University of Trás-os-Montes and Alto Douro

Reorganization of Web sites content based on Users Visual Behaviour

PhD Thesis in
Informatics

Martinho Fradeira Gonçalves

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VILA REAL, 2014

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The presented doctrines are of the exclusive responsibility of the author.

University of Trás-os-Montes and Alto Douro,

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MARTINHO FRADEIRA GONÇALVES

“The good news about computers is that they do what you tell them to do. The bad news is that they do what you tell them to do.”

Ted Nelson

This work is dedicated to my friends and family.

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REORGANIZATION OF WEB SITES CONTENT BASED ON USERS VISUAL BEHAVIOUR.

Abstract

One of the main problems in web development is that the pages are designed and built around the main task that a user will perform on the website. Usually e-commerce sites are oriented towards searching; on the other hand newspaper sites are more oriented towards the exploration of web pages, where a large amount of information is available to the user when the web page is loaded. When users try to perform a different task from which the site is arranged/designed, it becomes very difficult, taking a long time to find the desired information. The aim of this work is to improve web page's efficiency, by applying knowledge of the human visual mechanism. This is achieved by identifying how the Human Visual System operates when browsing web pages, and how it can be exploited.

In order to accomplish this concept, this work shows that it is possible to distinguish if a user is completing a task or simply exploring a web page. This difference can be identified by the operations of human visual mechanisms and by saccade distances. Clear differences can be observed in the visual patterns when users perform a task or simply explore a web page. With this knowledge an Eye Tracking Task Identification system will be proposed. The system is able to automatically detect if a user is completing a task or simply exploring a web page.

The application of this method allows for the possibility of automatically restructuring web pages based on the user's task/visual patterns. This work implements such a restructuring method, and the results obtained through experiments show that the proposed method restructures the web page with a success rate of 83,3%. Additionally, the collected data also indicates that the restructuring of web pages can allow users to complete tasks in the same time duration as a hand optimised web page.

KEYWORDS: Visual attention, World Wide Web, Eye tracking, Human-Computer Interaction.

REORGANIZAÇÃO DO CONTEÚDO DE WEB SITES BASEADO NO COMPORTAMENTO VISUAL HUMANO.

Resumo

Um dos principais problemas no desenvolvimento web é o facto dos sites serem desenhados e construidos com base na principal tarefa que os utilizadores irão realizar no site. Normalmente sites de e-commerce são orientados para a pesquisa, por outro lado sites de jornais online são mais orientados para a exploração das páginas, onde uma larga quantidade de informação é apresentada ao utilizador quando esta é carregada. Quando os utilizadores tentam realizar uma tarefa diferente da qual o site foi desenhado/construido para, fica muito difícil, demorando um longo período de tempo para encontrar a informação pretendida. O objectivo deste trabalho é aumentar a eficiência das páginas web, aplicando conhecimentos sobre o sistema visual humano. Isto é alcançado através da identificação de como o Sistema Visual Humano funciona quando os utilizadores navegam nas páginas web, e como pode este ser explorado.

De modo a atingir este objectivo, este trabalho apresenta a possibilidade de identificar se o utilizador está a completar uma tarefa ou simplesmente a explorar uma página web. A diferença pode ser identificada através das operações do sistema visual humano ou através das distância das saccades. Diferenças óbvias podem ser observadas nos padrões visuais quando os utilizadores realizam uma tarefa ou simplesmente exploram uma página web. Com este conhecimento, vai ser apresentado um sistema de Eye Tracking Task Identification. O sistema é capaz de automaticamente detectar se o utilizador está a completar uma tarefa ou simplemente a explorar a página web.

A aplicação deste método permite a possibilidade de automáticamente restruturar as páginas web baseado-se nos padrões visuais da tarefa. Este trabalho aplica este método de restruturação, e os resultados obtidos através das experiências mostra que este restrutura as páginas web com um sucesso de 83,3%. Adicionalmente, os dados recolhidos indicam que a restruturação das páginas permite aos utilizadores completar as tarefas em igual período de tempo ao realizado num site previamente optimizado.

PALAVRAS-CHAVE: Atenção Visual, World Wide Web, *Eye tracking*, Interação Homem-Máquina

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1. INTRODUCTION

The Internet has become an essential tool for many people. “Adding up all the users in individual countries around the world, there appear to be around 2.5 thousand million global internet users today – roughly 35% of the world’s population.” [Wearesocial, 2014].

Compared to last year, at the time of submission, a growth of 150 million users can be verified. However, there exists the possibility of there being even more because the data from some countries may be not accurate. The International Communications Union estimates that there are probably closer to 3 billion global internet users, especially when taking into account the increasing number of mobile accessing to the Internet.

Regarding e-commerce, based on the study of the International Data Corporation, global business-to-business and consumer transactions equate to 16 trillion dollars in 2013. Added to the global market for digital products and services (4.4 trillion dollars in 2013), it is estimated to be worth 20.4 trillion US dollars, representing about 13,8% of global sales [OxfordEconomics, 2011].

Based on the volume of online business, some companies devote a lot of resources to try to build the perfect layout in order to guarantee that their customers/visitors can find what they want/need and have a good experience while visiting their website. However, accomplishing this is not an easy task, as the user attention will be focussed on different areas of a website, depending on the task.

One of the main problems in web development is that the pages are designed and built around the main task that a user will perform on the website. Usually e-commerce sites are oriented towards searching; on the other hand newspaper sites are more oriented for the users to explore the web page, where there is a great amount of information available to the user when the web page is loaded. When users try to perform a different task from which the site is arranged/designed, it becomes very difficult, taking a long time or even becoming impossible to find the desired information.

The perception of a visual environment depends on the user and the task the user is currently performing. Models of the human visual system can be exploited to significantly reduce computational time when rendering high fidelity images, without compromising the perceived visual quality. This works by identifying which areas are going to capture the users' attention and reduce the image quality in the others. The models of the human visual system can be based in different visual mechanisms, depending if the user is performing specific tasks or simply exploring.

The bottom-up mechanism is more active when users are exploring, and usually these models are based on models of features which are deemed salient by the Human Visual System. These salient regions are typically encoded as Saliency Maps in the computer graphics literature. The Top-Down mechanism is active when the user is performing a task and long term cognitive processes are used to guide the visual search pattern. The Models for this stimulus are based on task related goals, where this tasks is most likely to be visualised by a user. A common example is detecting fire safety equipment, where the visually important regions are the areas around fire extinguishers and safety signs. Again, this importation regions can be encoded into an image, known as a task map [Sundstedt *et al.*, 2005].

In this work, the goal is to apply the same concept to web page restructuring based on the web page content and its perceptual importance. We propose the concept of a task identification system that can successfully detect if a user performed a task, or if the user was just exploring the web page. Starting by identify what the user is doing on the web page, identifying the visual mechanism and then identify the areas that will most likely attract their attention. Based on this, the proposed system will enable real-time restructuring of web pages. This presents the most important content in the visually important areas of the webpage. Furthermore, this information may be used to develop a dynamic web site interface that adapts to the tasks, in order to improve web sites.

1.1. Objectives

This work aims to investigate the possibility to automatically, and in real time, restructure the web pages based on the user's actions. This will be accomplished by identifying the task that the user is performing, and combined with knowledge of the Human Visual System and visual perception, web pages will be re-arranged based on their visual and perceptual importance. This will be used to highlight the most important and relevant information of the website, and thereby making the website more efficient.

To achieve this we conduct an extended user study in the use of internet. This study will characterize and identify browsing patterns in order to verify that they can be associated with the two mechanisms of visual attention (Bottom-Up and Top-Down). Based on this study, a methodology will be proposed to automatically detect the task the user is performing. To support this concept, the proposed methodology will be implemented, and additional user studies will be conducted to support its validity. Lastly, to verify the possibility of using the method for automatic and real-time restructuring of web pages in order to improve their efficiency.

1.2. Thesis contribution

- We present a literature review, discussing relevant aspects of visual perception, and examining issues regarding the study of the human visual system when using web pages.

- We hypothesise that people use different visual patterns when completing different tasks on web pages, and obtain evidence through our experiments to support this theory.
- We propose a method for an automatic task identification system, as well its implementation. We assessed this method through experiments to verify its validity.
- We studied the possibility of applying the proposed methodology to real time web page restructuring based in the participants' tasks. Evidence was found that using this method it would be possible to improve the efficiency of web pages.

1.3. Possible applications

Being able to improve the efficiency of web pages in terms of the time that users take to complete a particular task, as well as the information that the user is able to assimilate, is one of the major goals of this work. Besides this, there are several practical applications for this concepts, like publicity, web commerce, and web assistance, amongst others.

The Web advertisement is a way of financing web pages and is a very important market in the Wold Wide Web. Global Industry Analysts predicts that World Wide Web advertising market will reach almost 73 billion dollars by 2015. The advertisements may be presented in different ways, as banners, pop ups, floating advertisements, amongst others. There are different ways to charge companies for the publicity in different web sites. Some companies pay for the number of times the advertisement is clicked, others by the number of times that the advertisement is presented. Using the concept presented in this work, by knowing which visual mechanism of the human visual system is active at a particular moment, it will be possible to identify the probability of the user paying attention to the advertisement and then charging the advertising company accordingly. One of the biggest problems regarding charging by the number of times that the advertisement is presented, is that it doesn´t represent the actually number of times that the advertisement is seen by the users. On the other hand, when users are performing a task in the internet they may only pay attention to the task related areas, and ignoring all the other information present. This information can be useful, because it can potentially save money for the companies that are advertising and the area that is occupied by publicity could be used to place more information regarding the task that the user is performing [Advertising, 2014].

Knowing what areas/products the user is looking for, in e-commerce web pages could also be used to improve efficiency and present important products in the areas the user is most likely going to look at. This way not only is information going to be placed in strategic positions on the site, but also all the data can be selected by its relationship with what the user is looking for (accessories, promotions, amongst others). Even if these approaches only lead to a 1 - 2% improvement in search efficiency, a growth of thousands of dollars may be observed, especially for large companies.

Web assistance is other field where this concept can be applied. There are companies that offer web assistance, sometimes presented as a pre-recorded answer for specific questions, sometimes even in real-time and using a real person's guidance. This assistance starts by identifying what a user is searching for, or what are his goals and then provide efficient answers and solutions in order that the user can reach his goal. Our work can be used to improve the identification of the users' goal by transmitting in real time the areas/information that is capturing the users' visual attention and/or his visual behaviour. With this, the assistance can be improved and provide the users with a better and faster solution.

Lastly, one has to consider the growth of internet access using mobile browsers and apps. In the US, this is already used more frequently than desktop browser access. This is a very important sector and search strategies should be, and are already being taken in consideration for mobile access to web services, information seeking, online commerce, and online advertisement, amongst others. For example, many websites have a mobile version for use with small screen devices. Due to the small screen size the information display and page design needs to be carefully planned and precise. The amount of information displayed is greatly reduced when compared with regular screens, therefore identifying the users' visual attention and the task that is being performed could help to improve the efficiency of the web sites as well for the apps [Mobile, 2014].

Outline of the thesis

Chapter 2: Provides information on the Human Visual System and specifically visual attention. This chapter presents the visual mechanisms used to capture a visual stimulus, including taxonomy and models of eye movements. Additionally, this chapter presents an overview of eye tracking. Furthermore, this chapter reflects on the Human Visual Perception when viewing Web pages.

Chapter 3: Presents a formally-designed psychophysical study that was carried out in order to determine the possibility of distinguishing a user's visual behaviour when she/he is simply exploring a web page or performing a task on the same web page. It was concluded that it is possible to distinguish if a user is completing a task or simply exploring a web page, according to their visual patterns.

Chapter 4: Presents a method to identify if a user is completing a task or simply exploring a web page and its implementation in a computer system. In addition a formally-designed psychophysical study shows that the proposed system is able to automatically detect if a user is performing a task or simply exploring a web page.

Chapter 5: Presents a formally-designed psychophysical study that aims at verifying if the proposed method can be used to rearrange the web page structure and visual content in real time, depending if the user is performing a task or freely exploring a web page.

Chapter 6: This final chapter presents the main results and contributions of this thesis and suggests future work.

2. BACKGROUND

The works focuses on effective presentation of the content on web pages in real time. This is essential to help the user to efficiently find relevant information. This can be achieved by changing the web page structure, rearrange the information, suggesting paths or improve a web assistant by identifying what information the user is looking for, amongst others.

However for a better understanding of the work presented in this document, one needs to understand several different areas including, the Human Visual System (HVS), visual perception and the visual perception on web pages.

2.1. Human Visual System

The physical structure of the eye is quite well known. This physical structure is made of a set of visual organs, without which Visual Information Processing would not operate.

Vision begins when light rays enter the eyes through the cornea, the transparent outer covering of the eye. These rays then travel through the pupil, the lens, the vitreous humour until they hit the retina which is located at the back of the eye. The retina is a light-sensitive layer which consists of rod and cone cells, which are named after their distinct shapes. Cones are concentrated in the centre of the retina, and in bright conditions provide sharp central vision and detect colours and fine details. Rods are located in the region from the outer edge of the retina to the centre area containing the cones. They provide peripheral or side vision. They also allow the eye to detect motion and help us see in dim light and at night. These cells in the retina collect the light signals and send them as electrical impulses to the optic nerve. Then the optical nerve sends these electric impulses to the brain where they are processed, thereby allowing an understanding of the scene.

Visual psychophysics, when the brain processes the electric impulse, can be affected by the limitation of the neurological substrate. There are many characteristics that can affect vision such as the range of the visual field, the frequency that the stimuli is presented, colour perception, amongst others. Although these attributes are regarded as limitation of the HVS, these limitations can be used to improve applications in a way such that a minimal amount of information is lost. Therefore, characteristics of the scene such as information location, the speed at which it is presented, whether if it has movement, luminance, chrominance and contrast, should be taken into account when sending visual stimulus because they affect the visual attention.

2.2. Visual Attention

Research into how human senses work can lead to a more comprehensive knowledge of human behaviour and expected reaction with faced with external stimuli. For instance, studying the main characteristics of vision, the visual pattern, the capability of visual depth, perceptual consistency, ability to identify patterns, the visual sensitive and the contrast.

When the user is exposed to an external stimulus (for instance a web page) the stimulus is processed and a response is generated automatically. This response is influenced by a large number of factors, such as type of stimulus, socioeconomic factors pertaining to the observer, age, gender, amongst others.

The HVS is selective and only a small part of the visual information captured is preferentially processed. Several researches have studied visual attention and its features

[Helmholtz, 1925], [Gibson, 1941], [Broadbent, 1958], [Deutsch, 1963], [Yarbus, 1967], [Noton and Stark, 1971], [Posner, 1980]. This research studied different aspects of visual attention, such as the attention targets (where the attention is focused on), how these targets are selected, how this information is filtered and also the influence of the tasks that the users were performing.

In 1980 Treisman and Gelad studied the feature integration theory, where they made breakthroughs in the models of human visual attention. In this study [Treisman and Gelad, 1980], they performed several experiments where the results suggested that visual perception is formed between parallel detections of visual targets and perceptual grouping. Usually these two ways of visual perception operate together, but is possible to show either of the two working independently. In the parallel detections of visual targets, perception occurs automatically and unconsciously. In this stage the object is processed by details such as shape, colour, movement, amongst others, with each aspect being process in different areas of the brain. In the perceptual grouping, the attention focused on the object and the individual features of the object are combined in order to perceive the whole object. To combine the individual features of the object the HVS creates a map of the location of the features. When attention focused on one point of the map, that feature is processed and created a piece of image of the full object. Then that specific image is processed with prior knowledge and with the intent of identify the object.

In 1983 the psychologist William James created one of the most popular definitions of attention. In his study he described the attention has the process by which the mind captures what seems the different objects and trains of thought. When this process occurs the mind only focus in some features the entire scene, improving the efficiency when processing those features [James, 1983].

In 1994, kosslyn et. al presented a model of visual attention which they describe as a selection filter of the perceptual processing. They proposed a “window”, which is responsible for the selection of the visual patterns [Kosslyn, 1994].

As in 2004, psychologists [John, 2004], discussed the existence of a series of bottlenecks, when visual attention becomes selective and choose only one at a time of the memory representation for further processing results in attentional bottleneck, in the human visual system. They showed that these led to information processing problems when there were several sources of information to be processed. In study conducted by Tombu [2011], they concluded the existence of a unified attentional bottleneck in different regions of the brain. These bottlenecks were exhibited when performing temporally limited different operations such as perceptual encoding and decision-making. Regarding the visual perception of a stimulus, a specific bottleneck in visual information is very evident. As stated in section 2.1 the cells that capture the fine details of a visual stimulus, as acuity of the visual stimulus are the cones, located in a very small part of the retina. This area is only capable of registering a small portion of the visual field, thus when we look at a certain region of the visual stimulus, processing will be concentrate in that specific area of the visual stimulus. The remaining of the visual field will receive only a small part of the visual processing capacity. For example, when reading a book, one processes each word rather than the entire page.

The process by which subjects' quickly move their eye position directly to important areas in the visual field is called Selective Visual Attention. The visual attention can be attracted automatically by the stimulus, by bottom-up or top-down mechanism, which depends on the context.

2.2.1. Bottom-Up

As in feature integration theory, which has served as a basis for many computational models of bottom-up attention deployment, the bottom-up mechanism automatically attract the visual attention to features of potential importance without the person making a conscious choice. It operates on the raw sensory input, and attention is involuntarily driven to the salient visual features [Itti, 2000]. One example is if one is walking in a dark environment and a light is switched on, people tend to automatically look at the light source.

Through the study of the HVS, is possible to determine the approximate ordering by which people tend to focus on regions in a scene. This information can then be encoded into an image, termed a Saliency Map.

Saliency Map

The first neurally-plausible bottom-up computational architecture was proposed by Koch and Ullman [Koch and Ullman, 1985], based on the idea of the existence, in the brain, of a specific visual map encoding for local visual conspicuity. A Saliency Map can provide information about salient, ie. visually important, areas that will attract one's attention in an involuntary way. This work is deeply connected to the integration theory, and from the work born the "Saliency Maps" concept.

In this study they defined the saliency map as an explicit two-dimensional topographical map which combines the information of individual topographical maps, standing for different dimensions, such as colour, orientation of edges, disparity, and direction of movement. The saliency map codes conspicuous details belonging to each feature dimension, at every location in the visual scene [Bessa, 2007].

Over the years, saliency maps have been the target of several studies, with particular emphasis on its computational models' architecture. Over time the different approaches to this became more specific and differentiated. The characteristics of topographical maps were divided, making it possible to distinguish more layers. In Figure 2.1, the architecture presented is based on the model by Koch and Ullman [Koch and Ullman, 1985]. This architecture provides the implementation of the feature integration theory.

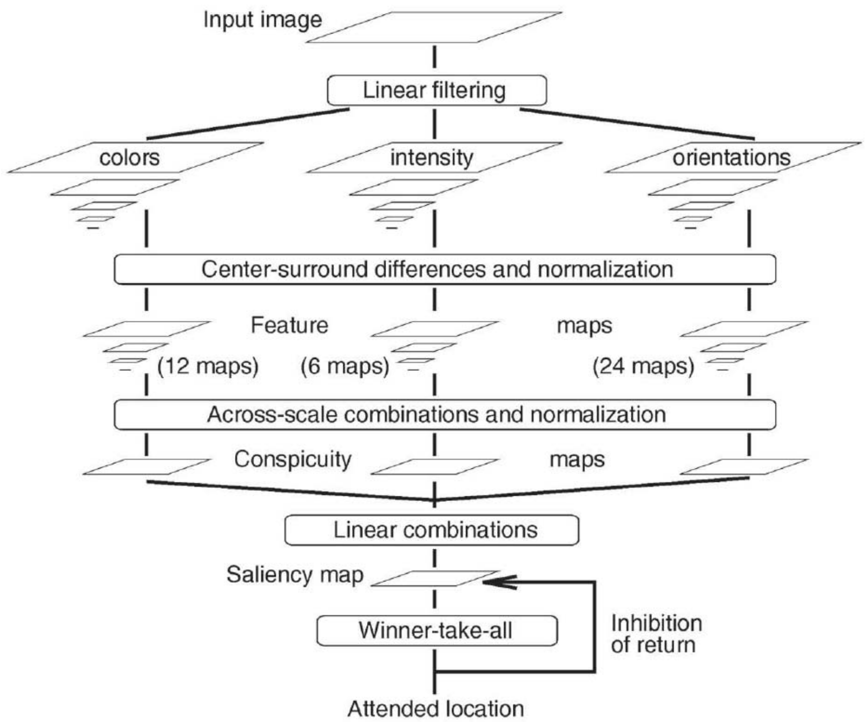


Figure 2.1. Itti and Koch computational model of attention. From [Itti *et al.*, 1998]

Saliency Maps are central to the architecture of several successful models of visual attention control based on Bottom-up mechanisms. The differences between these computational models are commonly found in strategies employed to analyse incoming sensory information for the construction of the saliency map. For instance in [Kock and Ulman, 1985], the visual input was computed in a parallel manner into a set of pre-attentive feature maps, and then for each point all the information from the different feature maps creates a topographic saliency maps. In the computational model by [Itti *et al.*, 1998] (Figure 1), the visual input is computed using a linear filtering at eight spatial scales.

In 1994 Wolfe, introduced a hybrid architecture to the models of visual attention, where he also considered that Top-down processes also contributes to the creation of the saliency maps. As the result of this architecture their method creates an activation map that “will guide the deployment of attention” [Wolfe, 1994]. The visual stimuli’s is processed in different channels generating the feature maps. In this feature maps, bottom-up and task related (Top-down) processes is also take into account. The sum of these features maps generates the Activation Map. Other models have also been proposed. For a more extensive review, please see [Itti, 2000].

2.2.2. Top-Down

As previously presented in the feature integration theory section 2.2, the visual stimulus can be processed automatically and unconsciously by bottom-up or top-down processes, using top-down process the visual stimulus is processed comparing with prior knowledge and with the intent of identify the object. The top-down mechanism is related to a subject's long-term cognitive strategies, where knowledge and context play a crucial role on how one selects where to pay attention to.

One of the best well known experiments was made by Alfred Yarbus [1967]with the observation of Repin's painting, “The Unexpected Visitor" (Figure 2.2). In this experiment he observed the fixations and the saccades of different participants when performing seven different tasks. Figure 2.2, presents three different gaze patterns from one subject. Figure 2.2b) shows the subject's gaze pattern when they were allowed to exam freely the painting. Figure 2.2c) shows the gaze pattern when the subject was asked to estimate the peoples' ages and in 2.2d) the subject was asked to remember the clothes worn by the people in the painting.

Figure 2.2. a) Ilya Repin. The Unexpected Return. 1884; b) the subject was allowed to examine Repin's painting freely. c) the subject was asked to estimate the ages of the people d) the subject was asked to remember what the people were wearing;

Yarbus showed that the way one perceives an environment depends on the socio-economic background and on the task that is currently performing in that environment [Yarbus 1967]. He stated that "the distribution of points of fixation on the object changes depending on the purpose of the observer", and "people who think differently also, to some extent, see differently". He also concludes that when subjects viewed complex scenes they use saccadic jumps (distances travelled between to fixations) between points of most interest.

This experiment has been one of the most cited to explain the differences in the Bottom-up and Top-Down mechanisms. In 2004, Lipps and Plez [2004], revised the Yarbus study and point out some aspects that should be considered; the primitive eye tracker, the conditions in which the experiments were conducted, the restricted movements, viewing times, painful optical stalks. All these aspects could affect the visual behaviour and the results presented in the paper. In this study they perform an experiment, conducted with 20 subjects, on the gaze patterns to verify the extent on which the results of Yarbus' study were affected by subject head restrains leading to variations on the oculomotor nerve behaviour. They conclude that the subjects' visual patterns were clearly task dependent as shown in study by Yarbus. However, the differences in the visual behaviour between tasks were less dramatic and they also verified that the time that the subject paid attention to the visual stimulus was considerably less. Despite this, they re-enforced the conclusion that eye movement patterns are influenced by high-level tasks.

2.2.3. Taxonomy and Models of Eye Movements

Almost all the basic movements of the eyes are the result of the combination of five types of movements: "saccadic, smooth pursuit, Vergence, vestibular and physiological nystagmus (small movements associated with fixations)" [Robinson, 1968].

The saccades are rapid eye movements which are used to reposition the fovea. This set of movements consists of reflexes and voluntary saccades. These can also occur as a response to the need to correct the position of the focus of the eye. The saccades have short duration, and make the subject effectively blind during the transition [Shebilske and Fisher, 1983].

The smooth pursuit eye movements are involved in the chase and search for a moving target. Depending on the speed of the target, the eyes are able to maintain a speed equal to the movement of the target [Grasse and Lisberger, 1992].

Vergence movements are used to focus the eye on a target at a distance. This movement enables the viewing / perception of depth. Other types of depth related eye movements, such as accommodation and adaptation, refer to non-positional features such as pupil dilation and focus.

The fixations are the focus of the retina on one object or target of interest of the visual stimulus. They are characterized by tiny eye movements: drift, tremor and micro-saccades. The fixations last between 150 milliseconds to 600 milliseconds. 90% of the time in which the HVS is capturing visual data is spent in fixations [Irwin, 1992].

The physiological nystagmus eye movements are related with saccades. In the case of Optokinetic nystagmus is necessary to compensate for the movement of the retina. The Vestibular nystagmus is a necessary move to compensate for head movement. These movements are fundamental to allow visual system to focus the target [Robinson, 1968], [Carpenter, 1977].

The main features in the analysis of eye movement are the identification of fixations, the Saccades and Smooth Pursuit. These three types of characteristics show us the voluntary movements of the subject's eyes, thus showing us visual attention. Fixations are used when we want to focus on a static target, saccades when we want to change the position of the focus of attention and Smooth Pursuit when we chase a moving target, and they all deliberate movements by the subject. One of the tools that allow the study of the user visual behaviour is the eye tracker.

2.2.4. Eye tracking

An eye tracker is a device for measuring eye positions and eye movement. Eye trackers are used in research on the HVS, in psychology, in cognitive linguistics, in product design, amongst others. Eye tracking is the process of measuring either the focus of gaze ("where we are looking") or the eye motion relative to the head.

The first studies related to eye movements were conducted through direct observation of the eyes. These studies raised some very important issues concerning the reading and visualization of images. Only at the beginning of the 20th century, Huey [1908], built the first prototype of eye tracker. In this study he also observed that not all words are read in order when reading a sentence.

After this demonstrated the different possibilities of studies that could be conducted with an eye tracker, the investigator Guy Buswell, created the first non-invasive eye tracker [Buswell, 1922]. With this technology, they conducted some studies on reading text and image visualization. In one of his studies [Buswell, 1922] he focused on reading, comparing mature adults and immature children. This allowed the evolution of reading to be investigated, including behaviours induced by reading and the effect of different teaching methods on reading ability.

In 1967, Yarbus studied the influences of tasks in visual patterns [Yarbus, 1967x2]. He showed that if the subject, when viewing a stimulus, is given task to perform, it will completely change the visual pattern. The examination of pictures "is dependent not only on what is shown on the picture, but also on the problem facing the observer and the information that he hopes to gain from the picture." This study was also conducted using a rudimentary eye tracker which implied that the subject was subject to some pain and some restrictions.

Later in 1980, Just and Carpenter [Just and Carpenter, 1980] formulated the hypothesis that the positions and durations of gaze fixations are related to information processing. New researchers use this hypothesis as granted, but it was just studied after a lot of reading and image processing studies (a good survey [Rayner, 1978]). It was also around this time that the eye tracking start to be used in the Human Computer Interaction, to gain an understanding how we interact with computers, and also to enable interaction by disabled users.

Through the 1980's, there were studies which challenged the Just and Carpenter [1980] hypotheses. Several researchers studied the differences between where the fixations and gazes were pointing and where the visual attention was focused. Eye tracking alone cannot lead to insights on the cognitive process, just the gaze patterns [Posner, 1980].

Despite the number of studies in this area, the cognitive processes that occur during a fixation on a particular object or place remain unknown. When a subject is fixing a car in an image with several cars, this can indicate different meanings, for example the subject recognizes the car, likes the car, dislikes the car, amongst many other possibilities. [Wright and Ward, 2008], [Hoffman, 1998], [Deubel and Schneider, 1996], [Holsanova, 2001]

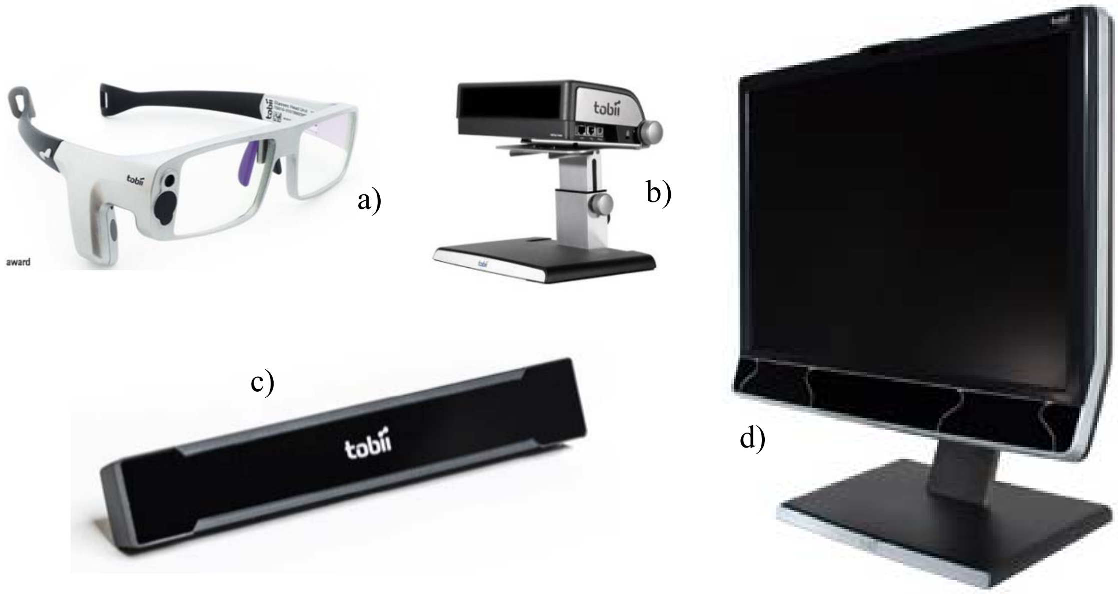


Figure 2.3. Different types of eye trackers. a) Mobile eye tracking - Tobii Glasses, b) Flexible eye tracking - Tobii X60 & X120, c) Tobii X2-60 Eye Tracker, d) Wide-screen eye tracking - Tobii T60XL. Images captured from tobii company web page [Tobii, 2013].

Nowadays there are several types of eye trackers, head mounted (Figure 2.4 a)), inside in the display (Figure 2.4 d)), some placed in a table in front of the user (Figure 2.4 b)), amongst others (Figure 2.4 c)). This newer hardware enables non-invasive studies to be performed with increased accuracy and efficiency. This can include performing eye-tracking without the subject being aware of what is happening. Furthermore it allows researchers to perform eye tracker studies in many everyday situations to better understand how the HVS works.

Applications

One of the fields where the eye tracking studies are most performed is web usability. Although the old techniques to verify the usability of the pages are quite important, most of the information that returned was the number of clicks, number of returns and number of times the page was scrolled. Utilising eye-tracking technology, a more detailed analysis of user interactions with the web page between mouse clicks can be performed. Specifically, eye tracking can be used to evaluate the efficiency of information retrieval, such as locating where the negative aspects are on a page, efficiency of online advertising, usability, navigation, overall design and many other components.

Other examples of studies using eye tracker are evaluate applications prototype, the visual attention when driving, study the actual site of a company or any life experiment using the eyesight.

An alternative to Eye tracking – Mouse tracking

Mouse tracking is the study of mouse' movements and clicks over one object (web page, application, amongst others). From the data gathered by this study it's possible to observe the interaction between the user and the correspondent object.

As both eye and mouse tracking have similar goals, both allow the generation of the task map (hotspots) of where the subjects navigated pages, this permits the methods to be directly compared. However, although they permit the same visualization does not mean that they exhibit the same results. Studies have been performed to compare both systems. These approaches investigated correlation values when users perform tasks in web pages. These values can range from 32% [Rodden *et al.,* 2008], 42% [Rodden *et al*., 2007], 69% [Cooke, 2006], or from 84% to 88% [Chen *et al.*, 2001].

The big question is: can the mouse tracker be used to replace the eye tracker? Mouse tracking has an advantage of being able to run without the user being aware, and thus is more realistic when people are surfing the internet. On the other hand, eye trackers are very expensive and can have some head limitations. Regarding the data retrieval from these methods, with the eye tracker there is access to data that would not be possible to collect from mouse tracking. The type of study, the variables that are to be studied, and also the significance of the study determine the hardware that we should use.

2.3. Visual Perception on the Web Pages

Recently, studies have been conducted on human visual behaviour when browsing web pages. Many researchers have focused on the topic of Internet search using search engines. Lorigo *et al.* [2008] studied the online search, describing what knowledge that could be retrieved from the experience and the difficulties encountered. Comparing different search engines, they concluded that the metrics they used did not show significantly different values, thus asserting that visual processing and the complexity of reasoning are similar between search engines. They also concluded that the SERP (search engine results page), affects the visual behaviour. However, there were no significant differences in the success factors, time taken to perform the tasks, number of fixations and number of clicks. The individual's satisfaction in relation to search engines differs due to subjective preferences of the individual. As the main difficulties identified when performing this study were interpreting the data gathered with the eye tracker, the difficulty of analysing the interaction between individuals and search results, and the difficulty of integrating the eye tracker studies with usability studies. The lack of feedback and analysis of the success of the task limit the types of studies that can be performed with eye trackers.

In 2004 a study was conducted where Granka *et al.* [2004] analysed the behaviour of individuals when conducting web searches to observe how they interact with the web page and the results they get from the search. Taking as a reference the time it takes for individuals to select a pre-determined link, this study demonstrates the complexity of the mental process involved in choosing the link, as well as the complexity of the information that is displayed. The order, search results are arranged, is related to the time that individuals give "attention" to them. Thus, the search is automatically restrained to the behaviour of the search engine and the way it presents its results.

Jansen and Pooch conducted a literature review of studies that have addressed the issue of Internet search engine results [Jansen and Pooch, 2001]. Initially they developed a survey which analysed all studies related to Internet search. Failing to directly compare the search engines, due to differences in the structure of the web pages, they used other information to verify if the concept of an information search on the Internet is universal. This compared the response time, number of responses, number of searches and information available. They concluded that despite the portals are different and the technology used in each is different, the concept of Internet search is universal. However, the researchers added that is necessary to standardize the metrics used to perform these types of studies on the Internet so that they become more conclusive and easier to facilitate comparisons.

Hsieh-Yee [2001] conducted a study on human visual behaviour during the development of research on the Internet, including a literature review from 1995 to 2000 where he summarised all the studies regarding children and adults visuals' behaviour. Most studies which focused on children's visual behaviour only described their interaction with the web. In the studies pertaining to adults, the main objective was to describe the visual patterns. Other factors in visual behaviour have also been investigated, including the organization of information and its presentation, the type of search task, the web experience, cognitive skills and affective state (experience of feeling or emotion). What distinguishes research in adults from children is the use of multiple methods of data gathering. Research on visual behaviour in web search requires that there be a commitment for the users perform the tasks in experimental conditions and requires a rigorous design and data analysis. Although these studies have an increasingly rigorous objective, there still exists a lack of acceptance of them as well as their validation.

In an experiment to establish if the difference in age groups influences the success in conducting research on the Internet, Bilal and Kirby conducted a study with adults and children [Bilal and Kirby, 2002]. In this study, they conclude that research on the Internet is affected by: the cognitive ability of users, affective state, and physical condition; variations in these leads participants to give differing answers depending on the task. The main results of this study highlight the ability of adults reformulate the search when faced with an impasse, the type of navigation used across pages and concentration while performing a task. The cultural experience of adults is one factor that distinguishes them from children, resulting in a higher success rate.

To investigate how people search for information when the best search result is not at the top, Guan et al, conducted a study using an eye tracker. They tried to determine what the most important areas were when seeing the results of a web search. The analysis showed that the performance decrease for searching for information is the result of: the decreased chance of willingly looking at lower down search results and/or the possible reliability in the ranking of search results of the search engine, although people may clearly see the other results in lower positions. People are more likely to depreciate their own sense of objective relevance and conform to the classification established by the search engine [Guan and Cutrell, 2007].

In addition to the studies conducted on the online search, a few studies have focused on the usability and interactions with web portals. Jacob and Karn conducted a study where they validate interaction and usability studies between subjects and a Web page, based on the results extracted from an eye tracker [Jacob and Karn, 2003]. The main conclusion is that is possible to use the eye tracker to perform these studies but they observed some difficulties in interpreting the data from the eye tracker. When performing studies using eye trackers the goal of the study will affect how the variables are analysed. For instance, the analysis can be made either top-down, or bottom-up. The top-down are based in the cognitive and task related studies. The bottom-up relays only in the observation of data without taking into account the cognitive knowledge.

Pan *et al*. [2004] studied the importance of human visual behaviour in Web pages, through the analysis of the order in which pages were visited and their complexity. They concluded that the human visual behaviour when viewing Web pages is the result of the order in which pages are displayed, by the subjects' cognitive knowledge and also the relationship between the sites visited. The results of gaze pattern (individuals' visual path when viewing a visual stimulus) have shown relations between the different subjects' visual behaviour and the structure of web pages.

Poole and Ball [2006] studied the usability and interactions between humans and computers using an eye tracker. With the results gathered with an eye tracker it's possible not only to quantify the interaction of subjects with the computer but also to obtain other information as its significance when relating that information to the Web pages. Analysing different studies in the field, they identified variables and factors that indicate not only the time it takes individuals to perform specific tasks, but also to determine the task complexity, the difficulty of information retrieval, the type of Web pages structure, among others. With the knowledge of the interaction between human and computer, as well as information that can be extracted from this type of study, it becomes a very important tool for exhaustive analysis of the systems usability, as well as the effectiveness of the used information technologies/structures.

The Internet is an extremely important place for sociology researchers for testing theories of technology diffusion and the effects of the media, especially because it is uniquely capable of integrating different media and different forms of content.

DiMaggio *et al.* perform an analysis of studies by different sociologists found on the internet where a recurring theme in many areas is that the Internet tends to complete and not replace existing devices, or behaviour patterns. Furthermore, in each domain the social implications of this new technology depend on economic decisions, and legal policies that are shaping the Internet and making it institutionalized. Sociologists need to study the Internet more actively and, above all, synthesize research findings on individual user behaviour with detailed analyses of institutional, political and economic factors that might influence it [DiMaggio *et al.*, 2001].

In a study conducted in 2001 by Bilal and Kirby they examined the success and information seeking behaviours of science students from seventh grade and graduate students in information science using Yahoo. Although graduate students have more success in finding the answer to the search task, and were more efficient in their use, they shared an information search behaviour common to children. The main factors that contributed to the differences in the pursuit of information between the two groups were: the ability to recover after an error, the navigation style and concentration on the task [Bilal and Kirby, 2001]. Moreover, Habuchi *et al*. conducted a study in which the aim was to investigate how the web browsing experience influences behaviour when viewing web pages. They used a detailed questionnaire to measure the web browsing experience from users and also analysed visual data using an eye tracking. This study found that previous experience of web browsing forms an effective visualization method or mental model of how to browse a Web page, increasing the efficiency of web browsing [Habuchi *et al.,* 2006].

Regarding comparisons between different users performing tasks online, Feusner and Lukoff, [2008] conducted a study where they define a mathematical formula to do statistical analysis on the differences in the visual scanpath obtained from users. Initially, based on the study of Salvucci and Anderson [2001] to detect differences in the viewing patterns of users (by area), this method was also used by other investigators [Holmes and

Josephson, 2002, 2006], [Pan *et al*. 2004], [Myers, 2005] [West *et al*., 2006]. In a second phase, they estimate the statistical deviation between the two groups, using their formula. As a main conclusion, they note the importance of doing the statistical analysis on the scanpath, in addition to the visual analysis. This allowed them to distinguish differences between visual behaviour of the group and the differences caused by random visualization variation [Feusner, 2008].

Browsing patterns

Fu *et al*., [2001] proposed an approach to reorganize web pages based on user access patterns. Their proposed methodology consists of three stages, pre-processing of the page, rating, and reorganizing the site. In the pre-processing stage, the pages were analysed to create an internal representation of the web page and the user's web pages navigation path (navigation between the different web pages) were extracted from the server. In the classification phase the researchers classified the pages into index pages and content pages. This classification was based on information gathered in the first phase. Finally, during the reorganization, the web site is examined to find better ways to organize the pages. In their tests, they concluded that this method was effective and practical to adapt the structure of the sites.

Different web sites offer different services to their customers. It is therefore inevitable that some of these customers have immediate access to desired information, while others will have to follow some links to get the information. Consequently the growth of the web site complexity, even for the customers who got the information very fast, they begin to be forced to go through several links to get it.

Doerr *et al*., [2007] described a system that analyses the data collected from a server to see what opportunities exist for improving the navigation of a site In their system, an administrator must manually enter a default query that is used to find issues with navigation. As shown in Figure 2.5, this system tracks and finds nodes that could be irrelevant, and with it remove it could be possible to improve the navigation.

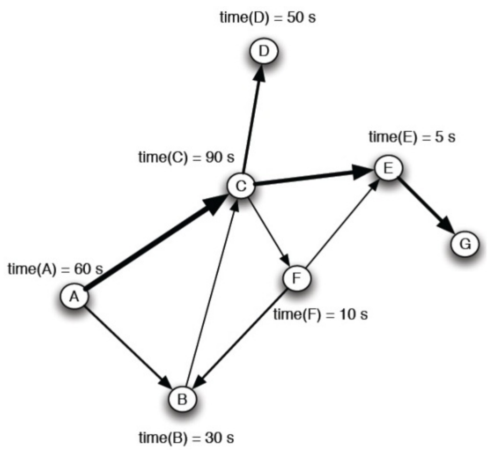


Figure 2.4. Irrelevant node: All users leave node E always towards node G with little average time spent within E - this node is likely to be irrelevant [Doer *et al.*, 2007].

Due to the evolution of technology and the Internet, the number of web pages has increased significantly in recent years. Web development has an important role in not only creating content, but also providing efficient and easy-to-use web pages. An important aspect in the development of a web page is to plan how the pages will be connected and how therefore the layout of the navigation path. In a study performed by Gillenson *et al.* [2000], they defined a taxonomy for web navigation between the different web pages in a website and its structure. They used this taxonomy to perform complex studies on features of the navigation between different web pages. This allowed them to verify if the web page is well built. This study also points to the ramifications of the main web page structures, which allow the user to jump between different branches' web pages from one big company. They also describe how efficient navigation and web page structure can prevent the user getting lost in the web page and therefore become more efficient when browsing.

Niu *et al.* [2002] conducted a study where they state that pattern mining was a promising approach to make it possible for administrators adapt websites and better serve consumers. Assuming that previous navigation paths made by other users is an indicator of the interest of the new users, then the recording of the navigation through a servers logs can be used to guide future customers. Under this assumption, a navigation aid can be automatically generated for new visitors. In this study they analyze data mining for dynamic adaptation of web sites. This approach is only valid for web pages that offer information on a specific theme and are well defined. However, this approach cannot be used for when users are exploring a site. The data mining process was based on three stages. In the first phase, information from the server logs was analysed and compressed to eliminate redundant errors and identify user sessions. The second stage uses the algorithm to retrieve the desired patterns. Finally these patterns are used to generate recommendations for other users who are browsing the same pages.

There have been other studies to improve structure on web page navigation and navigation patterns for further knowledge, please see: Eirinaki and Michalis [2007] and Ikumi *et al.* [2007]

Previously Gonçalves *et al.* [2011], studied if when users perform different tasks in the internet they use the same visual patterns depending on the task and on the web page where they perform the Task. In this study was presented an experiment using an eye tracker where the user visual behaviour was observed to verify the similarities and the differences, when performing different tasks in the internet. After recording all the user data, a statistical analysis was conducted. On this analysis was observed clear differences in the saccade rate when comparing the four different tasks': searching using search engines, online shopping, exploring a site and search in a company site. It was also verified that the saccade rate didn't depend on the web page where the task was realized. To validate the statistic data it was also presented the gaze maps, showing the visual patterns, where it can be seen the differences in the visual patterns, depending on the tasks that the user was performing.

Web analytics applications

Web analytics, sometimes mistaken as tools just for web traffic analyses, are tools that allow data measurement, collection, analyses and generates reports. These tools are used not just for web optimization but also to understand how the web pages works, what web pages were visited, if the ads were clicked, if the web pages is being profitable, amongst others. Companies and e-commerce web pages are the main users of web analytics tools. These tools are used to improve the efficiency of the web page and at the same time the visibility/advertising trough out the Internet.

One of the most known and widely-used applications [Rank, 2012] on web analytics is the Google Analytics [GoogleAnalitcs, 2012]. This tool offers the users detailed reports on websites' activity. Developed for marketers this tool allows sites owners to analyse their sales, review product banners to improve efficiency of the sales, improve the advertising on other web pages, amongst other. Mainly used for e-commerce this tool allows the integration of Google AdWords and Google Analytics Content Experiments, using just one control panel, the marketer, can cross information of this 3 application and significantly improve the web page and business behind it. Other related web analytics applications are BuiltWith [2012], ClickTale [2012] and Moat [2012].

Founded in 2007 in Sidney, BuiltWith became the second more used web analytics tool in the Internet. This tool includes "widgets, analytics, frameworks, content management systems, advertisers, content delivery networks, web standards and web servers…" [BuiltWith, 2012]. As Google analytics being developed for marketers, bring a sales intelligence market analyses tool to improve the business. For developers it includes an API for report personalization and with the possibility to adapt the web analyses to each type of business.

One application that analyses a subject's internet navigation is ClickTale [2012]. This application uses mouse movements and positions to create heat maps of where the user placed the mouse. The path through the web pages visualized is also tracked by changes in the URL of sites being visited. Despite the fact that the application records and saves the user's mouse navigation the information retrieval and the results of the analyses only are obtained / generated later. This means that the system is not useful for real-time applications.

Brand analytics by Moat [2012] is an application that studies advertising in a web page by trying to understand how a consumer pays attention to it in a web page. They study and analyse a series of 27 different metrics regarding to the users attention on advertisements. "These metrics focus on who's viewing the ad impressions and for how long, as well as whether you've engaged in any sort of interaction (did you click on something? roll over a photo gallery? play a video? listen to music or a podcast?) and how much time you spent doing so" [Moat, 2012]. With this approach they offer a new way of studying the visualization of advertisements through the analysis of human visual perception.

2.4. Summary

This chapter presented a background on the human visual system, visual perception and human visual attention when browsing web pages. The key structure of the human eye and it's functioning when receiving a visual stimulus was explained. Furthermore, this section described models of attention, namely the bottom-up and top-down models, and these influence how a visual stimulus is perceived and processed.

A review of the key studies on human visual attention when browsing web pages was presented. Applications and recent developments regarding web analytics were also presented to provide a better understanding of the work in this thesis.

3. WEB TASKS CLASSIFICATION

In previous research a study was conducted [Gonçalves, 2011], as described in chapter 2, that observed clear differences in the human visual system when performing different tasks. Although it is possible to state that the user's visual patterns when performing different tasks are diverse, the type of task the user is performing is unclear.

In the study of Pan *et al.* [2004], they considered that the categories of tasks users perform on the Internet consist of free exploration, search for information, reading an informational page (newspaper) and searching through search engines. They selected one page of each type to examine task. Although our previous study based our tasks / methodology on the study of Pan et al. [Pan *et al.*, 2004], we consider that first step is to distinguish whether the user is freely exploring a Web page or performing a task, considering that the tasks online all boil down to the mental process of search/finding information or else free exploration.

Therefore two approaches are presented in this chapter to detect the possibility of distinguishing a user's visual behaviour when she/he is simply exploring a web page or performing a task on the same web page and the two case studies that were carried out to validate the approaches and see if they are effective or not.

3.1. Web tasks classification based on the dominant visual mechanism identification

Visual attention is controlled by two main mechanisms, namely: Bottom-up, where one's attention can be captured involuntary through a visual stimulus, and Top-down where one's attention is captured depending on the task that is being performed and where all the long-term cognitive strategies take a real and important role [Yarbus, 1967].

Based in the Yarbus's research, we wanted to study if we could use the visual mechanism to identify if a user is performing a task or simply explored a web page. As described in Chapter 2 the saliency map model proposed by Itti *et al.* can identify the more salient regions of an image. As the bottom-up mechanism is driven by the salient stimulus our approach consists of the different percentage levels of the visual pattern matching with the saliency map. We planned to verify if it is possible to both quantify and distinguish if the users are accomplishing a task or just exploring the website.

To accomplish this we conducted an experiment with subjects whose visual patterns were recorded while performing a task or freely exploring in different web pages. These visual patterns were then compared with the computed saliency maps of each of the web pages.

3.1.1. Hypotheses

If there is going to a be difference in the level of similarity between the visual patterns and the saliency map we intend to verify if it is possible to both quantify and distinguish if the users are accomplishing a task or just exploring the website. For this experiment we considered the following null hypothesis:

H0: *The percentage of the image matching the visual pattern in the saliency maps is the same*.

3.1.2. Metrics

The main metrics used in eye movement research are: fixations and "saccades", which in turn occur between anchorages. There are also several metrics derived from these key measures, including the size of the "gaze" and the distance travelled, known as "scan path". Aspects such as the dilation of pupils and the number of times that the subject blinks his/her eyes are also possible objects of study [Salvucci and Goldberg, 2000].

In this experiment we have selected the metrics corresponding to the fixations: the points where vision focuses. With these fixations, the eye tracker software automatically generates hotpots, thus creating a “heat image” as to where the user was focusing. By using this metric, we can observe and verify the differences in the viewing patterns. This can provide a quantitative measure concerning the dispersion of the visual field.

3.1.3. Participants

This test consisted of 16 participants who were all University students. This set comprised 8 female and 8 male participants. The participants’ average age was between 22 and 25 years old. 10 of the participants had normal vision and 6 had corrected to normal vision. All the participants use the Internet on a daily basis.

3.1.4. Conditions and Procedure

All experiments were conducted individually and in a controlled environment. The room was equipped with a Computer and an eye tracker (Tobii X50), in combination with Clear View 2.0.1 software [ClearView, 2011] to collect eye movements’ data. The experiments were displayed on a 17” screen with a resolution of 1024 × 768 pixels. At the end of each task, the application automatically saved all the information. All the saliency maps for each web page tested were generated using the Ezvision software [Ezvision, 2011]. To analyse the data provided by the eye tracking system and the saliency map we used MatLab.

The experiment comprised six different tasks in three different websites namely: online journals (Figure 3.1. c)), e-commerce (Figure 3.1. a)) and company websites (Figure 3.1. b)). All participants performed one task in each type of website.

The assigned Task and websites were:

- Task 1 (T1): Explore a newspaper web page [Expresso, 2012];
- Task 2 (T2): Find specific news on a newspaper website [Expresso, 2012];
- Task 3 (T3): Search for specific publicity on an e-commerce web page [Miau, 2012];
- Task 4 (T4): Explore an e-commerce website Miau [Miau, 2012];
- Task 5 (T5): Explore a corporate website Microsoft [Microsoft, 2012];
- Task 6 (T6): Search for a specific web page on a corporate website [Microsoft, 2012];

Figure 3.1. The web pages used in the case study. a) Miau Ecommerc Web page. b) Microsoft Company web page. c) Expresso online journal Web page.

All these tasks were performed in well-known websites. After completing the tasks, the participants answered a short survey to collect their information such as age, gender, eyesight conditions and web navigation experience.

3.1.5. Results and Discussion

In order to verify the integrity of the information collected by the eye tracker, the existence of outliers in the data was investigated. Based on this, since there were some missing data from the visual patterns caused by some user's behaviour when performing the tasks that affected the eye tracker's ability to capture their data, it was decided to remove the data of subject 7 from T1, the data relating to subject 12 from T3, the data relating to subjects 2 and 7 from T4, and the data relating to the subjects 2, 5 and 7 from T5. After this outlier removal, the data was analysed to see if differences in the subjects' visual patterns corresponded to the Saliency Maps or not, H0.

In order to accomplish this we computed the saliency map, Figure 3.2 b of the original web page, Figure 3.2 ‘a’ using Ezvision software [Ezvision, 2011] and then we used MatLab to generate a dichromatic (0 or 255 pixel value) image of it, Fig. 3.2 c. The hotspots image obtained from each user’s visual patterns, Fig. 3.2 d, was also converted to a dichromatic image with MatLab, for example Fig. 3.2 e. After generating all images a comparison was made between the dichromatic images of the saliency maps, Fig. 3.2 c and the hotspots, Fig. 3.2 e.

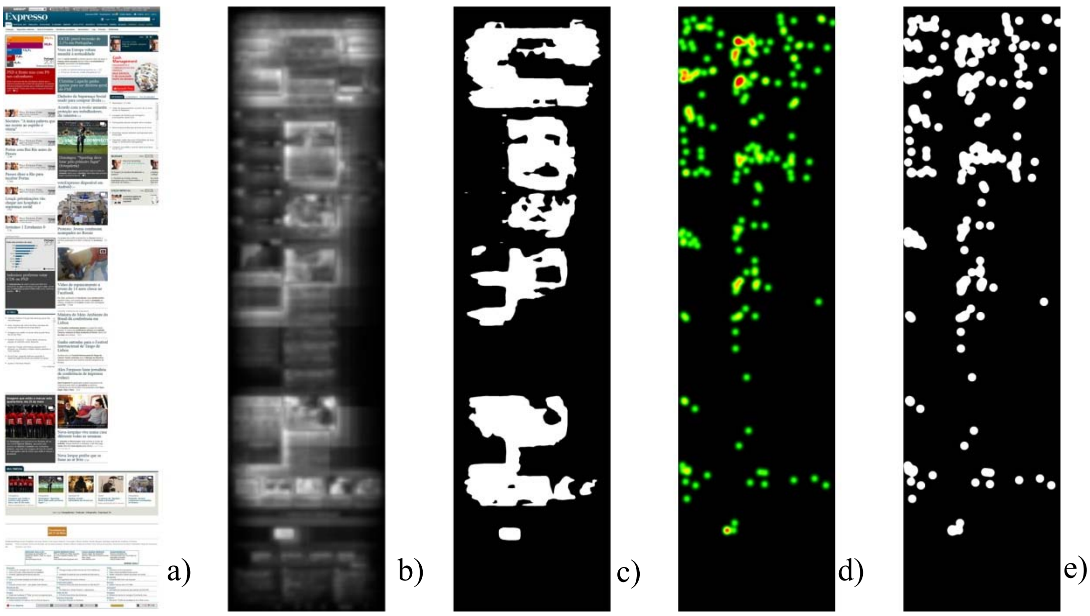


Figure 3.2. Example of the images used to compare the visual pattern of subject number six with the saliency map of a web page. a) Original web page image, b) Saliency Map generated using Ezvision, c) Dichromatic image generated in MatLab from image b), d) Hotspot image from user visual patterns and e) Dichromatic image generated in MatLab from image d).

From this comparison we considered two variables: the percentage of hotspots that are also saliency points and the percentage of hotspots per page. This process was repeated for the six different Tasks, to test the null hypothesis, H0.

Although the numeric data, using the Kolmogorov-Smirnov test was checked whether the data followed a normal distribution or not. Since the data didn´t follow a normal distribution the nonparametric Mann-Whitney Test was used.

Asymp. Sig. (2-tailed)	% hotspot in salmap	% hotspot/page
Web page 1 (t1 vs t2)	0,000	0.000
Web page 2 (t3 vs t4)	0,001	0,001
Web page 3 (t5 vs t6)	0,030	0,003
Explore / Task	0,000	0,000

Table 3.1. Nonparametric Test (2 Independent Samples)

As can be seen in Table 3.1, for the comparisons between exploring a web page and completing a task on the web page 1, web pages 2 and 3 have a significance level less than 0.05, rejecting the null hypothesis. This indicates significant differences in the percentage of saliency map covered by the users' visual patterns when performing a task or exploring a web page. In addition, when comparing the task, independently from the web page, the significance level is less than 0.05, also rejecting the null hypothesis.

The statistical analysis have shown that there are distinct differences in the percentage of a user's visual patterns that overlaps with the web page saliency map, Fig. 3.3. In addition, we also considered the hypotheses that if a salient region of a web page, is related to the task that a user is performing, and, if the users' time to complete the task was very short, then the user's visual patterns were analogous to the saliency maps when exploring the web page. We therefore analysed the percentage of hotspots per page considering the following null hypothesis:

H0: *The percentage of hotspots per page is the same*.

The comparisons show that the percentage of hotspots per page when exploring a webpage or completing a task have a significance level less than 0.05. Thus the null hypothesis is rejected indicating significant differences in the percentage of hotspots per page.

Furthermore, when comparing the task independently from the web page, the significance level is also less than 0.05. The null hypotheses is also rejected for the percentage of hotspots per page. As previously presented, the bottom-up mechanism is related with the saliency maps, therefore these results suggest there are clear differences in the dominant visual mechanism (bottom-up or top-down) when the users were completing a task or exploring a web page.

Figure 3.3 shows the images of the hotspots generated by the participants' visual patterns while exploring a web page and completing a task for each website. A similar kind of behaviour was observed in all participants. One can see clear differences in the dispersion and the number of fixations when the user is respectively exploring (Fig 3.3: 1.a, 2.a, 3.a) and completing a task (Fig. 3.3: 1.b, 2.b, 3.c). This information supports the statistical information previously presented.

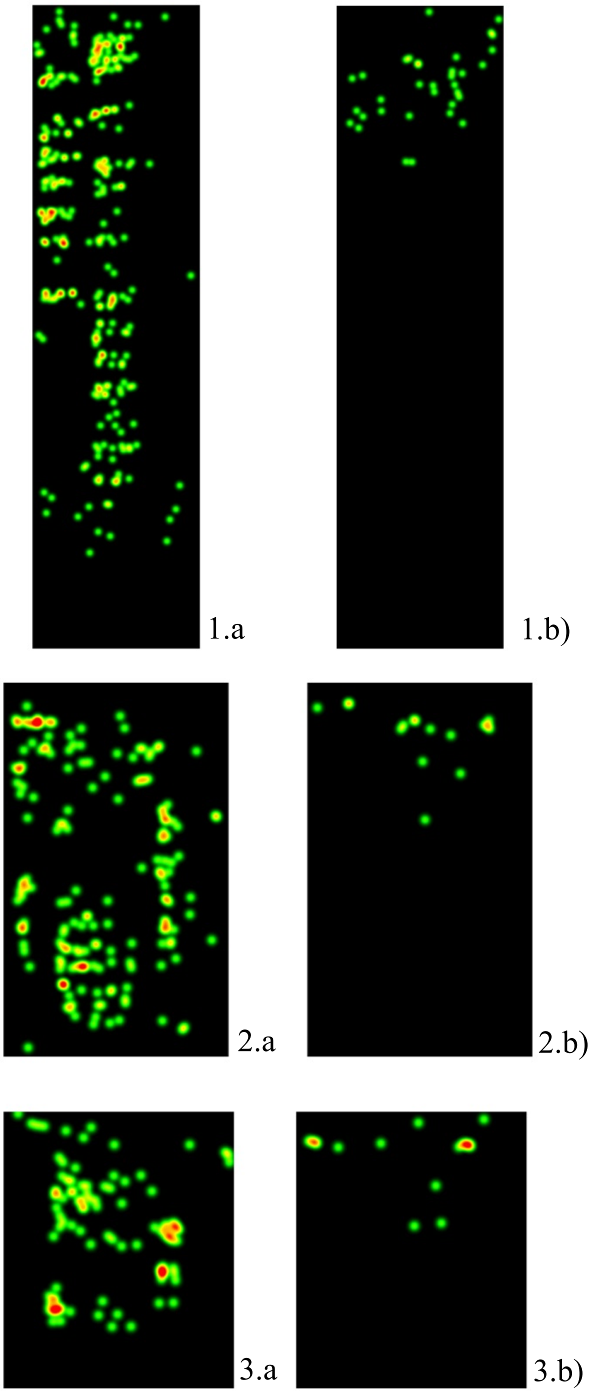


Figure 3.3. 1.a) visual patterns of one subject while exploring in Expresso; 1.b) visual patterns of one subject while performing a task in Expresso; 2.a) visual patterns of one subject while exploring in Miau; 2.b) visual patterns of one subject while performing a task in Miau; 3.a) visual patterns of one subject while exploring in Microsoft; 3.b) visual patterns of one subject while performing a task in Microsoft. The disparity of the images height and width results from the need to represent the complete web page.

3.2. Web tasks classification based on saccades distances

The previous section presented a study that observed clear differences in the percentage of hotspots when the user was performing a task or simply exploring a web page. Although it is possible to verify differences, our goal was to obtain quantitative data that allows us to make this distinction automatically. Therefore we observed the user's visual patterns when completing a task or freely exploring a webpage with the aim of identifying some distinctions that could solve our problem.

After reviewing the footage recorded in the previous experiments, some empirical evidences was observed of differences in the distances between fixations.

Figure 3.4. Gaze maps collected from Clear View. a) visual patterns from a user freely exploring Expresso Newspaper, b) visual patterns from a user performing a task in the Expresso Newspaper.

In figure 3.4 the blue dots represent the user visual fixations in the web page when in a) the user was freely exploring the web page and in b) other user was completing a task. The different size of the fixations represent the time that the user stay fixed at that point. As it can be seen, the distances between the different fixations are of different sizes. In Figure 3.4 b) when the subject was completing a task the distances travelled between fixations are bigger than the distances between fixations on figure 3.4.a) when the subject was exploring a web page. From this observation more research was conducted and by studying the saccades in the visual patterns it was observed that were some distinct characteristics. Therefore this section describes a case study that was carried out to verify if it is possible to both quantify and distinguish if the users are performing a task or just freely exploring the website based on the saccades.

3.2.1. Hypotheses

We present an experiment to investigate the possibility of distinguishing the user's visual behaviour when she/he is simply exploring a web page or performing a task on the same web page. To accomplish this we conducted an experiment with subjects whose visual patterns were recorded while performing different tasks in different web pages. From the visual patterns, the distances and durations of the saccades were calculated.

Based on the different distances of the saccade of the visual pattern we planned to verify if it is possible to both quantify and distinguish if the users are accomplishing a task or just exploring the website. For this experiment we considered the following null hypothesis:

H0: *The Mean saccades distance of the users visual patterns while performing a task and exploring a webpage is the same*.

3.2.2. Metrics

As presented in the previous chapter the main metrics used in eye movement's research are: fixations and saccades.

In this experiment we have selected the metrics corresponding to the distance and duration of a saccade. The aim of most of the saccades is to move the eyes to the next viewing position. Using this metric, it is possible to identify differences in viewing paths because it provides a quantitative measure of the visual behaviour providing with the distance travelled through the entire test, or the distance variance between fixations. From this data, the processing complexity of the task the user is performing can be inferred [Salvucci and Goldberg, 2000].

3.2.3. Participants

In this experiment 41 participants took part, who were all University students. Only 38 of the results were considered valid, i.e. without having any missing data. The set comprised 20 male and 18 female. The participants' age range was between 17 and 38, with 25 years old average. 28 of the participants had normal vision and 10 corrected to normal. All the participants use the Internet on a daily base.

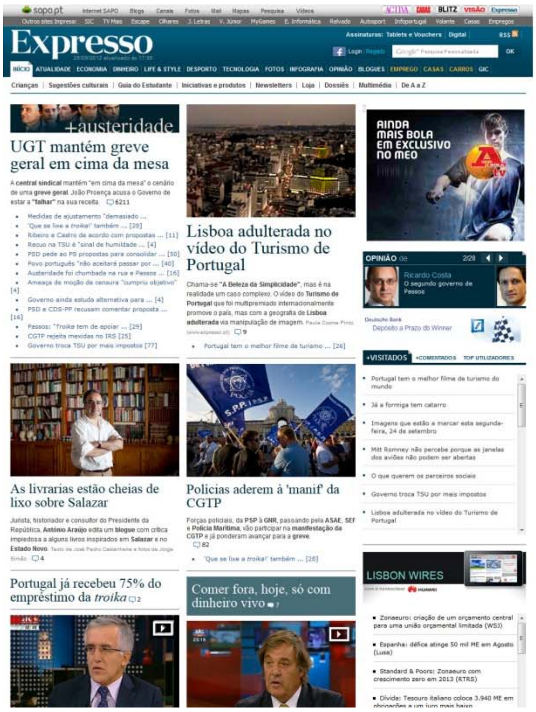
3.2.4. Conditions and Procedure

All experiments were conducted individually and in a controlled environment. The room was equipped with a Computer and an eye tracker (Tobii X50), in combination with Clear View 2.0.1 software [ClearView 2011] to collect eye movement data. The experiments were displayed on a 17" screen with a resolution of 1024 × 768 pixels. At the end of each task, the application automatically saved all the information. The statistical analysis software, SPSS 17.0 Statistic [SPSS 2012], was used to analyse the data provided by the eye tracking system.

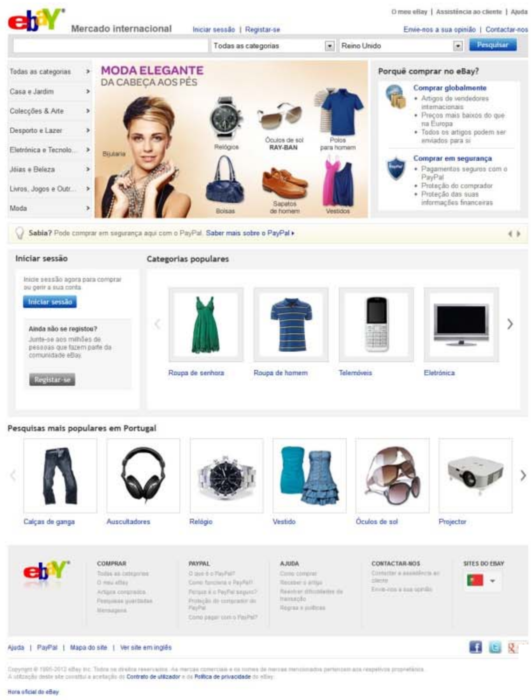
The experiment comprised 2 different Tasks in two different websites namely: Ebay e-commerce website (Figure 3.5 a)) and the online Expresso newspaper (Figure 3.5 b)). All participants performed one task on each type of website. The assigned Task and websites were:

- Task 1 (T1): Explore a Ebay web page [Ebay, 2012];
- Task 2 (T2) Find specific object on Ebay web page [Ebay, 2012];
- Task 3 (T3): Explore a newspaper web page [Expresso,2012];
- Task 4 (T4): Find specific news on a newspaper website [Expresso, 2012];

These tasks were performed on well-known websites. After completing the tasks, the participants answered a short survey to collect their information such as age, gender, eyesight conditions and web navigation experience.



a)



b)

Figure 3.5. The Web pages used in this case study. a) Part of the online Expresso Newspaper. b) Ebay e-commerce website

3.2.5. Results and Discussion

In order to verify the integrity of the information collected by the eye tracker, the existence of outliers in the data was investigated. Based on this, since there were some missing data from the visual patterns caused by the user behaviour when performing the tasks that affected the eye tracker's ability to capture their data, it was decided to remove the data of participant 13, the data from participant 38 from t3 and from participant 1 from t4.

After this outlier removal, the data was analysed to see if there were differences in the subjects' visual patterns when comparing the mean saccade distances between tasks, H0.

In order to accomplish this, first the Saccade Distances were calculated that is the distance between to fixations. Next, the Mean Saccade Distances between the different tasks in each web page was compared and also just between the same tasks in the different web sites. To normalize the data, the Mean Saccade distances were divided by the time participants took to perform the task (Task Time) and comparisons were performed between tasks and webpages.

The Kolmogorov-Smirnov test was used to verify whether data followed a normal distribution. Although following a normal distribution, as the sample size in each independent group was less than 30, the Independent-Samples T Test was used.

Asymp. Sig. (2-tailed)	Mean Saccade Distance	Mean Saccade Distance per Task Time
Web page 1 (t1 vs t2)	0,000	0,000
Web page 2 (t3 vs t4)	0,001	0,000
Explore vs Task	0,000	0,000

Table 3.2. Parametric Test (2 Independent Samples).

As can be seen in Table 3.2, for the comparisons between exploring a web page and completing a task on the web page 1, web pages 2, regarding the Mean Saccade Distance and The Mean Saccade Distance divided by the Task Time, have a significance level less than 0.05, rejecting the null hypothesis.

To observe the data distribution we build the boxplots as can be seen in Figure 3.6. In this image we can also see the clear differences in the values between the tasks in the website 1, namely task 1 and task 2 and in the values of the task performed in the site 2, namely task 3 and task 4. On the other hand, comparing the values from task 1 and 3 or task 2 and 4 the clear differences in the values in no longer observed.

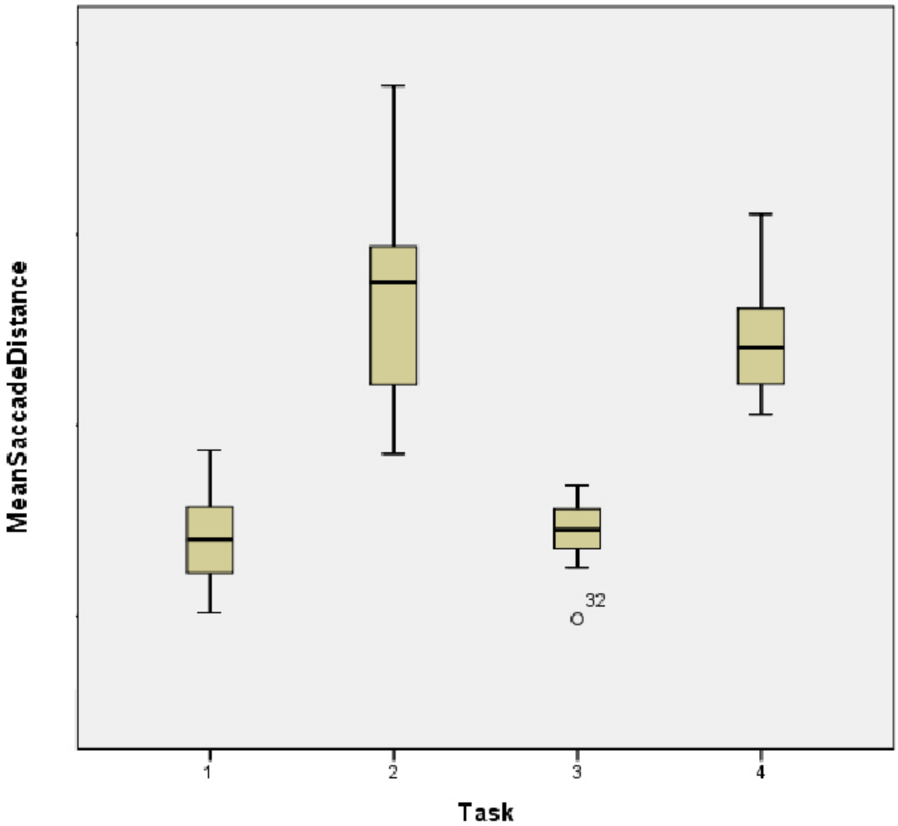


Figure 3.6. Boxplots of the Mean Saccade Distances in the different tasks

These results indicate significant differences in the distances travelled in the saccades of the visual patterns when participants are performing a task or simply exploring a web page. In addition, when comparing the task, independently from the web page, the significance level is less than 0.05, also rejecting the null hypotheses.

3.3. Summary

This chapter presents two studies which investigate the possibility of distinguishing a user's visual behaviour when she/he is simply exploring a web page or performing a task on the same web page.

Our first approach was performed by considering whether the visual mechanism, bottom-up or top-down, is more dominant .The statistical analysis, Table 3.1, showed clear differences (significance value less than 0.05) with respect to the users' visual patterns being similar to the saliency maps when completing a task or simply exploring a web page. Additionally, there are also clear differences (significance value less than 0.05) in the number of hotspots per page. The hotspot maps (Figure 3.3) generated from the participants' visual patterns support the statistical results (Table 3.1). We can conclude that there are differences in the visual patterns when users perform a task or simply explore a web page.

This study shows that it is possible to distinguish if a user is completing a task or simply exploring a web page, using their visual patterns and knowledge about the operation of the visual mechanisms.

In order to quantify the results was conducted a second study on users' eye tracker data of the visual patterns. As shown in Table 3.2, clear differences (significance value lesser than 0.05) can be seen with respect to the value of the Mean Saccade Distance, when comparing if the participant is completing a task or simply exploring a web page. We can conclude that the saccade distances in the visual patterns travelled depend on the task that is performed.

As Yarbus observed in Repin's painting, "The Unexpected Visitor"[Yarbus, 1967], we also found evidence that the differences in the participants visual patterns also can be found when they are browsing the internet, and accessing it's content. Moreover, we verified, see Table 3.2, that the visual patterns do not depend on the site where the task is being performed.

We can observe that there are differences in the visual patterns when users perform a task or simply explore a web page regarding the saccade distances. This study shows that it is possible to distinguish if a user is completing a task or simply exploring a web page, using their visual patterns.

4. PROPOSAL OF AN EYE TRACKING TASK IDENTIFICATION METHODOLOGY

In the previous chapters we presented studies to verify if it would be possible to quantify and distinguish the user's visual patterns when freely exploring or completing a task. As it can be seen in section 3.2 we study the possibility to define a metric that would allow us to determine what a user is doing in a web page. The results obtained in section 3.2.5 present clear differences in the data's distribution for the different visual patterns. From this data we tried to define a threshold value that would allow the identification of what a user is doing automatically. The boxplots presented in Figure 4.1 show that it is possible to draw a line which separates the data distribution of Task 1 and Task 3 (freely exploring) from the data of Task 2 and 4 (performing a task). Based on this result we propose a method that automatically identifies if the user is performing a task or simply exploring a web page.

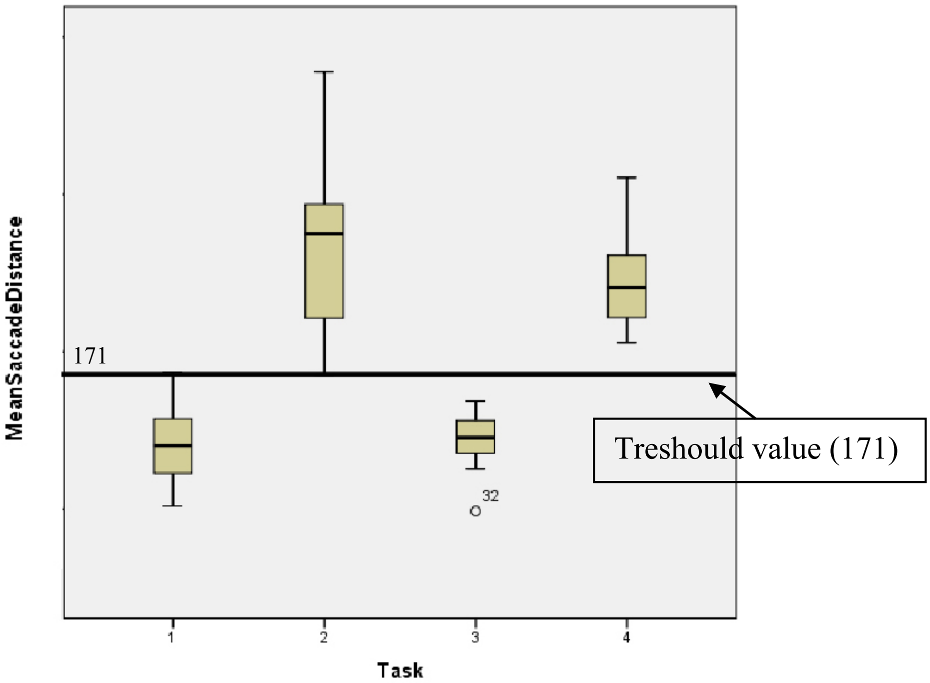


Figure 4.1. Boxplots of the Mean Saccade Distances in the different tasks (chapter 3, section 2).

4.1. Method / Algorithm

Based on the results obtained in previous studies, it was decided to develop a method/algorithm that would allow us to identify whether the user explored or accomplished a task on a web page using the metric defined from the data previously collected. The Figure 4.1 presents the data distribution for each task of the mean saccade distances travelled between fixations. As previously referred, and by observing Figure 4.1 it appears that a threshold value that distinguishes from completing a task and freely exploring might exist. In this case, based on the collected data, when the mean saccade distances is less than 171 pixels the users are freely exploring a web page, and when it is larger than this value, the users are completing tasks.

In order to identify if the user was performing a task we developed an algorithm that allows us to calculate the mean value of the saccade distances, therefore identifying if the user was performing a task or simply exploring the web page. The algorithm is divided in two processes (Figure 4.2 and Figure 4.3) since they occur independently. The first process calculates all the fixations of the human visual patterns. The second process analyses all the information gathered and identifies if the user is performing a task.

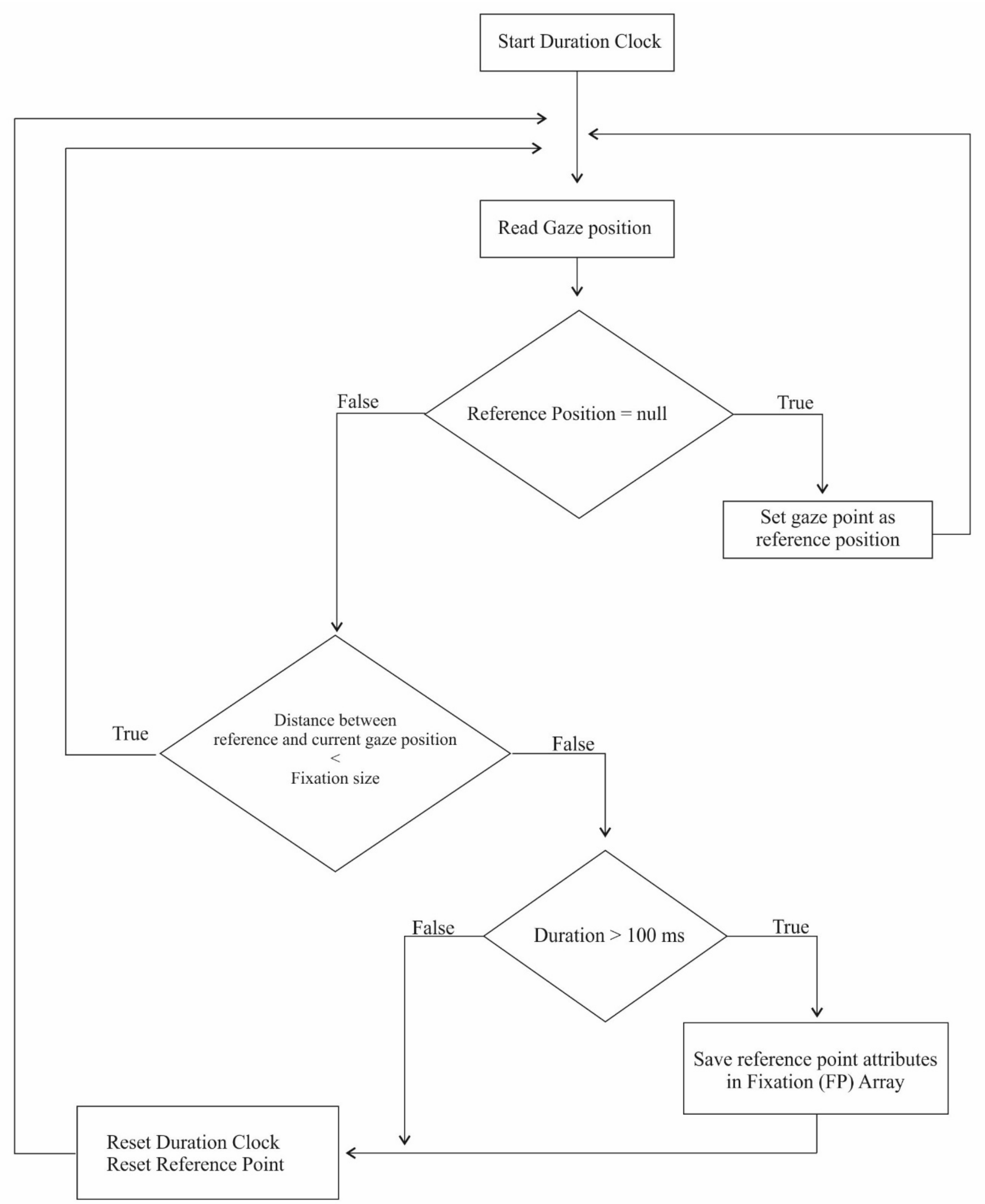


Figure 4.2. Fixation calculation (process 1).

This process starts after the user and the physical components are prepared. In order to determine the fixations, we verified when the user is looking at the same point. We developed the first process based on commercial eye tracking software. The method detects the very first gaze position (x, y) and defines it as a reference point. Then, a loop continues reading the next positions, comparing each read with the reference while the distance (Euclidean distance) between fixations are less than 30 pixels. If the distance between the current position and the reference point is bigger than 30 pixels that means that the new point is too far from the reference, and not part of the same fixation. Based on the Tobii system that we previously used, a fixation is occurring when the eye positions are focussed on an area that is less the 30 pixels. The radius of this area can range from 20 to 40 pixels, depending if the user is reading text (20) or looking at images (40), but 30 pixels is the default value when the stimulus has both types of content [FixationFilters, 2013]. Furthermore the fixation only is considered if the duration is more than 100ms. In order to verify this, each duration is checked and if it is bigger than 100ms, the reference point is a fixation. When a fixation is detected corresponding attributes are stored. This consists of the timestamp of the beginning of the reference point, the duration of the fixations, the x and y positions of the reference point, the length of the scroll and the real y position of the vision (adding the reference point's y coordinate to the length of the scroll). These attributes are used later for the calculations of the distances between different points. After this the clock and the reference point is reset and the cycle is restarted until the experiment ends.

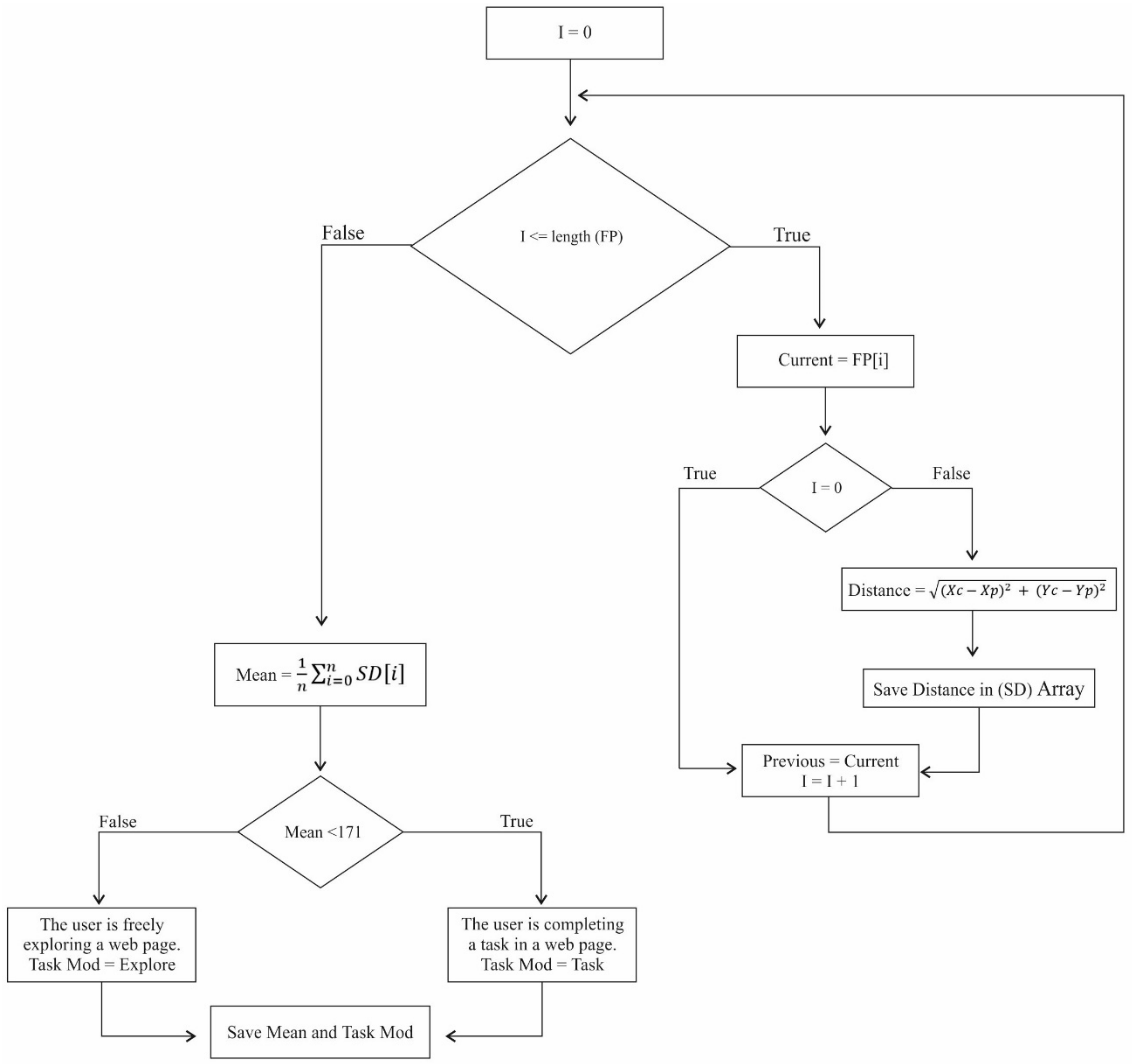


Figure 4.3. Identification of the task (process 2)

The second process consists of the calculation of the mean saccade distances and identification if the user is performing a task or freely exploring a web page. The process starts by accessing the data structure were all the fixations were saved. While there are fixations in the Fixation Points (FP) array, the Euclidean distance is computed between each consecutive fixation point, which corresponds to the saccade distance, and saves it in a new Saccade Distances (SD) array. After all the distances have been calculated, the algorithm calculates the Mean distance ($\frac{1}{n}\sum_{i=1}^{n} SD[i]$) of all the values saved in SD. The mean distance is compared with the threshold value (171) and if the mean is bigger than the threshold (171 pixels) the user is completing a task, and if it is lower the user is freely exploring a web page, defining the “Task Mod” value. Finally, the Mean value and the Task Mod are saved.

In this thesis we consider 171 pixels as the threshold value for our system, given that we always used the same setup making this value valid for our experiments. In order to normalize the value and use it with other screen sizes or resolutions we propose to relate this value to the fixation area. For example, if the fixation point is 30 pixels the saccade distance threshold should be 171/30 = 5,7.

4.2. Case study - Method Evaluation and Validation

In order to verify if the proposed algorithm works and allow us to detect if the user is performing a task or freely exploring a web page we implemented and tested it.

4.2.1. Prototype Implementation

To test the proposed method we built a task identification system prototype. The following sections present details of our proposed system.

4.2.1.1. Task Identification System Architecture

The proposed task identification system consists processing the data gathered from the eye tracker and the computer system. Figure 4.4 depicts the proposed system architecture, where the principal part of the architecture is the eye tracking task identification software.

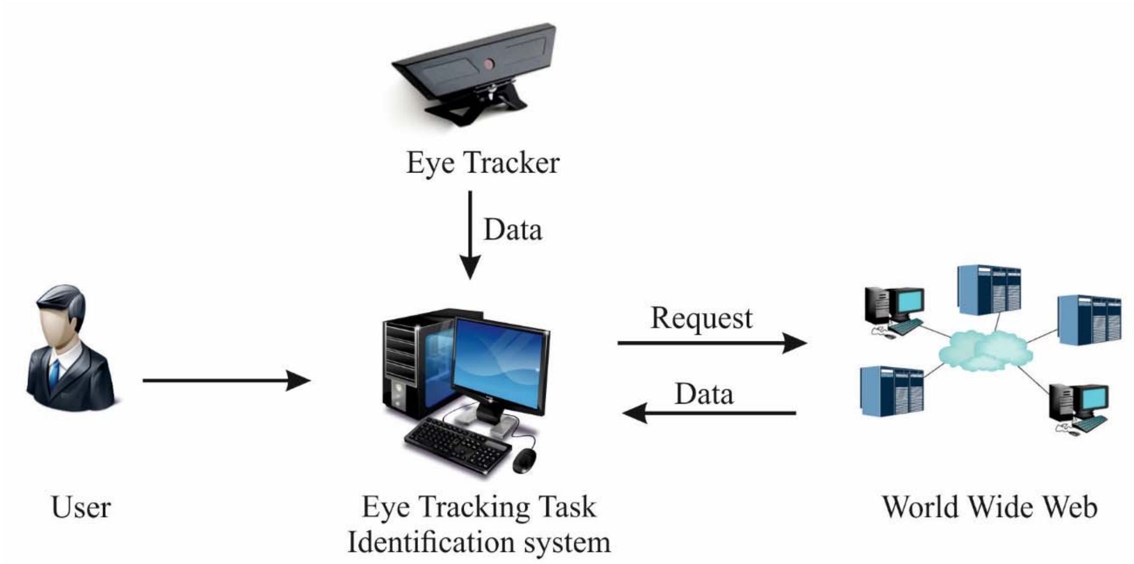


Figure 4.4. Task Identification System Architecture.

The task identification system architecture is composed of: the eye tracker device, computer system, and the external data source.

The users perform the experiments in the computer system, where the task identification software installed on the computer collects data from the eye tracker. This system will access the World Wide Web to get the stimulus/web pages.

4.2.1.2. Implementation

The software was built using the Tobii Software Development Kit (SDK) [Tobii, 2011] in combination with Visual Studio 2008 [Visual Studio, 2011]. A TET Server was used to connect the eye tracker with the computer. The SDK provided us with different tools to build our application, and a C# interface. Hence, the application was written in C# and used the .net framework [Net, 2012] in order to be able to gain access to high level features in the machine (i.e Web Browser, network communications, amongst other).

4.1.1.1. Task Identification System Flow Chart

For a better understand of how the prototype works, a flow chart of the proposed eye tracking task identification system is depicted on Figure 4.5.

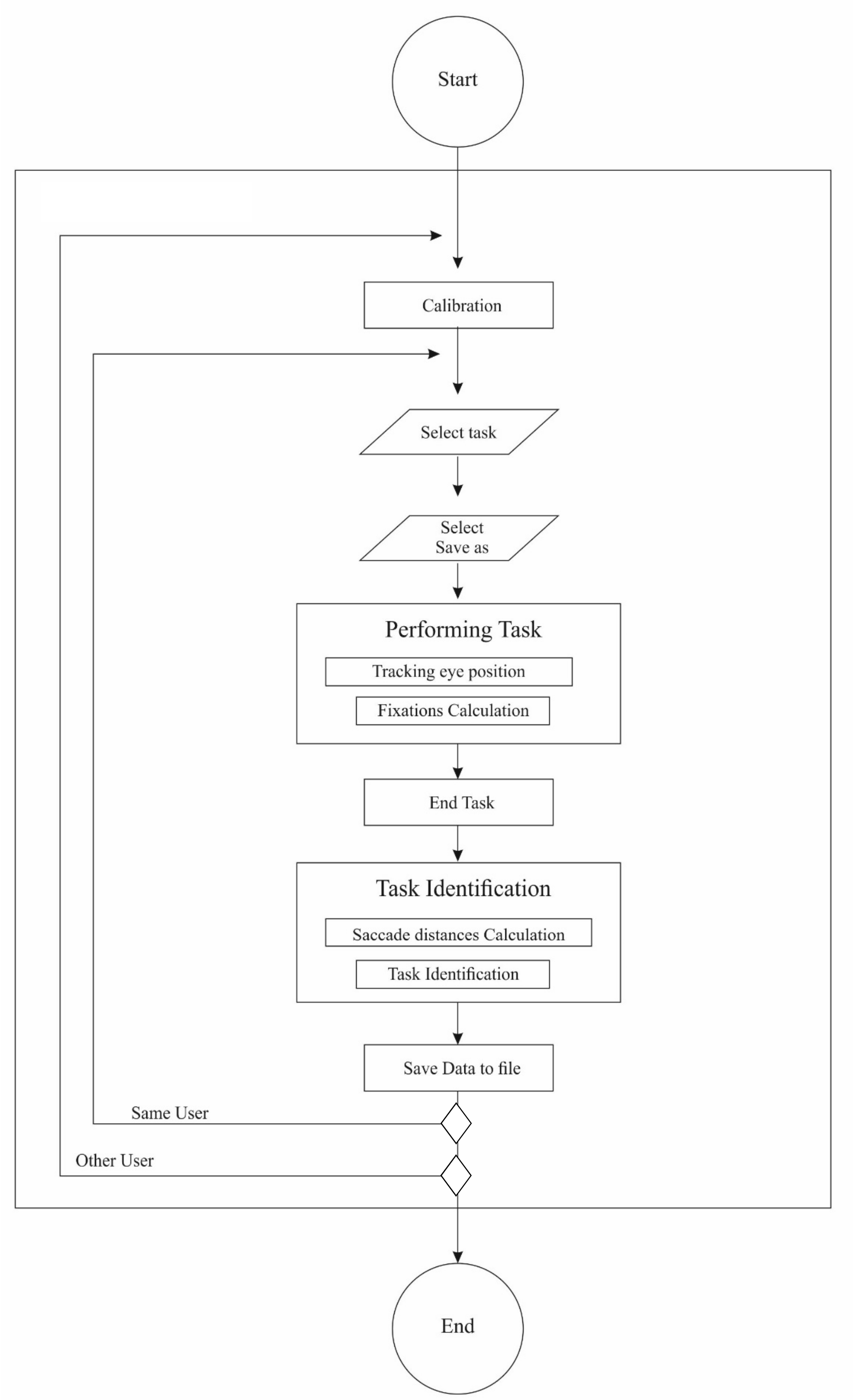


Figure 4.5. Task Identification System Flow Chart.

When the application starts, it opens a window, Figure 4.6, which allows the user to perform calibration and select the task which will be performed. When the user clicks on "Iniciar" button, the application asks the user to insert a user ID in order to save the data in the end of the experiment.

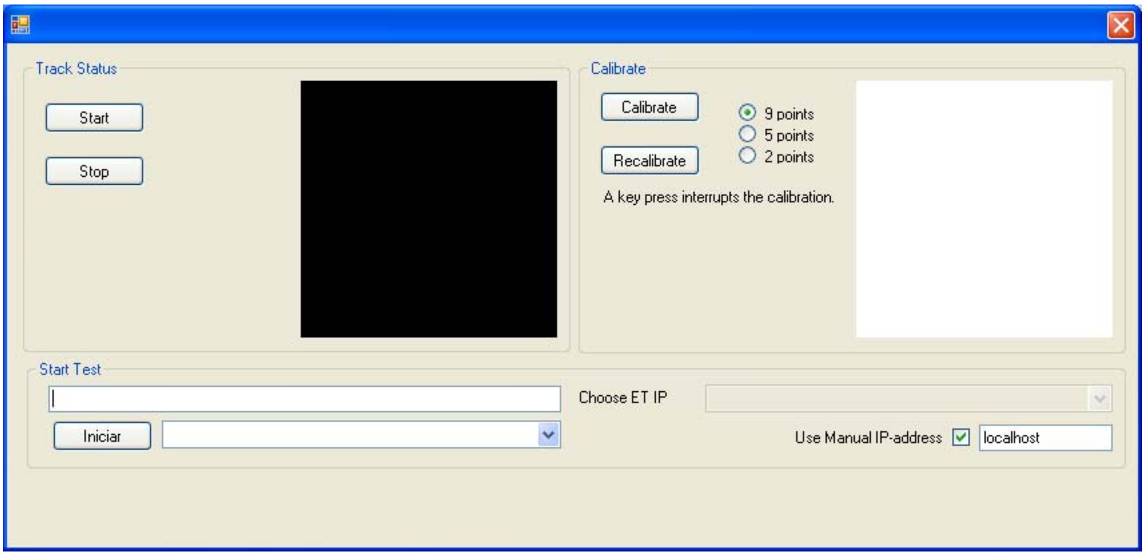


Figure 4.6. Print Screen of the application window.

After this initialization process, the application automatically opens the browser with the URL corresponding to the task that the participant has chosen and starts all the processes regarding the processing of the information gathered from the eye tracker and from the computer. While the participant performs the task, the application runs the first process (fixation identification) in background in order to record the eye positions and compute the fixations.

When the participant ends the test and closes the browser the application starts the second process (Task identification) and calculates all the distances between the fixations and identifies if the user was performing a task or simply exploring a web page. After this the application saved all the data in a txt or xml file. The application also allows the same participant to perform other tasks.

4.1.1.2. System data

While performing tests in order to use our prototype, it was necessary to create a data structure in order to store the data to allow further analysis. Since data is collected from the eye tracker, the computer and other processed data, there was the need to create some data collections. In the case of our application, while conducting experiments, the application saves the data into virtual "collections / arrays" which were constantly updated throughout the experiment. When the subject completes the task, the application automatically saves all data. Based on the eye tracking software, the data was saved in a text file or exported to a XML file.

Regarding the data obtained directly from the eye tracker, the variables stored were the timestamp, being the exact moment that a user stops at a given position, the duration that the user was fixated in the same position, the x and y coordinates of the visual position regarding the display that is being used to perform the experiment, the size of scroll and the real position on y (eye position y + scroll).

With the real-time processing of the gathered data other calculated variables as saccade distances between all the fixations were also stored. At the end of each experiment, the application also saved other global variables being: total time, the final mean saccade distance and the Task Mod.

4.2.2. Evaluation and Validation

The purpose of this study is to determine the effectiveness of the proposed task identification system, i. e. if it is able to automatically detect what a user is doing in a web page.

4.2.2.1. Conditions and Procedure

All experiments were conducted individually and in a controlled environment. The room was equipped with a computer and an eye tracker (Tobii X50), in combination with the application that we developed previously described (Section 4.2) to collect and analyse eye movement data. The stimuli were displayed on a 17” screen with a resolution of 1024 × 768 pixels.

Based on the results obtained in the experiment described in chapter 3, we calculated a threshold value for the saccade distances that would allow us to distinguish between completing a task and simply exploring. This condition was coded in the application and, at the end of each task performed by the participants, the application automatically saves all the information and determines if the user was exploring or completing a task.

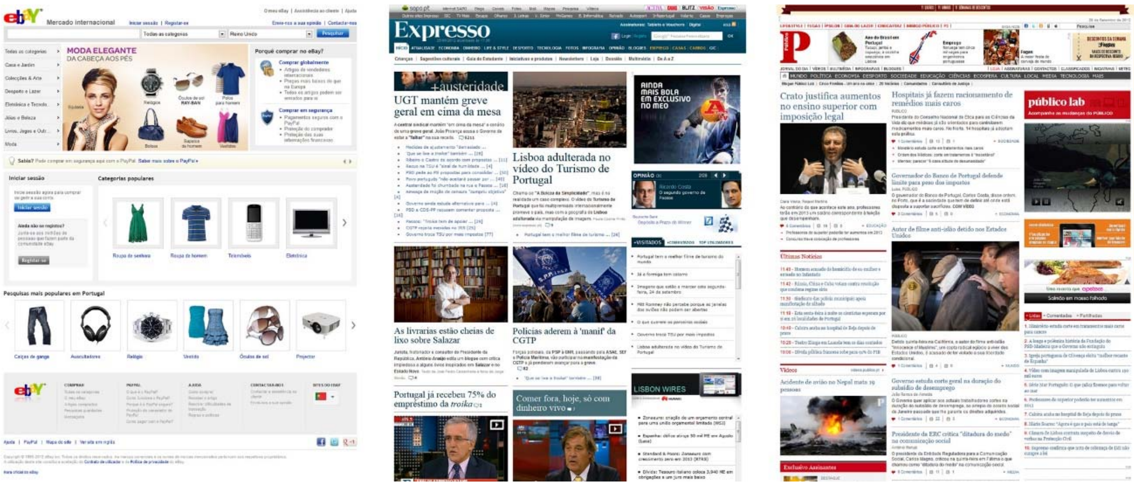
The experiment was comprised of completing a task or freely exploring as web page in three different websites namely the Ebay Ecommerce website (Figure 4.7 a)), the online Expresso Newspaper (Figure 4.7 b)) and the online Público Newspaper(Figure 4.7 c)), which are well-known websites. All participants performed one task in each website. The assigned actions and websites were:

Task 1 (T1)	Explore the Ebay web page [Ebay, 2012]
Task 2 (T2)	Find a specific object on the Ebay web page [Ebay, 2012]
Task 3 (T3)	Explore a newspaper web page [Expresso, 2012]
Task 4 (T4)	Find specific news on a newspaper website [Expresso, 2012]
Task 5 (T5)	Find a specific object on the Publico web page and then explore the web page. [Publico, 2012]
Task 6 (T6)	Explore the Public newspaper web page and then find a specific object on the web page. [Publico, 2012]

Table 4.1. Actions and Websites

For Task 5 and 6, we wanted to verify if it would be possible to distinguish between exploring or completing a task in the same test, for this reason the application guessed what the participant was doing each 3, 4 and 5 seconds and recorded this guess within the data files generated.

This way, each participant performed only three tasks. For example participant number 1 completed: Task 1, Task 4 and Task 5, and participant number 2 performed: Task 2, Task 3 and Task 6. The order in which the tasks were performed was random. After completing the tasks, the participants answered a short survey to collect personal information such as age, gender, eyesight conditions and web navigation experience.



a) b) c)

Figure 4.7. Print screens of the Web pages used in this case study. a) Ebay Ecommerce website, b) Parte of the online Expresso Newspaper, c) Parte of the online Publico Newspaper.

4.2.2.2. Participants

A total of 32 participants took part in the experiment. All participants were University students. The set comprised of 21 males and 11 females. The participants' age was between 19 and 30 with the average being 25 years. 20 of the participants had normal vision and 12 corrected to normal. All the participants use the Internet on a daily basis.

4.2.2.3. Results and Discussion

The existence of outliers in the data was investigated. Thereafter, the data from two subjects was removed since there were some missing data due to the failure during the capture of the eye gaze from the eye tracker. After this we compared the application identified task with the task that we asked the participants to perform. Results from this are presented in table 4.2.

	Web Page 1		Web Page 2		Web Page 3	
	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Percentage of Success	93,75 %	100 %	93,75 %	93,75 %	93,75 %	87,5%

Table 4.2. Success rate of the application guesses.

During Task 5 and Task 6, by direct observation we registered at what time the participant changed from task oriented task to an explore task (Task 5) or on the other way round (Task 6). After completing the experiment we compared the guesses provided by the application before and after the participant changes their task with the actual tasks that the users were performing.

In the results it can be observed that for Task 6 the application identified correctly 87,5%, failing to guess for two participants. For Task 1, Task 3, Task 4, and Task 5 the application identified 93,5%, only failing to identify behaviour for one participant. Finally, for Task 2 the application successfully identified the task for every participant 100%.

These results indicate that the proposed method successfully detects, in most cases, if a user is performing a task or simply exploring a web page, and even when there is a task change during the web page navigation.

4.3. Summary

This chapter presented a method for eye tracking task identification. It's implementation and assessment were performed to study the possibility of distinguishing if a user is completing a task or simply exploring a web page using the proposed method.

In the first part a complete description of the method and the eye tracking task identification system is presented. In this section the hardware, software and functionalities are presented, as well as the system architecture and the data structures used. Finally, the system flow chart was presented.

On the second part we present a case study to verify if the system proposed is able to automatically detect what as user is doing in a web page. As presented in Table 4.2, all the experiments had a success rate bigger then 87,5% showing an indication that it is possible to build and use this application to distinguish if a user is performing a task or simply exploring in a web page.

5. CASE STUDY - REAL TIME WEB PAGE RESTRUCTURING

The results obtained in the previous chapter show evidence that is possible to automatically distinguish if a user is performing a task or freely exploring a web page. This information may allow developers to prepare and adapt their web pages in order to improve their efficiency, by allowing web page restructuring based on the user's visual patterns. With this concept in mind and based in the previous results, in this chapter, we adapt our prototype to restructure the web page based on the user actions.

In order to apply the algorithm described in chapter 4 to web page restructuring, we need to implement some changes. In Figure 5.1 presents the changes to the algorithm regarding the linking of the two processes and the calculations of the mean saccade distances. In the previous version, the two processes are executed in sequence, meaning that the Task Identification process only happens after the complete execution of the process to identify the task. To apply the algorithm to web page restructuring, it is necessary to have this information in real time. Thus, the two processes are executed concurrently in two separated threads. The main change in the calculation of the mean fixations distances is the use of a time interval of 3 seconds. The analyses of the data gathered in Chapter 4 allow us to verify that the minimum time to identify if the user is completing a task or exploring a web we page was 3 seconds, thus using this time interval to calculate the mean fixations distances.

Despite the fact that the thread is running in real time, the mean saccade distance is calculated based only in the saccade distances of the last 3 seconds, and based on this the task the user is currently performing is identified. . After the task identification the algorithm sets a flag with the indication of the task and consequently the web page layout may change to the correspondent task layout. To accomplish this was prepared two different web pages with similar content but with different structure for when the users were performing tasks or simply exploring the web page.

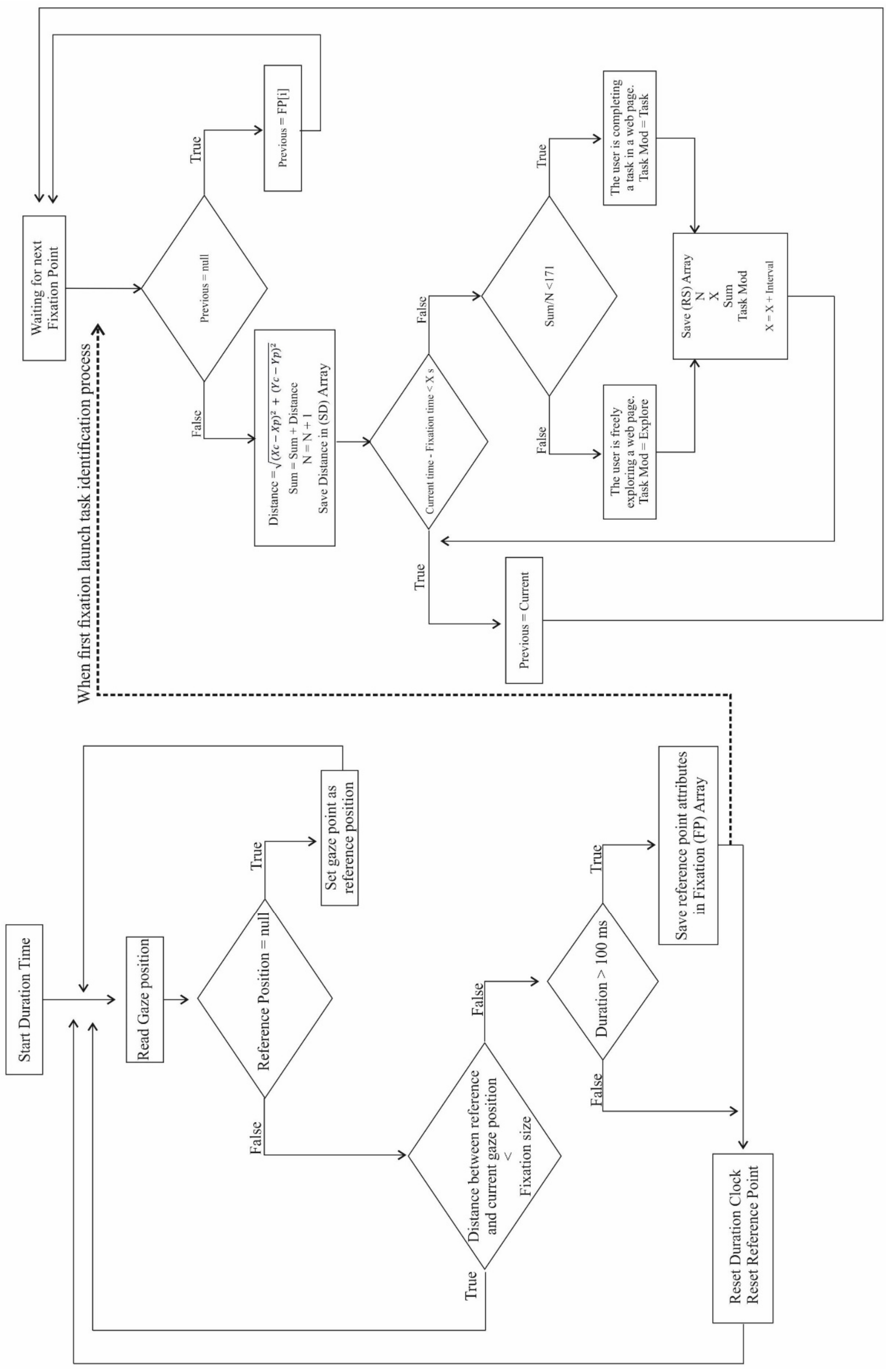


Figure 5.1. Real time Task Identification Algorithm.

With the implementation of these changes in the application used in the previous chapter we wanted to verify the approach, and what could be the improvements of using this tool while web browsing. Based on this we performed a case study in order to test our theory/hypotheses.

5.1. Objective

The main goal of this case study is to verify if it is possible to use our method to restructure a web page based in the task that the user is performing, to verify if there is any improvement in the performance by decreasing the time that the users took to perform the task, and verify if it is possible to do this in real time. Sites will be restructured page by page with specific content, depending if the user is freely exploring or completing a task.

5.2. Conditions and Procedure

As with the experiments described in Chapter 4.3, all experiments were conducted individually and in a controlled environment. The room was equipped with a Computer and an eye tracker (Tobii X50), in combination with the eye tracking task identification system to collect and analyse the eye movements' data. The experiments were displayed on a 17" screen with a resolution of 1024 × 768 pixels.

The proposed prototype is going to analyse and identify if the user is performing a task or simply exploring a web page and based on that, the application will automatically present a web page that is prepared for the task that the user is performing. Thus, there is the necessity to rearrange the web page depending on the task that the user is performing.

We compiled information from the Expresso online Newspaper web page [Expresso, 2013], and from this we rearrange the web page structure for the subjects that were going to perform the task, using the mobile Expresso newspaper web page as a reference, since it is already a compacted and structured web page, developed by the same company.

The online journal web page is presented when freely exploring, and when performing a task, a page is presented without any non-news related information (Figure 5.2).


a)

b)

Figure 5.2. Web pages used in this case study. a) web page for the subjects that are freely exploring a web page, b) web page presented to the subjects that are performing a task.

The experiment comprised of 5 different tasks, in which the users only performed one task. The tasks consisted of:

Task 1 (T1)	Search for a specific news item in the Online Journal Expresso (Figure 5.2 a))
Task 2 (T2)	Search for a specific news item in the restructured Journal Expresso web page (Figure 5.2 b))
Task 3 (T3)	Explore the Online Journal Expresso web page (Figure 5.2 a))
Task 4 (T4)	Search for a specific news item in the restructured Journal Expresso using the prototype (Figure 5.2 a) and b))
Task 5 (T5)	Explore the Online Journal Expresso web page using the prototype (Figure 5.2 b) and a))

Table 5.1. Tasks and websites.

For a better understanding, Figure 5.3, presents a scheme which represents the users' web pages navigation during the experiment.

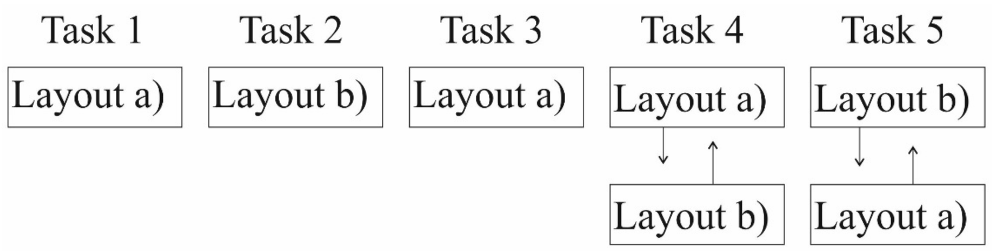


Figure 5.3. Web page layout scheme for each task.

As in the previous case studies after completing the task, the users answered a short survey to collect their personal information such as age, gender, eyesight conditions and web navigation experience.

5.3. Participants

This study was performed by 32 participants. From this only 30 participants' results were considered valid, i.e. without any missing data. The participants set consisted of 18 males and 12 females. The participants' age was between 19 and 35 with the average was 25 years. All participants could see clearly, and 13 had corrected to normal vision. All the participants use the Internet on a daily basis.

5.4. Results and Discussion

In order to verify the information collected by the eye tracker, the existence of outliers and/or any missing data was investigated. From this, 30 of the participants tests were considered valid. Subsequently in order to verify that the task identification system proposed worked for task 4 and 5 we compared the identified task by the application with the task that the participants should have performed and we verified if the page that participants navigated was in accordance with the task proposed. The results from the gathered data are presented in Table 5.2.

Tasks	Number of participants per test	Percentage of Success
T4	6	83,3%
T5	6	83,3%

Table 5.2. Results of the application task detection success.

In the results presented in Table 5.2, can be observed that for task 4 the application successfully presented 83,3% of the participants with the correct web page, showing the wrong restructured web page for one participant. The same results were obtained in task 5.

This results show evidence that may be possible to rearrange the web page and present different outcomes in real time, based on the user's visual patterns/task they are performing. In this case study, a distinction between freely exploring and completing a task was made, and successfully demonstrated that is possible to rearrange the web page in real time based on this result.

In addition to these results, we wanted to observe the differences in the time that the participants took to perform the tasks in the respective web pages. In table 5.3 is presented, for each task, the participants' time to complete the task.

Task 1	Task 2	Task 3	Task 4	Task 5
12328	9828	82640	14875	143156
32046	15937	64140	20171	102468
32203	26953	74718	13015	104500
57703	20609	84343	22468	91484
27125	13140	82796	10296	66375
22406	9828	92156	8968	55750

Table 5.3. Participants' task time (milliseconds).

For a better understanding, in Figure 5.4 we present a comparison of the time taken to perform the same task in the default web page (Task 1) and the rearranged web page (Task 2) and using the prototype that will change between the pages to present the most suitable (Task 4). As it can be observed in the boxplots Figure 5.4, between the default page and the rearranged web page exists a variation in 50% of the mean time that took to perform the task in the different pages. In task 4, despite the fact that the default web page is also presented, by changing the page when the proposed system detects that the user is performing a task, allowed the user to achieve similar times that when they started already from the rearranged web page. This can be observed in Figure 5.4, when comparing task 2 and task 4.

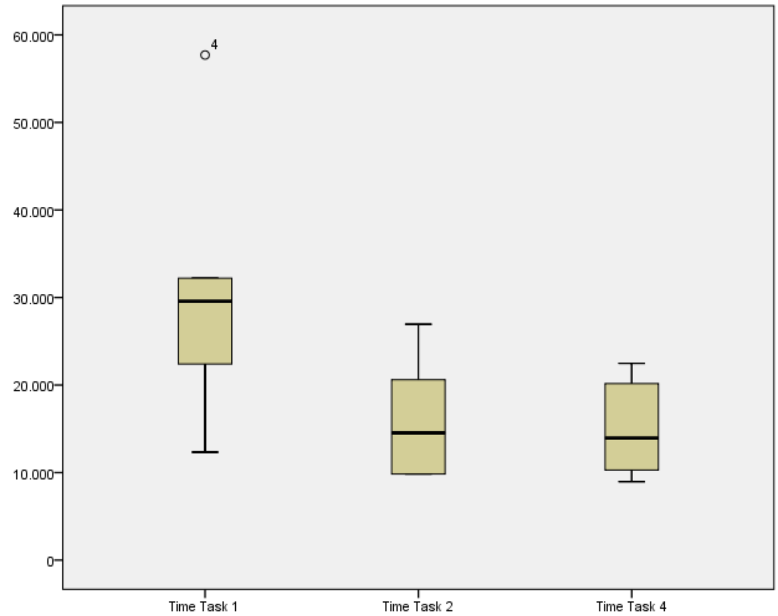


Figure 5.4. Boxplots of the participants´ task time.

Figure 5.5 shows the data distribution of the time that the participants took to explore in the different web pages. Though the mean times are different, they are not significantly different ($p > 0.3$ using the Independent Sample t-test). Nevertheless, the data distribution for task 5, when the proposed prototype is used, has a larger variation than the data distribution for task 3, when is used the default web page. One of the reasons for this could be that since the participants aren´t task driven, when changing the page layout they may take more time to adapt to the visual stimulus change.

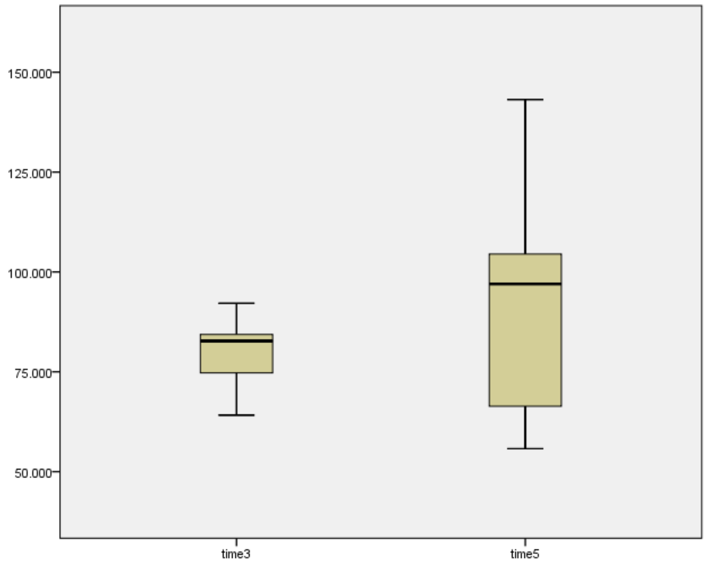


Figure 5.5. Boxplots of the participants´ time in the web page exploring task.

In addition to these results, some empirical data was observed regarding saliency maps and visual mechanisms. As described in chapter 3, we can verify differences between completing a task or simply exploring a web page using the similarities between the visual pattern and the saliency maps of the web page. Despite the fact that these differences do not allow us to distinguish what task the user is performing in a given moment, this type of comparison can allow a better understanding of the web page content and what are the most important information areas for the user. It can also provide guidelines for rearranging a web page.

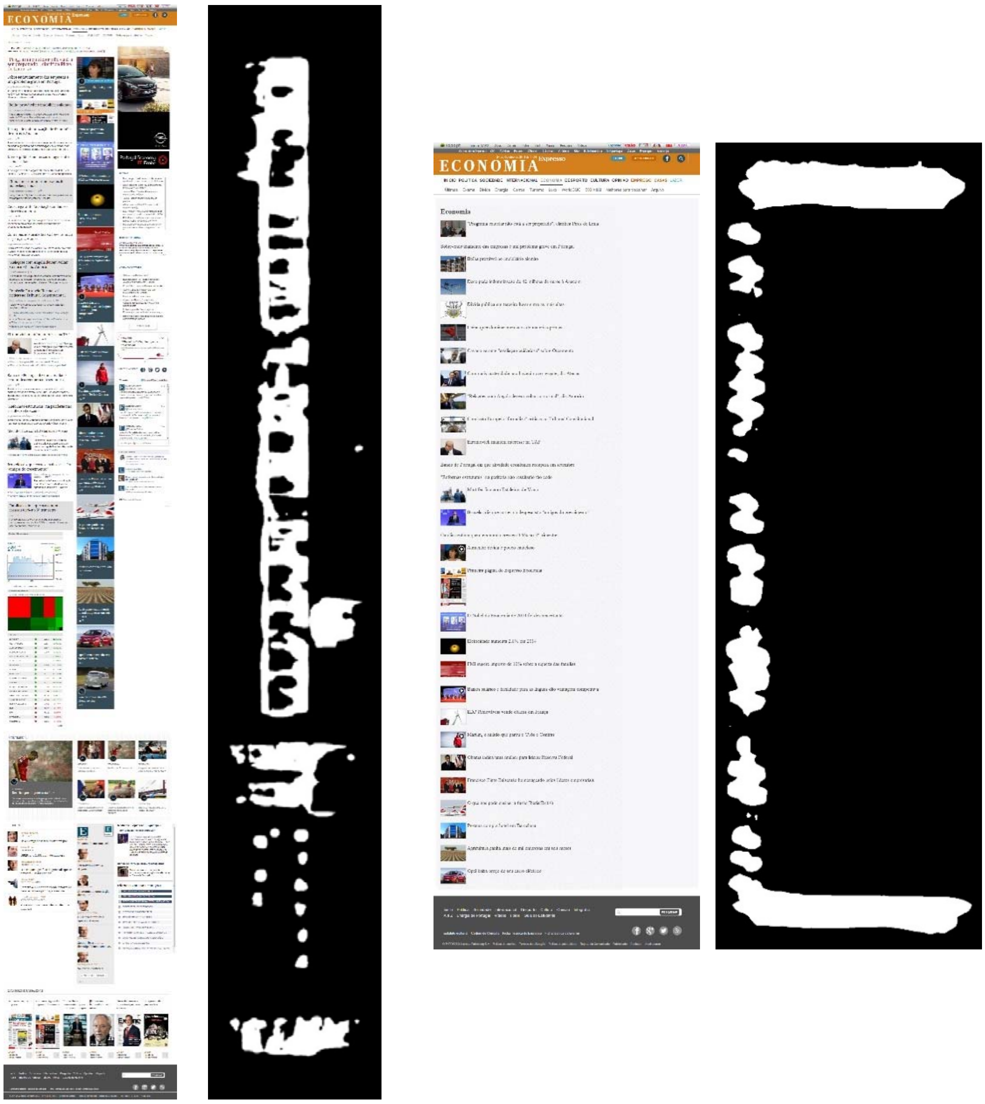


Figure 5.6. Web pages used and respective Saliency maps of the web pages.

In Figure 5.6 we present the saliency maps from the web pages used in this case study. As it can be observed, there are differences in the structure and display of the information on the web pages presented to the participants, as well the saliency maps generated based on them. In order to compare them with the visual patterns of the participants, a fixation map was saved for each participant, which contains all the participants' fixation points. Since the prototype preloads the saliency maps, before the participant performs the task, it becomes possible also to compare them in real time.

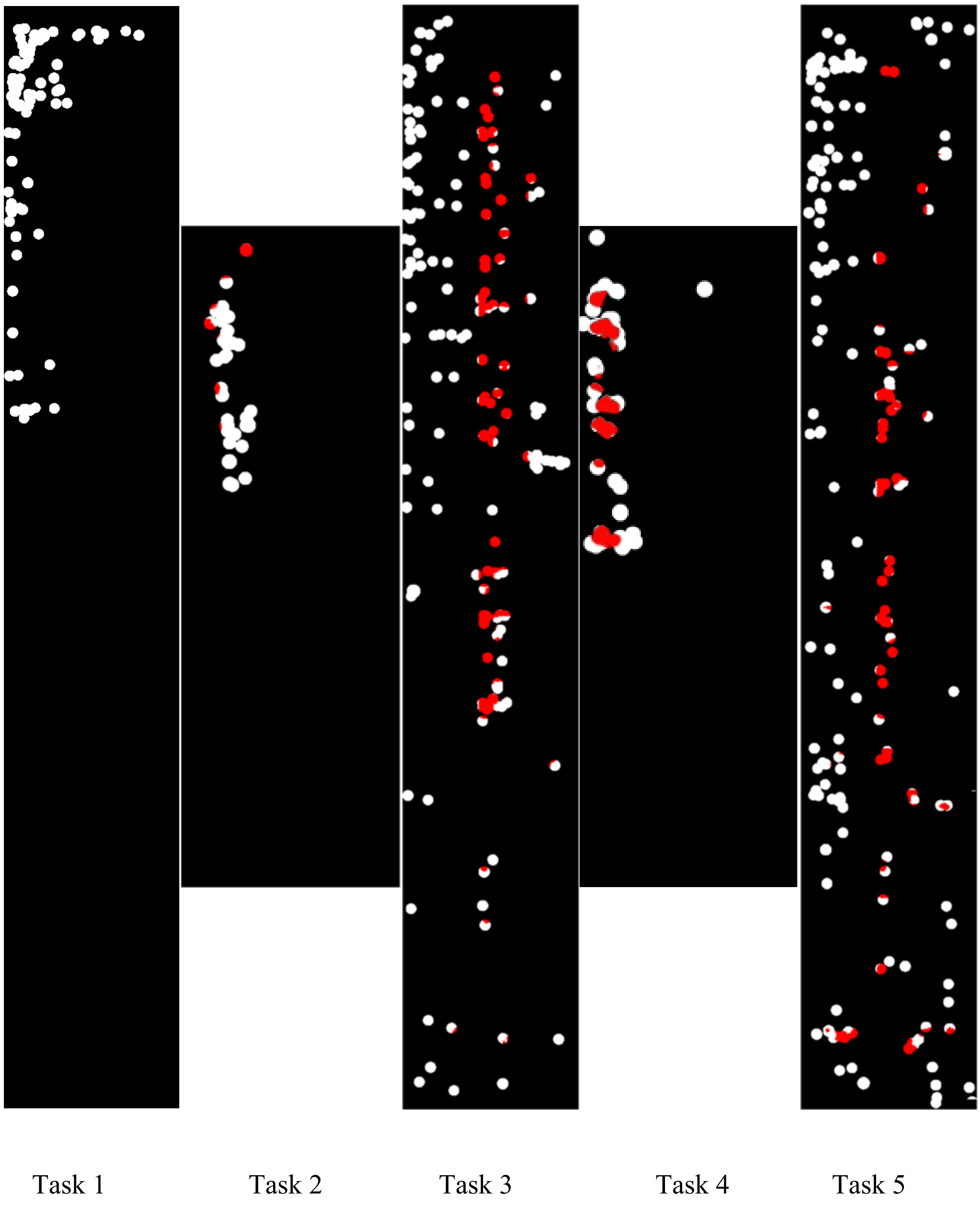


Figure 5.7. Fixations map for one participant completing a task.

In Figure 5.7, the red dots represent fixations that are also saliency points, being the common points between the participant's fixations and the web page saliency map. Similar visual behaviour was registered for the others participants.

Analysing the visual patterns similarities can be observed between task 1, task 2 and task 4, since they all correspond to the same task. Task 3 and Task 5 also present some similarities for the same reason. Regarding the comparison between the different pages, it can be observed that when the participants are completing a task in the default web page (Task 1) the participant did not look at any saliency point (no red dots in the image), but when comparing with the same task in the rearranged web page web (Task 2) we can already observe some gaze points matched salient areas as encoded by the saliency map. In task 4, despite the fact that this user started with the default web page, because the web page changed during the visualization, the user also looked at salient regions also presented with in red.

For task 3 and 5 similar visual patterns can be observed, as can be seen with the common similarities with the saliency maps. This is because despite the fact that in task 5 the users started with the rearranged web page, as the system detected that they were exploring the web page it changed, presenting the users with the default web page allowing the saliency information also to be presented and compared (red dots in Figure 5.7, Task 5).

As can be observed, when the users were completing a task using the web page rearranged from the default, the user looked at salient regions. Thus, this indicates that the saliency map resembles a task map for that specific task. These results show an indication that by rearranging a web page we may improve the web page's structural design, and at the same time place specific content in regions that the user is going to look at.

The empirical data observed during the course of the experiments was also analysed. The users who completed Task 4 and Task 5 noticed the restructuring of the Web page, since the structural changes are drastic when the web page presented to the user changes. In these cases it was observed that the user gets confused for an instant. These results indicate, as discussed in Chapter 2, that the users prior knowledge of the Internet or web page structuring, affects their expectations on how the web pages should look. Despite the fact that this did not affected the results it’s a fact that should be taking in account when rearranging the web page. In a pilot test we only applied the web page rearrangement when the user changed pages. In this case the rearrangement was unconscious for the users.

5.5. Summary

This chapter presented a case study to verify if it is possible to restructure a web page based on the user's task/visual patterns.

As presented in Table 5.2 for Task 4 and for Task 5 the application detected and restructured the web page accordingly with a success of 83,3%. This result shows that is possible to rearrange web pages and present different outcomes based on the user's visual patterns/task they are performing.

Moreover, the differences in the time that the users took to perform the tasks in the respective web pages was analysed. Between the default page and the rearranged web page, there exists a variation in 50% of the mean time that was required to perform the task in the different pages. For Task 4, the proposed prototype allowed the user to achieve similar times to the rearranged web page. Regarding the time that the users took to explore the web pages, no statistical differences were present.

Other empirical data collected was the task maps and the visual patterns, which can also allow for a better understanding of the web page content and what are the most important information areas for the user. It can also provide guidelines for rearranging web pages.

6. CONCLUSIONS AND FUTURE WORK

Web pages are built/designed considering the main task that users are going to perform on it. If the users try to perform another task it may be very difficult to obtain the desired information or take a large amount of time. In this thesis we focused on web page restructuring and adaptation, based on the users' visual patterns, to develop a task optimized web page.

We have investigated how the visual mechanisms operate when people are browsing the internet. By knowing what strategies people employ, we have found that if it is possible to know what a user is doing at a given time on a web page, the web page can be restructured or adapted in order to improve the efficiency of the task.

Despite the possibly of a web page already contain all the information the user might need, the knowledge of what the user is doing/ looking for can be used to develop a method that would allow companies to rearrange their web pages in order to only present the important information, saving time and helping the user to navigate through their web pages.

Regarding our specific goals, in Chapter 3, we conducted an extended study in the use of internet and characterized and identified browsing patterns in order to verify they can be associated with the two mechanisms of visual attention (Bottom-Up and Top-Down).

In this experiment, the users were asked to perform a task or to explore a web page, in a specific set of web pages.

Asymp. Sig. (2-tailed)	% hotspot in salmap	% hotspot/page
Explore / Task	0,000	0,000

Table 6.1. Nonparametric Test (2 Independent Samples) of the percentage of hotspots that are also saliency region and the percentage of hotspots per page.

The results of this research showed that there are clear differences (Table 6.1) in the percentage of hotspots (users' visual patterns) that are also salient points when the user is completing a task or simply exploring a web page. Additionally, there are also clear differences in the percentage of hotspots per page. The hotspot maps generated from the participants' visual patterns support this statistical result (Table 6.1). Consequently, we can conclude that there are differences in the visual patterns when users perform a task or simply explore a web page.

The next goal was to propose a methodology to automatically detect what task that the user is performing based on the results from the previous study. Despite the fact that it was possible to observe clear differences in the visual mechanism when completing different tasks, we sought to obtain quantitative data to allow to enable this distinction to be made automatically. The second part of the chapter presents a study that analysed the visual behaviour regarding saccade distances. A statistical analysis on the eye tracker data of the users' visual patterns resulting from the experiment was performed. As shown in Table 6.2, clear differences can be seen with respect to the value of the Mean Saccade Distance, when comparing if the participant is completing a task or simply exploring a web page. We can conclude that the saccade distances travelled in the visual patterns depend on the task that is performed.

Asymp. Sig. (2-tailed)	Mean Saccade Distance	Mean Saccade Distance per Task Time
Explore vs Task	0,000	0,000

Table 6.2. Parametric Test (2 Independent Samples) of the Mean Saccade Distance and the Mean Saccade Distance per Task Time.

As Yarbus observed in Repin's painting, “The Unexpected Visitor" [Yarbus, 1967], we also found evidence that the differences in the participants visual patterns also can be found when they are browsing the internet, and accessing its content. Moreover, we verified (Table 6.2) that the visual patterns do not depend on the site where the task is being performed. With further analyses of the data gathered, it was possible to define a threshold value (Figure 6.1) that would allow a system to verify what a user is doing automatically.

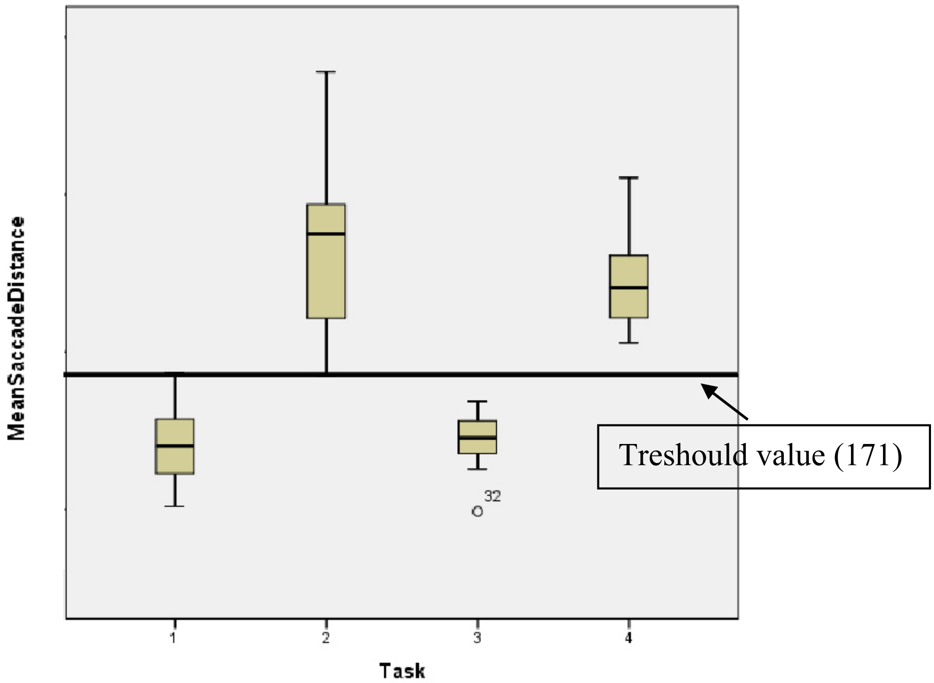


Figure 6.1. Boxplots of the Mean Saccade Distances in the different tasks.

Chapter 4, presented a Task Identification Method which aimed to detect how a user is interacting with a website. This chapter also presented a case study where we investigated the possibility of distinguishing if a user is completing a task or simply exploring a web page. The presented case study shows that the proposed method is able to automatically detect what a user is doing in a web page. As presented in Table 6.3 all the experiments had a success rate larger then 87,5% showing indication that is possible to build and use an application to distinguish if a user is performing a task or simply exploring a web page.

	Web Page 1		Web Page 2		Web Page 3	
	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Percentage of Success	93,75 %	100 %	93,75 %	93,75 %	93,75 %	87,5%

Table 6.3. Success rate of the method predictions.

Lastly we wanted to verify the possibility of using the proposed method to automatically and in real-time restructure web pages and improve their efficiency. Chapter 5 is presented a case study to verify this approach. This experiment was completed using normal and rearranged web pages, in which the restructuring was performed in real-time. As presented in Table 6.4 the application detected and restructured the web page accordingly, with a success rate of 83,3%. These results show evidence that exist the possible to rearrange the web page and present different outcomes based on the user's visual patterns/task they were performing.

Tasks	Number of participants	Percentage of Success
T4	6	83,3%
T5	6	83,3%

Table 6.4. Results of the application task detection success.

The differences in the time that the participants took to perform the tasks in the respective web pages was analyzed. Results for the rearranged page showed a 50% decrease in the mean time to perform a task compared to the default page. For Task 4 (Search for a specific news item in the restructured Journal Expresso using the prototype), the proposed system allowed the user to achieve similar times to the rearranged web page as can be seen in Figure 6.2.

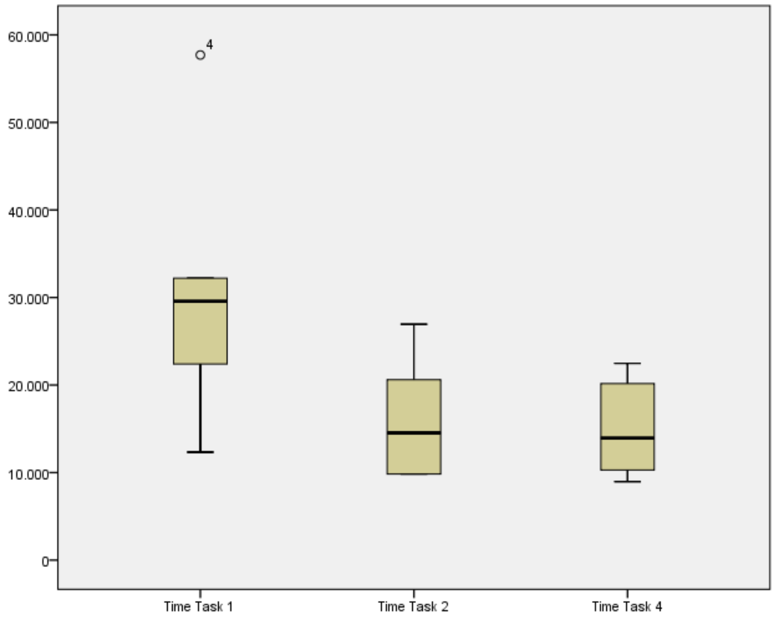


Figure 6.2. Boxplots of the participants´ performing a task time.

Future work

A future line of research consists of further analyses of the visual patterns to improve the method in order to detect not only if the user is completing a task but also which kind of task. Some categories should be identified to additionally improve the efficiency of the web pages.

Future investigation should seek to find out if the method proposed is also valid and what improvement can be made when using mobile devices. Human visual tracking has started to be used for saving energy by detecting when the user is not looking to the mobile phone screen. Knowing what a user intends do when using a web page to do can be used to improve navigation and or to save time to complete tasks.

Regarding the restructuring of the web pages in the future it should be taking in account the study of the task maps and the visual patterns collected by the proposed application as guidelines for the web page rearrange.

An additional and interesting study would be to investigate how different aspects, such as cultural background, gender, and age can affect the performance of subjects when performing navigational tasks and/or their visual stimulus. If valid, it can lead to the creation of exceptions to the proposed system or creation of guidelines when applying it, depending on the background of the user that is using the proposed method.

Another line of enquiry lies in the application of this method to other systems and/or fields. Knowing how the human visual system works can be used to develop some psychophysical tests to verify if the participants have some vision problem and/or reasoning process.

Final remarks

In this thesis we have investigated the possibility of developing a method that enables web page restructuring and adaptation based on the user visual patterns that could improve the efficiency of the web pages.

Therefore, throughout this work we have explored the fields of the Human Visual System and Computer Science, by employing and exploring the most important visual information for position location and visualization patterns to web pages structure and content restructuring.

Combining this multi-disciplinary knowledge has shown these areas should be considered to be combined more often in the wider field of computer science.

With this work we contributed to this development. Nevertheless, much more investigation is needed to further advance the use of the Human Visual System in the understanding of tasks performed on the web pages, and the resulting adaptation of web content.

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REORGANIZATION OF WEB SITES CONTENT BASED ON USERS VISUAL BEHAVIOUR / REORGANIZAÇÃO DO CONTEÚDO DE WEB SITES BASEADO NO COMPORTAMENTO VISUAL HUMANO.

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