Eye Tracking Visualization Methods

Category: Design Based Learning Project

Paper Type: Report

Fig. 1. Eye tracking data visualization.

Abstract—The overall purpose of the study is to investigate, design and implement multiple eye movement visualizations of a data set into a web-based tool. Several research problems that were investigated are the different features of eye tracking visualizations. Additionally, research was done on how to compute CSV data into a graphical output. The basic design of the design based learning project includes the use of an iterative design process.

Index Terms—Graphical User Interfaces, Eye Tracking Data Visualization

1 Introduction

Eye tracking has increased in popularity as a field of research. The term 'eye tracking' is used to define the act of observing, recording and analyzing eye movement. Eye tracking data has many applications, a few of which are academic and scientific research, market research, psychology research, medical research and usability research [4]. In most cases, the purpose of collecting data from eye tracking studies, is infer knowledge from a person's eye fixations and saccadic eye movement from specific visual stimuli. The data obtained from these eye tracking studies is by itself is hard to analyse. Therefore, there is a high demand for a method to make eye tracking data more comprehensible. For this reason, eye tracking visualization methods are created. These methods allow for easier identification and analysis of visual attention patterns.

Numerous eye tracking visualization methods have already been developed. A taxonomy of the various types of eye tracking visualization methods is made by Blascheck et al. In his paper, Dr. Blascheck describes that there exists a division between two categories of visualization methods [1]. The first being the category to which all point-based analyses belong and the second being the category to which all Area of Interest (AOI) based analyses belong.

Point-based analyses use the spatial and temporal information of recorded data points [1]. Thus, point-based analyses use a coordinate system and duration of eye movements to visualize the data set. The category of point-based visualization techniques can be divided into categories based on temporal approaches, spatial approaches and spatio-temporal approaches. The temporal approaches are timeline visualizations, the spatial approaches are attention maps, and spatio-temporal approaches are scan path and STC visualizations [1]. Thus, there is a diverse variety of point-based analysis methods that make use of coordinates and time intervals to visualize the eye tracking data set in different ways.

Area-of-Interest-based analyses use more than only spatial and temporal information of the recorded data points. In these types of analyses, additional information about regions or objects of interest are taken into consideration in visualizing the data set [1]. Area-of-Interest-based analysis techniques use a coordinate system, the duration of eye movements and the Areas of Interest the visualize the data set. The category of Area-of-Interest-based visualization techniques can be divided into temporal approaches, 3D visualizations, relational spatial approaches [1]. Therefore, there is a variety to visualization methods to chose from, when adding Areas of Interest to the eye tracking data set.

This paper describes the procedure of processing, understanding, and visualizing eye-tracking data of a research on varying public transport maps. The already existing data set on the public transport maps

combined with the used public transport maps are used to reproduce two prominent eye tracking visualization methods in context of a web-based tool. The two visualization methods are gaze plots and attention maps. The interactive web-based environment allows for the user-friendly conversion of the an eye tracking data set of a CSV file format to a visualization, making it easier to infer conclusions about the data set.

The web-based environment allows for the user's interaction with its own data set. The interaction tools include upload and the select option. The upload tool is used to upload the data set and the select option to select a visualization method. Using different visualization methods enables the user to highlight different aspects of the eye tracking data set. A combination of multiple techniques is required as there can be multiple visualizations suitable for specific eye tracking data. This paper first discusses the process of data handling, then it will continue with describing the process of converting the data into visualizations. Afterwards, the limitations and recommended future research will be discussed.

2 Related Work

In general, the field of eye tracking research is a novel field of research relative to other fields. Its origin dates back just a hundred years ago. In the year 1908 E. Huey built a device which could register eye movements. From that point on wards, research on eye tracking was mainly done by psychologists like G. Buswell and A. Yarbus. But the field of eye tracking flourished in the 1970's and the 1980 's. The main aspect that fuelled this increase in interest and accomplishments was the increase in improvement of technology. From 1980 on wards, computers were used as main asset to execute eye tracking studies. As eye tracking studies became cheaper and easier to execute, the interest in this field of technology increased in multiple sectors. Nowadays, eye tracking has various application in the business, scientific, market sector. Eye movement visualization are designed with the purpose of creating an easy and efficient method to analyze eye tracking data sets. Current research is moreover used to investigate the various different methods of visualization and its taxonomy [1].

The gaze plot is a common used visualization method in eye tracking research. The visualization method belongs to the category of point-based visualization methods. The visualization is devised from x-coordinates, y-coordinates and an interval value for time. The location of the gaze is combined to form a scan paths. The common frequency for the scanned gaze locations is between 50 Hz and 120 Hz [3]. From the data two types of values can be inferred. The first type of value is the fixation point. This value is calculated by reducing the sequences of points of focus The second type of value is the saccades. This type of value is calculated by reducing the sequences of rapid change. The combination the fixation points and the saccades enable the formation of scan paths [3].

The attention map is another popular visualization method in the field of eye tracking. The attention map is also referred to as a heat map. The visualization method also belongs to the category of point-based visualization methods. Attention maps are two dimensional representations where the intensity of the variables are visible as colors. This visualization method is comprehensible for two reasons. Firstly, since attention maps are shown directly on top of the stimulus the data is as close to the stimulus as possible. Secondly, people know from experience which colors represent the highest intensity. For example, people know that red represents a higher intensity than green [2]. Additionally, attention maps are relevant in the visualization field because difficult to understand numerical data sets can be visualized using attention maps. These attention maps show an overview of the data, which includes potential patterns in the data set [2]. Moreover, attention maps are easily obtainable. There are many tools that can generate an attention map on demand. This also has a downside. Since the attention maps are easily obtainable they are often misused. Even though the attention maps are easy to understand, there is still information that is less easy to understand. This means that attention maps get misinterpreted or unnecessarily used [2].

3 Data Handling

In this section the methods for data reading, data parsing and data storing will be explained. This data handling includes the code and algorithms used to extract the data from the data set and how this is used to calculate other needed values.

3.1 Data Reading

Data Reading is an action performed by computers, to acquire data from a source and place it into their memory for processing. The uploaded files were read using the Pandas library offered by Python, which enables you to read various files that can then be parsed. The CSV file is read into a data set. The data set is read into a Pandas DataFrame, which gives enables the modificiation of the data set. Additionally, it allows the creating of a new DataFrame based on a boolean mask, in order to focus on the data relevant to the given Stimuli.

3.2 Data Parsing

Data parsing is a method where one string of data gets converted into a different type of data. For eye-tracking data, the columns provided may vary per eye-tracking method, so, as an example, the focus will be on one particular data set, which was the provided eye tracking data. It contains eight types of data: 'Timestamp', 'StimuliName', 'FixationIndex', 'FixationDuration', 'MappedFixationPointX', 'MappedFixationPointY', 'user', and 'description'. The data set was received as a CSV, opened with Excel. Initially, the open web-based tool Jupyter Notebook was used to convert the data from a CSV file to a readable file on which computations could be made on the data, as it seemed the best choice for the group since all team members were acquainted with working with this interface. Later a more advanced source-code editor is used, namely the Visual Studio Code. To make the linking between the front-end and the back-end more efficient, the Bokeh library and the Flask application.

3.3 Data Storing

The data from the CSV file is stored in a Pandas DataFrame using the Pandas library. This data storage method was used because it allows the extraction of the data needed via the columns of the DataFrame in order to use them in our visualizations. Both the CSV file and the stimuli file are stored in a folder, from where all of the necessary information will be extracted, such as the dataset, the stimuli image, and the name of the stimuli file.

4 Visualization techniques

This section describes the graphical user interface, the types of visualizations used and the interaction techniques.

4.1 Graphical User Interface

Knowledge from Human Technology Interaction research is used to create the design of the Graphical User Interface. Thorough research in this field of psychology lead to the integration of specific features that are in compliance with the purpose of the website. The features that are integrated in the website design with a specific purpose are the structure of the website, ... These In Figure 2, the start page of the website is displayed.

The structure of the website influences the way in which the website visitor perceives the website. Eye tracking research has been performed on a how users scan a web page. According to this research, web page visitors are used to a specific structure of a web page design. This is generally due to the fact that all web site have a similar layout. Additionally, data obtained from this research indicates that web page users experience discomfort when a website does not follow the standard structure of website design. The logo of a website is depicted in the top left corner in the majority of website design [6]. Thus, the logo and the heading of project's website are centered in the top left corner.

A well-balanced combination of colors and fonts is an effective tool in engaging and influencing users. Every color has its own meaning, each evokes a certain emotion rooted deep in the human subconscious

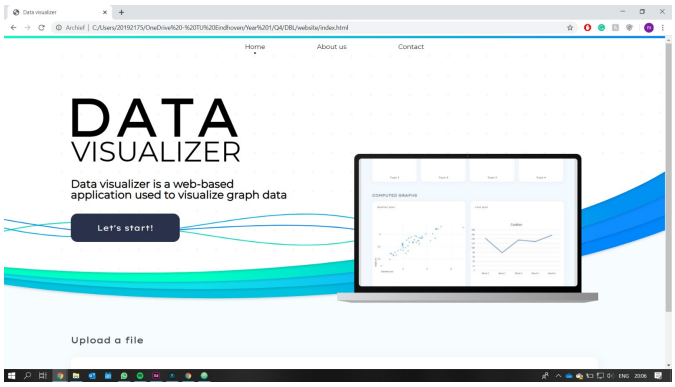

Fig. 2. Website Design of the Eye Tracking Visualization Data

[6] The colours blue, white, green and black are colours that convey trustworthiness Research shows that people favor max 2 or 3 dominant colours in a website design [5]

4.2 All Visualizations

In this section, the visualization techniques will be discussed. The visualization techniques are Heat maps and Gaze Plots.

4.2.1 Gaze Plots

Gaze Plots are a type of visualization used to generate the gaze areas when a user looks on a particular image, website, advertisement etc. They can be used to determine the positions on a stimuli when a user looks during a specific time. Gaze plots can also determine the duration at a certain point. For this visualization, the x-y axis is incorporated of a given stimuli, and use the x and y coordinates from the data set to plot the points and to also plot the line for each user's trajectory. The duration is used from the data set to determine the diameter of each point, where points with larger diameters show that a person has spent more time looking at that particular spot.

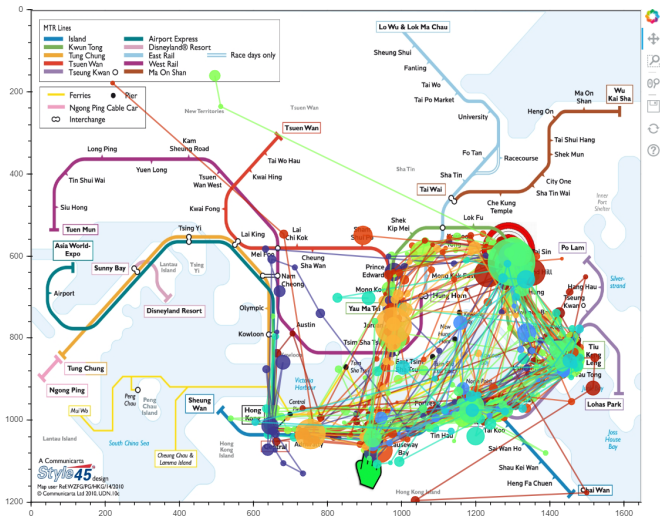

Fig. 3. Example of a Gaze plot

4.2.2 Attention maps

An attention map is a spatial visualization technique. This particular type of visualization uses the position of fixation points and the time duration of these fixation points to eye movement of dynamic stimuli. There are three different types of types of attention maps: projected attention maps, object-based attention maps and surface-based attention maps. In the context of visualizing eye tracking data of 2D metro maps, it is the most suitable option to chose the projected attention map format.

To create this projected attention map a multidimensional histograms is used. These multidimensional histograms use the intensities of x and y coordinates to create a figure similar to a heat map. To obtain a figure that fully looks like an attention map, the colour scheme needed to be changed. To make this color scheme look like the attention map given in the assignment description the top intensities(above 0.8) had to be red and the medium intensities(between 0.5 and 0.8) had to be green. The rest of the intensities values had to be transparent to make the metro map visible as the background image. This transparency was obtained by changing the alpha values of the color scheme. The alpha value represents how transparent the histogram is. For example, an alpha value of 1.0 is not transparent and an alpha value of 0.0 is fully transparent. This is visible in figure 4.

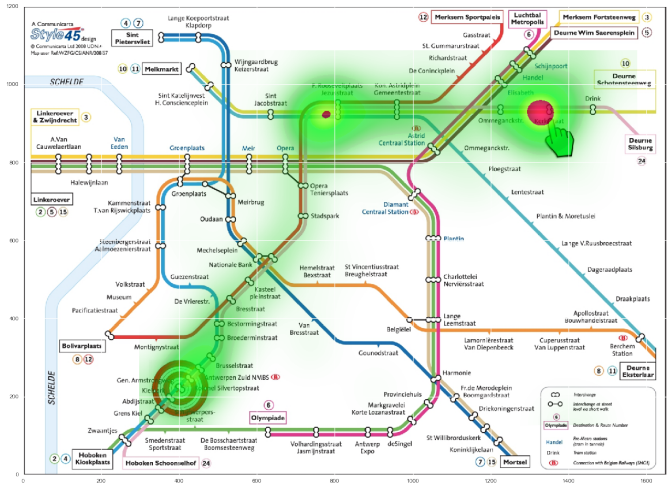

Fig. 4. Example of an Attention Map Using the Given Data Set

These attention maps are useful, because the maps show where people look at most often. This information can be used to optimize the images the people look at. Moreover, this information can be used when designing a new image in a similar category. For example, a map developer can use the data obtained from the attention map to see what draws the attention from the observer and how he could use this information to improve the map design.

4.3 Interaction Techniques

In this section, the website's interaction tools will be discussed.

4.3.1 Upload tool

The Upload Tool on the website is the basic interaction tool with which none of the visualizations can be formed. This tool allows the user to upload a csv file of their choosing (this product uses the provided eye-tracking data as a base for creating visualizations) followed by an image which acts as the stimuli to filter the data.

This Upload Tool was created using the basic form template allowed in HTML which lets the web designer create and design a button that performs a function of the designer's choice when the user clicks on it.

5 Application Example

The first page of our product lets the user enter a csv file and then a stimuli image.

After receiving the two files, the csv file is converted to a readable dataframe, the dataframe is then filtered based on the stimuli image that has been uploaded. With this data, a color is assigned to each user that has viewed the image and whose eye-tracking data has been collected.

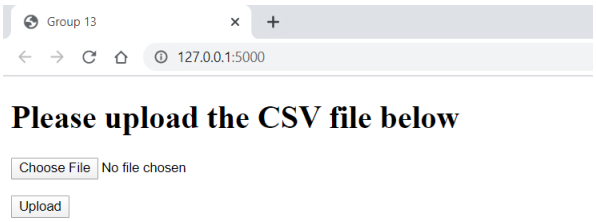

Fig. 5. HTML page to upload csv file

Fig. 6. HTML page to upload image

A gaze plot is then plotted according to the entered stimuli using the given data. The website then takes the user to a new page where the gaze plot is displayed on one of the two tabs. The second tab should display the heatmap visualization when clicked on.

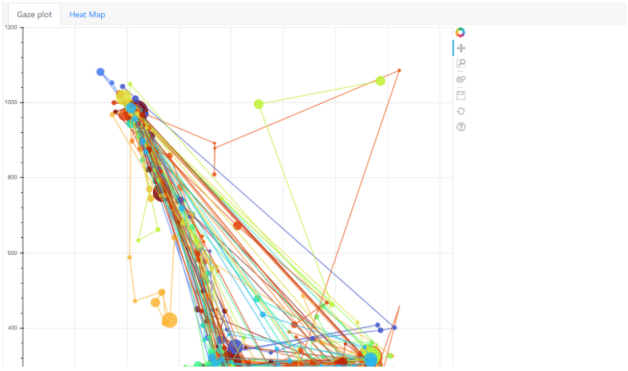

Fig. 7. Example of the website tabs

6 Implementation Details

For our implementation, in order to plot the points on a x-y axis and to visualize them, the Python programming language is used, as it provides a number of extensive visualization libraries. In order to enable the interaction with the website, for activities such as file uploading, the Flask framework is used for Python. The primary visualization library which is used is Bokeh. This library provides multiple tool sets such as interaction tools and it also includes a visualization library for the front-end, where it will be rendered into graphs. For certain visualizations, another library is used, namely Matplotlib.

For the front-end, where the website design is created, a combination of HTML is used, to create the layout of the website, CSS, to design the elements of our website, and JavaScript, which enables the interaction with the back-end, and to render the graphs using the visualization library BokehJS. As a framework for JavaScript, Vue.js is used. Next to Vue, in order to make it convenient when expanding the project, a solution which combines JavaScript code with HTML is found. This solution combines Bootstrap, which is a CSS framework tailored for creating responsive websites, and the aforementioned JavaScript framework, which results in BootstrapVue (insert reference for BootstrapVue). to following version for the respective applications and libraries are used: Python - 3.8, Flask framework - version 1.1.x, Bokeh - version 2.0.2, Matplotlib - version 3.2.1, Vue.js - version 2.6.11, Bootstrap 4 - version 4.3.1. Using these frameworks and libraries, it is possible to create a functional web-tool that allows the user to upload, visualize and interact with eye-tracking data.

7 Discussion and Limitations

While the initial pace of the group was slow, the entire team put in more effort and worked harder in the second sprint and was able to produce good results by the end.

A file uploader is created using Flask, which allowed a user to submit both a CSV File and a Stimuli file (as a .jpg image). It was possible to comprehend the concept of and implement the gaze plot using matplotlib initially, then adapted the code to Bokeh to help the link between the front and back end. By the end of the second sprint, the plot was rendered on the front-end, obtained our second visualisation, and were able to render graphs inside tabs on the website.

Like all projects, there were limitations our team faced as well. Most students on the team, having minimal experience with coding, had to spend most of the time in both sprints on background research and learning different aspects of Web Development. Although by the time the end of the second sprint came around, the members of the team were more experienced with Web Development and creating visualisations, there are still a few flaws in the project that are required to be repaired.

For example, the gaze plot in its current state has a bug where the background image does not show (as seen in Fig. 7). Another limitation is the implementation of the Attention Map in Bokeh, as Bokeh does not have an inbuilt visualization that comes close enough to our liking, investigation on the implementation for this visualization using the preferred library is still necessary in order to integrate it with the web tool. Despite all of the given limitations, the web tool does function correctly, and can be considered a minimal prototype.

8 Conclusion and Future Work

This paper has demonstrated the team's progress of our process of researching and implementing a web-based tool for processing and visualizing eye-tracking data. The tool in its current state meets our intended goals, but certain features need to be added which can greatly improve the website. For example, the website can be improved visually by implementing the design as discussed in the **Graphical User Interface** section. Other than the visual improvement of the website, there is also a technical improvement required as it necessary to implement a third and a fourth visualization, as well as it is necessary to implement multiple interaction tools which will help the user to display visualisations based on criteria they can choose. The third visualization will be the Gaze Stripe, and the fourth visualization is yet to be discussed.

Overall, the team is very optimistic and the team is convinced that with perseverance and hard work, it is possible to accomplish all of the the goals are planned, while being on schedule at the same time.

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