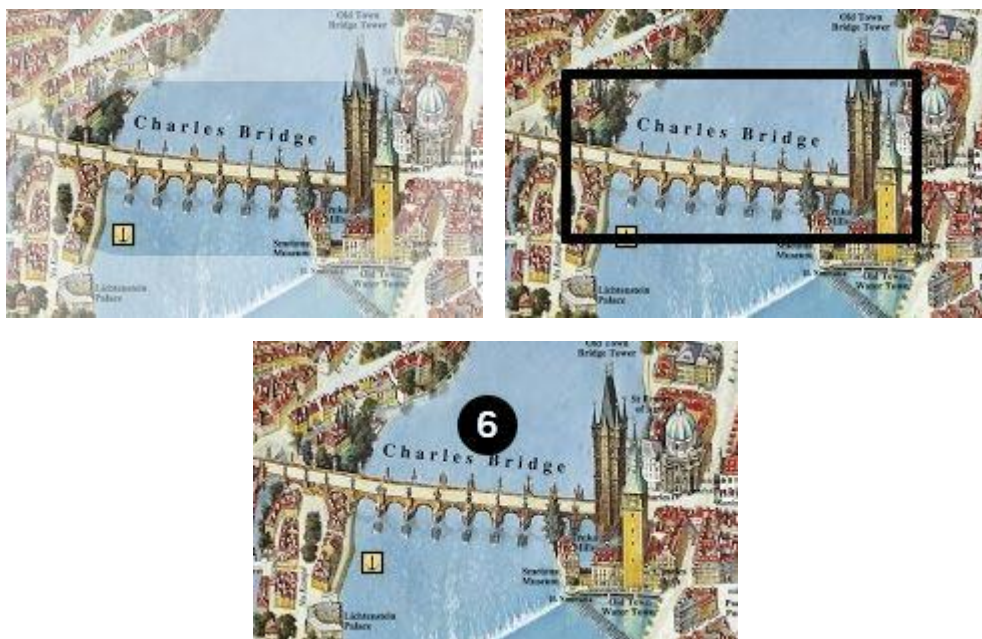


Figure 5-2: Screenshot from the prototype to display the style of each technique.

- Each technique has its own layer (mode) that does not overlap with the other and it is easy to switch between the techniques.

The techniques were built into their separate layers and radio buttons were added on the top left of the map to enable switching from one technique to another. There are four radio buttons on the top: None, Opacity Mask, Numbering, and Geometric Boundaries. The 'None' layer shows a clickable base map without any of the three techniques.

- The POIs have some information stored about them in the prototype that appears in the form of narration (text and image) upon clicking them.

The information from the guide of the map was decided to be used for textual and image narration. Adding this information into the map was a lengthy task. Firstly, a side-pane was created to appear upon clicking one of the POIs, then it was divided into divisions (divs) to contain the title, the image, and the text regarding the POI.

	A	B	C	D	E
1	1	Prague Castle	A2	Prague Castle, the residence for Bohemian sovereigns and presidents for the past thousand years, is unique thanks to the various structures of which it is co done	
2	2	St. George's Basilica	A2	St. George's Basilica in Prague Castle was founded by Prince Vratislav I in the years prior to 920. I acquired its present look after it was destroyed in a castle si done	
3	3	Church of Our Lady Before Tyn	A4	Conceived in the middle of the 14th century, the Church of our Lady Before Tyn, which is close to the fortified Tyn Courtyard, served as a customs house and done	
4	4	The town hall complex	A4	The town hall complex in Old Town was begun in 1338, when the town hall was founded and was added to until the middle of the 19th century. This involve done	
5	4.5	The Astronomical clock	A4	The astronomical clock in Old Town town hall was crafted by the clockmaker Mikulas from Kadan with the assistance of Jan Sindel, a professor at Charles University. I	
6	5	Old-New Synagogue	A3	The people responsible for building the Convent of St. Agnes probably also built the Old-New Synagogue, which is the oldest of its kind in central Europe ai done	
7	6	Old Jewish Cemetery	A3	Approximately 100,000 people are buried in the world's oldest Jewish cemetery. Within its one hectare are about 12,000 gravestones from across the centuri done	
8	7	Royal Summer Palace	A2	The Royal Summer Palace in the eastern part of the Royal Garden represnets the purist Renaissance construction north of the Alps. Emperor Ferdinand I ha done	
9	8	Charles Bridge	A2,3	Charles Bridge, which Charles IV had constructed in 1357 to replace the Romanesque Judith's Bridge that had been swept away by floods. One element remi done	
10	9	Vrtba Garden	A2	The Baroque Vrtba Garden, supposedly conceived by Frantisek Matous Kanka in 1712-1720, is accounted the most beautiful terrace garden in Prague. Its ste done	
11	10	St. Nicholas Church	A2	The Church of St. Nicholas in Little Quarter is the greatest high Baroque structure in Prague. In 1702-1737, Kystof Dientzenhofer constructed its nave, replaci done	
12	11	National Theatre	B3	The neo-Renaissance National Theatre on the bank of the River Vltava was built to encourage a Czech theatrical tradition. The construction dates back to 18 done	
13	12	Municipal House	A5	The ostentatious Municipal House, the most important construction of the Prague Art Nouveau, which was built in 1903-1912 to the design of A. Balsanek ar done	
14	13	Dancing House	B3	The building known as the Dancing House was built on a site between other structures on Rasin embankment to the plans of architects Vlado Milunic and Fi done	
15					
16					
17					
18					
19					
20					
21					

Figure 5-3: Title and information of the POIs in the Prototype, documented manually from the guide of the map.

These titles and the corresponding text were first stored in an excel sheet (Figure 5-3: Title and information of the POIs in the Prototype, documented manually from the guide of the map. Figure 5-3). Then each image corresponding to the text was captured through a camera. As these images had surrounding visuals as well and we only needed the specific structure of the building, each image had to be individually masked in *Adobe Illustrator*. This was a time-taking task, as it required digitizing a neat boundary around the image (Figure 5-4). The masked images then had to be reduced in size as they were quite heavy to be promptly loaded into the browser. Reducing the size of the image was done in software called *IrfanView* but this software turned the background for all images black. The masked images were then reduced in size by using an online image compression tool and then added to the prototype.

The size of the image was adjusted to fit well in the side pane and the relevant text was coded to appear below the image. The title was added at the top of the division

in bold. The size and styling of text were decided after trying several proportions of text and image.

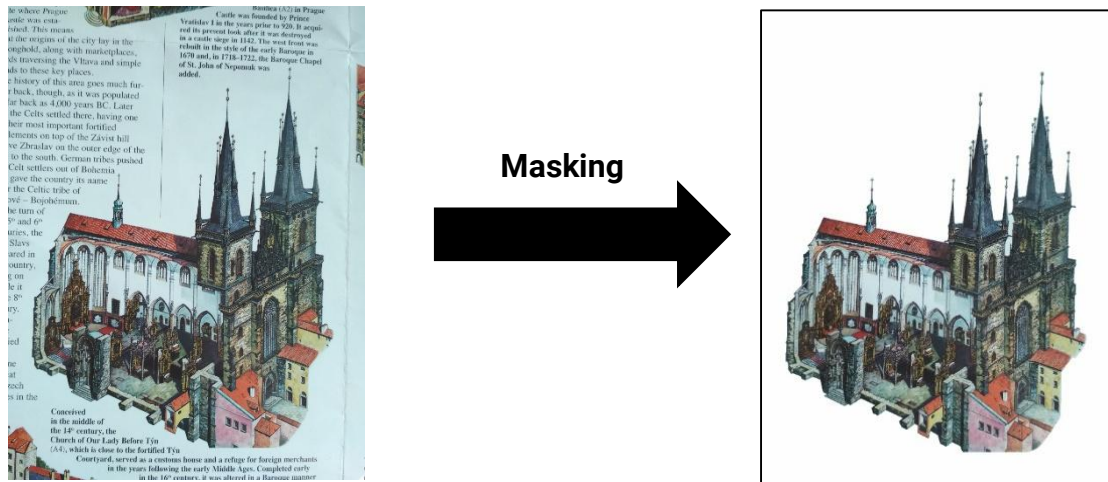


Figure 5-4: Conversion of a captured image to a masked image, fit for prototype.

The side pane was then finally connected to the POIs and contained relevant information. Another function added here was zooming into the POI upon clicking it on the main map. This was very difficult to achieve and was most difficult for the POIs at the border of the map. However, this was accomplished to a good extent and worked well for most POIs. (Appendix 10.4)

7. The main page has a title.

The name of the map was added in the heading container in the HTML file, as the title for the main page. The title is kept in all capital letters with a font-size of 150%.

5.5. Functions

This section aims to show the prototype in action and the capabilities it contains.

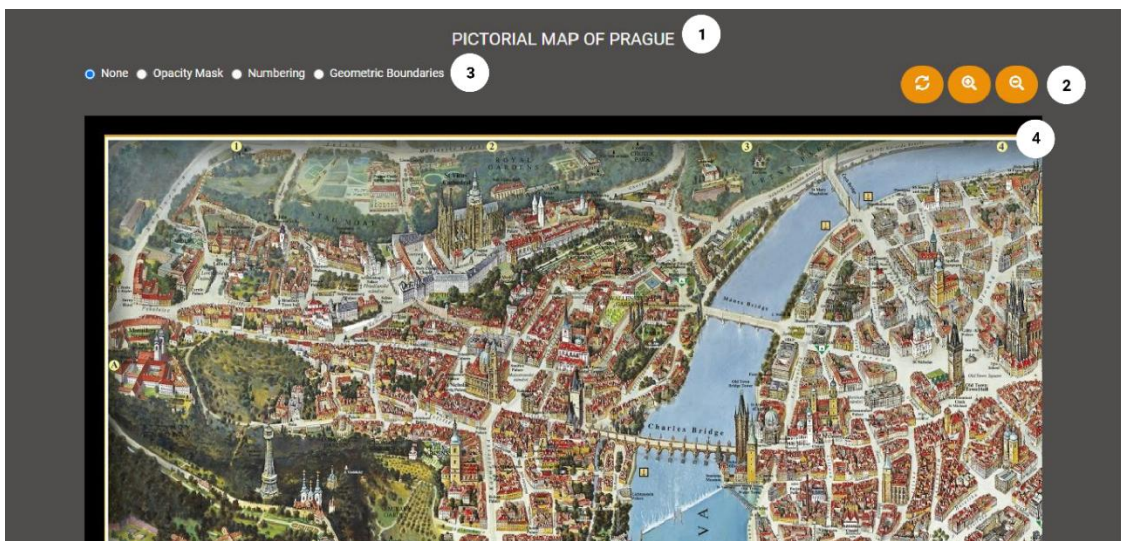


Figure 5-5: The interface of the prototype: Title (1), Zoom Buttons (2), Choice of Layers (3), Map area (4)

Figure 5-5 shows the whole interface of the prototype. The initial design introduced in the methodological section faced some changes, but the core idea remained the same. Introductory page was eliminated, while the map page and zoomed-in view remained the same, with some slight changes in the placement of buttons. The prototype interface has the 'None' layer active by default. The zoom buttons (2) show three options; refresh, zoom-in, and zoom-out respectively. The Choice of Layers (3) shows four choices; None, Opacity Mask, Numbering and Geometric Boundaries respectively. The buttons are self-explanatory in introducing the functions that the prototype allows.

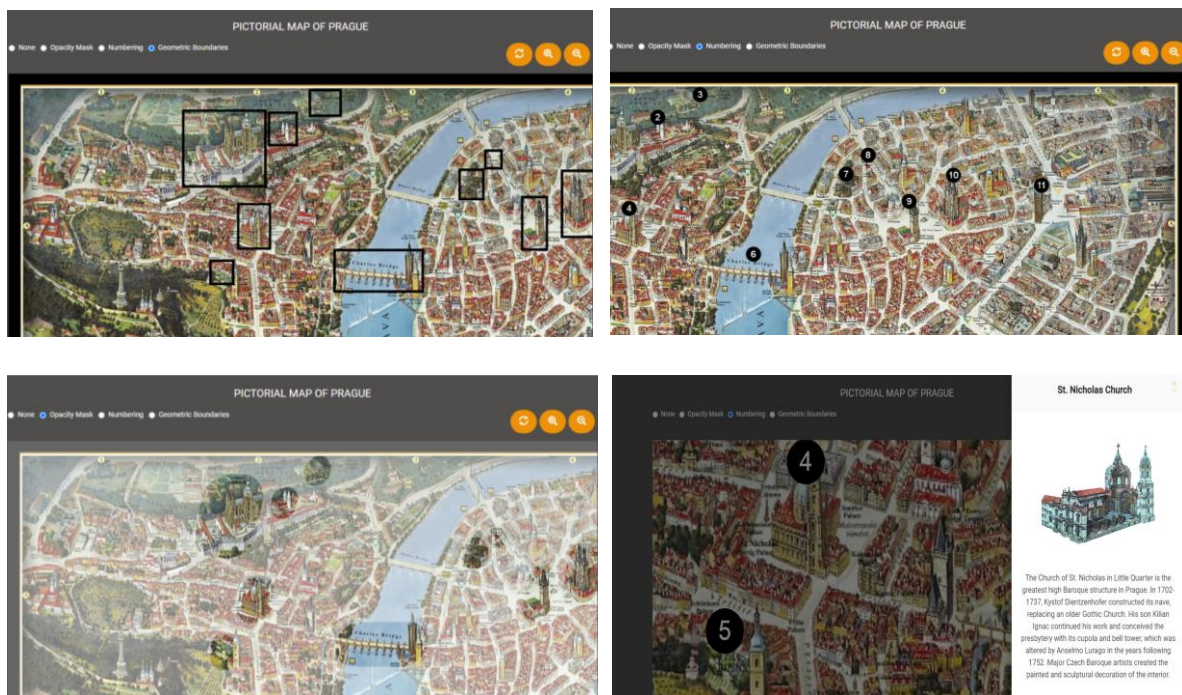


Figure 5-6: Views of the Prototype; top-left (a) showing the Geometric Boundaries layer applied, top right (b) showing the Numbering technique applied, bottom left (c) showing the Opacity Mask applied and bottom right (d) the Narration for a POI once it is clicked

Figure 5-6 shows all the techniques in action. It is clear to observe that all the techniques are highlighting the same set of POIs. On the bottom right of the Figure 5-6, there is a screenshot of the view that appears once a POI is clicked. The side pane is visible with the title, image, and narration of the POI and the map automatically zooms into the POI. The prototype can also be seen live in action using its URL (<https://ppmshajtaj.netlify.app/>). More zoomed-in screenshots of the prototype are added in the Appendix (10.4).

6. User study

This chapter discusses the design, components and implementation details of the user study. Testing the prototype with potential end users is the most important step of this research, as it captures different factors to evaluate the techniques applied.

6.1. Initial Draft

The user study starts by recognizing the factors that need to be measured (See Chapter 4.3.3.) and by identifying the information that needs to be conveyed and sought from the users. Firstly, the reader must be introduced to the prototype and study questionnaire to know what to expect during the experiment. That is why the user study starts from an introduction of the prototype (What it contains? How to use it?) and the questionnaire.

Secondly, the information on the user's demographics is asked for. It seemed fit to only know their age and whether they are familiar with GIS or Cartography, because this affects their understanding and navigation style through a map in comparison to someone who has no knowledge of this domain. Another important information is the user's understanding and familiarity with the pictorial map and the city of Prague, since it might also affect their response to the answers.

The questions that follow required the user to explore the prototype and complete certain tasks that familiarize them with the attention guiding techniques. Then they were asked to rate the tasks, the techniques themselves, their overall user experience, and feedback regarding the design of the user study.

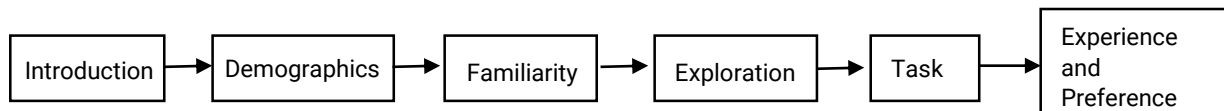
6.2. SoSci Survey

To host the user study, the SoSci Survey (<https://www.soscisurvey.de/test216312/>) platform is selected. It is found to be very flexible and convenient to design the user study. It is comprehensive in its provision of options for building a questionnaire from the ground up. The user-friendly interface and drag and drop options help in organizing the hierarchy of questions very easily and one can always preview the changes made. Furthermore, it has many types of questions available and provides the possibility of adding HTML and PHP codes.

The user study was first made live in the pre-test mode, which allows the reader to make comments and give feedback on each question. This was done to test the questionnaire and make changes if required before it is made live for collecting data for end study participants. After the pre-test, the user study was made live for 3 weeks (between 26.08.2020 and 16.09.2020) to collect data. The link to the study was shared with students, professionals and academic faculty of various domains, including but not limited to GIS and Cartography.

6.3. Study Design – Thematic Sections

The user study follows a thematic sequence as described briefly in the initial draft. This thematic sequence is divided into different sections of the user study and each section (except the first) contains questions relevant to the theme. The first three sections involve questions that do not require interacting with the prototype. The next three sections require the participants to use the prototype and then respond to the questions. The themed sections fall in the following order:



6.3.1. Introduction

The first section of the user study, as the name suggests, begins by introducing the reader to the topic of the study and then introduces them to the two parts of the survey: Questionnaire and Prototype. The section spans over a single first page. It prepares the participant to explain that the questionnaire has both qualitative and quantitative questions and what to expect from it in general. The time required to complete the questionnaire (i.e. 20-25 minutes) is also indicated. It also guides the user through the prototype elements (i.e. the base map, the applied techniques), so the participant can navigate through the prototype with some prior information regarding its functions. (Appendix 10.5, Pg. 70)

6.3.2. Demographics

This section collects information regarding the user that is useful in evaluating their responses to the rest of the questions in the survey. While it was possible to collect detailed information about them, the requirement and scope of the research only needed to record their age group, their current standing in the academic or professional domain, and the possibility of their knowledge in GIS or Cartography. This is because these factors might affect their interaction with the prototype and their understanding and acceptance of attention guiding techniques. (Appendix 10.5, Pg. 71)

6.3.3. Familiarity

The familiarity section is short but very powerful as it asks three very vital questions before participants investigate the prototype. It asks questions regarding the user's understanding and familiarity with the pictorial maps and their familiarity with the city of Prague. It contains a qualitative open question regarding the participants' understanding of what is a pictorial map. The response to this question is given in own user's words and helps in outlining a user's perception of the pictorial map. This also helps in forming a definition of the pictorial map (Section 7.2.1. Perception and definition of a pictorial map)

The question regarding having seen pictorial maps before determines the user's familiarity with the initial concept and possible elements of pictorial maps. The information about having seen Prague before is relevant to the questions in Exploration Section, where users are required to find certain places in the city. A participant who has been to the city before would experience less time and trouble finding POIs in the map. (Appendix 10.5, Pg. 71)

6.3.4. Exploration

The link to the prototype appears for the first time in this section as it requires the participant to explore the prototype firsthand and navigate the base map without any attention guiding technique applied to it. Having participants navigate the base map aims to let them compare the simple base map and the map with some attention guiding applied to it. This further helps to answer Research Question 11. (See Pg. 14)

The requirement from the participants is to see if they can find any clickable places on the map and what helps or makes it difficult to find them. This helps in assessing whether the applied micro-interaction plays a role. These clickable places are Points of Interest on the map of Prague that also have some narrative text and image stored to describe them and appear upon clicking. This section contains quantitative questions and filtered qualitative questions that appear or disappear in an if-and-else scenario based on the answer to previous question. The filter was applied through a PHP code since the default SoSci Survey filtering does not work for questions on the same page. (Appendix 10.5, Pg. 72)

6.3.5. Task

The section gives certain tasks to the participants. Firstly, we asked them to find different places on the plain map. Then they look for certain objects while switching between all the attention guiding techniques one-by-one. Users use a stopwatch to record the time it took to complete each task. Four tasks are using Plain Map, Opacity Mask, Numbering, and Geometric Boundaries respectively. The tasks are explained through a clear and complete set of instructions, so the participant is not struggling to understand what to find and which technique to use. (Appendix 10.5, Pg. 73 and 74)

The section has two parts: one that gives instructions of the tasks and asks to write the time it took to complete each task. Another asks to record the experience through the task by rating it, asking for the easy and difficult parts, and the reasoning behind it. This delivers quantitative as well as qualitative responses. The purpose of this task was to let participants see the attention guiding techniques in action and see their effect in highlighting the important places. It was recognized while analyzing the results that some aspects were not taken into consideration in the design of this section, which is further explained well in Chapter 7: Results and analysis

6.3.6. Experience and Preference

The last but the most important part of the user study is placed in Section 6. This section finally asks the questions that deliver evidence for answering Research Question 10 (See Pg. 14 for reference). It asks the participants to freely explore the

attention guiding techniques and then choose one out of the three as their favorite while giving a reason for it. It also asks users to rate each technique based on its hedonic quality stimulation and rate the navigation experience from each technique based on its pragmatic quality.

While there had been some opinion from the mid-defense presentation that the Numbering Technique can bias participants to prefer it on the other two. To remove that ambiguity there is also a question asking the comparison between Opacity mask and Geometric Boundaries. The usefulness of this question is assessed in Chapter 7: Results and analysis Finally, the section ends by asking the participants overall feedback on the user study and prototype. The response from this question is qualitative, so it will help see the limitations and improvements for the research as well as the prototype. (Appendix 10.5, Pg. 75, 76, and 77)

7. Results and analysis

This chapter shows the results from the responses of the user study. The findings are reported in thematic sections following the structure of the questionnaire. This section also gives the analytical reasoning where possible, but more discussion on results is provided in the next chapter. About 130 participants attempted to do the survey. Out of them 73 completed it and the responses were included in the results. Since the first thematic section in the user study was introduction, which it did not have any questions, the reporting begin from the second section.

7.1. Demographics

The demographics section collected data about participant's age, current status of education or employment, and knowledge of GIS or Cartography. The majority of participants, 80.8% had prior knowledge of GIS or Cartography, 16.44% did not have this knowledge and 2.7% did not respond to this question. The other two demographics are shown in the Figure 7-1 and Figure 7-2.

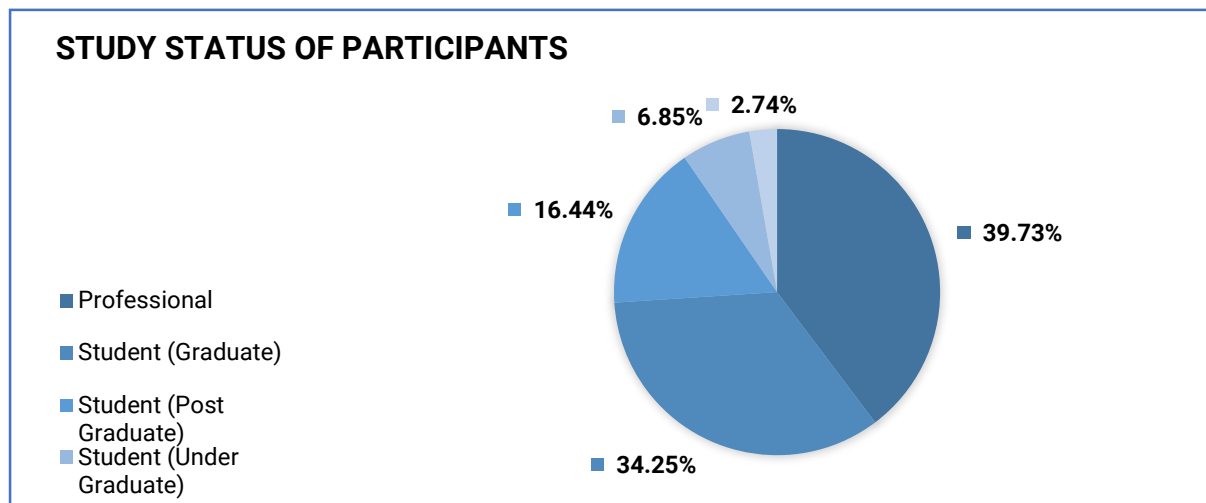


Figure 7-1: Result of the Current Status of Participants

Figure 7-1 shows that about 40% of participants were professionals while 34% were master students and this constitutes the majority of our responses. About 16% were postgraduate students and only 6.8% of undergraduate students took part in the study.

The age group of these participants is shown in Figure 7-2. It shows that about 68.5% of participants are between the ages of 25 and 34, 21% are between 18 and 24 and only 8% of the participants are from 35 to 44. A few of them, 3%, did not answer the question.

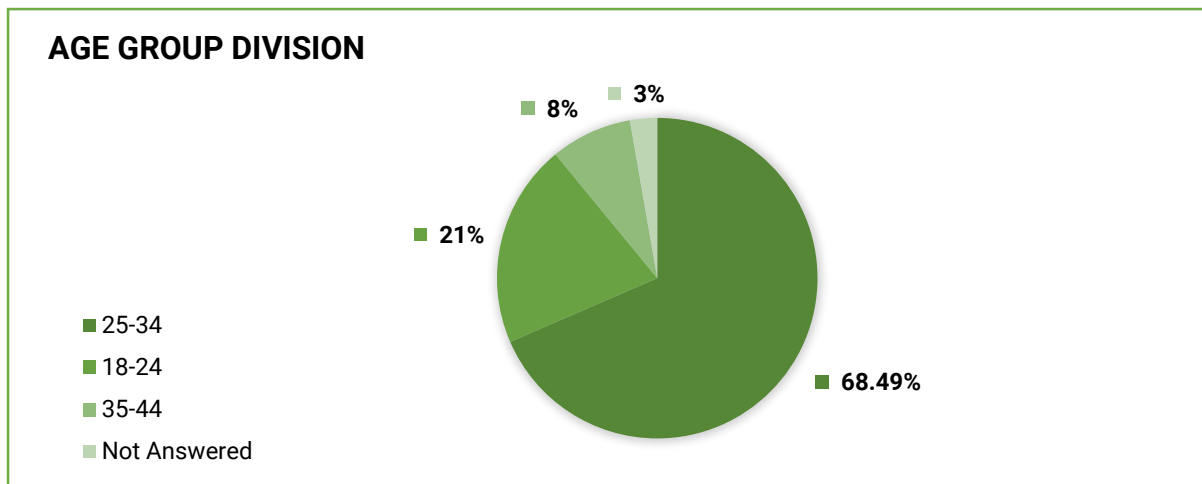


Figure 7-2: Age Group Division of Participants

Collectively the demographics say that most people who participated in this study were professionals or Master's students between the ages of 25 and 34 and had knowledge of GIS or Cartography.

7.2. Familiarity

Intended to determine the participants' familiarity and understanding of a pictorial map and the city of Prague, the section contains two quantitative questions and a qualitative question. The quantitative questions tell us that 64.3% of the participants had visited Prague, which means they were familiar with the general highlights of the city; however, it could be that some of them visited the city a long time ago and could not remember the details so well and 32.8% of the participants had not visited the city. A big number, 83.5% of participants had seen a pictorial map before and 12.3% of participants had not seen a pictorial map before.

In the qualitative question, where participants were asked about their understanding of the pictorial map, their answers helped to identify the perspectives in which a pictorial map is seen. This formed the foundation for a new definition of Pictorial Map, explained in the sub-heading below.

7.2.1. Perception and definition of a pictorial map

The statements about the pictorial map were evaluated by inductive coding of the information found in them. The coding was done by first reading through all the responses and identifying themes (hence inductive), then coloring the words or phrases indicating the same idea/theme in one color. (Appendix 10.7)

After a careful and thorough study of literature and qualitative analysis of participants' responses for a pictorial map, a pictorial map can be characterized through the following five emerging themes:

- **What it contains?** *the elements presented on the map,*
- **How it represents?** *thematic or artistic look of the map,*
- **What it preserves or distorts?** *geographical and factual adjustments,*

- **What is the viewing perspective?** e.g. top-down, panoramic, 3D,
- **What is the function or purpose?** e.g. storytelling or tourist guide.

From these emerging themes, I defined a pictorial map as follows:

“A map or map-like presentation, representing a theme, containing illustrations of actual or imaginary geographical features that are subject to scaling.”

Surprisingly, some participants thought a pictorial map was a map with pictures or pictorial elements in it. Some participants were also of the idea that perhaps it is an image with some map components in it. This was an interesting finding about perception and helped in identifying the fact that people cannot always differentiate between an image map and a pictorial map and sometimes consider both being the same.

7.3. Exploration

The participants were introduced to the prototype but only to the map with no attention guiding technique applied to it. The purpose was to see the level of ease or difficulty they experience in the absence of any guidance. The task was to explore and find clickable places on the map. The initial hypothesis for the outcome of this section was that *the incorporation of micro-interaction i.e., change of cursor on clickable areas will help in finding clickable places and the participants might find it difficult due to lack of any guidance.* The responses from the participants are as follows:

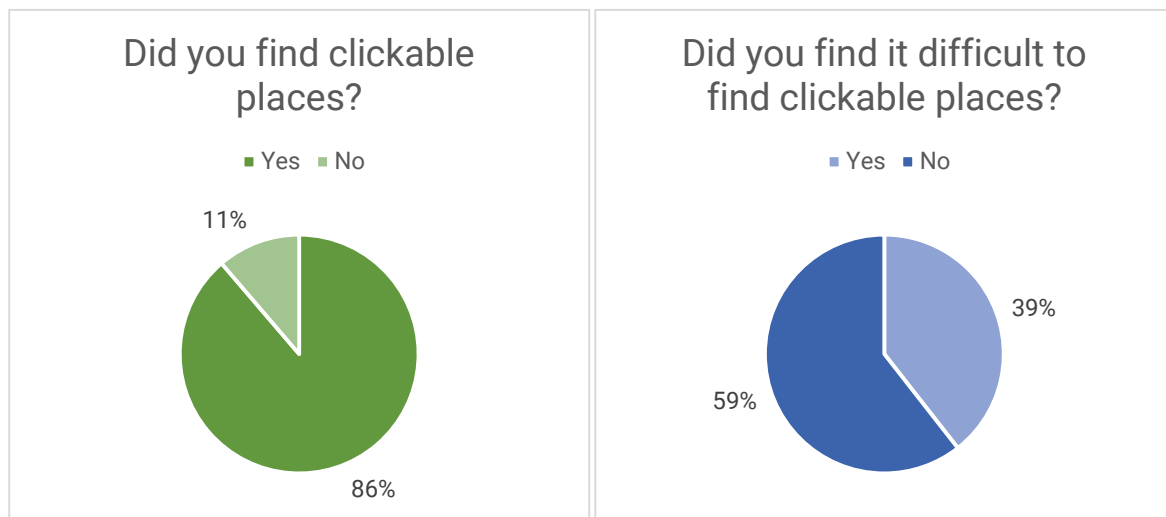


Figure 7-3: Responses on Questions 7 and 9 from the User Study. Whether participants found clickable places and if it was difficult to find them.

The responses show that majority of the participants, 86% were able to find clickable places. However, 39% of participants said they found it difficult to find clickable places. About 3% of participants did not answer these questions.

The reasons that helped people in finding clickable places are, change in cursor (micro-interaction), size and appearance of buildings, prior knowledge, and labels on the map itself. The size and appearance of buildings and labels mean that the pictorial map itself is designed to make important places stand out from the rest of the map. The participants pointed out that the size of the important buildings was relatively larger and more exposed, their towers had spikes and were protruding out. Overall, these buildings looked unique. This reason appeared 16 times and 5 times participants pointed out that the original labels within the map also helped.

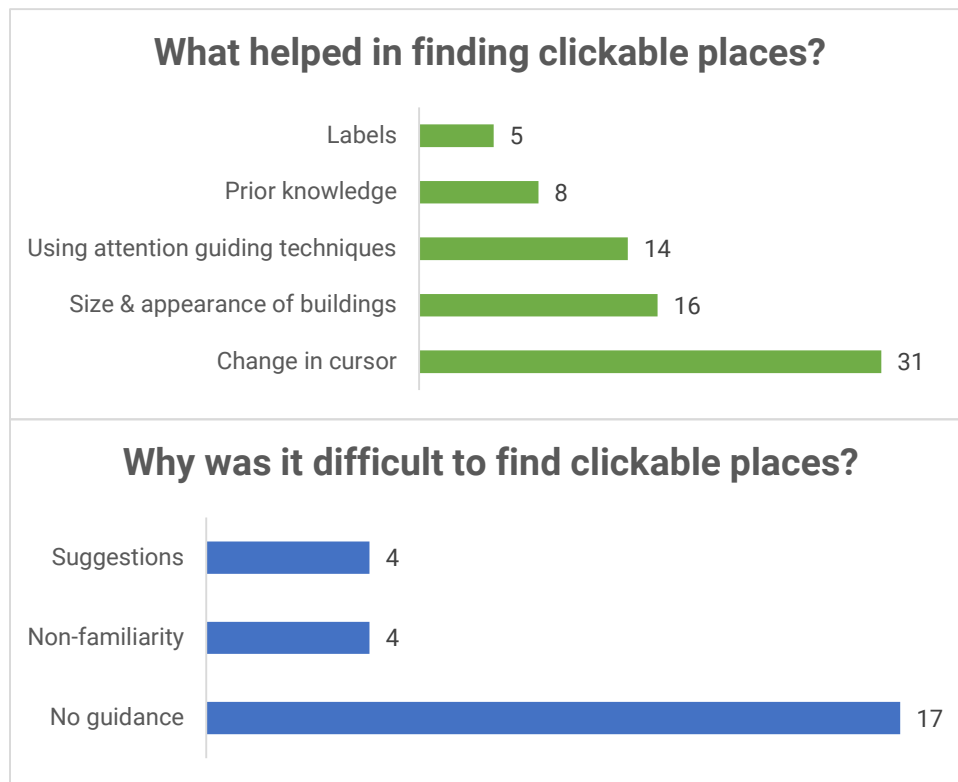


Figure 7-4: Responses to question 8 & 10 from the user study. Reasons that helped and made it difficult to find clickable places

About 8 times participants mentioned that they had prior knowledge of the city of Prague and they had an idea about the places that might be clickable due to their importance. Some of them used one of the attention guiding techniques to find the places, which was not the purpose of this task.

The most frequently occurring reason has confirmed the hypothesis that the cursor change will make it easier to find clickable places. This micro-interaction was specifically added to the map to facilitate finding important places when there is no guidance available.

About 4 times participants said that the clickable places were not familiar and they did not find places where they expected to. However, the hypothesis is proven right here: the most mentioned reason was that there was no guidance available providing any visual guidance would make this task easy.

7.4. Task

The task was to find out the selected places on the map, to note the time needed to fulfill the task and then to assess which attention guiding technique was more helpful in the process. However, the learning effect from the previous exploration was not considered. When multiple factors got involved it became difficult to conclude that the noted time truly represented what was expected of it, i.e. the ease of finding places through each technique. Another mistake was to let people enter their own time, Users had different time measuring formats and it resulted in a non-homogenous collection which was difficult to understand, yet to reason about. I could not differentiate whether people meant 20 seconds or 20 minutes and no coherent time patterns were observed. (Appendix 10.6)

However, the task served its purpose to help people get familiar with attention guiding techniques and get to know how to navigate through the map. The answers from the rest of the results are as follows:

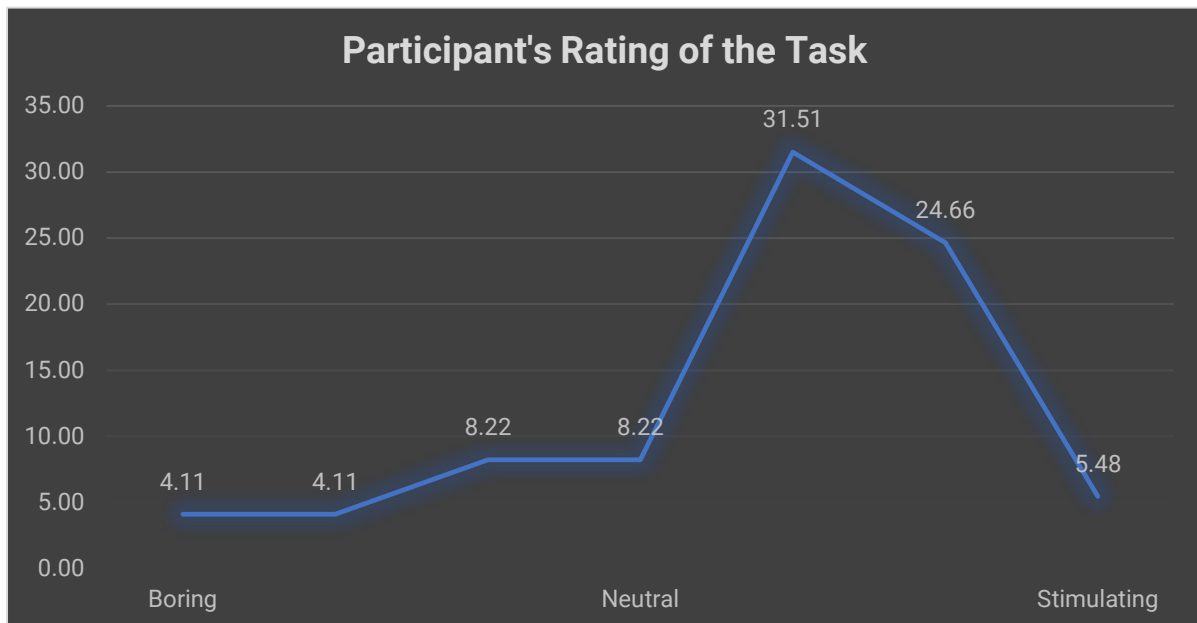


Figure 7-5: Response to question 15 of the user study, Rating of the task by participants. Y-axis shows percentages of participants.

The numbers on the Y-axis show percentage of participants. The graph clearly shows that most participants found the task rather stimulating than boring. Some of the participants, 13.7%, did not answer this question.

Despite the mistakes with the time recording activity, the participants got a chance to explore the techniques. Their responses to rating places as easy or difficult to find are interesting and insightful (Figure 7-6).

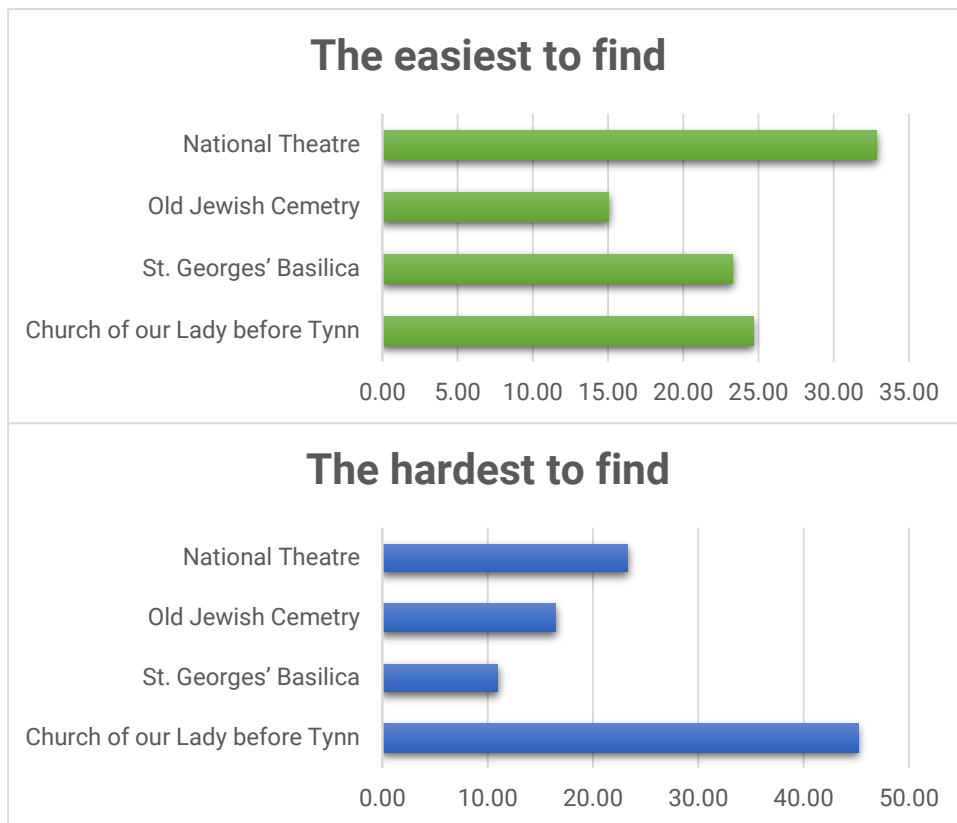


Figure 7-6: Responses to questions 16 & 18 of the user study. Percentage of participants rating places as easy and hard to find

The reasons why National Theatre was easy to find by the majority of participants were the learning effect (the fact that some of them already found it) and knowing where it is in Prague. Secondly, the Numbering Technique helped to keep counting of the places and to remember what was where. On the other hand, participants found it the hardest to find the Church of our Lady before Tynn. Because they were supposed to look for it without any attention guiding technique, this result was expected. More reasons for it might be that there were many churches depicted on the map and users had to go search for one of them through the whole map.

This also brings attention to the comparison between the simple pictorial map (no attention guiding technique applied) and a map with an attention guiding technique applied to it. As shown in Figure 7-4, the most stated reason for the difficulty in finding clickable places is 'no guidance'. Additionally, in Figure 7-6 as well it is clear that the place that has to be found with the 'None' layer was the most difficult to find. Hence, this shows that participants experienced difficulties in map exploration without any attention guiding and they preferred attention guiding techniques over a simple map.

7.5. Experience and Preference

The last and most conclusive section of the user study shows interesting results about the preference of technique and experience through all three techniques. Figure 7-7 shows a clear lead of Opacity Mask over the other two techniques. Numbering and Geometric Boundaries have equal amounts of appreciators.

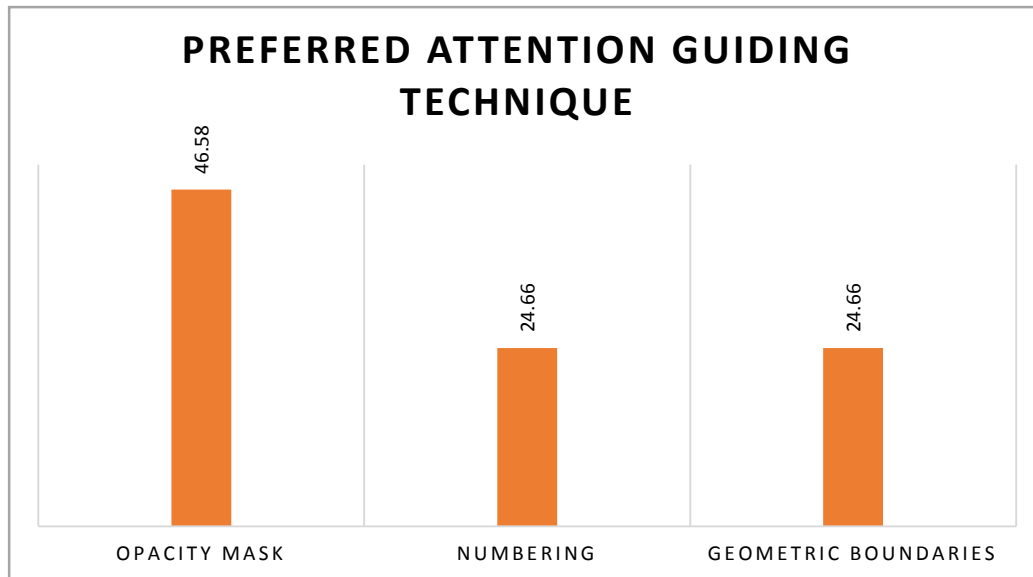


Figure 7-7: Choice of attention guiding techniques by participants, numerals show percentage of participants that opted for that techniques

The reasons given by the participants in free-form feedback showed a positive inclination towards the chosen technique as well as a negative inclination towards other techniques. So, these reasons were clustered and sorted to show both angles. It is interesting to note that people chose the technique that they found to be most visually appealing and whatever technique they chose, in their opinion, it did not obstruct the view and did not affect the aesthetics of the map, while the others did that. They also thought that the chosen technique looks good and guides the attention well, making the task easy. This pattern can be observed in the positive inclination of all three techniques.

However, some observations also point out important reasons that help understand users' choices better. It is pointed out that the Opacity Mask narrows focus and fades the rest of the map, thus gives immense attention to important areas. It is also mentioned that the user experience of Opacity Mask is preferred, explaining further that it takes the shortest time. The negative remarks point out that it hides the rest of the map, has a low level of transparency, and hence does not work well in areas of a white background. The tilted shape of the Opacity Mask around objects is also criticized and it was suggested that it should have highlighted the exact shape of the boundary of the object.

The important observations regarding the rest of the techniques are written in the Table 7-1. They will be further discussed in the Chapter 8: Conclusion and Discussion for the implementation of these techniques.

Technique	Positive Inclination	Negative Inclination
Opacity Mask	Does not obstruct the view Improves readability Nice contrast Gives immense attention Narrows focus, fades the re User Experience Most visually pleasing Took the shortest time	Did not work well in areas of white or bright colors Should have highlighted the exact shape of boundary Hides the beautiful map Low transparency Ignored details
Numbering	Does not affect aesthetics Links number to buildings Easy to follow Looks good Interfered least with the ma Easy navigation Gives a total count	Does not make sense Does not explain order What object the number points to
Geometric Boundaries	Distinctive boundary Highlights Leaves beauty of map intact Guides attention Easily visible Makes task easy	Intrusive Not aesthetic Made map visually turbulent Area not well defined Overlap of boundaries Hides structure with borders

Table 7-1: Participants' reasons for preferring the chosen techniques

The experience rated by participants for each technique is shown in the Likert chart by calculating the average response to each technique. This gives an overall view of the rating of the technique on each scale. The scales are originally 1-7 with 4 as a neutral value. Figure 7-8 narrows the X-axis to show the area where data points exist.

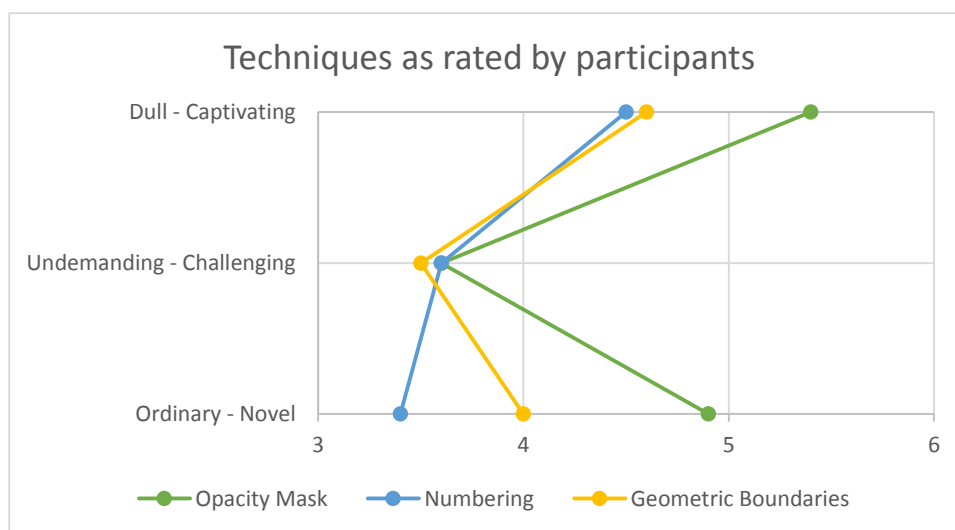


Figure 7-8: Average rating on each scale for all three techniques. Responses to questions 22, 24 and 26

The three techniques scored similarly in the Undemanding-Challenging pair. The Opacity Mask was perceived as the most captivating, while Geometric Boundaries and Numbering were almost equally rated as slightly captivating. The most ordinary (or most-seen) technique was Numbering, followed by neutrally perceived Geometric Boundaries and novel Opacity Mask.

Figure 7-9 shows the average rating of the navigation experience of participants through each technique. This is measured by two scales, Unruly-Manageable and Complicated-Simple, ranging from 1-7. Value 1 means Unruly and Complicated and 7 means Manageable and Simple. The graph shows that the average rating for navigation experience is inclined that users found it slightly simple and manageable.

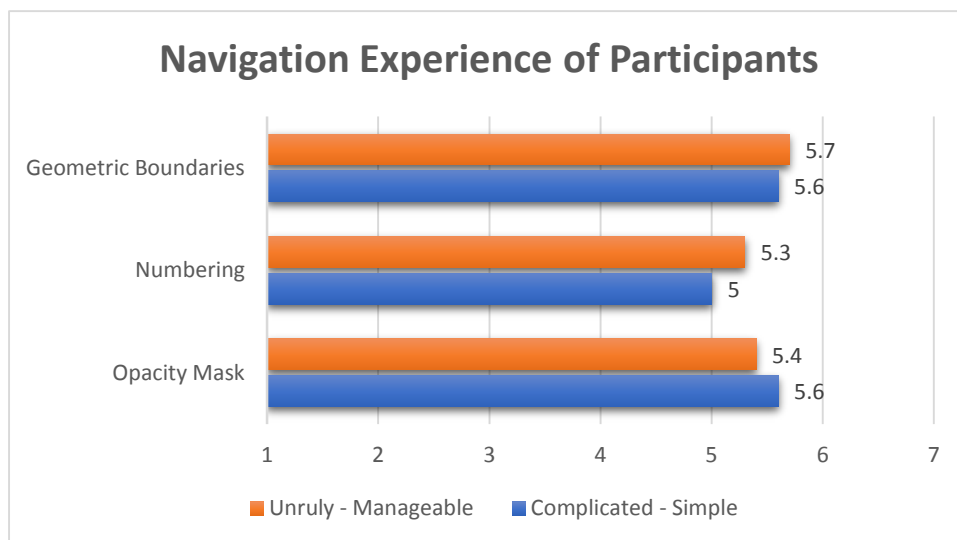


Figure 7-9: Average rating of Navigation Experience of all three techniques. Response to questions 23, 25, and 27.

Numbering technique has a different style and imposes a sequence, therefore has a more unique characteristic than the two remaining techniques. To rule out the possibility of the participants being inclined towards Numbering, additional question to choose between Opacity Mask and Geometric Boundaries was given. But since Opacity Mask took the lead initially, this comparison did not show any difference in results or reasons of choice. Figure 7-10 shows clearly this preference of participants.

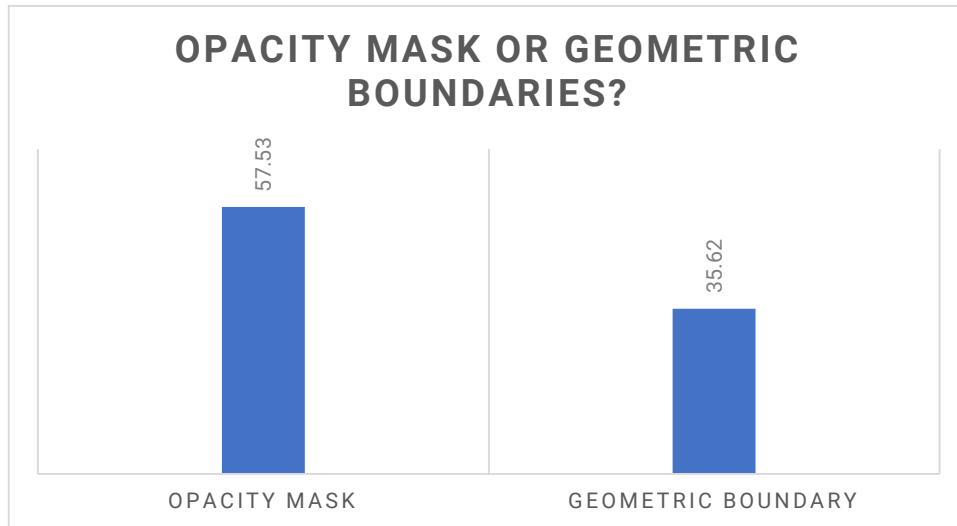


Figure 7-10: Choice of Participants between Opacity Mask and Geometric Boundaries. Responses to question 28

The user study ended by finally asking for feedback and the responses were uplifting. It was observed that most participants found the study to be very interesting and enjoyable. Few of the participants, particularly with no prior knowledge of GIS or Cartography found it to be long and complicated. However, there were some valuable suggestions for improvement that are added in Chapter 8: Conclusion and Discussion.

8. Conclusion and Discussion

This chapter concludes the research and distinctively answers research questions. It discusses the limitations experienced in the study and provide the recommendations and design implications for future studies in this domain.

8.1. Conclusion

After observing the outcomes of the results and analyzing them, I have reached the two conclusions. Firstly, in the comparison of a simple pictorial map (with no attention guidance) and a pictorial map with some attention guiding technique applied to it, the former is preferred. It is found to be more helpful in exploring the places within the map. Secondly, out of the three applied attention guiding techniques Opacity Mask, Numbering, and Geometric Boundaries, Opacity Mask is most liked by people. It is also found to be more captivating and novel than the other two.

8.2. Answers to research questions

Although some of the research questions are answered in the chapters above, this section aims to answer the questions or point to specific sections distinctively so there is no confusion left.

1) What are the group of attention guiding and narrative techniques available in the literature?

The groups are shown in Table 2-2 in the literature review.

2) Have any of these techniques been researched on for Cartography?

The research on the techniques is sparse. In recent years Song (2017) compared black leader lines with black color highlighting on maps. Further details are explained in Section 2.1. Foundational Literature.

3) What are the main groups of attention guiding techniques and narrative techniques available online?

Figure 3-3 and Figure 3-5 show the main groups of attention guiding and narrative techniques available online.

4) Do these techniques exist in combinations or solo?

Most attention guiding techniques exist in isolation, while narrative techniques are usually found in combination. Figure 3-4 and Figure 3-6 show these numbers in detail.

6) What attention guiding and narrative technique did I choose for this study and why?

The selected attention guiding techniques were: Opacity Mask, Numbering and Geometric Boundaries. The selected narrative techniques was Textual

Narration with Images. The reasons for choosing these techniques are explained in Table 4-2 and Section 0.

7) What technologies are used in the development of the prototype?

The development made use of the web frameworks (AngularJS, NodeJS), coding languages (JavaScript, Typescript, HTML, CSS), editing tools (Visual Studio Code, Notepad++) and sharing and hosting services (GitHub and Netlify). More details in Section 5.3. Technologies used.

8) How to design and deploy attention guiding techniques using visual encoding and interactions?

The question is answered in detail in Section 5.4. Requirements checklist.

9) Which method is employed for the evaluation of techniques?

The method employed for the evaluation of techniques is a quantitative and qualitative user study. Further details can be found in Section 4.3. Phase III.

10) Which technique performed better in the user study and on what grounds?

Opacity Mask took the lead on the other two techniques, the reasons for that are well explained in Section 7.5. Experience and Preference.

11) What are the differences observed between the baseline pictorial map and the attention guiding technique applied to it?

The baseline pictorial map fails to guide the reader to the areas of interest, while the one with attention guiding technique applied to it highlights these areas so they are quickly found. However, the baseline map keeps the beauty and aesthetics of the original map intact, while attention guiding techniques hinder some elements of the map to bring attention to the important ones.

8.3. Study limitations

During the span of this research, there were several limitations due to which the course of our action had to be changed.

- **Lack of relevant literature:** There has not been much research on narrative visualization of maps especially in the case of pictorial maps. This is also because this is a narrow domain and any of the useful research is quite recent.
- **Limited Scope:** The initial plan was to compare narrative techniques as well as attention guiding techniques, but the given time and scope of this study did not allow for it. The narrative techniques should be further evaluated in follow-up studies.
- **No expert-based Interviews:** For the qualitative study, the idea was to conduct in-person interviews with experts and record their responses. As the pandemic limited the access to such facilities, the interviews were given up and the user study became the only source of gathering results.

8.4.Recommendations for future pictorial maps

Some of these recommendations are my suggestions I noticed during the research process. However, some of them are suggested by participants through feedback. The recommendations are further split into two parts. The first one is based on the design guidelines for applying the attention guiding and narrative techniques on a pictorial map, the other on the applications of these techniques with or without a pictorial map to solve real-world problems.

8.4.1. Design guidelines

When applying the Opacity Mask, different levels of transparency must be explored to observe how opaque the mask should be over the used base map. To keep the rest of the map visible it is advised to keep the mask at least 70% transparent.

One of the participants suggested that it would be convenient to have a list of numbered objects that are important in the map, somewhere visible in the web application. This would connect the Numbering technique to the list and give an overview as well as a total count of objects to look for.

For Geometric Boundaries, the design recommendations are to reduce the border width and perhaps use a softer color if the background map allows. One can experiment with rounding the borders as well, but keeping in mind that the boundaries might not remain geometric with such changes.

In case of designing the web pictorial map from scratch or adding its own labels, keep the labels legible in terms of color, font, and size. Another design recommendation is to add pop-ups on hover. I did not add them to keep the applied interactions minimal and focus more on attention guiding. However, they are a good addition to other scenarios. The transition from one part of the information to another should be smooth and accessible via a single click. However, navigation experience depends highly on the extent of information available on the screen. If the map must be scrolled left and right, navigation becomes more difficult. Finally, when designing the user study, one should try to take the learning effect of the participants into account.

8.4.2. Applications

One could think of several applications of the results for the following use scenarios:

- Tourist maps can be designed using pictorial maps on the base and the attention guiding techniques applied to them.
- Maps for games and scavenger hunts can make use of both pictorial maps as well as attention guiding techniques.
- Storytelling maps can adapt Opacity Mask to narrow focus.
- Navigation maps can make use of Numbering to guide users, even if the base is not a pictorial map.
- Geometric Boundaries are a great way to highlight exits and assembly points in health and safety maps.
- The plant and site maps of Oil and Gas exploration can make use of attention guiding techniques along with narrative information of the facilities available.

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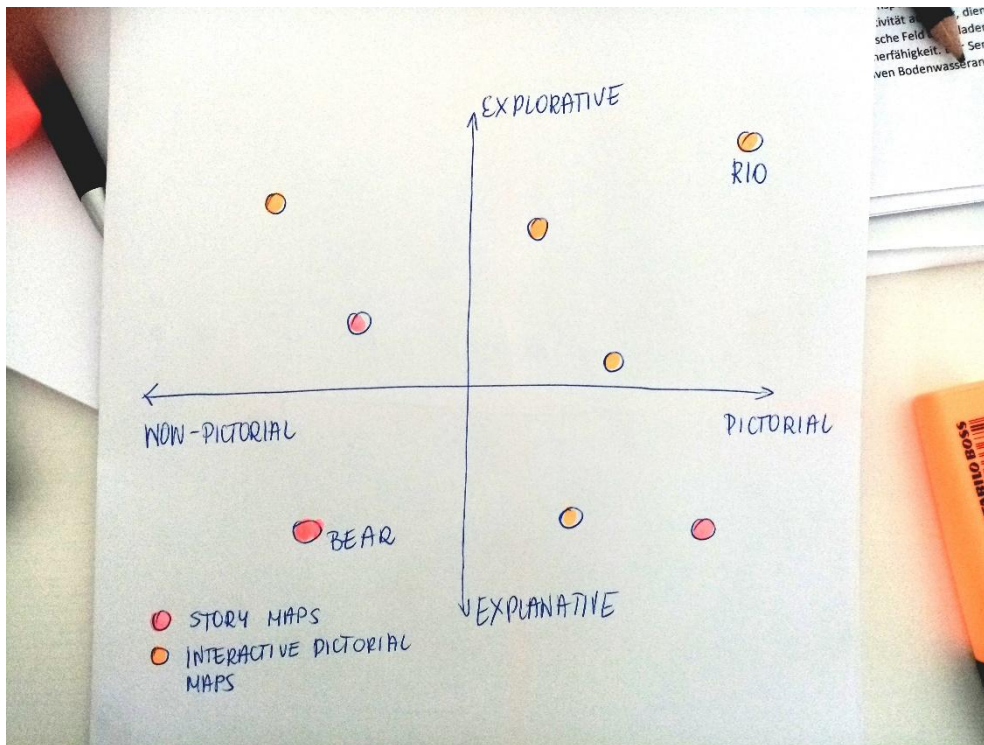
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10. Appendices

10.1. Initial Draft of Coding for Map Application



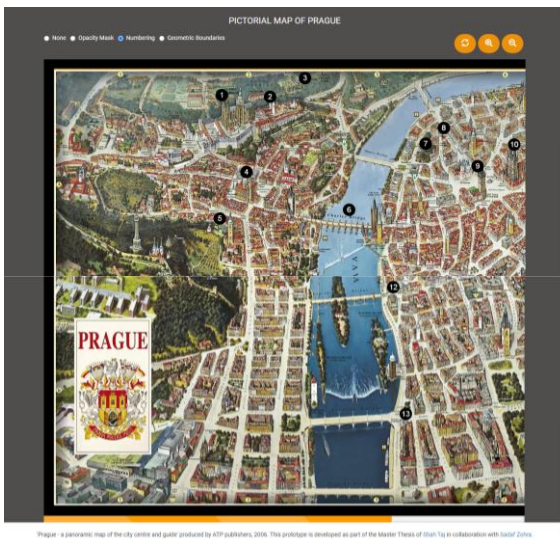
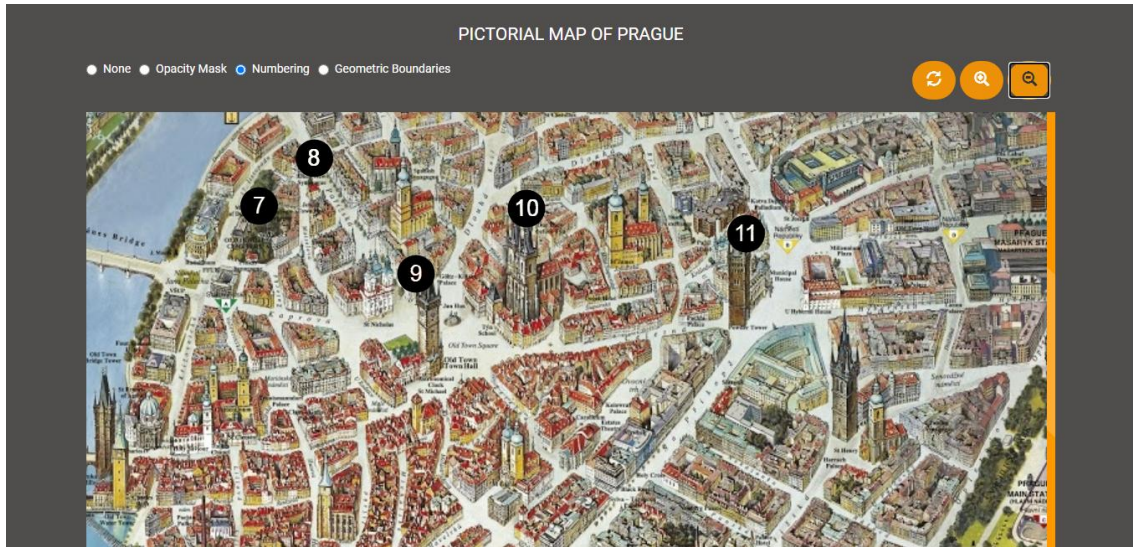
10.2. Collection and coding of Map Applications in Excel

	A	B	C	D	E	F	G
1	Titles	URL	X	Y	Focus Attention Technique Used	Narrative Technique	Image
2	#5DLDN - Webatvantage	http://london.webatvantage.be/en/map	1	3	Highlighting, call outs	Images, Captions	Y
3	#MetKids Map	https://www.metmuseum.org/art/online-features/	3	3	Opacity mask, markers	Images, Video, Text, Accompanying	Y
4	Chasing the Matterhorn	https://storytelling.nzz.ch/2015/matterhorn/	-2	-2	Dynamic panning/zooming, call-outs, labelling	Images, Text Narration, Animations	Y
5	City of Red Deer WebMap	http://webmap.reddeer.ca/webmap/	0	3	Visual variables, Color Highlighting, flickering	labels, map	Y
6	Costing Nature	https://costingnature.infoamazonia.org/en/	0	3	none	legend, text narration	Y
7	DM	https://sims2.digitalmappa.org/36	2	3	Highlighting, call outs	text narration	Y
8	Dreamscapes	https://www.lufthansa-dreamscapes.com/en	0	2	Markers	labels, images, video, text	Y
9	Explore The Hidden Worlds of our National Parks	https://artsandculture.google.com/project/national-parks	-2	-3	Dynamic panning/zooming, call-outs, labelling	text, images, videos	Y
10	Google Maps: Miniatur Wunderland Street View	https://www.google.com/maps/about/behind-the-scenes/	2	2	markers	images, text, animations	Y
11	House at Khleby	https://hlebdom.ru/en/location.html	3	2	Highlighting, call outs	text, images	Y
12	Interactive Map of France French Cities, Regions & Dep	https://www.francetoday.com/france-map/	3	2	Dynamic flickering	labels, text, accompanying articles	Y
13	Interactive Map of Germany - Search Landmarks Hiking	http://www.orangesmile.com/travelguide/germany	0	3	markers, shadows	labels, images, text	Y
14	Interactive Storytelling Codrops	https://tympanus.net/Development/StorytellingMap/	0	-3	visual heirarchy	text narration, animation, images	Y
15	John Mandeville and the Hereford Map - Omeka	http://historiacartarum.org/omeka/outline/fullscreen/	2	3	highlighting	text	Y
16	Map of Germany	https://www.germany.travel/en/map-of-germany.html	-1	3	visual heirarchy	text, images	Y
17	Map of the Northern Kingdoms :: Witcher 2	http://vitaln.com/ehalos/witcher2/map.html	3	3	visual heirarchy change on hover	labels	Y
18	matthew-paris	https://bl.ocks.org/mapsmania/0dc755cab24d76dc	2	3	none	text	Y
19	Netflix The Witcher Karte des Kontinents	https://www.witchernetflix.com/de-de	3	2	highlighting, dynamic zooming, animation	text, headlines, images	Y
20	Places of Poetry	https://www.placesofpoetry.org.uk/	-2	2	labels	text	Y
21	Radio Garden	http://radio.garden/	-1	3	highlighting	text	Y
22	Reprojected Destruction	http://hansack.com/aleppo/	0	3	highlighting on polygon fill	text, labels, pop-ups	Y
23	Rio 2016 Interactive Map	https://rio2016interactivemap.com/	3	2	animation, call-outs on hover	text, sound	Y
24	Shipmap.org	https://www.shipmap.org/	-1	0	highlighting, animation	audio narration, animation	Y
25	Ships in the San Francisco Bay	https://labs.mapbox.com/bites/00318/	0	0	color highlighting, visual variable: size	image, text, animation	Y
26	Sochi 2014 Interactive Map	http://www.sochi2014interactivemap.com/#	3	2	animation, call-outs on hover	text, map	Y
27	Soundscape	https://nps.maps.arcgis.com/apps/Cascade/index.html?appid=39111111111111111111111111111111	-2	-3	Dynamic panning/zooming, visual variables	audio, sound, images, videos, text	Y
28	Statskogmillionen	https://www.statskog.no/statskogmillionen	1	3	visual variables, highlighting, dynamic zoom	text, images, accompanying articles	Y
29	Susie King Taylor	https://www.loc.gov/ghe/cascade/index.html?appi	0	-3	markers, numbering	text narration, images, headlines	Y
30	Home grown pride	https://www.loc.gov/ghe/cascade/index.html?appi	0	-3	color highlighting	text narration, images, headlines	Y
31	Stunning Interactive map of Myanmar	https://www.insideasiatours.com/step-inside/myanmar/	3	2	animation, dynamic panning, variable levels	text, images, labels, map	Y
32	The world of Airbnb	https://www.airbnb.com/map	2	2	animation, dynamic flickering	video, text	Y
33	ThingLink Feature: Interactive World Map by Daily Mail	https://blog.thinglink.com/marketing/interactive-world-map/	3	3	variable scale	labels, interactive visualization	Y
34	This is Bears Ears	http://bears.ears.patagonia.com/	-3	2	visual variable:color	image, video, text, sound, map	Y
35	Tour de France: the climb of Alpe d'Huez – interactive	https://www.theguardian.com/sport/ng-interactive/tour-de-france-the-climb-of-alpe-d-huez-interactive	-2	-3	changes in map scale, variable levels of detail, dynamic panning	image, video, text, sound, map	Y
36	Urbanization in East Asia	http://nbremer.github.io/urbanization/	0	-3	visual variables, highlighting	text, Headlines, animations, static vi	Y
37	Visualizing The Racial Divide	http://vallandingham.me/racial_divide/#ch	0	2	visual variable: color, animation	text, Headlines	Y
38	Wealth Divides	http://storymaps.esri.com/stories/2016/wealth-divides/	0	-3	feature boundaries, visual variables, dynamic	Intro text, text, Narration, Headlines	Y
39	Welcome To Fillory	http://www.welcometofillory.com/	0	2	animation, dynamic panning, zooming	label, Headlines	Y
40	Which Flight Will Get You There Fastest?	https://projects.fivethirtyeight.com/flights/	0	1	visual variable: color	animation, intro text, textual narrati	Y
41	Worldwide remittance flows	http://remittances.herokuapp.com/?en	0	0	feature boundaries highlighting, visual variat	Intro text, Headlines, Vis. Summary	Y
42							
43							

10.3. An entirely non-pictorial map

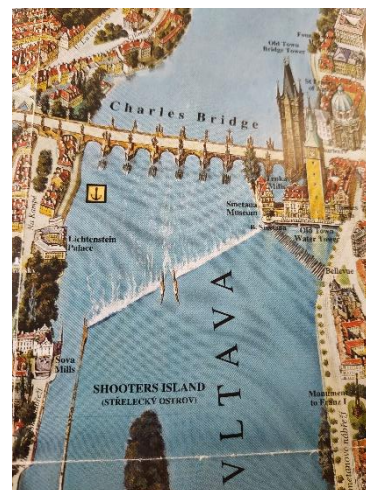
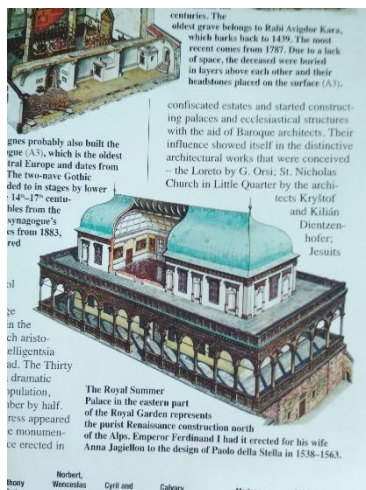


10.4. Different views of the prototype and initial pictorial map




Prague - a panoramic map of the city centre and galler produced by ATP publishers, 2006. This prototype is developed as part of the Master Thesis of Stan Tu in collaboration with Saša Čížek

Prague - a panoramic map of the city centre and galler produced by ATP publishers, 2006. This prototype is developed as part of the Master Thesis of Stan Tu in collaboration with Saša Čížek



10.5. User Study



Cartography M.Sc.

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Page 01
1

Introduction

Hello and Welcome to this survey, which is being conducted by Shah Taj, M.Sc Cartography student, as a partial fulfillment for the Master Thesis, 'Navigating Pictorial Maps using Attention Guiding and Narrative Techniques'.

Before you begin the survey, please note that it has two parts,

- 1) Questionnaire
- 2) Prototype

The Questionnaire is meant to measure your experience of the associated prototype and the techniques integrated in it. This is both a quantitative and qualitative evaluation so you might need to enter your experience in words in some sections. You are also free to leave the survey wherever you want. However, it is encouraged that you complete the survey and make your response count.

The Prototype is a website, having a base map, the pictorial map of Prague for tourists. The map contains the most visited part of the city by tourists. You will find some areas of the map grasping your attention through the 3 techniques available. These areas will also have some additional information about them in the side panes, which appear as you click certain places. The link to the prototype will be provided to you further in the questionnaire.

Before you begin, it is recommended that you have a stopwatch ready, either manual or in your smartphone. The time required to complete this survey is 20-25 minutes.

The data collected from you will only be used for the purpose of this study and will not be shared to third parties. For any questions or concerns, please write an email to shahtaj02@gmail.com. By clicking the Next button to move further in the survey, you admit that you are at least 18 years old and agree to participate in this study.

1. Which age group do you belong to?

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

2. Please select your current status

- Student (Under Graduate)
- Student (Graduate)
- Student (Post Graduate)
- Professional

3. Do you have any knowledge from the domain of GIS or Cartography?

- Yes
- No

4. What in your understanding is a pictorial map?

5. Have you seen pictorial maps before?

- Yes
- No

6. Have you visited Prague?

(If you visited it but didn't explore the city, select No)

- Yes
- No

PHP code

```
library('jQuery');
```

Open the link below. Now look at the map, get familiar with the interface. There are 4 buttons on the top left of the map, don't switch them for this part of the exercise. They are attention guiding techniques that you will use in later tasks. Note that the extent of map shown depends on your screen resolution, you might have to scroll the map vertically and horizontally to reach its full extents. The orange buttons on the top right of the map are for refreshing the map to its original extent, zooming in and zooming out respectively. Now explore the map and see if there are any places you can click on.

<https://qomshahhaj.nellify.app/>

7. Did you find clickable places?

- Yes
- No

8. What helped in identifying the places that were clickable? List down the things that helped

9. Did you find it difficult to identify place that were clickable?

- Yes
- No

10. Why was it difficult to find clickable areas? List the reasons below

Task Description

This is a task section. For the tasks below, keep your stopwatch ready and the prototype open in the next window. The task generally requires you to look for certain places in the map in a specific layer and note the time taken to find them. Complete each task in the following sequential steps:

- 1) Read which layer to choose and the place to find for the task
- 2) Open the prototype and select the layer from the top left buttons
- 3) Start the stopwatch
- 4) Look for the place mentioned in the task
- 5) Once the place is found, stop the watch and enter the time taken to complete the task
- 6) Repeat until finished

11. Layer: 'None'

Place: 'Church of Our Lady Tynn'

12. Layer: 'Opacity Mask'

Place: 'St. Georges' Basilica'

13. Layer: 'Geometric Boundaries'

Place: 'Old Jewish Cemetry'

14. Layer: 'Numbering'

Place: 'National Theatre'

15. How did you find the task?

Boring ○ ○ ○ ○ ○ ○ ○ Stimulating

16. Which one of the following places was the easiest to find?

- Church of our Lady before Tynn
- St. Georges' Basilica
- Old Jewish Cemetery
- National Theatre

17. Please list the reasons that made one of the places easiest to find.

18. Which of these places was the most difficult to find?

- Church of our Lady before Tynn
- St. Georges' Basilica
- Old Jewish Cemetery
- National Theatre

19. Please list the reasons that made one of the places the most difficult to find.

Now feel free to explore the techniques yourself and read the information that appears upon clicking the highlighted places. Once you have explored enough, answer the following questions.

20. The visual techniques you just observed in the form of 3 layers are attention guiding techniques. Which of these techniques did you like the most?

- Opacity Mask
- Numbering
- Geometric Boundaries

21. Please state the reasons that made you incline towards the above chosen technique.

22. Rate 'Opacity Mask' on the following scales in its attempt to guide your attention on the map.

Dull	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Captivating
Undemanding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Challenging
Ordinary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Novel

23. Rate your navigation experience of the above mentioned technique on the following scale:

Navigation experience counts as the possibility of moving from one point to another on the map and the elements that contribute to it

Complicated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Simple
Unruly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Manageable

24. Rate 'Numbering' on the following scales in its attempt to guide your attention on the map.

Dull	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Captivating
Undemanding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Challenging
Ordinary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Novel

25. Rate your navigation experience of the above mentioned technique on the following scale:

Complicated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Simple
Unruly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Manageable

26. Rate 'Geometric Boundaries' on the following scales in its attempt to guide your attention on the map.

Dull	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Captivating
Undemanding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Challenging
Ordinary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Novel

27. Rate your navigation experience of the above mentioned technique on the following scale:

Complicated Simple
Unruly Manageable

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28. Among the techniques, Opacity Mask and Geometric Boundaries, which one do you prefer and why?

29. What feedback or comments do you have regarding this survey or the prototype?

Last Page

Thank you for completing this questionnaire!

We would like to thank you very much for helping us.

Your answers were transmitted, you may close the browser window or tab now.

10.6. Color-coding of Qualitative Responses for Definition of Pictorial Map

	A	B	C	D	E	F
1	A107_01 - What is a pictorial map?	Coding		73-7=66 responses		
2	a map with little pictures in it	Contains		How it represents?		
3	A map containing illustrations	Contains		What it contains?		
4				What it preserves/distorts		
5	A map that does not follow standard mathematical projections and cartographic principles and relies more on artistic visuals instead.	contains, preserves		What is the viewing perspective?		
6	Map with pictures or maps with more details in them in the form of pictures or art	contains		What is the function/purpose?		
7	A map that contains pictures?					
8	Pictorial maps are more artistic rather than technical	represents, preserves				
9						
10						
11	Map in which illustrations and pictures are used to display information	contains, function				
12	An image/picture with a spatial/map component	represents, contains				
13	map with illustrations/pictures e.g a tourist map with sights not just "technical" information like a road map					
14	A map telling a story.					
15	A map which is more artistic as opposed to practical, eg. a panorama map, a 3D illustration of a scene					
16						
17	Map with pictures					
18	A more artistic map meant to bring a city alive, but not as helpful for navigation or practical use.					
19	Its a map which looks like a picture					
20	its a picture like map					
21	A map that uses pictures as symbology, i.e. to represent geographic features.					
22	Images used to create a map					
23	An image acting as a map. You can navigate, pan, view etc					
24	Artistic map highlight a theme					
25						
26	A map that relies on visual information, for instance images or illustrations.					
27	Pictures caters the geographical information					
28	more artistic map rather than street/topographic map. Spatial features may be depicted by 3d perspective or 2d models/pictures, that what I understood about pictorial maps					
29	The emphasis of pictorial maps is less on showing a specific territory to scale and more on the choice of particular landscape features so as to delineate a place and at times to emphasize a specific feature.					
30	artistic maps					
31	A map which would show certain landmarks in an area with pictures resembling its appearance.					
32	Type of map displayed in an illustrated way.					
33	A map which gives more detailed and clear view of the sight.					
34	A map with pictures of landmarks					
35						
36	Map of artists and graphics designers I guess					
37	a pictorial map is advanced version of simple maps containing more details of the objects					
38	A map that is very similar to a image, having a lot of artistic or natural detail, but with limited amounts of map symbology and abstraction overlaid.					
39	An informal kind of a geographic map which presents the features in a given area.					
40	A map that depicts an area with symbols and pictures rather than through technical elements					
41	Pictorial maps depict a given territory with a more artistic rather than technical style.					
42	A map which makes use of illustrative elements of concrete things, rather than only abstract shapes (like charts etc.)					
43	A map with pictures at locations with specific buildings					
44	map w pictures					
45	A map using illustrations to depict real world phenomenon/features. Focuses on certain areas/parts and geography is somewhat distorted.					
46	The depiction of a specific area with a more artistic rather than technical style.					
47	Map complimented with pictures					
48	They are a representation of our perception of the use of camera					

10.7. Non-Homogenous responses of recorded time for Task in User Study

	A	B	C	D	E	F
1	Layer: 'None', Church of Our Lady	Layer: 'Opacity Mask', 'St. Georges'	Layer: 'Geometric Boundaries'	Layer: 'Numbering'		
2	A301_01	A302_01	A305_01	A304_01		
3	15	20	9	1		
4	5.81	24.04	9.7	8.54		
5	0:00:00	6:28:48	0.013240741	32.65		
6	420	15	10	3		
7	19.26	17.9	6.99	36.87		
8	25	13	16	18		
9	35	15	10	20		
10	35 -	9	21	40		
11	24	20	5	7		
12	26.6	17.1	21.55	24.5		
13	25.04	17.7	8.7	10.01		
14	68	15	11	10		
15	10	16	18	7		
16	60	90	48	30		
17	10	4	9	9		
18	18	4	10	5		
19	120 -	20	4	5		
20	120	60	120	30		
21	40.00	24.20	10.00	5.00		
22	1	1	3	4		
23	50	12	10	10		
24	9	5	18	14		
25	2	1	2	15		
26	8.71	10.77	5.5	11.11		
27	16.22	18.06	52.21	1.04		
28	12.3	7.25	6.3	1.7		
29	68	12	8	7		
30	60	30	26	60		
31	50	10	10	15		
32	5'	10'	5'	5'		
33	18	4	5	12		
34	32	24	11	30		
35	52	38	40	26		