EYE TRACKING IN CARTOGRAPHY: RESEARCH ON THE PERCEPTION OF SYMBOLS AND SIGN SYSTEMS IN WEB MAPS

Nikoleta Nikolova

PhD Nikoleta Nikolova,
University of Architecture, Civil Engineering and Geodesy
Sofia, Bulgaria
nikoletan765@gmail.com

Abstract
This research project investigates the perception of symbols and sign systems in web maps using eye tracking technology. The goal is to improve the quality of web maps by optimizing the layout, symbol design, and overall user experience.
The project will be conducted in three stages. First, it will be tested the usability of existing web maps. For this goal it will be used eye tracking devices for high-precision and detailed analysis of visual perception. Then it will be implemented software for data recording and processing. Based on the time measurements it will show how fast users orient themselves in the map, how they find objects, and identify symbols on different web maps. The results will be analyzed to identify factors that affect usability, such as symbol design, map layout, and user characteristics.
The second stage is developing recommendations for improving web map design. Based on the findings from the first stage, recommendations will be developed for improving the design of web maps. The purpose of exploring cognitive processes involved in map will focus on factors such as symbol clarity, map layout, and user-friendliness.
Finally, the study will test the effectiveness of the recommendations. The recommendations developed in the second stage will be implemented in a set of prototype web maps. These prototype maps will be tested with users to evaluate their effectiveness in improving usability.
The project offers valuable foundations for the field of cartography by providing new insights into the perception of web maps. The results of the project will be useful for establishing a research infrastructure for future studies on map reading and cognitive processes in cartography.

Keywords: *eye tracking, web maps, cartography, usability, symbols, sign systems*

INTRODUCTION

Cartography, the art and science of map-making, has evolved dramatically with advances in technology. Traditionally focused on physical maps, the field has expanded significantly with the advent of digital cartography. Web maps, which represent this digital transition, are now integral to numerous applications, impacting navigation, urban planning, disaster management, and more. These maps not only need to be accurate but also user-friendly, as they are accessed by a diverse audience with varying levels of expertise and experience.

Despite their widespread use, many web maps suffer from issues related to the perception and usability of their symbols and sign systems. Users often experience difficulties in understanding and interacting with these elements, which can lead to misinterpretations or slower response times. Current designs of symbols and sign systems in web maps may not fully accommodate the diversity of user groups, and having to figure them out can compromise the effectiveness of the maps.

This research aims to expose these issues by using eye tracking technology to study how users perceive and interact with symbols and sign systems on web maps. The ultimate goal is to optimize the design of these elements to enhance user experience and usability. By analyzing visual attention and interpreting user behavior, this study intends to develop a set of design guidelines that improve readability and intuitive use of web maps.

This research is likely to make a major impact on map-making by creating web maps easier to use. By improving the way symbols and signs are understood, it can help not everyday users but also professionals in areas different areas. Moreover, this study aims to set the stage for future improvements in digital map design, contributing to both researches and practical applications.

PRIORITY AREA

The priority area is the one which includes the development and application of contemporary methods, presented in geodesy, cartography, and remote sensing fields. Development of scientific infrastructure is exposed by creation of workstations to study the perception of signs Two research positions will be equipped in the Cartography Laboratory at the Department of Photogrammetry and Cartography. They will be used for conducting various experiments aimed at studying the methods of reading cartographic materials and improving the sign systems and layouts of maps. The experience gained from working on this project will be applicable to the research of other cartographic productions.

METHODOLOGY

Through developed tests, the time required to recognize signs of different shape, size, and color by various user groups will be determined. The study will explore the time and accuracy in grouping signs that differ by one or more visual variables.

The algorithm for searching for signs on the map field by users of different gender, age, and education will be defined, and conclusions will be made regarding the placement of map components during composition.

As a result of the project's execution, suggestions will be made to improve the quality of sign systems on web maps, aimed at faster recognition and grouping of signs and more secure appropriation of their meanings.

This main aims are to analyze and improve the sign systems used on web maps. To achieve this goal, the following research methods will be employed:

Study of Existing Web Maps

The research will begin with a comprehensive evaluation of existing web maps, including those available through geoportals, tourist maps, navigation maps, and other sources. Key performance indicators will be analyzed, including:

- Time for Map Orientation: How quickly can users orient themselves using different maps?
- Time to Locate Objects: How efficiently can users find specific objects on the map?
- Sign Identification Accuracy: How often do users incorrectly identify signs on these maps?
- Ease of Finding Map Components: How easily can users locate and recognize various components of the map?

Eye-tracking techniques on cartographic products

To gather data, it will be used eye-tracking systems to monitor where users' gazes linger on the map, which will help identify which aspects of the map draw attention and which do not. This technology provides insights into how users interact with and perceive graphical elements on web maps. By analyzing where, how long, and in what order viewers look at different areas of a map, cartographers can refine the design of web maps to make them more intuitive and effective. This technology not only enhances user experience but also provides empirical data that can inform the optimization of symbol systems and map layouts.

For the successful conduct of experiments and analyses in the study of the content and sign system of web maps, modern computer hardware and specialized software are preferably required.

Utilizing eye tracking, researchers like Horbiński, Cybulski, and Medyńska-Gulij (2021) have examined how responsive design principles influence user interactions. Their study emphasizes the critical role of visual attention dynamics, such as the time to first fixation (TFF) and mouse click responses, in evaluating the effectiveness of web map interfaces.

In this paragraph first it will be explored some of the most prevalent and effective eye-tracking techniques, which will be employed to gather accurate, rapid, and reliable data regarding user observations on maps.

- EyeTech VT3 Mini provides highly precise eye-tracking with a frequency of 40/60 Hz. This device is essential for experiments, allowing the measurement and analysis of exact eye movements. This tool will provide valuable data on the perception of signs in web maps and will support the main aspects of scientific activity. It enables further use in scientific and educational activities. This device will not only meet the needs of the current project but will also be integrated into future research and educational programs, maintaining a continuous set of valuable data.

Figure 1. EyeTech VT3 Mini

- P3 HD Eye Tracker with a high frequency of 150Hz represents a significant advancement in eye-tracking technology. This device will be crucial for the detailed and precise study of visual perception of signs in web maps. The purchase of the P3 HD Eye Tracker will lead to a comprehensive study of its capabilities for subsequent use in scientific and educational activities. With its high technical specifications, this device will not only enrich current experiments but will also serve as a key tool for future scientific projects and educational initiatives.

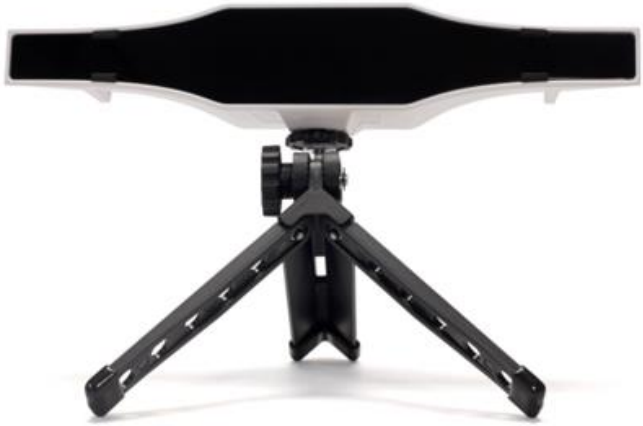

Figure 2. P3 HD Eye Tracker

- Gazepoint Analysis UX Edition is specialized software for recording and processing data from eye-tracking devices. It allows for enhancements through various programming languages, making it suitable for tasks beyond the goals of the project.

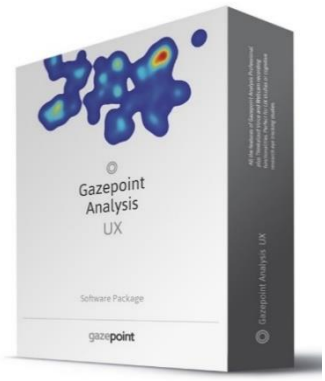

Figure 3. Gazepoint Analysis UX Edition

These eye-tracking devices and software ensure the collection of precise and reliable data regarding user interactions with web maps. The EyeTech VT3 Mini, with its ability to operate at 40/60 Hz, provides high-precision tracking of gaze patterns, critical for detailed analysis of visual attention. Similarly, the P3 HD Eye Tracker, operating at a frequency of 150 Hz, allows for an even more granular examination of eye movements, facilitating a deeper understanding of user engagement with map features.

To complement the hardware, the Gazepoint Analysis UX Edition software will be utilized, which is specially designed for processing and analyzing eye-tracking data. Such a robust setup is indispensable for accurately assessing how users perceive and interact with cartographic representations, thereby informing the optimization of web map design for enhanced user experience.

Cognitive Theories and Methods in Cartography

Emphasize the need for a deeper integration between cognitive psychology and cartographic design is essential for better understand how users interact with maps. This approach aims to enhance the cognitive compatibility of map designs with user expectations and perceptual capabilities.

Ongoing research, as highlighted by Kiefer et al. (2017), underscores the significance of eye tracking in unraveling spatial cognition challenges and opportunities. Observing user behavior can be applied to the design of interfaces where it requires an understanding of cognitive processes for information acquisition. Behavioral data show which elements of the interface are of interest to users and which are used to solve specific tasks.

Cognitive mapping uses cognitive theories and methods to understand, create, and read maps and geo-applications.

According to Dr. Montello's 2002 publication ("Cognitive map-design research in the twentieth century"), the informational and cognitive processes in cartography involve several aspects: perception, learning, memory, thinking, reasoning, problem-solving, and communication.

Data Analysis and Hypothesis Testing

After collecting the data, it will be analyzed the interaction patterns between users and different types of web maps. This analysis will set some potential hypotheses that could be explored.

To differentiate and organize the workflow and examination first it will be distinct two categories of hypothesis. First group can contain presumptions focusing on map design and cartographic sign systems. The second group combine conceptions about user experience elements, placed around every web map.

Hypotheses Related to Map Design and Cartograpic Sign Systems

These hypothesis focus on the graphical elements and visual design aspects of web maps that directly affect how users perceive and interact with the map content.

1. ***Hypothesis: Increasing the clarity and size of symbols on web maps improves user recognition speed and accuracy.***

   Is in reality larger and clearer symbols reduce cognitive load and enhance quick identification, which is crucial for users navigating or seeking information swiftly?

2. ***Hypothesis: Utilizing a more diverse color palette that includes high-contrast colors will enhance the distinguishability of different symbols, improving user comprehension and interaction efficiency.***

   Colors play a significant role in visual perception, and high-contrast colors may help users quickly differentiate between various types of information.

3. ***Hypothesis: Integrating preattentive features into the design of map symbols and utilizing conjunctive searches with multiple visual and dynamic variables will enhance the effectiveness of map reading.***

   A researcher Vassilios Krassanakis (2013), stresses the need for further experimentation to understand the map reading process. Exploring similarities between map design tools and preattentive features can enhance comprehension. By combining two or more preattentive features in the design of map symbols or elements (e.g., a red, blinking point to indicate an emergency location), can we hypothesize that users may more quicker and effectively find or understand these elements, enhancing the overall usability of the map.

4. ***Hypothesis: Employing base maps with varying levels of abstraction will help identify specific locations that attract gaze attention more frequently and effectively demonstrate how the inclusion of additional map information influences the map reading process.***

   This suggests that using maps with different levels of detail can identify which elements draw the user's attention most strongly. It will be also examined how, for instance, adding or removing details (like street names, landmark

labels, etc.) impacts the user's ability to perform tasks requiring map reading, such as navigating from one point to another or locating a specific feature.

Hypotheses Related to User Experience and Content around Web Map Content

Utilizing eye tracking, researchers like Horbiński, Cybulski, and Medyńska-Gulij (2021) have examined how responsive design principles influence user interactions across different devices. Their study emphasizes the critical role of visual attention dynamics, such as the time to first fixation (TFF) and mouse click responses, in evaluating the effectiveness of web map interfaces.

Evaluating web map usability solely through task performance. This research proposes analyzing user interaction with specific website areas (search bars, menus, map, information areas, scale options) using eye tracking to gain deeper insights into usability efficiency and effectiveness.

Approaches can be made for:

- Employment eye tracking technology to capture gaze patterns while participants complete tasks on different web maps.
- Analyze user interaction with:
  - ✓ Search bars: Fixation duration, scanning patterns, success rates;
  - ✓ Menus: Selection time, error rates, frequently used options (favourite users' options);
  - ✓ Map area: Exploration patterns, POI click frequency, time spent on key information;
  - ✓ Information area: Reading behavior, comprehension of provided details;
  - ✓ Scale, coordinate systems and map projects configuration: desirable, confusing and practical ones for defined task or measurements.

1. ***Hypothesis: Implementing a feedback loop in web map applications that collects user input on symbol effectiveness will lead to continuous improvements in sign systems.***

Direct feedback from users may provide actionable insights that help cartographers all around the world to refine symbols and interfaces to meet actual user needs more effectively.

2. ***Hypothesis: Pinpoint specific design elements affecting performance.***

If users with inefficient eye-movement patterns perform poorly on specific tasks, it suggests issues with those elements that can be addressed (e.g., unclear search bar options, poorly organized information panels, missing essential informations for a professional tasks such as data source, is the map up-to-date, insufficient filtering options).

Prototype Testing

Following the analysis, it will be developed prototype maps that incorporate the improvements suggested by the earlier phases of the research. These prototypes will be tested using the same criteria to verify if the proposed changes lead to better user experiences.

Further Testing

Implement the changes suggested by the prototype testing phase. A new series of tests will be conducted with these updated maps and web content to gather more refined data and to assess the effectiveness of the modifications made to the web maps.

Option for Extended User Studies

Further studies will be conducted involving a broader group of users to validate the changes. These studies may focus on measuring the effectiveness of the modified maps in real-world scenarios, and necessary adjustments will be made based on feedback.

The methodology aims to provide a thorough understanding of how web map sign systems can be optimized for better user engagement and comprehension. The iterative nature of this research ensures that each phase builds upon the insights from the previous one, leading to a comprehensive set of recommendations for enhancing web map designs.

IMPACT OF THE RESULTS

Contribution to Significant Social Issues

Opportunities for popularizing the results of projects and the forms in which they will be implemented are presented. By studying the way signs and sign systems on maps are perceived in the web space, conclusions will be drawn about the time needed to perceive the signs and assign meaning to them. This will reduce the percentage of incorrectly identified signs when working with maps and shorten the time to locate signs in the field of web maps.

Applicability of Expected Results

The results of the conducted research will be used in cartography to create higher-quality maps through proper arrangement of map components and optimal symbol sizes. The findings from the research can be utilized by cartographers worldwide to produce better cartographic works.

Cognitive Processes in Related Fields

The accumulated experience from the project will also facilitate the exploration of cognitive processes in related fields such as architecture, civil engineering, and geodesy. This includes the possibility to study 3D models for the perception of buildings or terrains forms, an impact of interior design, spatial arrangement of urban squares or photogrammetry applications in mapping and surveying techniques.

Integration of Research and Educational Activities

The results of the study on the perception of signs and sign systems will be incorporated into the education of students in the disciplines of the regular course of Geodesy - Basics of Cartography (topics from syllabus 7, 8, 9, 10, 12) and Cartography and GIS (topics from syllabus 3, 5, 8, 28). Currently, the lectures are based on data on the perception of signs and sign systems obtained from studies on paper maps. The data obtained as a result of the project will allow demonstrating to students the differences in requirements for designing digital and paper maps.

CONCLUSION

This research aims to enhance the usability and effectiveness of web maps through a detailed examination of user interactions. Through the efforts, the project will provide valuable insights into the design and functionality of web maps, leading to more user-friendly interfaces that cater to the needs of diverse users. Here are the expected outcomes:

- Identify areas causing difficulty or confusion through excessive fixation or low engagement.
- Quantify the efficiency of user interaction (e.g., search bar completion time, information retrieval speed).
- Uncover correlations between interaction patterns and task performance/completion time.
- Provide data-driven recommendations for web map design improvements across interfaces.

This research goes beyond traditional task-based evaluations, offering a comprehensive understanding of web map usability. By delving into user interaction with specific features, can identify friction points and optimize them for improved efficiency and effectiveness. The findings can contribute to more user-centric web map design, enhancing user experience and promoting the value of cartography in digital platforms.

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BIOGRAPHY

Nikoleta Valentinova Nikolova is a graduated geodetic engineer. Currently, she is pursuing her Ph.D. at the University of Architecture, Civil Engineering and Geodesy in Sofia, Bulgaria. Her specialty is "Cartography and Geographic Information System". With proficiency in a variety of industry-leading tools such as ArcGIS Pro, AutoCAD, Civil 3D, and ProgeCAD, she has consistently demonstrated her ability to manage complex spatial data and perform advanced geoprocessing tasks. Her expertise also extends to programming in Python, handling databases in MSSQL and PostgreSQL, and utilizing QGIS for diverse mapping projects. She is adept at data analysis, and presenting and visualizing it in computing platforms, such as Jupiter Notebook, which is a perfect option for coding and documenting scientific analysing projects efficiently.