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Trends in Eye Tracking Scanpaths: Segmentation Effect?

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ABSTRACT

Eye tracking has been widely used to investigate user interactions with the Web to improve user experience. In our previous work, we developed an algorithm called *Scanpath Trend Analysis (STA)* that analyses eye movement sequences (i.e., scanpaths) of multiple users on a web page and identifies their most commonly followed path in terms of the visual elements of the page. These visual elements are mainly the segments of a page generated by automated segmentation approaches. In our previous work, we also showed that the STA algorithm performs better than other existing algorithms in terms of providing the most representative scanpath of users. However, we did not know whether the validity of the algorithm is limited to a particular segmentation approach. In this paper, we investigate the effect of two different segmentation approaches on the STA algorithm. The results suggest that the validity of the algorithm is not affected by the segmentation approach used. Specifically, the resulting scanpath of the STA algorithm is the most representative scanpath of users in comparison with the resulting scanpaths of other existing algorithms regardless of the segmentation approach used.

CCS Concepts

•Human-centered computing → Human computer interaction (HCI); *User models; Usability testing; Laboratory experiments; Empirical studies in HCI;*

Keywords

eye tracking; scanpath; trend analysis; web pages; visual elements; segmentation

1. INTRODUCTION

Eye tracking has been widely used to understand how users traverse the Web with the goal of improving user experience [6]. In particular, [3] conducted an eye tracking study

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Figure 1: A gaze plot that represents a particular scanpath on the AVG web page

to understand how sighted users interact with tabular calendars to enter dates and then developed an audio interface for these calendars based on their findings. According to their evaluation, the audio interface improved the experience of visually impaired users. Eye tracking studies can also be a guide to evaluate the usability of web pages. For instance, transition probabilities between elements of a web page can be a guide to assess the efficiency of the arrangements of the elements on the page [6].

While a user is traversing a web page, his/her eyes become relatively stable at certain points called *fixations*. A quick eye movement made from one fixation to another is referred to as a *saccade*. A sequence of fixations and saccades represents a *scanpath*. Figure 1 shows two user scanpaths on the AVG web page which is segmented into its visual elements, such as logo and menu items. [2]. As illustrated in the figure, fixations are illustrated by circles where the radius is directly proportional to the fixation duration. Additionally, straight lines are used to illustrate saccades.

Scanpath analysis allows to investigate user interactions with visual elements of web pages which can be used for various goals. For example, web pages can be transcoded (i.e., re-engineered) to improve user experience in constrained en-

vironments, such as on small screen devices [1] and in audio access by screen readers [27]. Specifically, the firstly and mostly fixated visual elements can be moved to the earlier positions of web pages, such that the users can directly access these elements without a lot of scrolling/zooming or listening clutter. This is referred to as *Experiential Transcoding* in the literature [27]. Scanpath analysis can also be a guide for web designers to make their design more usable and/or investigate whether their expected path for a specific goal is followed by users [6].

Individual scanpaths are mainly related to specific users, and therefore they are not useful for providing generalisable results. Hence, they have a limited benefit for evaluating and improving the usability of web pages. For example, if a web page is transcoded for a particular user, it may not be suitable for another user as their interests may not be the same. In our previous work, we developed an algorithm called *Scanpath Trend Analysis (STA)* that analyses multiple scanpaths on a particular web page and identifies the most commonly followed path in terms of the visual elements of the page (Section 3) [10]. The resulting scanpath is called a *trending scanpath*. It differs from an absolute path which is followed by all users. Existing algorithms tend to identify an absolute path, however they typically fail in providing a representative path due to the variations caused by individual differences (Section 2). In the STA, if a particular visual element is not shared by all users but it gets at least the same attention as the shared elements, it deserves to be in the trending scanpath.

In our previous work, we also evaluated the STA algorithm by using an eye tracking study and our evaluation showed that the STA algorithm performs better than other existing algorithms in terms of providing the most representative scanpath of users (Section 3) [10]. The degree of representativeness was measured by the sequential similarities between the individual scanpaths and the resulting scanpath. However, in the evaluation, we only used the improved and extended version of the Vision-based Page Segmentation (VIPS) approach to discover the visual elements of the web pages [2]. Therefore, we did not know whether the validity of the algorithm is limited to the VIPS approach. In this paper, we investigate the effect of two different segmentation approaches on the STA algorithm (Section 4). Our experimental results show that the validity of the algorithm is not affected by the segmentation approach used (Sections 6-8). Specifically, the STA algorithm provides the most representative scanpath in comparison with other existing algorithms regardless of the segmentation approach used.

2. RELATED WORK

In order to investigate how users interact with visual elements of a web page, user scanpaths are firstly represented in terms of the visual elements. These scanpaths can then be analysed for different goals by using various algorithms. Existing algorithms are mainly designed for comparing a pair of scanpaths, computing transition probabilities between visual elements, detecting patterns in given scanpaths and identifying a representative scanpath of users [9]. The comprehensive review of all of these algorithms can be found in [9].

The Levenshtein algorithm, commonly known as the String-edit algorithm, has been widely used to compare two scanpaths to find a distance between them [16]. The distance is

the minimum number of editing operations (addition, deletion and substitution) needed to transform one scanpath to another. It can then be used to calculate the similarity between the two scanpaths as a percentage with Equation 1 below where S is the similarity, d is the distance and n is the length of the longer scanpath [23, 9].

$$S = 100 \cdot (1 - \frac{d}{n}) \quad (1)$$

By default, the costs of the editing operations are the same and they are equal to one. Due to the differences in the sizes of visual elements and/or the geometrical distances between visual elements on a page, the substitution cost for a particular pair of visual elements may differ from the substitution cost for another pair of visual elements [16]. It has been suggested to generate a substitution cost matrix to keep the substitution costs between all pairs of visual elements and then integrate this matrix into the String-edit algorithm [22]. Albeit this algorithm is useful to compare two scanpaths, it is not applicable for identifying the most commonly followed path of multiple users.

To compute transition probabilities between visual elements of a web page, a transition matrix can be generated by analysing all available scanpaths on the page [25]. This matrix, however, does not tell the most commonly followed path of users [15]. Specifically, it does not directly tell which visual element should be positioned at the end of the common scanpath.

There are various options for User Experience (UX) researchers who want to detect patterns in multiple scanpaths. One of these options is *eyePatterns* tool¹ which allows to discover patterns in given scanpaths. However, its algorithm to discover patterns is mainly designed for detecting exact patterns which consist of minimum three visual elements [25]. Particularly, it is not able to detect ABC in the scanpaths ABCY and ABXC because of the extra element X. Another option is the Sequential Pattern Mining (SPAM) algorithm² [14, 12]. In contrast to *eyePatterns* tool, the SPAM algorithm is more tolerant to extra elements in scanpaths. Next option is the T-Pattern Detection which is a commercial product³. It has been used to recognise repetitive patterns in user scanpaths on web pages by [4, 17]. It consists of many parameters, such as the critical interval type, and the adjustments of these parameters can easily affect the detection process.

In order to identify an absolute path which is followed by all users, the Dotplots algorithm was suggested for hierarchical clustering of individual scanpaths [13]. In addition to the Dotplots based hierarchical clustering, *eMINE* scanpath algorithm⁴ was proposed which also uses a hierarchical clustering but with the String-edit and the Longest Common Subsequence (LCS) algorithms [8, 7]. In this clustering, the String-edit algorithm is used to find the two most similar scanpaths from the list and then the LCS algorithm is used to find the common scanpath of the two similar scanpaths.

Due to the variations in individual scanpaths, existing algorithms are likely to provide no result or an unacceptably short result that may not be representative for understand-

¹<http://sourceforge.net/projects/eyepatterns/>

²<http://www.philippe-fournier-viger.com/spmf/>

³<http://www.noldus.com/theme/t-pattern-analysis>

⁴<http://emine.ncc.metu.edu.tr/software.html>

ing users' behaviors on web pages. To address this limitation, in our previous work, we developed an algorithm called *STA (Scanpath Trend Analysis)* to analyse multiple scanpaths on a particular page and identify the most commonly followed path in terms of the visual elements of the page. The STA algorithm is briefly introduced in the following section and detailed description can be found in [10].

3. STA: SCANPATH TREND ANALYSIS

The STA algorithm consists of three stages which are as follows: (1) Preliminary Stage, (2) First Pass, and (3) Second Pass. These stages are briefly introduced below.

Preliminary Stage: The STA algorithm firstly takes eye tracking data (a series of fixations for each user) on a specific web page and the visual elements of the page. In the preliminary stage, the fixations are correlated with the visual elements. As a result, the individual scanpaths are represented in terms of the visual elements. For instance, according to the scanpaths illustrated in Figure 1, one of the users fixated the elements I, G, I and I respectively, and therefore his/her scanpath is represented as IGII.

First Pass: The first pass is responsible for analysing the individual scanpaths to identify the trending elements by considering the total number of fixations and the total duration of fixations (i.e., dwell time) on the elements. The same element can be fixated more than once by a user and this can be consecutive (e.g. KIGG) and/or non-consecutive (e.g. GKIG). In the STA, each non-consecutive visit is called a visual element instance. For instance, the scanpath IGII includes two instances of the element I. The algorithm differentiates these instances by assigning them different numbers based on their total durations as the durations are correlated with information processing [24, 11]. Specifically, the first number is assigned to the longest instance of a particular element in an individual scanpath (e.g. I1 G1 I2 I2). Once the instances are differentiated, the trending instances are identified. The instance becomes trending when it satisfies the following two criteria: (1) The total number of fixations on the instance is greater than or equal to the minimum total number of fixations on the instances shared by all of the individual scanpaths (2) The total duration on the instance is greater than or equal to the minimum total duration on the instances shared by all of the individual scanpaths. When the trending instances are identified, other instances are removed from the individual scanpaths as they will not be included in the trending scanpath.

Second Pass: The trending scanpath is constructed in the second pass. The STA algorithm firstly abstracts the individual scanpaths (e.g. G1 [100 ms] G1 [200 ms] I1 [200 ms] → G1 [300 ms] I1 [200 ms]) and then calculates the priority value (ψ) for each instance in each individual scanpath with Equation 2 below where P is the instance position in the individual scanpath (the first position is zero) and L is the length of the individual scanpath. We take the max and min values as 1 and 0.1 respectively to give 1 point the first instance and 0.1 points to the last instance.

$$\psi = 1 - P \cdot \frac{\max - \min}{L - 1} \quad (2) \quad \Psi = \sum_{i=1}^n \psi_i \quad (3)$$

When all of the priority values are calculated, the total priority value (Ψ) for each instance is calculated with Equation 3 above where n is the number of individual scanpaths. The algorithm then positions the instances into the trending scanpath based on their total priority values in descending order. If multiple instances have the same total priority value, their total duration and the total number of fixations on the instances are also considered.

Once the trending instances are positioned in the trending scanpath, their numbers are eliminated (e.g. G1 → G) and then the consecutive repetitions are removed (e.g. IGII → IGI). Thus, the trending scanpath is represented in terms of the visual elements.

4. EYE TRACKING STUDY

We have already evaluated the STA algorithm by using an eye tracking study [10]. In the evaluation, we used the extended and improved version of the VIPS approach to segment the web pages into their visual elements [2]. According to our evaluation, the STA algorithm is able to provide the most representative scanpath of users in comparison with other existing algorithms. However, we did not know whether the validity of the STA algorithm is limited to the VIPS approach. Therefore, our research question here is:

“Is the STA algorithm able to provide the most representative scanpath of users regardless of the segmentation approach used?”

In order to investigate whether or not the validity of the STA algorithm is restricted to a particular segmentation approach, we conducted a new eye tracking study with 41 users at Middle East Technical University Northern Cyprus Campus. The methodology used in this study was previously used in our another eye tracking study [8, 7, 10]. The details of the complete methodology can be found in [8, 7, 10].

4.1 Participants

Twenty-one male and 20 female users participated in the study. The majority of these users were students, along with some academic staff at the university. There were also some other users from outside of the university. All the users were daily web users, apart from one male user who claimed that he used the web a few times in a week. Thirty-six users were between the ages of 18-24 and five users were between the ages of 25-34. Moreover, all the users had a high school diploma, except from one user who also held a master's degree.

4.2 Equipment and Materials

The eye movements of the users were recorded by using Tobii T60 eye tracker that was built-in a 17" monitor. The screen resolution was 1280 x 1024. These users were requested to perform specific tasks on the stored versions of the Apple, Babylon, AVG, Yahoo, Godaddy and BBC web pages (See Open Data Section). As an example, Figures 2-5 show the Apple and BBC web pages with their segments discovered by two different approaches [2, 21].

4.3 User Tasks

The tasks performed were classified into two categories which are the browsing and searching tasks. For the browsing tasks, the users were requested to browse on the web

Figure 2: The Apple web page segmented with the VIPS approach

Figure 4: The Apple web page segmented with the BOM approach

Figure 3: The BBC web page segmented with the VIPS approach

Figure 5: The BBC web page segmented with the BOM approach

pages without a particular goal. However, for the searching tasks, they were asked to find specific information or items on the web pages. The searching tasks are listed below.

- **Apple** a) Can you locate a link which allows watching the TV ads relating to iPad mini? b) Can you locate a link labelled iPad on the main menu?
- **Babylon** a) Can you locate a link that you can download the free version of Babylon? b) Can you find and read the names of other products of Babylon?
- **AVG** a) Can you locate a link which you can download a free trial of AVG Internet Security 2013? b) Can you locate a link which allows you to download AVG Anti-virus Free 2013?
- **Yahoo** a) Can you read the titles of the main headlines which have smaller images? b) Can you read the first item under the News title?

- **Godaddy** a) Can you find a telephone number for technical support and read it? b) Can you locate a text box where you can search for a new domain?
- **BBC** a) Can you read the first item of the Sport News? b) Can you locate the table that shows market data under the Business title?

4.4 Procedure

The users were firstly requested to read an information sheet about the study. After that, they were requested to sign a consent form to accept that they were informed about their rights and they were volunteer to participate in the study. Following this, their gender, age-group and education level were noted. The eye tracking sessions were then started. During the sessions, they visited the web pages two times in a random order where one of views was for the browsing tasks (30 seconds) and another view was for the searching tasks (maximum 120 seconds).

5. METHODOLOGY

The objective of this paper is to investigate whether or not the STA algorithm provides the most representative scanpath of users in comparison with other existing algorithms regardless of the segmentation approach used. Therefore, the result of the STA algorithm should have the highest similarities to the individual scanpaths in comparison with the results of other algorithms. In order to achieve our objective, we firstly segmented the six web pages by using both the VIPS [2] and the Block-o-Matic (BOM) [21] segmentation approaches. Both of these segmentation approaches use the DOM structure and the visual representation of the web pages, but uses different algorithms for segmentation. In particular, the BOM segmentation also applies a logical approach to group the segments based on the four Gestalt laws (Proximity, Similarity, Closure and Simplicity) [21]. As a result of segmentation process, both of these approaches provide a tree of segments. Thus, they have a granularity parameter which affects the number of segments and the size of segments. The VIPS provides more and smaller segments at higher granularity levels whereas the BOM provides fewer and bigger segments at higher granularity levels. A study conducted by [2] suggests that the fifth granularity level is mostly preferred by users, and therefore we used the fifth level to segment the web pages with the VIPS approach. In contrast, there is no suggestion for the BOM's granularity level, so we used the default one (0.3).

Unfortunately, the current publicly available implementation of the BOM segmentation approach⁵ failed to properly segment some of the web pages. Hence, we applied a systematic approach to fix these problems by following the algorithm given their paper [21, 20]: (1) If there is an empty block (i.e., segment) which covers only white space, the block is excluded. (2) If there is a larger block which covers other smaller blocks, the larger block will be used. (3) If there is a number of blocks which have overlaps, the borders of these blocks are adjusted such that they do not have overlaps. (4) If there is a group of items which are not covered by any block, they are included in the closest block. Figure 6 shows the segmentation of the AVG page with the implementation of the BOM approach. There was a group of menu items (For Home, For Business, For Mobile and Support) between the block L4 and the block L5 and they were not covered by any block. Because of the rule 4, these items were included in the closest block which is the AVG logo (the block L4).

Once the web pages were segmented properly and the visual elements were discovered, the individual scanpaths were represented in terms of the visual elements. We then applied the STA and other existing algorithms (the *eyePatterns* Discover Patterns algorithm [25], the Dotplots based algorithm [13], the SPAM algorithm [14, 12], and *eMine* algorithm [8, 27]) to all of the individual scanpaths on the six web pages for the browsing and searching tasks. With the SPAM algorithm, multiple scanpaths were detected for some of the pages. To be fair, we selected the one with the highest similarities to the individual scanpaths. This means that we chose its best result from this aspect.

We then compared the resulting scanpaths with the individual scanpaths. For this purpose, we used the standard String-edit algorithm to calculate the similarities to the individual scanpaths as it has been widely used in the literature

Figure 6: The AVG web page segmented with the BOM approach

(see Section 2). To investigate whether the differences between the results of the STA and other existing algorithms are statistically significant and not caused by chance, we conducted a statistical analysis [19]. Since the algorithms were applied to the same scanpaths, the repeated measures design was used here. Hence, when the differences between the results of two algorithms (i.e., the similarities to the individual scanpaths) were normally distributed, the dependent T-Test was applied which provides t value. Otherwise, the Wilcoxon Signed Rank test was applied which provides Z value. We assessed the normality of the results by using the Shapiro-Wilk test.

The statistical analysis was conducted with 95% confidence interval [19]. In this confidence interval, when the p value is less than 0.05, we can mention a significant difference between the results of two algorithms. However, the probability of identifying a significant difference due to chance raises when the number of pairwise comparisons raises [18]. In our statistical analysis, the STA algorithm was compared with other four algorithms in a pairwise manner on each web page for both the browsing and searching tasks. Therefore, the p value was adjusted by using the Bonferroni correction method [18]. In other words, the p value was divided by the number of pairwise comparisons ($0.05/4 = 0.0125$) [18]. As a result, the p value should be less than 0.0125 in our analysis to show a significant difference between the results of two algorithms.

In order to illustrate the strength of the differences between the results of the STA and other algorithms, we also calculated the effect sizes. The Cohen's d value was calculated as the effect size when the T-test was appropriate (0.2: Small Effect, 0.5 : Medium Effect, 0.8: Large Effect). Otherwise, the r value was calculated as the effect size (0.1: Small Effect, 0.3: Medium Effect, 0.5: Large Effect) [5, 19]. The following section presents our statistical analysis for both the VIPS and the BOM segmentation approaches [2, 21].

6. RESULTS

This section presents the statistical comparison of the results of the STA and other existing algorithms for both the

⁵<http://www-poleia.lip6.fr/~sanojaa/BOM/>

Table 1: The trending scanpaths generated by the STA algorithm (See Open Data Section for the pages with their visual elements)

Segmentation Approach	Task	Apple	Babylon	AVG	Yahoo	Godaddy	BBC
VIPS	Browsing	FCGHIFHBGEJF	MHIRQP	IGI	IJH	ONO	LP
	Searching	CFEFCHIEDBEGB	MNPQRS	GI	IGJI	OMNFM	LPRSN
BOM	Browsing	DBADCED	K	ECEC	IJLH	HGIHKE	B
	Searching	BDCECA	GK	CE	IGI	HGIHKDGBG	B

VIPS and BOM segmentation approaches. Table 1 shows the results of the STA algorithm. The individual scanpaths and the results of other existing algorithms can be found in our external data repository (see Open Data Section). The repository also includes the computed similarities between the individual scanpaths and the resulting scanpaths of the STA and other existing algorithms.

6.1 Results for the VIPS Approach

Table 2 and Table 3 present the mean (M), median (MD), standard deviation (SD), minimum (MIN) and maximum (MAX) similarities between the individual scanpaths and the results of the STA and other algorithms on the six web pages for the browsing and searching tasks when the VIPS approach was used to segment the web pages [2]. As presented, the *eyePatterns* Discover Patterns algorithm could not provide any results in none of the cases. Moreover, *eMINE* algorithm and the Dotplots based algorithm could not provide any result in some cases. For example, no result could be provided by *eMINE* algorithm on the Babylon page for the browsing task when the VIPS was used [2].

Table 2: The similarities between the individual scanpaths and the results of the STA and other existing algorithms for the browsing tasks when the VIPS is used [^a: No result is provided]

Page	Algorithm	M	MD	SD	MIN	MAX
Apple	STA	25.64	25.36	4.85	14.29	38.89
	eMINE	2.82	2.78	0.72	1.75	5.56
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	11.26	11.11	2.88	7.02	22.22
Babylon	STA	13.14	11.90	4.31	6.35	27.27
	eMINE	^a	^a	^a	^a	^a
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	2.66	2.27	1.01	1.47	6.25
AVG	STA	13.14	11.54	7.50	5.26	37.50
	eMINE	4.38	3.85	2.50	1.75	12.50
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	17.52	15.38	10.00	7.02	50.00
Yahoo	STA	14.26	13.04	4.64	8.57	27.27
	eMINE	4.75	4.35	1.55	2.86	9.09
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	19.01	17.39	6.19	11.43	36.36
Godaddy	STA	12.66	11.11	4.94	5.36	30.00
	eMINE	4.22	3.70	1.65	1.79	10.00
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	4.22	3.70	1.65	1.79	10.00
	SPAM	12.66	11.11	4.94	5.36	30.00
BBC	STA	7.49	6.78	2.86	3.45	16.67
	eMINE	3.81	3.51	1.45	1.72	8.33
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	3.81	3.51	1.45	1.72	8.33

As illustrated in Table 2 and Table 3, in the majority of the cases, the results of the STA algorithm were more sim-

Table 3: The similarities between the individual scanpaths and the results of the STA and other existing algorithms for the searching tasks when the VIPS is used [^a: No result is provided]

Page	Algorithm	M	MD	SD	MIN	MAX
Apple	STA	28.93	29.41	7.88	13.79	45.00
	eMINE	5.98	5.88	2.08	2.30	10.00
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	14.95	14.71	5.20	5.75	25.00
Babylon	STA	19.77	18.75	8.57	5.56	50.00
	eMINE	13.28	12.50	5.67	3.70	33.33
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	16.60	15.63	7.08	4.63	41.67
AVG	STA	10.01	9.11	4.10	2.78	22.22
	eMINE	10.01	9.11	4.10	2.78	22.22
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	10.01	9.11	4.10	2.78	22.22
	SPAM	20.02	18.22	8.20	5.56	44.44
Yahoo	STA	24.07	25.66	11.38	6.67	62.50
	eMINE	4.85	5.13	2.30	1.33	12.50
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	4.85	5.13	2.30	1.33	12.50
	SPAM	14.56	15.39	6.89	4.00	37.50
Godaddy	STA	15.60	14.81	4.47	7.14	29.41
	eMINE	6.75	6.67	1.84	2.86	11.76
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	3.37	3.33	0.92	1.43	5.88
	SPAM	10.12	10.00	2.75	4.29	17.65
BBC	STA	15.75	15.63	5.61	5.81	26.32
	eMINE	6.96	6.90	2.69	2.33	12.50
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
	SPAM	10.44	10.34	4.03	3.49	18.75

ilar to the individual scanpaths in comparison with other algorithms. For example, on the Apple page for the browsing task, the mean similarity between the result of the STA and the individual scanpaths are equal to 25.64% whereas the mean similarities between the results of *eMINE* algorithm and the SPAM algorithm to the individual scanpaths were equal to 2.82% and 11.26% respectively. Moreover, no result was provided by the *eyePatterns* Discover Patterns algorithm and the Dotplots based algorithm on the Apple page for the browsing task.

According to our statistical analysis (see Table 4 and Table 5), the STA algorithm performed significantly better than all other algorithms in eight out of 12 cases with a large effect in terms of providing the most representative scanpath and this not an occurrence by chance ($p < 0.0005$). In some cases, the results of the STA and some algorithms had the same similarities to the individual scanpaths. For example, the result of the STA algorithm and the SPAM algorithm have the same similarities to the individual scanpaths on the Godaddy page for the browsing task. In three cases, the SPAM algorithm performed better than the STA algorithm (the browsing and searching tasks on the AVG page and the browsing task on the Yahoo page). However, apart from the

Table 4: The statistical comparisons of the STA and other existing algorithms for the browsing tasks by using the VIPS [^a: No result, ^b: The same similarities to the individual scanpaths, ^c: Not relevant to the Wilcoxon test, N: The sample size, *p<0.05, **p<0.01, ***p<0.0005]

Page	Algorithm Compared	Test	N	df	t or Z	d or r
Apple	eMINE	T-Test	40	39	33.952***	6.6
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	T-Test	40	39	32.230***	7.5
Babylon	eMINE	a	a	a	a	a
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	Wilcoxon	39	c	-5.446***	0.6
AVG	eMINE	Wilcoxon	40	c	-5.512***	0.6
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	Wilcoxon	40	c	-5.512***	0.6
Yahoo	eMINE	Wilcoxon	40	c	-5.513***	0.6
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	Wilcoxon	40	c	-5.513***	0.6
Godaddy	eMINE	Wilcoxon	40	c	-5.513***	0.6
	eyePatterns	a	a	a	a	a
	Dotplots	Wilcoxon	40	c	-5.513***	0.6
	SPAM	b	b	b	b	b
BBC	eMINE	Wilcoxon	40	c	-5.445***	0.6
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	Wilcoxon	40	c	-5.445***	0.6

Table 5: The statistical comparisons of the STA and other existing algorithms for the searching tasks by using the VIPS [^a: No result, ^b: The same similarities to the individual scanpaths, ^c: Not relevant to the Wilcoxon test, N: The sample size, *p<0.05, **p<0.01, ***p<0.0005]

Page	Algorithm Compared	Test	N	df	t or Z	d or r
Apple	eMINE	T-Test	33	32	21.743***	4.0
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	T-Test	33	32	20.694***	2.1
Babylon	eMINE	Wilcoxon	39	c	-5.444***	0.6
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	Wilcoxon	39	c	-5.305***	0.6
AVG	eMINE	b	b	b	b	b
	eyePatterns	a	a	a	a	a
	Dotplots	b	38	b	b	b
	SPAM	T-Test	38	37	-	-1.5
Yahoo	eMINE	Wilcoxon	34	c	-5.089***	0.6
	eyePatterns	a	a	a	a	a
	Dotplots	Wilcoxon	34	c	-5.089***	0.6
	SPAM	Wilcoxon	34	c	-5.089***	0.6
Godaddy	eMINE	T-Test	35	34	17.701***	2.6
	eyePatterns	a	a	a	a	a
	Dotplots	T-Test	35	34	19.665***	3.8
	SPAM	T-Test	35	34	13.632***	1.5
BBC	eMINE	T-Test	39	38	16.686***	2.0
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
	SPAM	T-Test	39	38	13.622***	1.1

SPAM algorithm, none of the algorithms performed better than the STA in our tests.

6.2 Results for the BOM Approach

Table 6 and Table 7 show the mean (M), median (MD),

Table 6: The similarities between the individual scanpaths and the results of the STA and other existing algorithms for the browsing tasks when the BOM is used [^a: No result is provided]

Page	Algorithm	M	MD	SD	MIN	MAX
Apple	STA	26.85	26.20	5.39	15.91	40.00
	eMINE	4.43	4.17	1.47	2.27	10.00
	eyePatterns	a	a	a	a	a
	Dotplots	4.43	4.17	1.47	2.27	10.00
Babylon	STA	4.16	3.13	2.89	1.92	14.29
	eMINE	4.16	3.13	2.89	1.92	14.29
	eyePatterns	a	a	a	a	a
	Dotplots	4.16	3.13	2.89	1.92	14.29
AVG	STA	22.60	18.18	11.85	8.33	66.67
	eMINE	5.71	4.55	3.01	2.08	16.67
	eyePatterns	a	a	a	a	a
	Dotplots	5.71	4.55	3.01	2.08	16.67
Yahoo	STA	15.95	15.38	4.36	9.30	30.77
	eMINE	4.25	4.01	1.26	2.33	7.69
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
Godaddy	STA	12.75	12.02	3.77	6.98	23.08
	eMINE	21.84	20.71	5.95	10.91	35.29
	eyePatterns	3.93	3.45	1.31	1.82	8.33
	Dotplots	a	a	a	a	a
BBC	STA	15.72	13.81	5.23	7.27	33.33
	eMINE	9.52	6.07	15.03	3.33	100.00
	eyePatterns	9.52	6.07	15.03	3.33	100.00
	Dotplots	9.52	6.07	15.03	3.33	100.00
BBC	STA	9.52	6.07	15.03	3.33	100.00
	eMINE	9.52	6.07	15.03	3.33	100.00
	eyePatterns	a	a	a	a	a
	Dotplots	9.52	6.07	15.03	3.33	100.00
BBC	STA	9.52	6.07	15.03	3.33	100.00
	eMINE	9.52	6.07	15.03	3.33	100.00
	eyePatterns	a	a	a	a	a
	Dotplots	9.52	6.07	15.03	3.33	100.00
BBC	STA	9.52	6.07	15.03	3.33	100.00
	eMINE	9.52	6.07	15.03	3.33	100.00
	eyePatterns	a	a	a	a	a
	Dotplots	9.52	6.07	15.03	3.33	100.00

Table 7: The similarities between the individual scanpaths and the results of the STA and other existing algorithms for the searching tasks when the BOM is used [^a: No result is provided]

Page	Algorithm	M	MD	SD	MIN	MAX
Apple	STA	27.30	25.00	10.24	10.00	54.55
	eMINE	9.42	8.70	3.66	3.33	18.18
	eyePatterns	a	a	a	a	a
	Dotplots	a	a	a	a	a
Babylon	STA	23.55	21.74	9.14	8.33	45.45
	eMINE	10.94	9.09	5.46	2.70	28.57
	eyePatterns	10.94	9.09	5.46	2.70	28.57
	Dotplots	5.47	4.55	2.73	1.35	14.29
AVG	STA	10.94	9.09	5.46	2.70	28.57
	eMINE	11.14	10.53	4.29	3.57	22.22
	eyePatterns	11.14	10.53	4.29	3.57	22.22
	Dotplots	11.14	10.53	4.29	3.57	22.22
Yahoo	STA	22.29	21.05	8.59	7.14	44.44
	eMINE	13.87	14.29	6.47	3.95	33.33
	eyePatterns	4.62	4.76	2.16	1.32	11.11
	Dotplots	a	a	a	a	a
Godaddy	STA	4.62	4.76	2.16	1.32	11.11
	eMINE	13.87	14.29	6.47	3.95	33.33
	eyePatterns	13.87	14.29	6.47	3.95	33.33
	Dotplots	4.62	4.76	2.16	1.32	11.11
BBC	STA	25.30	24.00	7.22	16.67	44.44
	eMINE	7.04	6.90	2.05	3.85	12.50
	eyePatterns	a	a	a	a	a
	Dotplots	3.52	3.45	1.02	1.92	6.25
BBC	STA	14.08	13.79	4.10	7.69	25.00
	eMINE	9.33	7.69	4.98	2.08	25.00
	eyePatterns	9.33	7.69	4.98	2.08	25.00
	Dotplots	9.33	7.69	4.98	2.08	25.00
BBC	STA	9.33	7.69	4.98	2.08	25.00
	eMINE	9.33	7.69	4.98	2.08	25.00
	eyePatterns	a	a	a	a	a
	Dotplots	9.33	7.69	4.98	2.08	25.00

standard deviation (SD), minimum (MIN) and maximum (MAX) similarities between the individual scanpaths and

Table 8: The statistical comparisons of the STA and other existing algorithms for the browsing tasks by using the BOM [^a: No result, ^b: The same similarities to the individual scanpaths, ^c: Not relevant to the Wilcoxon test, N: The sample size, * $p < 0.05$, ** $p < 0.01$, * $p < 0.0005$]**

Page	Algorithm Compared	Test	N	df	t or Z	d or r
Apple	eMINE	T-Test	40	39	34.303***	5.68
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	T-Test	40	39	34.303***	5.68
Babylon	SPAM	T-Test	40	39	32.244***	2.75
	eMINE	^b	^b	^b	^b	^b
	eyePatterns	^a	^a	^a	^a	^a
AVG	Dotplots	^b	^b	^b	^b	^b
	SPAM	^b	^b	^b	^b	^b
	eMINE	Wilcoxon	40	^c	-5.513***	0.62
Yahoo	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	Wilcoxon	40	^c	-5.513***	0.62
	SPAM	Wilcoxon	40	^c	-1.000	0.11
Godaddy	eMINE	Wilcoxon	40	^c	-5.513***	0.62
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
BBC	SPAM	Wilcoxon	40	^c	-4.939***	0.55
	eMINE	T-Test	40	39	23.654***	4.16
	eyePatterns	^a	^a	^a	^a	^a
BBC	Dotplots	^a	^a	^a	^a	^a
	SPAM	Wilcoxon	40	^c	-5.376***	0.60
	eMINE	^b	^b	^b	^b	^b
BBC	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^b	^b	^b	^b	^b
	SPAM	^b	^b	^b	^b	^b

Table 9: The statistical comparisons of the STA and other existing algorithms for the searching tasks by using the BOM [^a: No result, ^b: The same similarities to the individual scanpaths, ^c: Not relevant to the Wilcoxon test, N: The sample size, * $p < 0.05$, ** $p < 0.01$, * $p < 0.0005$]**

Page	Algorithm Compared	Test	N	df	t or Z	d or r
Apple	eMINE	T-Test	33	32	15.323***	2.33
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^a	^a	^a	^a	^a
Babylon	SPAM	T-Test	33	32	9.358***	0.39
	eMINE	^b	^b	^b	^b	^b
	eyePatterns	^a	^a	^a	^a	^a
AVG	Dotplots	Wilcoxon	39	^c	-5.444***	0.62
	SPAM	^b	^b	^b	^b	^b
	eMINE	^a	^a	^a	^a	^a
Yahoo	eyePatterns	^b	^b	^b	^b	^b
	Dotplots	T-Test	38	37	-16.001***	-1.64
	SPAM	^a	^a	^a	^a	^a
Godaddy	eMINE	T-Test	34	33	12.492***	1.92
	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	T-Test	34	33	12.492***	1.92
BBC	SPAM	^b	^b	^b	^b	^b
	eMINE	Wilcoxon	35	^c	-5.160***	0.62
	eyePatterns	^a	^a	^a	^a	^a
BBC	Dotplots	Wilcoxon	35	^c	-5.161***	0.62
	SPAM	Wilcoxon	35	^c	-5.160***	0.62
	eMINE	^b	^b	^b	^b	^b
BBC	eyePatterns	^a	^a	^a	^a	^a
	Dotplots	^b	^b	^b	^b	^b
	SPAM	^b	^b	^b	^b	^b

the results of the STA and other existing algorithms on the six pages for the browsing and searching tasks when the BOM approach was used to discover the visual elements of the web pages [21]. As illustrated in these tables, no result

could be provided by the *eyePatterns* Discover Pattern algorithm again. The Dotplots based algorithm also could not provide any result on the Apple page for the searching task and on the Godaddy and Yahoo pages for the browsing task.

According to Table 6 and Table 7, the results of the STA algorithm were more similar to the individual scanpaths in comparison with other algorithms in five out of 12 cases. For example, on the Apple page for the browsing task, the mean similarity between the result of the STA and the individual scanpaths are equal to 26.85% whereas the mean similarities between the results of *eMINE* algorithm, the Dotplots based algorithm and the SPAM algorithm to the individual scanpaths were equal to 4.43%, 4.43% and 13.30% respectively. Moreover, as mentioned above, no result was provided by the *eyePatterns* Discover Patterns algorithm on the Apple page for the browsing task.

As illustrated in Table 8 and Table 9, the STA algorithm performed significantly better than all other algorithms in five out of 12 cases with a large effect in terms of providing the most representative scanpath with a large effect, except on the Apple page for the searching task where the effect size was small between the STA algorithm and the SPAM algorithm. In three cases, apart from the *eyePatterns* Discover Pattern algorithm, all of the algorithms provided the results which have the same similarities to the individual scanpaths (the browsing task on the Babylon and BBC pages and the searching task on the BBC page). In addition, the SPAM algorithm performed better on the AVG page for the searching task in comparison with the STA and other algorithms. In the rest of the cases, none of other algorithms provided better results than the STA algorithm, even though they provided the same results as the STA algorithm in some cases.

To sum up, the STA algorithm provided the most representative scanpath in the majority of the cases. In the rest of the cases, it still provided more representative scanpath in comparison with some of other existing algorithms. As the SPAM algorithm performed better than the STA algorithm in only four out of 24 cases, we can suggest that the STA algorithm is able to provide the most representative scanpath of users regardless of the segmentation approach used.

7. DISCUSSION

The validity of the STA algorithm was tested with the VIPS and BOM segmentation approaches [2, 21]. The results mainly show that the validity of the STA algorithm is not affected by the segmentation approach used. Even though there were some cases where the STA could not provide the most representative scanpath, the STA algorithm performed significantly better than other existing algorithms in the most of the cases regardless of the segmentation approach used (see Section 6).

Our experimental results show that the STA algorithm may not perform better than other existing algorithms when visual elements cover large areas on web pages. In particular, when the BOM segmentation approach was used to segment the web pages [21], the visual elements of the BBC page were quite large, especially the element B which is almost half of the page (see Figure 5). Although none of the existing algorithms performed better than the STA algorithm on the BBC page, the STA algorithm could not provide the most representative scanpath on that page. It is an expected situation because when there are very large visual elements, the

variations between the individual scanpaths will be lower as the number of visual elements is limited.

In our previous work, we also showed that when there are more and smaller segments, the STA algorithm provides more representative scanpath [10]. We can also see this conclusion from this paper. As illustrated in Figures 2-5, more and smaller segments were generated by the VIPS segmentation approach in comparison with the BOM segmentation approach. For example, the elements G, H, I and J of the Apple page generated by the VIPS approach are covered by the element E generated by the BOM approach. Thus, the STA algorithm performed better with the VIPS segmentation approach (eight out of 12 cases) in comparison with the BOM segmentation approach (five out of 12 cases). Therefore, we can suggest that the granularity level is an important factor in scanpath analysis with the STA algorithm as it affects the sizes of segments and the number of segments on web pages. If there are very large segments on a web page, the difference between the results of the STA algorithm and other existing algorithms may not be significantly different. However, according to a study conducted by [2], users prefer more and smaller segments in comparison with fewer and larger segments.

As the STA algorithm identifies the trending scanpath by analysing the individual scanpaths, the trending scanpath should be similar to the individual scanpaths as much as possible. Unless all the users follow exactly the same path, a 100% similarity to the individual scanpaths cannot be achieved. Furthermore, when the individual scanpaths are entirely different from each other, such as ABC, DEF and GHI, no trending scanpath can be identified. Hence, the similarities between the trending scanpath and the individual scanpaths are strongly associated with the similarities between the individual scanpaths. Table 10 shows the minimum similarities between the individual scanpaths in the test cases. Based on Tables 2, 3, 6 and 7, we can suggest that the median similarity of the trending scanpaths to the individual scanpaths are greater than the minimum similarity between the individual scanpaths in the most of the cases (VIPS: 9 out of 12 cases, BOM: 8 out of 12 cases).

Table 10: The minimum similarities between the individual scanpaths

Segmentation Approach	Page	Browsing Task	Searching Task
VIPS	Apple	10.20	19.54
	Babylon	3.33	11.11
	AVG	10.00	12.50
	Yahoo	17.65	9.33
	Godaddy	8.70	13.89
	BBC	10.00	14.89
BOM	Apple	21.74	18.33
	Babylon	9.62	9.46
	AVG	12.50	16.07
	Yahoo	15.38	10.61
	Godaddy	18.18	20.00
	BBC	3.33	8.33

Since there is a limited number of segmentation approaches with a publicly available implementation, we could only investigate the effect of two different segmentation approaches on the STA algorithm in this paper [26]. When there is another segmentation approach available with its public imple-

mentation, the same methodology can be applied to investigate its effect on the STA algorithm. However, based on the results presented in this paper, we can suggest that the STA algorithm is likely to provide the most representative scanpath in comparison with other segmentation approaches as it also considers the visual elements which are not shared by all users but get at least the same attention as the shared elements.

A new eye tracking study was conducted to investigate the effects of two segmentation approaches on the STA algorithm. This allowed us to re-evaluate the STA algorithm with the VIPS approach by using different users as we had already evaluated the algorithm with the VIPS approach in our previous work [10]. Although the age distribution of our participants was concentrated in the range of 18 and 34 (See Section 4), all of the participants were daily web users (apart from one participant) and they had different educational backgrounds (such as, computer engineering, civil engineering, psychology and business administration). Therefore, we believe that they are an indicator for other web users. Based on the results, we can suggest that the STA algorithm is able to provide the most representative scanpath regardless of the users included. The validity of the STA algorithm could also be tested with a completely different eye tracking dataset with different user groups (such as, older users). In particular, we could test whether the validity of the STA algorithm is limited to specific web pages. For example, a search engine can be included in the evaluation process. However, since the focus of the algorithm is not the contents of the web pages, we believe that the validity of the STA algorithm is not significantly affected by the selection of the web pages. By testing the STA algorithm with a different dataset, however, would allow to generalise the validity of the algorithm.

The STA algorithm is designed to cluster multiple scanpaths into a single representative scanpath. However, there may be some users who use different strategies while they are interacting with web pages. In such cases, the user scanpaths can firstly be categorised into multiple groups where the similar scanpaths are located in the same group, and then the trending scanpath for each group can be computed by using the STA algorithm.

The STA algorithm can be used to improve user experience in constrained environments by guiding web page transcoding (see Section 1). Since the algorithm highlights the most commonly fixated elements in order, the firstly and mostly fixated elements can be accessed earlier in the transcoded version. This allows to avoid spending unnecessary time to find targets. The algorithm also contributes to usability studies, for example, it can be used for identifying whether or not users use an expected path for a specific goal. The STA algorithm can also be used in different fields. For example, it can be used in Information Retrieval (IR) research to identify which parts of web pages have higher priority to be shown to users. It can also contribute to Web advertising by guiding to position advertisements on web pages to attract attention of users when they visit the pages.

8. CONCLUSIONS

Eye tracking provides insights into how users interact with web pages. Hence, it helps to identify problems and improve user experience on the Web. In our previous work, we devel-

oped the STA algorithm which analyses multiple scanpaths on a web page and identifies the most commonly followed path in terms of the visual elements of the web page [10]. Although we validated the STA algorithm by using an eye tracking study, we did not know whether the validity of the algorithm could be affected by the segmentation approach used. This paper presents the investigation of the effect of two segmentation approaches on the STA algorithm and illustrates that the validity of the algorithm is not limited to a particular segmentation approach.

UX researchers may prefer to analyse user scanpaths by using different types of segmentations for their studies, and therefore a scanpath analysis algorithm should not be restricted to a particular segmentation approach. Based on our experimental results, we can suggest them to use the STA algorithm if they want to identify a trending scanpath on a particular page.

Open Data

The eye tracking study materials (the information sheet, consent form, questionnaire and web pages with their visual elements) are provided in our external repository (http://iam-data.cs.manchester.ac.uk/data_files/24). The repository also involves the individual scanpaths in terms of the visual elements of the web pages. The resulting scanpaths of the STA algorithm and other existing algorithms are also provided with their similarities to the individual scanpaths.

9. REFERENCES

- [1] E. Akpınar and Y. Yeşilada. “Old Habits Die Hard!”: Eyetracking Based Experiential Transcoding: A Study with Mobile Users. In *Proceedings of the 12th Web for All Conference, W4A '15*, pages 12:1–12:5, New York, NY, USA, 2015. ACM.
- [2] M. E. Akpınar and Y. Yeşilada. Vision Based Page Segmentation Algorithm: Extended and Perceived Success. In Q. Z. Sheng and J. Kjeldskov, editors, *Current Trends in Web Engineering - ICWE 2013 Workshops and PhD Symposium.*, volume 8295 of *Lecture Notes in Computer Science*, pages 238–252. Springer, 2013.
- [3] A. Brown, C. Jay, and S. Harper. Audio access to calendars. In *W4A '10: Proceedings of the 2010 International Cross Disciplinary Conference on Web Accessibility (W4A)*, pages 1–10, New York, NY, USA, 2010. ACM.
- [4] M. Burmester and M. Mast. Repeated Web Page Visits and the Scanpath Theory: A Recurrent Pattern Detection Approach. *Journal of Eye Movement Research*, 3(4):1–20, 2010.
- [5] J. Cohen. *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum, 1988.
- [6] C. Ehmke and S. Wilson. Identifying Web Usability Problems from Eye-tracking Data. In *Proceedings of the 21st British HCI Group Annual Conference on People and Computers: HCI... but not as we know it*, volume 1 of *BCS-HCI '07*, pages 119–128, Swinton, UK, 2007. British Computer Society.
- [7] S. Eraslan and Y. Yesilada. Patterns in Eyetracking Scanpaths and the Affecting Factors. *Journal of Web Engineering - Special Issue on “Engineering the Web for users, developers and the crowd”*, 14(4&5):363–385, 2015.
- [8] S. Eraslan, Y. Yesilada, and S. Harper. Identifying Patterns in Eyetracking Scanpaths in Terms of Visual Elements of Web Pages. In S. Casteleyn, G. Rossi, and M. Winckler, editors, *Web Engineering*, volume 8541 of *Lecture Notes in Computer Science*, pages 163–180. Springer International Publishing, 2014.
- [9] S. Eraslan, Y. Yesilada, and S. Harper. Eye Tracking Scanpath Analysis Techniques on Web Pages: A Survey, Evaluation and Comparison. *Journal of Eye Movement Research*, 9(1:2):1–19, 2016.
- [10] S. Eraslan, Y. Yesilada, and S. Harper. Scanpath Trend Analysis on Web Pages: Clustering Eye Tracking Scanpaths. *ACM Transactions on the Web (Accept subject to minor revisions)*, -:-, 2016.
- [11] B. Follet, O. L. Meur, and T. Baccino. New insights into ambient and focal visual fixations using an automatic classification algorithm. *iPerception: Open-access journal of human, animal, and machine perception*, 2(6):592–610, 2011.
- [12] P. Fournier-Viger, A. Gomariz, T. Gueniche, A. Soltani, C.-W. Wu, and V. S. Tseng. SPMF: a Java Open-Source Pattern Mining Library. *Journal of Machine Learning Research (JMLR)*, 15:3389–3393, 2014.
- [13] J. H. Goldberg and J. I. Helfman. Scanpath Clustering and Aggregation. In *Proceedings of the 2010 Symposium on Eye Tracking Research & Applications, ETRA '10*, pages 227–234, New York, NY, USA, 2010. ACM.
- [14] P. Hejmady and N. H. Narayanan. Visual attention patterns during program debugging with an ide. In *Proceedings of the 2012 Symposium on Eye Tracking Research & Applications, ETRA '12*, pages 197–200, New York, NY, USA, 2012. ACM.
- [15] S. Josephson. Using Eye Tracking to See How Viewers Process Visual Information in Cyberspace. In S. Josephson, S. B. Barnes, and M. Lipton, editors, *Visualizing the Web: Evaluating Online Design from a Visual Communication Perspective*, volume 1, chapter 5, pages 99–122. Peter Lang Publishing Inc., New York, 2010.
- [16] S. Josephson and M. E. Holmes. Visual Attention to Repeated Internet Images: Testing the Scanpath Theory on the World Wide Web. In *Proceedings of the 2002 Symposium on Eye Tracking Research & Applications, ETRA '02*, pages 43–49, New York, NY, USA, 2002. ACM.
- [17] M. Mast and M. Burmester. Exposing Repetitive Scanning in Eye Movement Sequences with T-pattern Detection. In *Proceedings IADIS International conference interfaces and human computer interaction (IHCI)*, pages 137–145, Rome, Italy, 2011.
- [18] M. A. Napierala. What is the bonferroni correction? *AAOS Now - American Academy of Orthopaedic Surgeons*, April:1–3, 2012.
- [19] J. Pallant. *SPSS Survival Manual: A Step By Step Guide to Data Analysis Using SPSS version 15*. Maidenhead: Open University Press/McGraw-Hill, 4th edition edition, 2007.
- [20] A. Sanoja and S. Gançarski. Block-o-Matic: a Web

- Page Segmentation Tool and its Evaluation. In *29ème journées “Base de données avancées”, BDA’13, Oct 2013*, Nantes, France, 2013. <hal-00881693>.
- [21] A. Sanoja and S. Gançarski. Block-o-Matic: A web page segmentation framework. In *Multimedia Computing and Systems (ICMCS), 2014 International Conference on*, pages 595–600, April 2014.
 - [22] H. Takeuchi and Y. Habuchi. A Quantitative Method for Analyzing Scan Path Data Obtained by Eye Tracker. In *Computational Intelligence and Data Mining, 2007. CIDM 2007. IEEE Symposium on*, pages 283 –286, 1 2007-april 5 2007.
 - [23] G. Underwood, K. Humphrey, and T. Foulsham. Knowledge-Based Patterns of Remembering: Eye Movement Scanpaths Reflect Domain Experience. In A. Holzinger, editor, *HCI and Usability for Education and Work*, volume 5298 of *Lecture Notes in Computer Science*, pages 125–144. Springer Berlin Heidelberg, 2008.
 - [24] B. M. Velichkovsky, A. Rothert, M. Kopf, S. M. Dornhöfer, and M. Joos. Towards an express-diagnostics for level of processing and hazard perception. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5(2):145 – 156, 2002.
 - [25] J. M. West, A. R. Haake, E. P. Rozanski, and K. S. Karn. eyePatterns: Software for Identifying Patterns and Similarities Across Fixation Sequences. In *Proceedings of the 2006 Symposium on Eye Tracking Research & Applications*, ETRA ’06, pages 149–154, New York, NY, USA, 2006. ACM.
 - [26] Y. Yesilada. Web Page Segmentation: A Review. Technical report, Middle East Technical University, March 2011.
 - [27] Y. Yesilada, S. Harper, and S. Eraslan. Experiential transcoding: An EyeTracking approach. In *Proceedings of the 10th International Cross-Disciplinary Conference on Web Accessibility*, page 30. ACM, 2013.