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# **EyeTal – A Fully Eye-Controlled Map Editor**

**Master's Thesis (30 ECTS)**

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# **EyeTal – A Fully Eye-Controlled Map Editor**

## **Abstract:**

This thesis presents a novel implementation of a fully eye-controlled map editor – EyeTal. The main goal of this application is to provide people with neuromotor disabilities the means to enter the labour market by enabling them to create and modify spatial data. Spatial data collection is a labour intensive work that is generally performed manually or semi-automatically using a mouse and a keyboard. EyeTal allows doing this using eyes as the only input modality. Such a user interface could also provide an alternative for able-bodied users if the solution performs well enough to merit their consideration. The thesis discusses problems and challenges encountered when designing the elaborate user interface for EyeTal. The design ideas are supported by empirical data collected from usability testing where subjects performed various tasks that replicate the actual usage of the map editor. The usability test results were used to improve the system and another test was conducted to validate the improvements. The thesis concludes that it is possible to edit spatial data using eye movements as an only input. The results of this thesis can be generalised for other similar systems and problems.

## **Keywords:**

Gaze input, eye tracking, eye-controlled interfaces, human-computer interaction, spatial data collection, digitising, user interface design, user experience

**CERCS:** P170 Computer science, numerical analysis, systems, control

## **EyeTal – silmadega juhitud kaardiredaktor**

### **Lühikokkuvõte:**

Käesolev magistritöö esitleb täielikult silmade abil juhitud kaardirakendust EyeTal. Selle rakenduse eesmärgiks on võimaldada füüsiliste puuetega inimestel luua ja muuta ruumiandmeid ning seeläbi siseneda tööturule. Ruumiliste andmete kogumine on manuaalne või poolautomaatne töö, mida tavaliselt tehakse hiire ja klaviatuuri abil. EyeTal võimaldab seda tööd teha kasutades sisendina vaid inimese pilgu liikumist ekraanil. Selline kasutajaliides võib olla alternatiiviks ka puueteta inimestele, kui selle kasutamine on piisavalt mugav. Magistritöö käsitleb probleeme ja väljakutseid, mida sellise uude kasutajaliidese loomine ja disainimine endas kätkeb. Valminud rakenduse disainilahendusi toetab empiiriline info kasutatavuse testi tulemustest. Kasutatavuse testis osalejad lahendasid ülesandeid, mis imiteerivad süsteemi lõplikku kasutust. Testi tulemusi kasutati süsteemi parendamiseks. Tehtud parenduste valideerimiseks viidi läbi teine, identne kasutatavuse test. Lõputöö tulemustest järeldub, et ruumiandmete loomine ning muutmine vaid silmaliigutuste abil on võimalik. Leitud tulemusi ning tehtud disainiotsuseid saab üldistada ka teistele sarnastele pilgujälgimist kasutavatele süsteemidele.

**Võtmesõnad:** Pilgujälgimine, pilguga juhitud kasutajaliidesed, inimese ja arvuti interaktsioon, ruumiliste andmete kogumine, digiteerimine, kasutajaliideste disain, kasutajakogemus

**CERCS:** P170 Arvutiteadus, arvanalüüs, süsteemid, juhtimine  
(automaatjuhtimisteooria)

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## 1. Introduction

The use of conventional methods of interaction with computers - such as a keyboard and a mouse - can be an impossible task for people with neuromotor disabilities. For some of them, their eyes may be their only means of communication. It is estimated that in EU, there are about 571,205 persons with physical disabilities who could benefit from eye tracking technologies [1]. Eye gaze reveals the location of our attention and can hint intention, as we usually look the object we wish to interact with [2]. This makes eye tracking attractive as an alternative input modality in human-computer interaction.

The goal of the EyeTal project is to create a map editor that uses eye-gaze as its only input modality. This approach would allow disabled users to access and edit digital maps. The challenge is to build a user interface that is effortless to use and feels fast and convenient enough to allow users to use it for extended periods. While the main goal of the application is to accommodate disabled users, such a user interface could also provide an alternative for able-bodied users if the solution performs well enough to merit their consideration.

In Chapter 2, the background information is presented about eye movements and using gaze as a form of input. An overview of eye tracking technologies is given, and common challenges faced when developing an interactive eye-controlled application are presented. Chapter 3 presents the map application that was created by the author of this thesis. In this chapter, the functional requirements, the architecture of the solution and the design of the user interface are described. Chapter 4 describes the explorative usability testing that was conducted on the application prototype. The results are presented, discussed and UI improvements are proposed. The improvements are implemented and validated with another, identical usability testing. Discussion follows in Chapter 5 with suggestions for further work and the thesis concludes with Chapter 6.

## 2. Eye tracking

Eye Tracking is a process of measuring the point of gaze of a person, revealing where the visual attention is and what is the person looking at. Humans move their eyes to acquire information from the environment. The movements and eye positions can be measured using an eye tracker. This chapter gives an overview of the biological capabilities and the limitations of the eyes, the movements that eyes make and technologies that are used to measure the eye movements. Finally, advantages and disadvantages of using eye tracking as an input device are discussed.

### 2.1. Eye movements

The visual field of a human eye is highly non-uniform in terms of acuity. Based on acuity, the visual field can be divided into three regions: foveal, parafoveal and peripheral, as shown in Figure 1. The foveal vision covers about 1–2 degrees of the visual field and provides the highest acuity. Acuity falls sharply outside the foveal vision, ranging from 15% to 50% of that of the fovea, depending on the distance from the fovea. This peripheral vision cannot be used for reading or inspecting details as it is inadequate to see objects clearly. To overcome the limitation of the narrow high-acuity field, humans move eyes rapidly around the scene, placing foveal vision from one point of interest to another. These rapid eye movements with durations between 20–40 ms [3] and velocities as high as 500 degrees per second are called **saccades**. The periods between saccades when the foveal vision stays on the target are called **fixations**. Fixations range from under 100 ms to over 500 ms and during that period, new information is obtained. The direction of foveal vision during fixation is tightly coupled to our attention because it is used to identify objects in the environment and to collect the finest details from the scene. Measuring the position of eyes with an eye tracker gives us an opportunity to identify where our visual attention is. As we

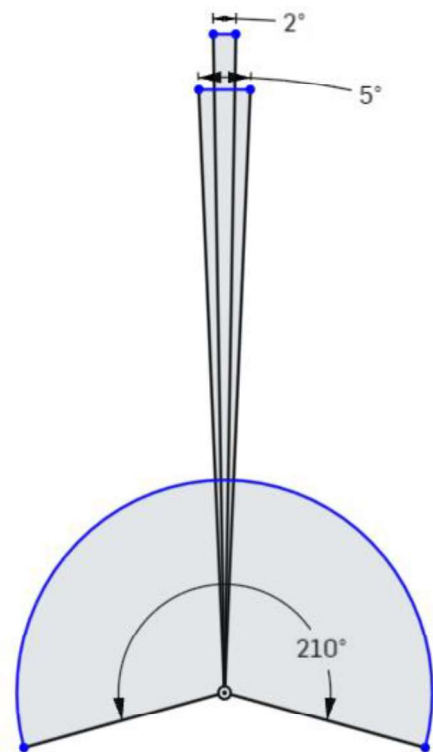


Figure 1: Three regions of visual field: foveal (2 degrees), parafoveal (5 degrees) and peripheral (210 degrees).

usually look at things we wish to interact with, there is a good potential of using gaze as an input method [4, 5].

Even during fixations, the eyes do not remain completely still. Tiny adjustments called microsaccades are made during fixations to correct drift and to further align the eye with the target and to prevent fading. When the eyes track moving targets, another type of movement occurs called **smooth pursuit** that keeps foveal vision aligned with a slow moving target. This smooth movement can not be triggered voluntarily on a static scene in absence of a slow moving target [3, 4, 5].

## **2.2. Overview of the eye tracking technologies**

Eye gaze trackers (EGTs) are devices that can estimate the user's direction of the gaze. A variety of techniques has been used to achieve this. Techniques for tracking eyes can be intrusive, requiring physical contact with the user, or non-intrusive, requiring no direct contact. Techniques that require physical contact with the user are generally more accurate or technically simpler than remote ones but can be restrictive, inconvenient or uncomfortable to use. Intrusive technologies include scleral coil contact lenses, electrodes and head mounted devices [5, 6].

### **2.2.1. Intrusive eye gaze trackers**

One of the most accurate methods to measure eye movements is to use specialised contact lenses with embedded search coil. The contact lenses are placed over the corneal bulge with a slight suction to prevent slippage. Once the contact lenses are in place, the eye movements can be tracked by tracking the search coil. The users head is placed in a variable magnetic field, and the gaze can then be estimated by measuring voltages induced in the search coil. This technique interferes with blinking and is uncomfortable, but provides an accurate estimate of the gaze point. The accuracy less than 0.1 degrees is possible with data rates up to 10 kHz [7].

Another technique is electrooculography where eye movements are tracked by measuring electric potentials on the skin around the ocular cavity. For the measurements, electrodes are placed around the eyes of the subject. This technique is used extensively in clinical applications. Although this is less accurate (about 2 degrees), it is technically simple, provides a high temporal accuracy and is low cost [6].



### **2.2.2. Remote eye gaze trackers**

Remote eye gaze trackers (REGTs) are EGTs that use non-intrusive technologies. Non-intrusive techniques are mostly video based, using visible-light or IR cameras to track various features on the eyes. Pupil and limbus are common features to track on the eyes. Although the accuracy of REGTs is generally lower than intrusive EGTs, they are more appropriate for use during long periods, because they do not need any physical contact with the user. State of the art eye gaze trackers use video-based techniques and allow some range of free head movement for the user. These systems usually provide accuracy of about 0.5 to 1 degree of visual angle [2].

Today, many REGTs use pupil-corneal reflection technique that is a video base technique that allows for some head movement. Devices using this technique need an external IR-light source that would create a trackable reflection on the cornea of the eye. Two features are measured on the eyes: the location of the pupil and the reflection of an artificial IR-light source. Calibration procedure is needed to map the measurements to monitor screen coordinates. The calibration procedure usually requires the subject to look at 9 or more calibration points on the monitor. Tracking two features on the eye allows some head motion, but the further away the head is from the original position the less accurate the tracking will be [6].

### **2.3. Gaze as an input**

Gaze has both advantages and disadvantages over common input devices such as a keyboard and a mouse. The most prominent advantage is speed – gaze is a very fast pointing method, as eyes can move from point to point in rapid saccades much quicker than a mouse. Gaze is also an intuitive method of pointing that needs very little training, as humans are used to looking at things they want to interact with. Humans usually do not think about eye movements, but if needed, the gaze can also be controlled at will. Nevertheless, unconscious eye movements are made even during wilful controlling of the eyes. The eyes continue to make small adjustments and dart from point to point, even when a person looks at a single object [8, 9].

Eyes are normally used to observe our environment. By using vision also for control, we assign it two roles in interaction with the computer. Failure to disambiguate the user's intention from its attention leads to the “Midas Touch” problem: user can unintentionally

activate targets that it only wanted to inspect, triggering unwanted actions. The challenge for the systems that use eye-gaze as an input is to avoid “Midas Touch” problem – distinguish between a visual inspection and intent to act on a target [10, 2].

Eyes are not a very accurate pointing method compared to a mouse that can point at a single pixel on the screen. Eye trackers have a margin of error that makes it difficult to select small or closely positioned targets. Furthermore, during a fixation, the centre point of the foveal vision does not always coincide with the centre of a person’s attention. A person is able to pay attention to smaller areas inside the foveal region and move his or her attention around this small circle without triggering any eye movements. Therefore, it is not possible to infer the location of user’s attention with higher precision than the width of the foveal vision, regardless of the accuracy of the eye tracker [4, 10].

## 6. Conclusions

The aim of this thesis was to create a map editor that can be used to create and modify spatial data using eyes as an only input modality. The thesis presented a novel browser-based map editor prototype created in JavaScript. The thesis presented the proposed architecture of the application and design of the user interface of the map editor. A number of eye-controllable UI components were developed to serve as building blocks for the map application, such as Eye Button, Eye Dropdown, Eye Keyboard and others.

To evaluate the usability of the new user interface, two user studies were conducted, where participants had to resolve various tasks using the proposed system. The first user study was used to identify usability problems and to collect information. A number of most important problems were identified and possible solutions were discussed. Based on the problems found in usability testing, improvements were made to the prototype. The improvements were validated with the second user study. The changes made to the application reduced the number of problems users experienced and the average time taken to complete the test was reduced from 42 minutes to 24 minutes. Average time taken to type one word was reduced from 46s to 28s.

In both user studies, System Usability Scale was used to assess the system. SUS scores below 68 are considered below average. On both tests, the application received mean scores below 68: in the first test 63 and 61 in the second. This indicates that for able-bodied people the editor underperforms compared to the systems that use mouse and keyboard in terms of speed and comfort.

While the speed and comfort of using EyeTal does not currently match similar systems that use a keyboard and a mouse, it offers an alternative for disabled persons. Using eye tracking is a viable alternative and the work on the EyeTal map application will continue.

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