Automated Rear View Mirror

Developing and testing an automated rear view mirror for use in personal transportation vehicles

Aalborg University
Elkjær & Mosbæk
Group 1034
Medialogy

AALBORG UNIVERSITY

Department of Architecture, Design & Media Technology
Niels Jernes Vej 12-14
Phone +45 9940 8792
Fax +45 9940 9788
http://www.sict.aau.dk/

Title:

Automated Rear View Mirror

Description:

Developing and testing an automated rear view mirror for use in personal transportation vehicles.

Project period:

10th semester:
February 8th 2011 - May 31st 2011

Participants:

Morten Elkjær (Design)

Svend Emil Mosbæk (Design)

Supervisor:

Ann Morrison

Abstract:

The purpose of this project is to investigate the necessary conditions for developing an automated rear view mirror. Mirror automation serves the user by adding to the comfort and safety of the car by including the user in the formula. Observing the users on a predetermined drive have documented their behavior in regard to usage of the interior rear view mirror. It showed that the area of adjustment for all users span over a 5 degree angle in both axes, and that the mirror approximately is used once per minute, in a city environment.
The project resulted in a concept evaluation conducted on a semi-complete prototype. The participants had a positive attitude towards the concept idea as long as the product fulfill all requirements in regard to accuracy. The idea of the car adapting to the user, instead of the other way around is the road ahead for the modern car.

Publications: 4

Number of Pages: 102

Appendices: A - F

Finished: May 31st 2011

Preface

Formalities

Sources are referred to as ["author's surname", "year the text is written"] or ["organization/website", "year the text is written"] such as [Cowan, 2000] or [DrowsyDriving.org, 2011]. The Bibliography is listed in alphabetical order and attached at page 102.

Appendix F contains a DVD with all the referred sources, and also a video presentation of the project.

Acknowledgments

We would like to thank Preben Fihl for his technical assistance during the project, and our supervisor Ann Morrison for her support and encouragement.

Contents

1. Introduction

The car has come a long way from the invention of the steam car by Nicholas Cugnot [Mysteries, 2011] in 1769 till the modern fuel-driven cars of today. Affordable prices for the average citizen and the mobility and freedom that the car provides has made it the largest success since the invention of the wheel [Ideafinder.com, 2011]. Since the invention of the automobile traffic has had an exponentially growth. Over the years technology has improved both speed and mileage of the car. Increased speed also increase problems like traffic accidents. In order to lower the number of accidents, solutions in the form of technological improvements along with traffic laws were issued to protect the people in traffic. This resulted in a number of safety improvements that would become standardized equipment in all cars like seat belts, shock absorbers, frame safety features and more. In order to maintain ease of use, new innovations within the car industry would show the way. This leads to a number of the car functions being automated. Reducing the number of components and tangible artifacts to negotiate when entering and operating a car would also require less attention from the driver. This could allow more focus on safely navigating through traffic and improve comfort and safety.

Today and in the future the automation of the car continues. By implementing safety regulations as an active part of the car it will nonetheless provide better results than the momentarily effective scare campaigns and other government actions that ensure considerate driving of the population.

> The focus of this project is car automation and how comfort and safety implementations help the driver before and during a drive.

2. Research

Research and development has always been a part of the competition within the car industry. Technological progress has resulted in car prices low enough to include automation as a part of the standard package in most modern cars. The move towards increased automation in the modern car has increased comfort and safety for drivers. Therefore the Research Chapter will look into state of the art electronic innovations in the area of personal transportation vehicles.

2.1 Automated Car Equipment

Automation in cars has had priority in connection with the comfort and safety of the car. The automation technology supports the driver by handling uncomplicated features of the car, such as the automated response of windshield wipers when detecting rain and reminder sounds when passengers have forgotten to buckle up their seat belts. The automated support systems and processes aid the driver before, during and even after getting on the road, allowing the car to support the driver and makes it easy to remember safety issues when entering the vehicle. The adaption of technology means that modern cars are equipped with a lot of sensor devices. These gather information about the car and its surroundings, such as detecting rain and other cars on the road. For further references a list of car equipment can be found in Appendix A. Modern cars have approximately 80 different controllers as a part of the standard package [Broy, 2010].

The automated car equipment can be classified as the personal settings of the car. To limit the descriptions, only the equipment which has an effect on the driver will be further described in the following section.

2.1.1 Personal Settings

In order to register which conditions the driver prefers, the car can through sensor devices store personal settings for each driver. This can be recognized as things that would normally require the drivers attention when entering a car. The settings are individually customized for each person and need to be adapted according to height, leg length and head position. This means altering the seat adjustments, steering wheel and mirrors. These settings must be properly adjusted when the driver was not the last person to operate the car, or when they are going on a longer journey than their daily commute.

Keyless Lock

One existing method for automated personal settings can be found in the keyless lock. The keyless lock is used in many high-end cars. This is the contemporary version of the car key that relies on electric signals and electromagnetic fields to unlock the car replacing the ordinary key lock [eHow, 2011]. A keyless lock allows the user to enter the car without having the trouble of looking for the key to unlock it. The only requirements are that the driver opens the handle while the keyless lock is within a certain range of the car.

Today this technology has already been implemented by a number of different car manufacturers like Mercedes, Volvo and VW to mention a few [Mercedes-Benz, 2011] [Volvo, 2011] [VW, 2011]. BMW presents a system, which automatically will unlock the car when the key gets within 1.5 meters of it. The car will automatically lock when the key is outside the specified range [BMW, 2011b]. The selling point of the key-less lock is that of convenience. The user will no longer have to search for the key in bags or pockets. Although it is not a factory installed option it is also possible to remotely start the car, meaning that the user can start the car when approaching it and start driving right away. Although this is a small feature, it will combined with other features of the car save time for the driver.

If there are more users of the same car, each of them will have their own personal keyless lock, which means that the car will adapt its settings to the user whose key is the closest to the steering wheel. This means that the car will be able to automatically suit the settings of the person that is driving, even before entering the car.

CASE: Personal Settings in a Family Car

The following describes a fictional scenario with a four-person family with two teenage children. Their personal settings could be very different and it will require quite some time adjusting the car when switching from one driver to the other. This applies even more when the eldest teenager is 18 years old and would like to drive.

In the following a usual day in the life of a family will be described: The mother takes the car to drive the children to school, since the workday of the father starts earlier in the morning and the option of public transportation is at his disposal. As both of them are office workers the car will not be used again until some time in the afternoon. After work it is time to pick up the children and shop for the daily supplies. The oldest daughter who has just got her drivers license is asked to drive home to increase her driving experience. In the evening the younger son needs to go to soccer practice and as he has no license yet the father will take him. This shows how every member of the family uses the car during the day and gives an understanding of the convenience that automation and personal settings in the car can provide for a family.

If there are a lot of adjustments to do when changing driver, it increases the risk of forgetting to adjust some of the settings, which then will be adjusted when on the move. If the car were to adapt on its own in accordance with the person who is behind the wheel, these risks will nonetheless be lowered since the drivers will not forget any adjustments, and then feel tempted to make them later on during driving.

CASE: The Stressed and Rushed Driver

In comparison to the entire family scenario, this case describes an active person who is always in a hurry and behind schedule getting in the car and therefore has very little concern about the adjustment of the car. For this type of person, customized settings will be most useful. If the drives consist of a lot of small-distance driving, the driver will probably neglect the minor adjustments to the mirror and other adjustable equipment of the car, in comparison to going for an hour-long drive on the high way.

The following will describe a usual day in the life of this rushed driver. In this scenario the main person is a single career oriented woman with a modern almost fully automated car: In the morning she takes her car to work. Because it is early in the morning she appreciates the time saving functions that her car has. When getting within range of the car it automatically unlocks preventing time wasting with finding keys. The mirrors will automatically roll in when the car is in park and roll out on start-up. Because she is busy she does not want to adjust the mirrors and seat settings because of the minutes this task can require. At lunch time she will go by car to a small sandwich shop near her work. During the day it is not unusual having to go to a couple of different departments to participate in meetings, each located so the car will be used for this task as well. In the evening she will be going to a restaurant in the city before going home. In the weekends she appreciates going for longer journeys to see the country side and getting a bit away from the everyday rush.

Because the car is used for many tasks the automated adjustments are appreciated because they save time in a hectic lifestyle.

From the scenarios and the study in car equipment it can be derived that automation in cars have several benefits in both comfort and safety of the passengers. This applies whether the car is used by a single person or a group of individuals.

Because the interior rear view mirror has not yet been automated in modern cars it could be of interest to research whether or not automating this mirror would be beneficial for the driving experience and whether or not the comfort and safety will increase. To do this it will be relevant to research if there are any guidelines or rules of law that describes or can help define the optimal position of the mirror.

2.2 Adjusting the Mirrors - Law & Regulations

Among the personalized settings, the drivers view is one of the most important features within the car that can more readily assist with the prevention of traffic accidents. In accordance with this, a set of rules have been defined by the Danish Transport Authority [Færdselsstyrelsen, 2011] and they state the following requirements:

1. The car must be equipped with:
    - Interior rear view mirror.
    - Exterior rear view mirror on the left side of the car.
2. The car must also be equipped with an outside rear view mirror on the right side if:

- The interior mirror and exterior mirror on the left side of the car does not provide sufficient view of the rear view.
- The light transmittance in the rear window or the rear side windows are below 70%.
- The car is right-hand driven (Due to left-hand driven cars in Denmark).

3. If the car has been approved for a trailer and this reduces the vision of the rear view mirror, then the car must be equipped with an exterior rear view mirror on the right side.
4. The rear window must be equipped with a defrosting appliance.
5. Objects that unnecessarily obstruct the view of the driver must not be placed in the rear window. Examples of unnecessary objects could be commercial streamers or non-transparent film. This does not include headrests or a sun shield.

The requirements for education when acquiring a drivers license in Denmark are all listed in the declaration by [Justitsministeriet, 2009]. The parts of relevance to this project concern use and adjustment of the mirrors, listed in paragraph 1.2.9 (Special Equipment), 2.1.1 (Control, operation, adjustment and use of equipment) and 7.8.3 (Skills in Orientation). The rules state that it is mandatory to have an interior rear view mirror and an exterior mirror on the left of the vehicle. The mirrors must be clean, intact and adjusted properly. As part of preparation before driving, the driver must clean the mirrors if they are dirty or foggy. This also applies to the windows and lenses. The driver must then *"adjust the mirrors in a way which provides the best possible view without having to change driving position"* [Justitsministeriet, 2009] (paragraph 2.2.1 #6). When driving, the driver must *"with frequent intervals look briefly in the mirrors to be updated of distance, speed and intention of vehicles in the rear"* [Justitsministeriet, 2009] (paragraph 7.8.3 #6).

Adjusting the mirrors to cover the right angles or blind spots is of further interest for this project. Tony Quiroga [Quiroga, 2010], an associate editor on Car and Driver [Caranddriver.com, 2011] has made a good illustration of how the rear view mirror settings could be, in order to cover the blind spots. This is based on suggestions by the Society of Automotive Engineers [SAE, 1995]. Figure 2.1 shows the difference between the view in the mirrors when following the suggestion by SAE and how people will normally adjust the mirrors.

The point of the article is that the mirror angle do not have to divert very much before a blind spot will occur. George Platzer is a member of SAE and a known person for his research in car mirrors and how to avoid blind spots. His findings are shortly presented in this folder [Platzer, 2011], and it conclude that the side mirrors should not display the car in their field of view but focus on the other car lanes. Then, by combining all three mirrors of the car, the driver will have the optimal view.

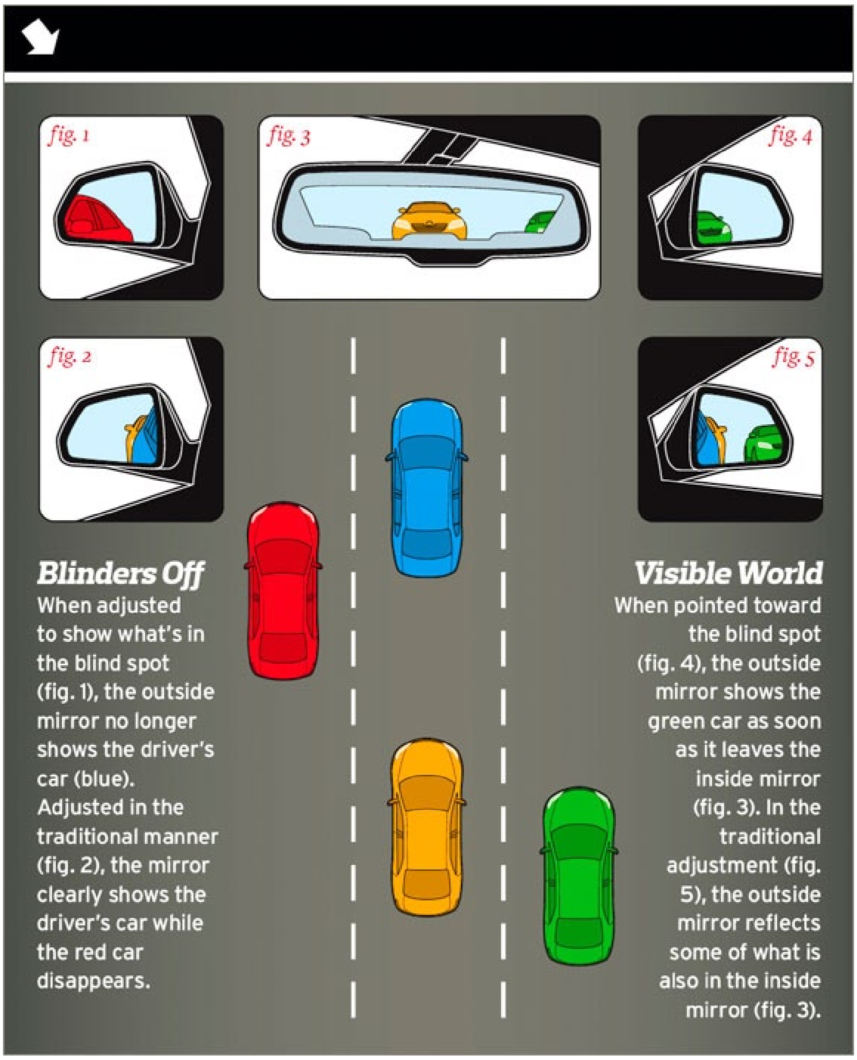


Figure 2.1: Guideline on how to adjust your mirrors to avoid blind spots suggested by Society of Auto Engieneers [Quiroga, 2010].

2.2.1 Teaching Mirror Adjustment

According to the driving regulations there is no exact definition of how the rear view mirrors must be adjusted. Most important is that the vehicle is equipped with the required mirrors. To ensure that nothing had been overlooked and because it seemed unlikely that there are no rules for adjusting mirrors, contact was made with a driving instructor at Driving Academy Aalborg [Driving-Academy, 2011] to get an expert opinion. The mail correspondence is attached in Appendix B. The received response stated that according to the traffic regulations there are no specific guidelines for adjusting mirrors in a car. The traffic regulations do however state that a driver cannot be a danger to others in traffic and therefore everyone must set the mirrors in a suitable position. In the education of new drivers they focus on teaching the students to combine the mirrors with a head-turn, because both is necessary to obtain the best overview when driving in traffic.

The conclusion is that the correct settings are in the hands of the individual driver. In context of the project it would therefore be necessary to test on users to determine a general setting that could be comfortable for the driver and what they usually do.

2.2.2 Adjustment Station for Adjusting Truck Mirrors

There are no specific guidelines for cars, but there are several resting places in Denmark which have special test stations with the purpose of helping truck drivers to adjust their mirrors correctly [Statoil, 2011] [Truckernet.dk, 2011]. The reason for this is an increase in accidents caused by trucks preforming right turns, especially causing cyclists getting caught under the vehicle [Politiken.dk, 2004] [sikkertrafik.dk, 2010] [HVU, 2006]. This has let to intense media coverage of the topic and thereby implementation of new steps to prevent these accidents. Steps include adding mirrors to the trucks to give a better view of the bike path at the right of the vehicle, and also experiments with installing sensors to detect the bikes and let the truck driver know by auditory feedback that there is an oncoming cyclist which needs extra attention [Færdselsstyrelsen, 2004] [DTA, 2011]. Regulations state that trucks must be fitted with a side guard on the right hand side of the vehicle to avoid other motorists and unintended objects getting caught under the truck [DTA, 2010]. The focus in these accidents has initially been on the truck drivers. However, it is a of course a two way responsibility, because a lot of the responsibility is in the hands of the cyclists. They do not take enough notice of the trucks, and are not as aware as they need to be of their own vulnerability. Therefore they do not take the necessary precautions when going into traffic and encounter the trucks. Campaigns on TV and bill boards in traffic have tried to focus on the situation to give the needed cautiousness to both drivers and cyclists [SikkerTrafik.dk, 2011].

2.3 Attention & Distraction

Statistics show that distracting the driver can lead to accidents [MichaelPines, 2011]. Distraction comes in many forms, such as other cars on the road doing unexpected turns, passengers inside the vehicle, control of in-vehicle equipment or just being mentally somewhere else than on the road [Larson, 2011]. These are all factors, which will draw the attention from the main task which is to keep attention on the traffic. Having complete attention on traffic and what is going on around the vehicle can be just as critical as distraction, as it over time will become tedious to the vision, brain and concentration and can in some cases lead to drowsiness and boredom [Kar, 2011].

2.3.1 Cognitive Load & Senses

Cognitive load describes the phenomenon that the human brain is only capable of containing a certain amount of information before some of it will be forgotten and replaced with some of the new information entering the brain. M. Asif Khawaja, Fang Chen and Nadine Marcus are professors at the University of New South Wales, Sydney, Australia and they have produced several papers within the cognitive load area. According to their paper [Khawaja *et al.*, 2010] cognitive load can be defined as follows:

> *"When a person performs a particular problem-solving task, it imposes a mental load on the person's working memory, known as Cognitive Load. It is caused by the limited capacity of the person's working memory and his or her ability to process new information."*
>
> [Khawaja *et al.*, 2010, p. 333]

In regards to this project the mental load on people are of interest when they head into traffic in a car. Traffic offers a variety of different situations that adds to the cognitive load. An example could be when driving on the highway; then the focus should be on adjusting the speed, watching out for traffic from behind and keeping proper distance to those in front. All these tasks add to the cognitive load required from the driver. They also determine his or her performance when driving. Of course an experienced driver will be better at distinguishing the most important information and thus mind the most relevant pieces first. For the inexperienced driver devices that can help reduce the cognitive load could improve their driving performance.

The cognitive load, or "chunks of information", which the human brain are able to process in the short term memory ranges within 7 ± 2, stated by [Miller, 1955]. Nelson Cowan has made further research based on the work of Miller, and states that the average person is only able to process four chunks of information in the short term memory [Cowan, 2000].

Another well-known professor within the field is Sharon Oviatt. Her focus is on designing human computer interfaces to reduce the cognitive load. This is believed to make people think more clearly when they need to make decisions within a short time frame [Oviatt, 2006]. The research of Sharon Oviatt also shows that a system rarely adapts to the user. The most common situation is that the user adapts to the system [Oviatt, 2006, p. 872]. This is especially seen in situations where the end products has been designed by engineers. The end users cope with a user design, which is not always logical, but over time they will adapt to the design of the system and not vice versa. Car producers have during the last decade put much more development into interfaces that adapt to the needs and wishes of the user.

The driver of a vehicle has a lot of elements to keep in mind and it can in some situations increase stress on the drivers mind, which also increase the cognitive load. Imagine a situation where a car in the city are in the process of crossing a road which has pavement and a cycle path on both sides. The driver then needs to keep notice of traffic traveling at different speeds in both directions, before assessing whether or not it is safe to cross the road.

In the city when doing a right turn at an intersection the driver must keep a mindful eye on bikes approaching from behind and at the same time be mindful of the pedestrians crossing the street. This situation is however made easier for the driver by the traffic lights (a green right-turn arrow), which lets the driver know when no bikes will be crossing the intersection. Only traffic making right turn will go through and pedestrians will not be crossing at the same time. Although traffic lights are not a 100% fail safe solution (pedestrians can be jaywalking, so the car drivers still need to be mindfull of their intentions), the trust in the system will lower the cognitive work load of the driver.

Cognitive load is closely connected to the senses. In cars the senses of sight, hearing and tactile feedback are used. Too much information addressed to a single sense will make it overload over time. The majority of the mental resources related to the senses of a driving person are allocated to process visual information. This can be as much as 90% [Rockwell, 1972]. This is due to the fact that the biggest task when driving a car is related to visual tasks such as navigation, positioning of the car on the road, and paying attention to hazards.

As the cognitive load when driving in some cases becomes too high and gives the driver a hard time keeping focus on traffic. Some manufacturers have made products and systems, which are meant to avoid accidents caused by the driver by maintaining the driver's attention. Two examples of solutions that keep the attention of the driver are presented by Anti Sleep Pilot by ASP-Technology ApS and Saab Driver Attention Warning System by Saab. These are just two examples of solutions to keep the attention of the driver alert, and in Appendix A is listed more systems which assist the driver in avoiding accidents.

2.3.2 Anti Sleep Pilot

Figure 2.2: The Anti Sleep Pilot is a device which is positioned on the dashboard of the car. At certain intervals it will require the driver to touch the device as part of determining the fatigue level of the driver. Image from [ASP, 2011a]

The thought behind the Anti Sleep Pilot is based on statistics that reveal 20% of traffic accidents occur because of fatigue [ASP, 2011b] [DrowsyDriving.org, 2011]. While driving, a specially designed algorithm monitors the fatigue level based on inputs given by the driver at the beginning of the drive. The device is programmed to know the driver and processes the input data for the specific drive. Based on these inputs, the device makes the necessary attention tests to predict and prevent driver drowsiness and informs the driver when it is time to take a break. The prediction and estimation of the fatigue level are calculated by use of 26 different parameters split into 3 categories as shown in Figure 2.3. Figure 2.2 shows the device placed at the dashboard from where it will signal to the driver by use of sound and light.

	Category	Input parameter	How and when?
Fatigue level	1. Individual risk profile	▪ Age ▪ Gender ▪ Work hours pr. Week ▪ (12 factors total)	▪ Set by the driver before the first drive
	2.Current fatigue level before the drive	▪ Medicine/alcohol intake ▪ Hours awake ▪ Sleep the last 2-3 days ▪ (8 factors total)	▪ Set by the driver before each drive
	3. Drive data	▪ Time since break ▪ Time of day ▪ Reaction time ▪ (6 factors total)	▪ Automatically registered by sensors in Anti Sleep Pilot® during a drive

Figure 2.3: The Anti Sleep Pilot algorithm consist of 26 parameters split into 3 categories in order to predict the driver fatigue level [ASP, 2011c].

2.3.3 Saab Driver Attention Warning System

The Driver Attention Warning System developed for Saab examines the drivers direction of sight to monitor if the attention is on the road. If the attention of the driver is away from the road for more than 2 seconds, the driver will experience an alert in the form a vibration of the seat cushion. According to Lisbeth Almén [Almén, 2002] tactile feedback is a good method for alerting the driver to redirect the attention to the road. The work load of the visual sense is already high when driving, and it is therefore not desirable to put additional load on the visual sense [Wierville, 1993, p. 134]. The attention of the driver is estimated by detecting and monitoring the movement of the head and the pattern of closing the eye-lids as depicted in Figure 2.4. When the system sense that the driver is dozing off, the car's audio system will inform the driver firmly but politely to take a break as soon a possible [saabnetwork.com, 2007] [Articlebase.com, 2007].

Figure 2.4: By tracking the head and eyes of the driver the system is able to determine whether or not the attention of the driver is focused on the windshield and the road. If not, the system will alert the driver by rumbling the seat cushion and later by auditory feedback. Image from [saabnetwork.com, 2007].

Both distraction and loosing attention while driving are causes for accidents. Even though systems to prevent accidents have been introduced, accidents are still a significant problem in traffic.

2.4 Accidents in Traffic

In order to decrease the number of accidents it is necessary to look at the different circumstances that cause them and figure out how to prevent them from happening in the first place. In Denmark there has been a reduction in traffic casualties from 2008 to 2009. The total number of casualties in 1998 was 499 and in 2009 it decreased to 303 [DST, 2011a] [DST, 2011b]. Although this could appear like a small number of casualties the total number of accidents is much higher. In 1998 the number of traffic accidents were 7556 and in 2009 the number had dropped to 5250 meaning a reduction by approximately 30%. Although automation of car safety is just one of the factors in play it most certainly is one of the best causes with an effect.

Wrongly adjusted rear view mirrors cannot be blamed as the main reason for traffic accidents in any of the statistics, but it can be included as a factor that combined with other road issues put lives in danger.

In Denmark there has been a lot of information campaigns and initiatives appealing to people for traffic safety [SikkerTrafik.dk, 2011]. The union [LivOgTrafik, 2011] has researched accidents in Denmark, and according to them the top 5 causes for accidents are speeding, alcohol, missing seat belt, right swing accidents and road-design.

Speeding and alcohol related accidents are considered the biggest dangers in traffic outside of Denmark [NSW-Government, 2011] and [SST, 2011]. Therefore it can be assumed that developing the automated rear view mirror would only play a minor part in reducing the number of accidents. Although this is the case, an automated rear view mirror could aid in reducing the number of accidents.

2.5 Summary

Because the purpose of the car is transportation from A to B, the safety issues can be easy to overlook when entering the car. Forgetfulness is not necessarily with ill intent, but a result of stressful weekdays that provide enough hassles as they are, and because people adjust the mirrors without needing exactness. In modern cars many of the integrated comfort attributes also support the car safety. Because of this the safety issues that the driver does not need to pay any attention has become an integrated part of the car's comfort, since all focus then can be directed to giving attention to traffic.

Cars of today are equipped with an increasing amount of new technology that could have resulted in more systems to operate by the driver, had it not been for automation. Automation is a solution that allows the driver to direct attention on the road instead of operating the equipment in the car.

The development of an automated rear view mirror for this project serve both as a comfort and safety device. First of all it could prove to be a great comfort when the rear view mirror is able to adjust to suit the needs of the driver. When the driver does not have to remember adjusting the rear view mirror, the attention will more likely be on traffic. The safety of such a mirror is relevant when it is not in the desired position. Under normal circumstances this would require the driver to manually adjust the mirror while driving, which draws the attention of the road, potentially increasing the risk of traffic accidents.

Because mirrors are an important part of the driver's attention this leads to the focus of developing an automated rear view mirror, as it could heighten the comfort and safety for the driver.

3. Concept Description

In the Research chapter the field of automation in cars has been analyzed and researched with the purpose of confirming that the automated rear view mirror is not already a part of the standard equipment in the modern car. Part of the research was focused on how the automated devices are able to reduce the cognitive load on the driver. Reduced cognitive load would mean that both comfort and safety in the vehicle increase. With the knowledge gained in the Research chapter in mind, the overall concept and thoughts about the automated rear view mirror can be presented to give the overview of how the final system should be implemented. Due to limited project time, this chapter will be followed by a Delimitation chapter, which describes the research areas of the complete concept that will be further investigated and implemented through this project.

3.1 The Idea

The main idea is that the rear view mirror will automatically adjust to the optimal position of the driver during a drive. The automation will allow the driver to pay attention on traffic. Also changing driver will provide faster transition because the mirror is included as an automated variable.

Automating the mirror is based on position changes made by the driver during a drive, meaning that over time a gradual slouch in body-position might occur compared to the position of the driver at the start of the drive [ErgonomicsSimplified.com, 2011]. This lead to the idea of automating the interior rear view mirror, simplified by the illustration in Figure 3.1. In the Research chapter we learned that a lot of equipment that used to require the driver's attention are being automated by the car industry. The automation will help increase safety while driving due to reduction of cognitive load on the driver. Because this project is a part of the automation process it will be interesting to determine how a technical solution could be made. It is also necessary to identify the elements that will be used for this automated rear view mirror system.

Figure 3.1: Simple illustration of the concept. If the mirror is in a wrong position relative to the driver, it will automatically adjust to a satisfying position.

3.2 Driver Movement - Delay and Smoothing

The system will continuously detect the position of the driver's position. When calculating the mean position of the driver it is possible to detect when the driver's position has changed according to the mirror. When the position of the driver change the mirror change position accordingly.

Assuming that while driving, the driver will over time not maintain a constant position, as driving a car requires frequent orientation in both exterior and interior rear view mirrors. This also apply when looking over the shoulder to avoid hitting cars or persons in the blind spots. These movements will make the task of detecting the driver's position much harder, and will involve calculating a mean value for the position of the driver, to prevent the mirror from repositioning when it is not needed. The mirror should therefore not adjust to all movements detected from the driver, but instead readjust if the system detects a sustained change in driver position over time. This will give fluent control of the mirror and cause little if any distraction to the driver. Therefore the mirror will not change position if the driver returns to the position prior of i.e. looking out the side window or over the shoulder checking the blink spots. If a driver position change has been registered the mirror will slowly adjust it's position accordingly. Slow enough to not be noticed by the driver.

The automated rear view mirror, which is always adjusted to the position that yields the best view through the rear window is a comfort device designed to aid and improve the safety of the driver. The comfort consist of not having to spend time adjusting the mirror. Furthermore, not needing to readjust it when driving in traffic or changing driver, because the mirror will automatically position the mirror in the most satisfying position. When the driver's attention is directed towards traffic, and less on personal car adjustments, the general comfort and safety increase.

3.3 Practical Issues and Driving Behavior

Implementing an automated rear view mirror does not only concern the technical aspects of detecting the position of the driver and make the mirror adjust according to it. People cannot be classified in a box labeled as drivers. Everyone has different skills and habits when getting behind the wheel, which can derive different driving behaviors. They might not accept the predetermined control of the mirror, and some situations will require a more free and customizable use of the mirror. The final product is supposed to be an incorporated part of the car, therefore investigating driver behavior could provide indications on which mirror functions the general driver feel comfortable with. These considerations have been formed into product guidelines, describing the system. These are described in the following section:

Children on the Back Seat

When parents drive with children on the back seat they might want the possibility of keeping an eye on them while driving. This requires the rear view mirror to be adjusted to a position pointing more downwards compared to the automated "best" position. The downwards adjustment will allow for both surveying the activity on the backseat and cover part of the rear window. This however means that approximately half of the windshield can be seen in the mirror, requiring the driver to change position to get a satisfying view through the rear window. In a scenario where the driver opts to monitor both traffic and the kids he or she will have to willingly adapt to the situation.

Mirror Movement Delay Adjustment

Like some cars have windshield wiper speed adjustment according to the amount of rain on the windshield, it could also be available for the driver to selects how responsive the mirror will be, in connection with the mean position of the mirror mentioned in "Driver Movement - Delay an Smoothing of the Mirror Movement" 3.2. This will help the driver to have the system adjust in a way which fits the personal needs and wishes.

Makeup and Personal Care

Using the mirror for putting on makeup requires adjustment of the mirror or in the automated example moving to an undesirable position. The concept of the automated mirror has been presented to family and friends of the group members. The responses was concerns about these types of situations that require alternative use of the mirror, and how these situations can be handled. A solution to fulfill this driver requirement is to have the option to turn off the automation and manually adjust the mirror to a alternate position. This is presented below in the "On/Off Setting".

On/Off Setting

Even though it is a tremendous help to the driver to have a automated rear view mirror, there might be situations in which the driver just wants to turn the automation off and drive with the mirror in a completely static position as known from a traditional interior rear view mirror. The motor control of the mirror must be designed to allow this, making it possible for the driver to position the mirror to their personal liking, if not by use of moving it by hand as a traditional mirror, then by use of a two-way control knob as used to adjust the exterior side view mirrors.

Soundless Adjustment

The system must be able to adjust without making noticeable noise. If a noise is emitted during the mirror adjustment, it can be assumed to annoy the driver and steal focus while driving.

Sensing the Driver

The product must be able to sense the presence of a person and only activate when the person is present. A safe solution for this could be to make use of the integrated pressure sensors in the seat, along with the car ignition and the key proximity sensor.

Spacial Limitations

The physical space occupied by the mirror must not exceed the size of a normal mirror. In modern cars the trend is to leave enough room for electronics in the mirror, making the back of the mirror broad. The mirror cannot obstruct existing technologies like the auto dimming of the mirror when light from other cars or the sun is reflected. The controls of the mirror will be placed in the box behind the mirror and consist of two small servo motors. This means that there should be enough room to incorporate the project system.

Save Function

Finally the system should be able to save the last known position so it will not reset to a factory setting whenever the driver enters the car.

3.4 Summary

The Concept Description chapter has defined the concept of the automated mirror, while taking the information found in the Research chapter into account. The research has shown that this mirror has not been implemented by any of the larger car companies. Since there is no preceding cases for an automated mirror it is necessary for the project to identify and define the guidelines for the system and final product. This also includes user experiences and applying the results into the system.

The guidelines are mainly focused around the user experience. These seek to determine which features are necessary for the user, and will benefit the driver. The research areas of importance are: driver's behavior, functionality, hardware- and software requirements.

4. Delimitation

The Concept Description chapter has presented the overall concept of the automated rear view mirror, and seeks to define the requirements for the optimal solution of the automated rear view mirror. Implementing and testing all requirements would demand more time than allowed by the time frame for the semester. It is therefore necessary to set up delimitations that can be accomplished within the given time frame. The Delimitation chapter presents the aspects of the Concept Description, that will investigate the conditions for developing the first prototype.

4.1 User Related Research Questions

In a car there are usually two exterior side mirrors and one inside the car cabin. The automated mirror system could include control of the exterior rear view mirrors, but in order of limiting the project the focus will only concern the cabin rear view mirror. Even when focusing only on the cabin rear view mirror for the project, there is still a need to prioritize the research areas to cover those of immediate concern in the first iteration. This method of progress is chosen since developing a complete system that honor the requirements and ideas in the Concept Description chapter would require an extended amount of time. Therefore, the research of this rapport will concern the following research questions for the first iteration:

- How much do people use the rear view mirror when driving?
- How accurate are people when adjusting the mirror?
- Further investigation - How accurate does the system need to be?
- How can the technical solution behind the rear view mirror be made?

When investigating how to make the automated rear view mirror there are a number of considerations that needs to be accounted for. These should be done before making the technical solution to reinforce decisions made for the physical part of the prototype. Researching the usage of the rear view mirror is necessary in order to determine situations in which automating the system is relevant.

The next investigated area concerns how accurately people adjust the mirror. If people adjust the mirror to the same setting over a number of adjustments would mean that the system accuracy needs to reach a high level of accuracy. However, if people have relatively large differences in their adjusted settings, and feel that the positioning of the mirror is optimal after each adjustment, the conclusion will be that there is room for a certain margin of error without this being of annoyance to the driver. The system could then be limited to the area in which the the relevant information can be found. Regardless of the outcome, the mirror adjustment time spend by people could be measured to find the amount of time saved by an automated mirror. The time saved could further increase when the mirror auto adjusts while driving. We assume that the user starts slouching after driving for a while and would need to reposition the mirror on the go. With an automated mirror, time and concentration would be spared because the mirror would not need to be readjusted manually.

The next part concerning the project is implementation. Which requirements are needed for this system to work in either a car or simulated car setting. Because this is the first iteration, the points of interest concerns observing the users.

4.2 Prototype Related Research Questions

When knowledge about the user observations have been recorded the next step will consist of building the first iteration of the prototype. This first version of the prototype is necessary because it is impossible for the test participants to evaluate a system that does not exist. Also simply explaining the idea through illustrations and videos does not provide the same experience that a physical system does. Although the possibility for having a prototype implementation in a test car is present, the time frame of the project also set the frames for developing the prototype. To ensure that the features can be implemented within the given time frame, some of the time consuming variables should be avoided. The main variable that should be avoided is implementing the Computer Vision part in sunlight. Therefore the second part of the test will consist of a concept user evaluation in a controlled environment, using the prototype as a physical representation of the system.

- Is the manual and automated control of the mirror understandable to the users?
- How accurate is the system, in terms of specific positioning?
- How fast can the system smooth between positions, without being an annoyance to the user?
- How does the users evaluate the system, positive or negative?
- Do the users consider it to be an improvement of their cars comfort, safety?

The manual system control is of interest because it needs to be intuitive for the users, both in park and while driving. If the driver decides to use the off setting, positioning the mirror should be equally intuitive, or easier to adjust, compared to adjusting the non-automated mirror.

Evaluating the technical aspects of the system would help calibrate the mirror when it is positioning itself. The technical aspects of the prototype are accuracy and smoothing. The accuracy are of interest to determine when the users start noticing and feeling uncomfortable about the inaccuracy of the mirror, to further define how accurate the mirror must be. The smoothing are of interest to determine at what adjustment speed, people start noticing that the mirror is repositioning itself. When the speed is determined, the system could be accurately set to not exceed it and thereby continue to not steal focus while driving.

Furthermore it would be interesting to learn more about what people think of the concept in general. Since the prototype test will take place in a controlled environment the questions regarding the concept of the system will be kept at a conceptual level.

5. User Observations

Having described the overall concept and derived the delimitations for the first iteration, the next step concerns how to answer the research questions. In order to do that, users will be included in an user observations test. The test will take place in a car with a normal rear view mirror, while driving in a live city environment. The test will focus on observing and recording how people use and interact with the mirror.

5.1 Test Walk-Through

The test will take place in a natural environment to generate realistic observations of people's behavior while driving, as suggested by [Sharp *et al.*, 2006, p. 591]. This means that the participants will be driving a predetermined route in traffic. The test participants will be allowed and encouraged to adjust the car settings (seat and mirrors) to a position they are comfortable with. This serves both as a safety precaution and reinforces a realistic driving scenario.

Because this project contains both technical and usability aspects in regards to the user observations, two approaches will be used. In terms of usability it will be an observation of the mirror usage during the drive. The observations will consist of a video recording to document how much the participants use the mirror, the time they spend adjusting it and recording the number of times they look in the mirror. The camera to record the test participants will be mounted firmly on top of the rear view mirror with the lens in the middle of the vertical axis of the mirror, as depicted in Figure 5.1

Figure 5.1: The camera mounted on top of the rear view mirror used to record the test participants during the observations.

To measure and record these data we will as test leaders both observe and confirm when the mirror has been looked into. These markings will only be made when the person is not in park and they will be marked with a time stamp in Windows Movie Maker. The technical focus will be to make the users adjust the mirror four times during the test drive. The participants will be asked to park the car at predetermined locations, shown in Figure 5.2. Following the rear view mirror will be placed in a wrong setting and the participant will be asked to re-adjust it. After each adjustment the setting will be recorded for further referencing. The video footage will reveal the adjustment time measured in seconds, which can also be timestamped in Windows Movie Maker.

The rear view mirror is of course the main focus in the test setup. In order of making the test participant move it, the start position of the mirror must be arranged in a position that is clearly wrong. This means that when one participant has ended his turn the test leader will "reset" the mirror to a wrong position.

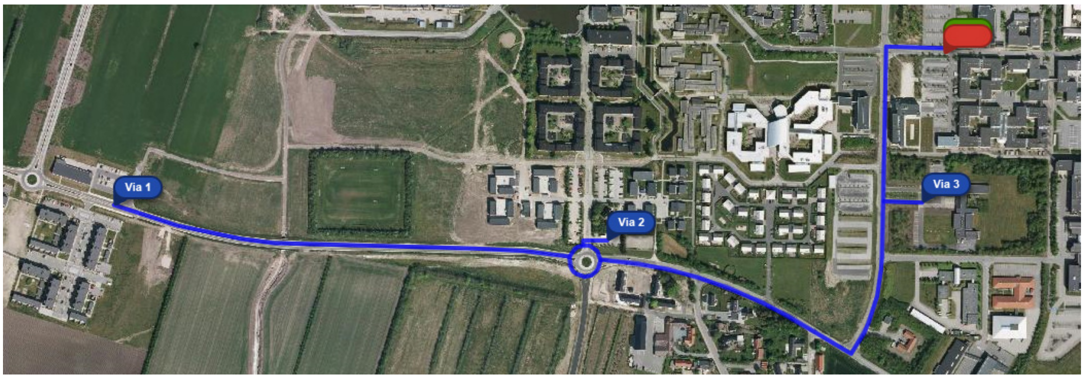


Figure 5.2: Overview of the route, consisting of the first part without interruption, and 2 via-points on the route back to the starting location.

The drive will furthermore consist of two phases. In the first phase the usability observations will be made without interrupting the driver apart from giving driving directions. The second phase of the drive will be focused on how the test participants adjust the mirror.

The starting position of the user observations will be within the university campus and include an 3 km route as shown in Figure 5.2. The first half is a 1,5 km drive to a parking lot at a nearby grocery store, marked as Via 1 in Figure 5.2. On the route back stops will take place at appropriate parking locations (Figure 5.2 - Via 2 and Via 3). As earlier mentioned the mirror will then be positioned wrongly after each stop, and the driver will be asked to readjust it. After the fourth readjustment (Via 3 in Figure 5.2) the participant will be asked to return to the starting position. The test drive will approximately require around 10 minutes per participant. This depends on traffic on the route that is a factor of concern since the test do take place in a live environment. After the test the height of people will be measured. By recording the height of the test participants for the user observations and comparing it to the average height of Danes as presented by [Garcia & Quintana-Domeque, 2007, p. 343] it is possible to determine how well the test sample compares to the population. The basis of that should conclude whether the angle setting and the limits derived from the observations can be transfered to the system when developing the prototype.

The car used in the test will be a Ford Mondeo Trend from 2001, which is classified as a middle- to large sized car. The reason for this choice of car is availability within the designated time period of test.

The following will be recorded for the test:

- Video recordings of the drives, by use of a camera mounted on top of the rear view mirror pointing towards the driver.
- Height measurement of each test participant.

From the video recordings the following will be observed :

- Number of times looked in the rear view mirror.
- Time spent looking in the mirror when driving the predetermined route.
- Time spent adjusting the mirror.
- Accuracy between the four times the mirror is adjusted during the drive.

5.2 Results of User Observations

The following are the observed test results provided by 10 different test participants.

5.2.1 Number of Times and Duration of Views

As concluded in the test walk-through the observations consist of the number of times the participants oriented themselves in the rear view mirror and the duration of these.

	Number	**Duration**
Test Person 1	11	5,5 sec
Test Person 2	9	2,5 sec
Test Person 3	8	3 sec
Test Person 4	16	7 sec
Test Person 5	11	5 sec
Test Person 6	5	2,5 sec
Test Person 7	16	7 sec
Test Person 8	**5**	1,5 sec
Test Person 9	**25**	12 sec
Test Person 10	7	1,5 sec
Average	**11,3 times**	**4,75 seconds**

Figure 5.3: Number of times the mirror was used for orientation and total time spent looking in the mirror for each participant.

Table 5.3 shows variation in the number of times the test participants looked in the mirror, with a minimum of 5 and maximum of 25 for the same route. A total of 113 looks in the mirror with a total duration of 47,5 seconds gives a duration of 0,42 seconds for each mirror orientation. The number of times and the duration of the mirror orientations are recorded by noting each time the test participants looks in the mirror. The video recordings of the test participants show the timings. Meanwhile the duration of the orientation are estimated.

5.2.2 Time Spend Adjusting the Mirror

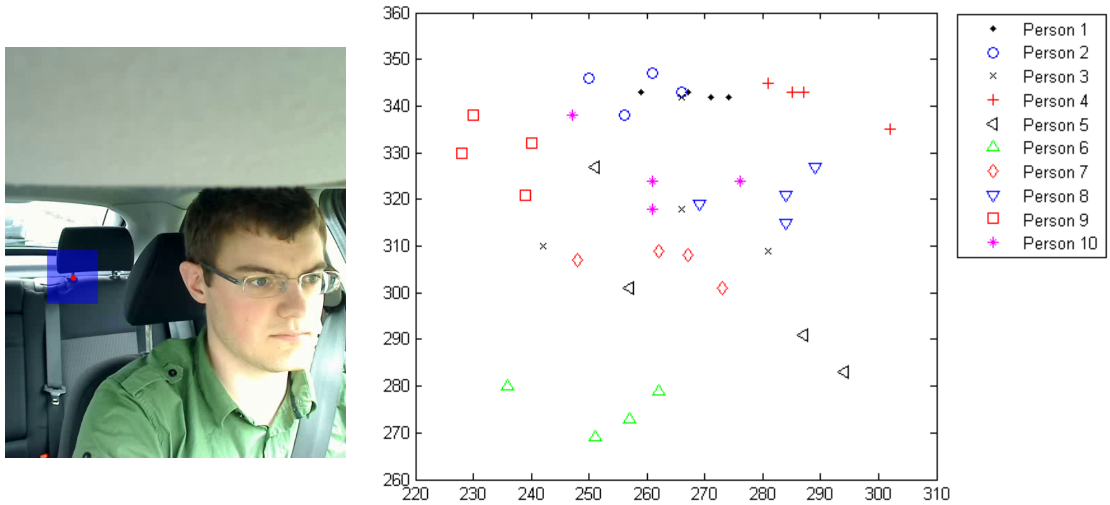
From the video recordings of the test participants is was possible to derive how much time the user spends on adjusting the rear view mirror. The result was an overall average time spent for the test participants to adjust the mirror at 8,65 seconds. The fastest average adjustment time for a participant was 4,5 seconds and the longest was 15,5 seconds. The total recordings for each adjustment can be seen in Appendix C.

5.2.3 Adjustment Accuracy of the Mirror

During the test each test participant was adjusting the mirror four times. This provides an estimate of peoples accuracy when adjusting the mirror and gives an understanding of how sensitive people are to their ”correct” mirror setting.

The item of interest is when the mirror has been readjusted. If the test participant adjust the mirror into the same position as the one of comfort from his or her previous setting, then there can be only a little movement before it will be detected by the driver. However, if the person has a relatively large difference in the readjusted settings then there is room for a movement, since it will not significantly affect the user experience. To record the position which the test participants have considered satisfying, the video recordings will be analyzed. They give the possibility to determine the position between each adjustment done by the participant by comparing the position of the head rest support in the car, as illustrated in Figure 5.4 (a).

Figure 5.4 (b) shows the plot of the measurement for each participant with a corresponding symbol and color for their four mirror adjustments.



(a) (b)

Figure 5.4: (a) The fixed point used as a reference is the bottom of the support for the headrest, marked by a red dot, and the blue square shows the area of deviation among the test participants. (b) Plot of the accuracy for the adjustment of the mirror during the test.

The average standard deviation of each test participant for their horizontal adjustment is 10,86 pixels, with a minimum deviation of 6,13 and maximum of 21,41, and for the vertical adjustment the average standard deviation is 7,29 with a minimum at 0,58 and a maximum at 19,14. The results for the observation are attached in Appendix D.

Additional Test Participants

All the participants for the observations were found among fellow students at the university, which can be suspected to represent a very narrow sample of the entire driver population. They can be categorized as young men in the age of approximately 22-26 years and all being students at the same department. It is therefore of further interest to also collect data from other segments. Carrying this out will confirm or reject the results of the first test group. If the results of the second group are within the data collected from the first, all data can be placed in the same pool.

Figure 5.5 shows the plot of the first test participants, marked in blue, and the additional test participants, marked in red. The additional four test participants consisted of three women and a man, all within the age span of 26-38.

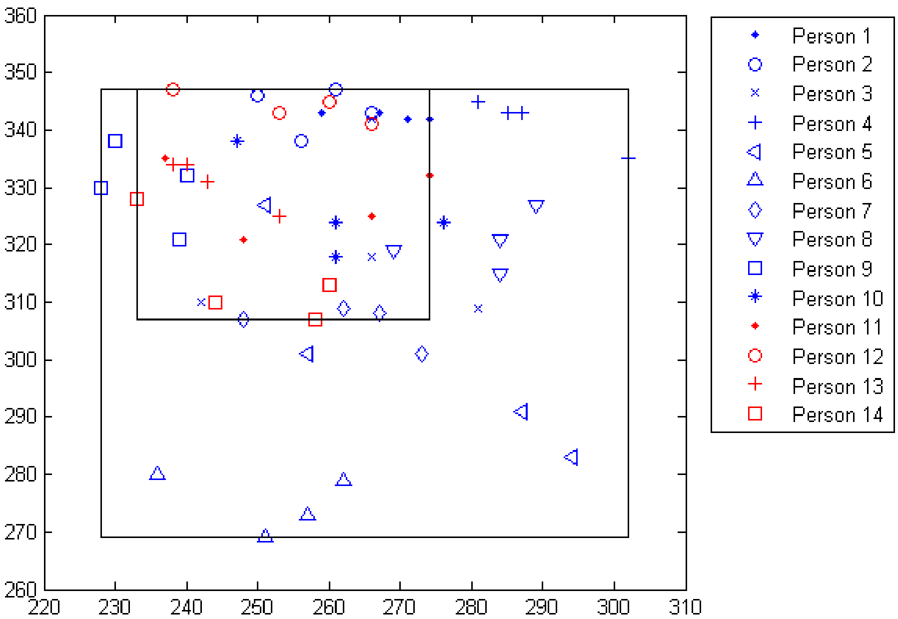
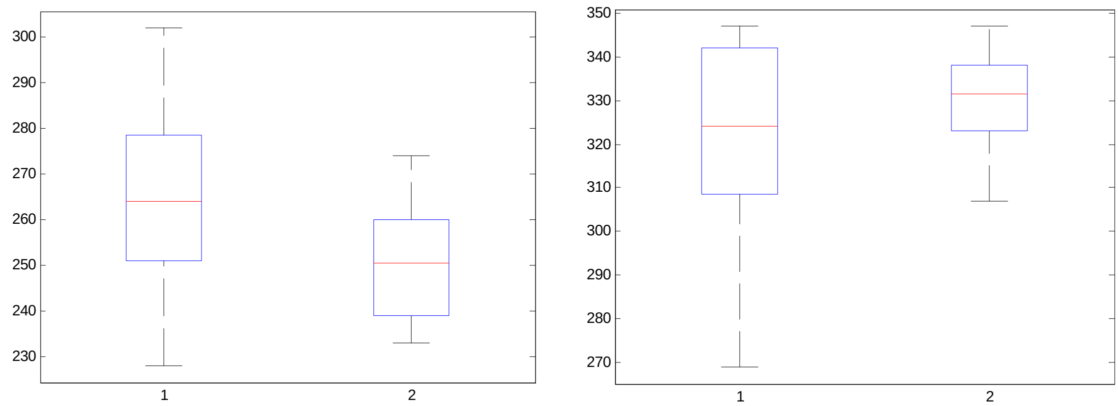


Figure 5.5: Figure showing the additional test participants plotted among the first test participants. The illustration shows overlap between the two groups marked by the rectangles, spanned by the maximum and minimum x and y value.

Figure 5.5 shows an overlap between the two test samples. The added rectangles for the first and the second test sample, which span from the minimum and maximum value in both the x and y direction illustrate their overlap.

Figure 5.6 (a) and (b) shows box plots comparing the x and y values of the two test samples in Figure 5.5.

This shows an overlap between the two group of samples, and confirms that even though



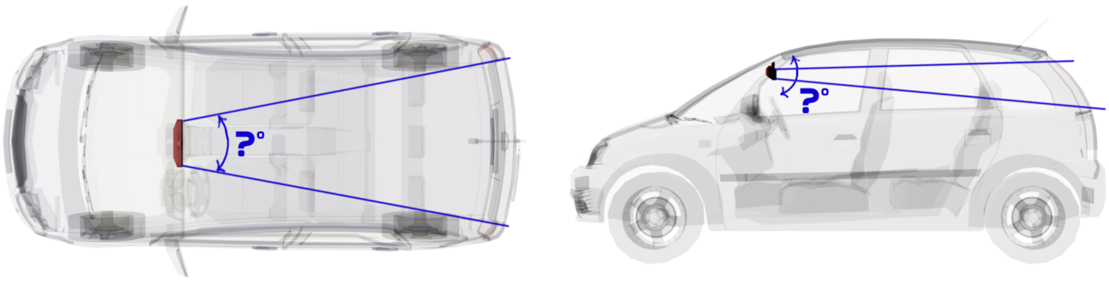
(a) (b)

Figure 5.6: Overlap of sample groups. (a) Box plot showing the two sample groups in the x axis (b) Box plot showing the two sample groups in the y axis.

the initial 10 test participants were taken within a narrow spectrum of the population it is still valid as a representation of the entire population.

Pixel to Angle Conversion

For the setup in the test car it is desirable to calculate how these deviations relate to degrees instead of pixels to be able to determine how the angle of mirror movement must be to cover the area of the different adjustments done by the test participants as illustrated in Figure 5.7.



(a) (b)

Figure 5.7: Angles of movement to determine for the rear view mirror inside a car: (a) Horizontal axis. (b)Vertical axis.

To help define the constraints of the automated system the positioning of the existing mirror in the car used for the user observations will be used as reference. The mirror had been aligned horizontally and vertically with the x and y axis. The measurements show that the mirror's maximum movement was 16 degrees up, 23 degrees down, and 32 degrees to both sides horizontally. This gives a total of movement 39 degrees in the vertical axis and 64 degrees in the horizontal axis.

From the plots in Figure 5.4 (b) it can be seen that the extrema for the observations span 74 pixels in the horizontal axis and 78 pixels in the vertical axis. By measuring the physical distance in the car marked by the blue square in Figure 5.4 (a) it has a size of 17 times 17 centimeters. The distance from the camera is 170 centimeters, and by use of the law of cosine as presented in Equation 5.1 and 5.2 the square is calculated to span a area of approximately 5,7 degrees horizontal and 5,7 degrees vertical if not taking the four pixel difference into account.

$$\cos B = \frac{a^2 + c^2 - b^2}{2ac} \tag{5.1}$$

$$Angle = 2\left(\cos^{-1}\left(\frac{a^2 + c^2 - b^2}{2ac}\right)\right) \tag{5.2}$$

$$2\left(\cos^{-1}\left(\frac{170,42^2 + 170^2 - 8,5^2}{2 \cdot 170,42 \cdot 170}\right)\right) = 5,7 \text{ degrees} \tag{5.3}$$

From these observations and the calculation in Equation 5.3 it is concluded that having a mirror which can move 10 degrees in both the horizontal and vertical axis will satisfy the need of mirror adjustment to the majority of the population and the movement of the existing mirror satisfy this need with much adjustment space to spare.

5.2.4 Height of Participants

As mentioned in the Test Walk-Through, [Garcia & Quintana-Domeque, 2007, p. 343] presents the average height for men in Denmark to be 183.7 cm. This data accounts for men born between 1976 and 1980 which is an age segment around 5-10 years older than the segment used for the test, but we still see it as a satisfying point of measure and comparison. Table 5.8 shows the measured heights for each participant, and with an average of 183,9 cm having a minimum at 174 and a maximum at 192 it is a group of test persons that comes relatively close to the country's average. The observations will therefore be considered an satisfying representation to the general population.

Person	1	2	3	4	5	6	7	8	9	10	**Average**
Height	186	188	174	191	181	179	181	192	188	179	**183,9 cm**

Figure 5.8: Height of the 10 test participants used for the observations

5.2.5 Observation Considerations

From the video recordings and by observing the test firsthand, the variation in number of times the test participants looked in the mirror can be explained by variables related to traffic. When testing the rear view mirror the amount of traffic plays a significant role in how much people use the mirror. Although the tests are held outside rush hour, between 10:00 AM and 3:00 PM, the traffic cannot be kept consistent in a live city environment. The test persons that made little use of the mirror, should have had less traffic in the mirror than others, which would make them react accordingly. Another factor that could cause people to act unnaturally is the camera that has been attached on the mirror. Being observed by "Big Brother" adds to the feeling of attending a driving test, which then cause some participants to use the mirror more frequently than they normally do. Finally, there were personal traits and habits that can be observed from the different individuals. An example are the double-look: some participants would look in the mirror and then within seconds look again to confirm their observation. To keep the settings as similar and comfortable as possible the test was conducted using friendly tone of voice and answering any questions that the participants would ask during the test.

5.3 Summary

The purpose of the User Observations chapter was to determine driver behavior in relation to the rear view mirror of a non-automated car. The results derived from the video footage have been observed by both group members and the relevant points in the individual videos have been annotated.

The number of times the mirror is used vary between 5 and 25 for the approximated 10 minute drive in this observation test with the average of 11 times looked in the mirror. This means that the rear view mirror approximately is used once a minute in a lightly trafficked city environment. The average length of orientations done by use of the rear view mirror are 0,42 seconds.

Screen shots for every time the mirror was adjusted in the video recordings was taken and used for deriving the differences from each adjustment. This resulted in a difference of 5 degrees in both axes for the readjustments of all participants. The system is therefore evaluated to need at least 10 degrees of movement to ensure that the mirror can meet the movement requirements of the users.

6. Prototype Development

The User Observations in Chapter 5 concluded that people regularly use the mirror to stay orientated of rear traffic. It also showed that there are differences from person to person when adjusting the mirror to the driver's position. The next step is to look further into the technological possibilities that can provide a solution for building the prototype. The approach is based on the ideas described in the Concept Description chapter. This chapter will document the first iteration of the implementation and state the reasons for the chosen methods.

6.1 Prototyping The Automated Rear View Mirror

The purpose for making the prototype is to enable the test of the automated rear view mirror concept and identify problems that will occur in connection with the development of the system. Although it is possible to anticipate many of the problems beforehand, there will always be unforeseen contingencies. To understand and describe the requirements of the final product, it is therefore necessary to make a prototype. The first iteration of the prototype is focused on the functionality of the system and the implemented elements will be described in the following. Further development and considerations will be described chapter 8, Next Iteration.

The system in its entirety can be split into three elements with a number of sub elements:

- **Detection** of the position of the driver
  - Camera Placement
  - Camera Resolution
- **Mirror Control** by use of motors attached to the mirror
  - Choice of motors
  - Mirror movement (at least 10 degrees in both axis derived from user observations)
- **Communication** between the detection and motor control
  - Send information to the motors based on the detection

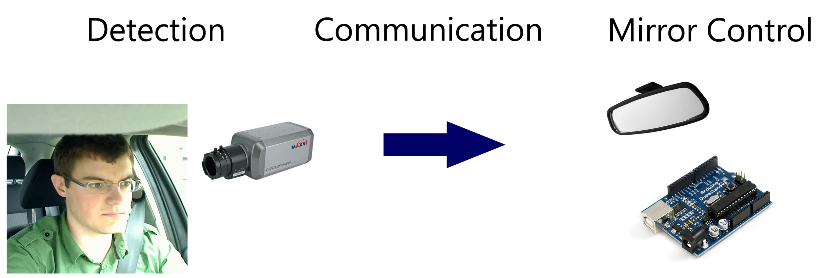


Figure 6.1: Figure showing the building blocks of the system. Detection of the driver position is send to the control unit which makes the necessary adjustments to make the rear view mirror move according to the movement of the driver.

6.2 Detection

For the first prototype iteration a camera that focus on detecting infrared light will be used. An infrared LED will then be used as the input device in representation of the head. The surrounding setup will consist of a laboratory environment to avoid the problems regarding light conditions due to sunlight emitting infrared light. This method is chosen because reducing the number of variables allows a relatively fast implementation of the first iteration. The software used for developing the prototype is openFrameworks and openCV, which is an open source C++ development toolkit that allows for easy access and interaction with camera inputs, graphics, sound and sensor in- and outputs [openFrameworks, 2011] [OpenCV, 2011].

The prototype detects infrared light emitted from a LED that represents the head. The infrared LED is attached to a cap to simulate the head movements as shown in Figure 6.2. Converting the input image to gray scale and applying a threshold on the input image means that the light from the LED is detected as a Binary Large OBject (BLOB). Then using edge detection through a function called ofxCvContourFinder, allows the BLOB to be detected and framed by a square. This allows the system to detect the centroid of the BLOB in the input image. The detection process is shown in Figure 6.3.

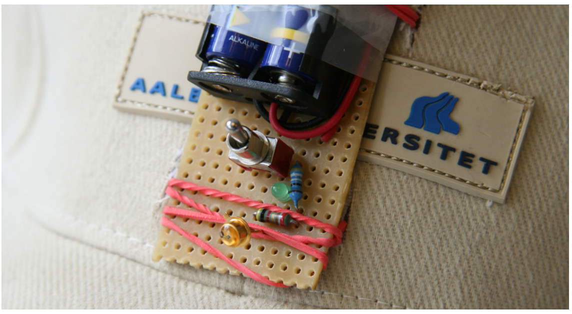
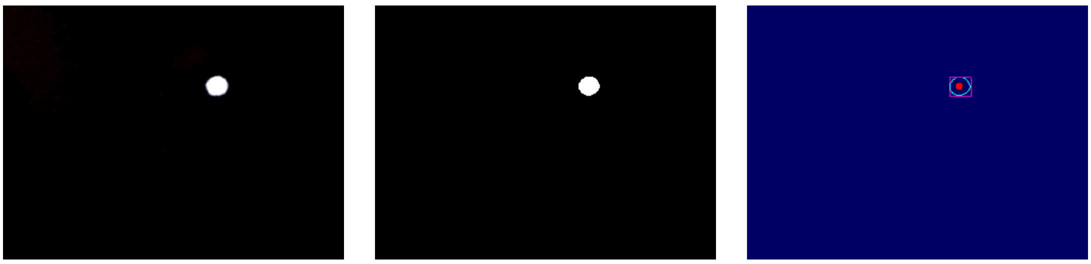


Figure 6.2: Infrared diode mounted onto cap.



(a) (b) (c)

Figure 6.3: Figure showing the steps in the detection. (a) shows the input image from the infrared camera. (b) shows the gray-scale image. (c) shows the contour of the BLOB and a red dot is placed in the it's centroid.

With the detection up and running, the next step is to make the mirror move according to the input. The camera input is dependent on placement in the car, which will be described in the following section.

Camera Placement

The requirement for camera placement in this project are that the head of the driver must be within the camera's field of view at all times. Two solutions for placing the camera when building the system are:

- Placing the camera in a fixed location in the cabin pointing towards the driver.
- Mounting the camera on the mirror, making the camera move whenever the mirror is adjusted.

Both options have pros and cons, but the choice for the prototype will be to mount the camera on the mirror. Camera placement on the mirror decreases the needed field of view for the camera. This is because the head of the driver will be maintained within the image when the mirror readjusts to the movement of the driver. If the mirror is pointing in a completely wrong direction compared to the driver entering the car, the mirror will not be able to detect the driver when the camera is mounted on the mirror. This can be avoided by having the camera return to a default starting position when the engine turns on. Having the camera as an integrated part of the mirror gives feedback whenever the mirror moves, which is advantageous when programming the movement of the servo motors.

Camera Resolution

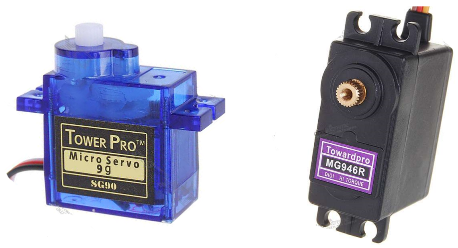
When dealing with live camera vision (CV), choosing the smallest possible resolution, which still meets the requirements of the system is optimal. This is because the continuous processing will require a lot of CPU power. For this prototype a resolution of 320x240 is available along with a laptop that have enough processing power to deal with this. This could be a realistic setting as the computers in cars have increased in processing power during the last decade. It is even possible to install an additional *"CarPuter"* in the car in case that the standard hardware does not meet the requirements [Instructables.com, 2011]. The point of interest is that processing power should not be as big an issue today as it would have been 10 years ago, meaning that it is possible to get a relatively high resolution camera installed in the car.

6.3 Mirror Control

6.3.1 Choice of Motors

When choosing the motors for the prototype, the main areas to choose from is whether to use DC Motors, Servo motors or Stepper motors. DC motors allow for endless rotation in both directions, whereas servo motors often are restricted to doing a rotation of 180 degrees. Stepper motors move in predefined step angles.

Servo motors were chosen for the implementation because they allow for fairly accurate control of the angle of the rear view mirror and it is easy to gain control of them by use of the openFrameworks and Arduino environments. Due to the fact that the mirror will only have to move within a defined area, the limitations of moving 180 degrees is of no concern. Servo motors are cheap, and during the project two different servo motors were at disposal, the SG90 [DealExtreme, 2011b] and the MG946R [DealExtreme, 2011a] as shown in Figure 6.4. Both are frequently used and recommended by people working with Arduino but the main reason for choosing these was because of availability. Both are small in size and the main difference between the two are mainly that SG90 consists of plastic gears while MG946R has gears of metal. This is the reason why the MG946R was the preferred choice. One of the MG946R motors was later replaced with a SG90 due to inconsistent movement of the MG946R.



(a) (b)

Figure 6.4: Servos used for the project showing (a) the SG90 with plastic gears [DealExtreme, 2011b], and (b) the MG946R with metal gears [DealExtreme, 2011a].

The reason why the setup needs two servos is that the mirror can rotate around both the x and y axis. Each servo motor will then either pull or push the mirror as illustrated in Figure 6.6 (a).

A visual schematic of the breadboard mounted with the servo motors and connections to the Arduino is shown in Figure 6.5.

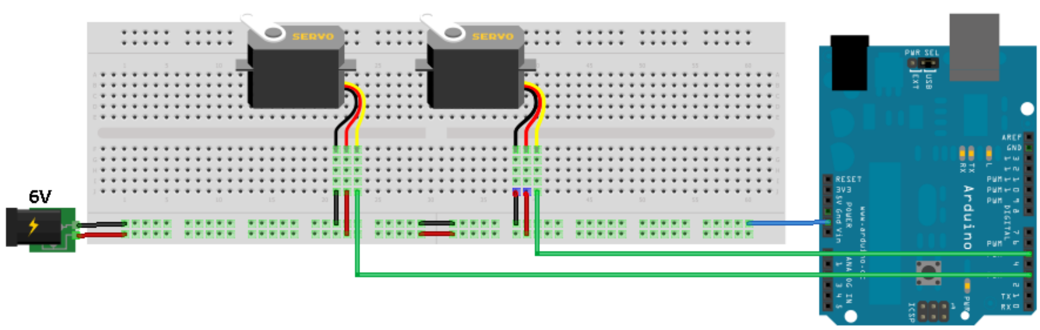
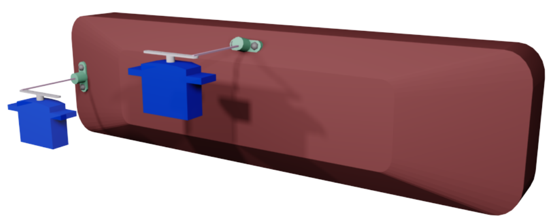


Figure 6.5: A visual schematic of the connection of the servo motors to the Arduino.

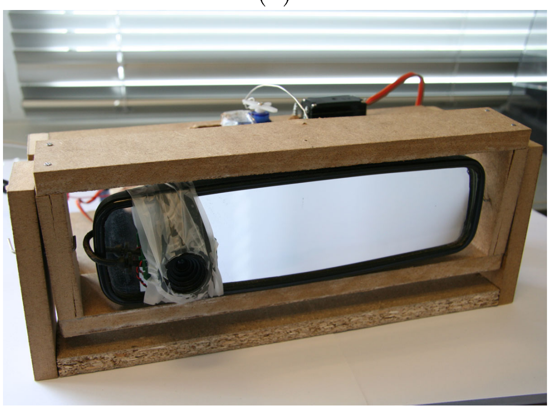
6.3.2 Mirror Movement

To make mirror control easy and accurate, it is necessary to constrain the mirror's movement. The setup is inspired by the old wood labyrinth puzzle game as shown in Figure 6.6 (b). The mirror is mounted to make it rotate around the center of the x and y axis of the mirror, as similar as possible to the movement around the knob of a regular mirror. Figure 6.6 (c) and (d) show how the mirror and camera are mounted in the prototype. When an ordinary rear view mirror is mounted on its knob in the windshield it is also possible to tilt the mirror. The option of tilting the mirror will not be possible in the project setup, due to the constraint that only allows mirror rotation in two axes.

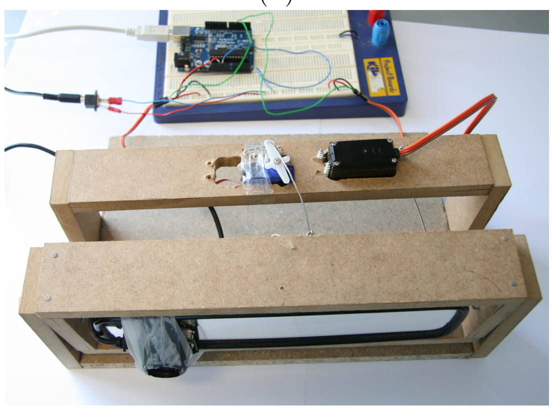


(a)

(b)



(c)



(d)

Figure 6.6: The Prototype: (a) Placement of the servo motors behind the mirror to push or pull. (b) Inspiration for the setup are taken from the wooden labyrinth puzzle game. (c) From the front showing the webcam mounted to the front of the mirror. (d) From above showing how the servo motors are mounted in a rigid frame with metal wires connecting them to the mirror.

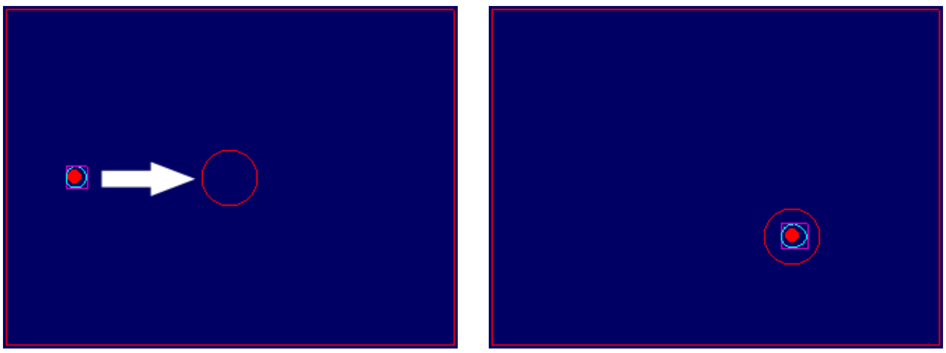
To explain how the mirror control operates, this section will give an example of how the first simple implementation of the system works. The detected position of the BLOB is compared to the position of the center of the image. If the BLOB is in the left side of the image, the servo motors adjust to the left until the BLOB is in the center of the image, and the same accounts for the vertical axis. The scenario with adjusting in a single axis is depicted in Figure 6.7 (a) and a simple version of the code for moving the BLOB towards the center of the image is shown in Listing 6.1.

```
if (ImageWidth/2 - Xposition > 0){
            ServoMotorValueX = ServoMotorValueX - 1;
            }
else if (ImageWidth/2 - Xposition < 0){
            ServoMotorValueX = ServoMotorValueX + 1;
            }
    Send ServoMotorValueX to Arduino;
```

Listing 6.1: Comparing the driver position with the center of the image will make the servo motors adjust accordingly.

Now that the system is responsive and adjusts the position of the detected BLOB to the center of the image, the next step is to add a personal setting for the driver. This is because the center position of the image will not be a satisfactory setting.

The mirror has two control methods. The first is a manual control of the mirror, which is controlled through the arrow keys. The second is the camera controlled by the infrared LED. When the user is satisfied with the manually adjusted setting, the 'space' bar is pressed saving the positioning of the user and changing the system to automated control. The mirror will then keep the selected user position by adjusting it to the new "center point" as shown in Figure 6.7 (b).



(a) (b)

Figure 6.7: (a) In the first iteration the servo motors will adjust the mirror to keep the BLOB in the center of the image. (b) By manually adjusting the mirror to a preferred setting it will adjust to that point instead of the center of the image

6.4 Communication

The communication between the detection and mirror control happens by use of serial connection between OpenFrameworks and the Arduino. openFrameworks sends a byte value between 0 and 255 to the Arduino. The Arduino code has included the Servo library, which makes it possible to send a value between 0 and 180 to the servo motors. By converting the byte by a ratio of 180/255 in the Arduino code it is possible to translate the byte value send from openFrameworks into a 0-180 degree value send to the servo motor.

6.5 Summary

The implementation of the automated mirror is made without regard for the variables and constraints that exist in a standard car. These are the light conditions and physical space requirements. The reason for this is to make an operational prototype for the first iteration. When it is completed and meets the requirements in the Concept Description chapter, the variables can be included into the solution again.

The transition when changing position of the mirror should be smoothed to an unnoticeable extent. The detection works satisfactory in a controlled environment, however in an environment where the sun is an active variable the system is rendered unusable. By using openFrameworks as the connection tool provides the possibilities that is required for the system. This means that the system requires a computer to function as the prototype still is in this first iteration.

7. Prototype Test

The purpose of the Prototype development chapter was to make the prototype based on the ideas in the concept. This resulted in the implementation of the first iteration prototype. This is used for a technical and conceptual evaluation of the current system and the ideas behind it. During the development of the prototype it was considered advantageous to limit the number of variables that affect the system. These variables can be controlled in a lab environment. Therefore the implemented prototype will be tested in a controlled environment.

7.1 Preparations

The prototype test will once again focus on the research questions set up in the Delimitation chapter, and through them seek to verify the direction for the further progress of the product. The idea behind the prototype test is to simulate a driving situation, while keeping the mirror in focus. The other main focus of this test is to investigate the participants opinions on the automated mirror. This early prototype test is the first iteration of how the technical solution can be made, which means that the operational solution is still some iterations away. This test can be seen as the necessary step that needs to be made before further research can be conducted, and an operational solution can be placed in a car. The laboratory test setup will consist of:

- 3 laptops
- 1 projector and 1 large screen ("Windows" of the car)
- Recorded videos in a car, using footage from the front and rear view of the car [Group1034, 2011a] & [Group1034, 2011b]
- The mirror prototype in a position equal to the position in the car
- 1 infrared light mounted on a hat and a USB-Keyboard for the users to manually control the mirror

As preparation for the test two video cameras were used to record a drive on the highway between Aalborg and Svenstrup. One was placed in the front- while the other was placed in the rear-window. A screen shot of the video recordings can be seen in Figure 7.1. This is done to ensure simultaneous recordings, meaning that when a car passes by it will be synchronous, aiding the illusion of being in a car. The purpose of the videos is to give the participant a reason for looking in the mirror. When the participant overtakes another car or truck he or she should, per reflex look in the mirror to estimate when it is safe to change lane, even though the route of the car is predetermined due to the video recordings.

The test will be conducted by placing the user in a chair in the light controllable laboratory environment. Two of the computers are wired to the projector and the large screen, which function as the front- and rear windows in the car while the third handles mirror control and the system processing, and acts as the manual control through the USB-keyboard. The rear view will make use of the projector because the rear view mirror image is the subject of interest to the project. The front view consist of a laptop wide screen, acting as the front window.

To ensure that the participants are presented for the same test setting, the chair must be firmly placed in the same position, as must the 'windows' and mirror.

The reason for keeping as few variables as possible in the first iteration is to get an early system up and running. When it runs it will be possible to start including the variables

(a) (b)

Figure 7.1: The videos will be played back to represent the synchronization shown in image (a) and (b).

Figure 7.2: Overview of the setup for the laboratory test.

again one at the time, and troubleshoot during the process.

7.2 Technical Evaluation

The prototype system is based on the requirements from the Concept Description chapter, and has served as the guidelines for building it. The prototype is evaluated from these requirements.

The technical evaluation of the system concluded that the system runs as anticipated in manual mode. The mirror movements and positioning corresponds to the input from the user. The only issue of the manual setting is minor inaccuracies caused by the physical setup.

When the system run in automated mode, there are a number of instabilities. The reasons for the instabilities are caused in both soft- and hardware. The main issue regarding the hardware, the servo motors, are that they are not moving fluently. The response to this was to change them with new motors, but they are still a cause for inaccuracy.

Software-wise the system seeks to position the mirror according to the position of the infrared light source. When the detected BLOB is close to the position it is supposed to adjust to, the adjustment done by the servo motors will make the input value of the BLOB go below the threshold, thus moving the mirror outside the desired position. Meanwhile the repositioning that account for the movement in the wrong direction will make it go above the desired position. When this is the case the mirror continues making adjustments to position itself in the desired position. The reason for this is having the camera as an integrated part of the mirror.

This endless adjustment has been accounted for by making an area around the desired position, which will make the servo motors stop their movement. The BLOB then has to be outside this specified area before the mirror will readjust. This allows the mirror to keep a stationary position, as long as the driver does not move. This is called the stop-zone. If the stop-zone is too big, the mirror will be very inaccurate because the mirror will stop moving when the center point of the BLOB gets inside the stop-zone. On the other hand if the stop-zone is too small it will never stop adjusting because the center point of the mirror keeps ending up outside of it. These issues, in soft and hardware, is the current cause for the system's inaccuracy.

Another of the system requirements regards smoothing. When the mirror change position the mirror must slowly adjust to avoid stealing focus from the driver. In order to determine when the mirror must change position, the input for the system consist of samples that will be averaged to make sure that movements of the driver, like turning the head will not have an effect on the mirror. The mirror will therefore change position over a small timespan when the sample average determine that the position has changes. An attempt to include this into the system was made, but once again the inaccuracies of the physical system rendered the smoothing to inaccurate for testing.

Due to the limited time frame, it became clear that the automation part of the prototype would require more development time to reach a satisfactory level for testing. Prior to implementing it in a real car for testing purposes, the system needs more accuracy to avoid dangerous situations and to provide accurate measurements. However, in regards to concept testing this prototype will be able to serve its purpose.

7.3 Concept Evaluation

Since the automated part of the system did not preform according to our requirements within the time frame, there were limitations to what could have been tested in the laboratory. These limitations meant that most of the technical studies, regarding accuracy smoothing transitions and specific positioning would be unable to be conducted. The purpose of the laboratory test is to research the questions of the prototype, as seen in the Delimitations chapter. The overall research questions regard:

- Manual and Automated Control

  - (Accuracy)
  - (Smoothing Transitions)
  - (Specific Positioning)
- Concept Investigations
  - Positive Elements
  - Negative Elements
- Comfort and Safety

The research questions encircled in brackets are those of technical research and will not be further discussed in this chapter.

The test is defined as a usability test, where the current prototype is being evaluated by the participants one at a time. In his book "Don't Make Me Think", Steve Krug describes usability testing in the following manner:

> *"In a usability test, one user at a time is shown something (whether it's a Web site, a prototype of a site, or some sketches of individual pages) and asked to either (a) figure out what it is, or (b) try to use it to do a typical task."*
>
> [Krug, 2006, p. 133]

Prior to entering the test, people were informed that this test was made in regard to the concept of the system. During the test the participants were asked to try out the manual setting and find the projected rear window in the rear view mirror while aligning the mirror to the best possible position. While trying out the system, they were asked to think out loud. This was followed by questions inquiring about the mirror as listed below, and the questions are also attached in Appendix E.

1. Which positive elements do you see in the concept just presented to you?
2. Which negative elements do you see in the concept just presented to you?
3. Would you find this automation uncomfortable? Why/Why not?
4. How would you categorize such a system? Comfort or Safety? Why?
5. Would you like it installed in your car? What would the requirements then be? Which functionalities would you expect?

The first area of testing regards peoples usage of the controls for the mirror. For this discussion 4 people were available for participation. The initial thoughts concerning the interface will help determine the needs and expectations of the users towards the amount of control they would like to have in regards to the mirror. The mirror controls are derived from the considerations made in the Concept Description chapter. People are estimated to spend the same amount of time manually adjusting the mirror by keyboard, as they did in the car. There were however positive comments in regard to using the arrow-keys, because of the ease of use and as a way of avoiding finger markings on the mirror.

7.4 Concept Investigations

The test consisted of a structured interview [Sharp *et al.*, 2006, p. 299] regarding the concept in order of having it evaluated. The participants were able to understand and acquaint themselves with the concept by trying out the prototype. Any questions during the session were answered to avoid confusion about the concept. Furthermore to ensure that all questions was covered, they would be systematically asked at the end of the session. The opinions of the participants can be described as hypothetical opinions since they do not have the possibility to experience an automated mirror in a real car, yet. When the prototype is further developed, this test can be further improved in the following iterations.

The positive elements about the mirror concept were that the participants liked the fact that they would not have to position the mirror by themselves when entering the car. One participant tells about the inconvenience about sharing the car with his wife since their preferences are very much apart. He found that saving the time and trouble connected with adjusting the personal settings in a car to be very appealing. Other participants believed that if the mirror is able to find the best position for the driver to look through the rear window it would be beneficial for people who does not customize the mirror before driving.

The negative elements commented by the participants concerns the smoothing of the mirror. It should definitely not follow the movement of the user at all times, meaning while looking away or even adjusting the mirror while not focusing out the windshield. This is because the mirror would then be offset when turning the head to look through the windshield. Some participants were concerned about the other functionalities that the mirror provides, like the offset modes, where the possibility of checking up on their children on the back seat or when it is used for setting the makeup. However when explained, that the mirror of course would keep the manual setting similar to the one provided by the prototype, the attitude towards the mirror got more positive.

7.5 Comfort and Safety Evaluation

The general attitude was that the idea would provide a good addition to a car, that equally focus on comfort and safety. This answer did depend on the personal preferences towards the mirror. The participants that chose comfort, believed that the system is best described as another service function, like heat in the seat or automatic seat settings. There is a difference between those and a safety function like the airbag. In accident situations, poor viewing conditions will only be part of the cause, while other subjects such as road conditions or alcohol would be more dangerous factors.

The participants that saw the product as a safety feature, do not usually think about correcting the mirror unless it is very uncomfortable. When they discover the wrong setting the mirror adjustment often happen after they have entered traffic and have stopped in a junction, waiting for the traffic lights to change.

The automated part of the mirror was included into the test in its current form. It was tried by all participants to provide some idea of how the prototype will work. The prototype in its current form instantly reacts to the placement of the infrared light source. The participants clearly stated that the smoothing part, in which the mirror moves after detecting a prolonged change in driver position, will be an essential part of the final system. Also the concept idea was well received provided that the functionality of it would be working.

Knowing that the driver would not have to worry about mirror positioning appealed to people. No participants would feel uncomfortable with implementing the automated mirror in their cars. The requirement was of course that the product must perform as promised and be well documented to not have errors through extensive testing. It is also important that if the automation fails the system should be able to automatically switch to manual mode, because people feel that they use the mirror so much that they would put themselves in danger if it does not respond.

The necessity of having such an installation in the car became a side-topic discussion. Also people who are the main driver found that they rarely have to move the mirror, because they do not often share their car with others. The product could also be seen as excessive by people who are used to the current method of adjusting the mirror by hand. They would need some convincing if they were to purchase the automated mirror. Comments regarding price of the product concluded that it definitely should be accessible for everybody.

7.6 Summary

The prototype test confirmed that the reason for continuing the research of the automated rear view mirror exists. Even with the current inaccuracies in the system people are interested in having the final product installed in their cars. This is of course if the price is right. The product can be equally classified as comfort- and safety car equipment, since the participants were equally divided in classifying it, with reasonable arguments on both sides. The participants were able to easily control the mirror through the manual controls, which means that these operations could be implemented in the final product as well as the automated part.

8. Next Iteration

Through the use of participants the Laboratory test confirmed that the concept is of further interest for development. Therefore further research and development of the prototype will be made in this chapter. The main purpose of describing future iterations is to present the next steps in the process of developing the automated rear view mirror. Although the project time frame does not allow the complete development of the prototype, it is still possible to describe thoughts behind further project iterations. The Next Iteration chapter concerns improvements, that will bring the prototype further towards completion and will be split into the following sections:

- Detection Improvements
- Mirror Control Improvements
- Additional Considerations

8.1 Detection Improvements

Further research in the field of CV provided us with ideas that are based on other approaches than the one chosen for the prototype. These would also be workable solutions that could solve the challenges of the project and therefore would be interesting to take into consideration for the next iteration.

8.1.1 Light Conditions

The next iteration will be using camera detection in an outdoor environment, which always is a challenge because the weather and light conditions is constantly changing. The camera input varies a lot from when the sun is shining compared to cloudy weather. Therefore the system should be able to adjust to the weather conditions like for instance taking advantage of adaptive threshold.

Solutions for handling the outdoor light conditions do exist and it would be necessary to look further into those if the system is to work. Examples of existing implementations can be found in the Saab Attention Warning system, as described in the Research Chapter, Section 2.3.3. If the issue regarding the light conditions was solved, it would mean that the system would work in an outdoor environment. Furthermore the accuracy of the system would increase as the error BLOBs would be reduced to a minimum.

8.1.2 Eye or Head Detection

The main idea concerning when the system detects the eyes and their direction, which could provide data to calculate how the rear view mirror should auto adjust to suit the best possible angle for looking through the rear window. For this project it must however be determined whether or not eye detection is a necessity, or if head tracking will be able to provide sufficient data for the system.

Eye detection will for this project provide the following issues: To find eyes in a car by using camera detection means that the BLOB, which the system is looking for will be very small, if not undetectable. If the eyes cannot be found the system can of course not adjust the mirror according to them. Furthermore, depending on the weather, the eyes will not be visible at all times due to being hidden behind sunglasses. Finally, they will of course not be focused on the rear view mirror all the time, which would make it very hard to determine a proper sample frequency for the system.

The head provides a much larger area to detect compared to the eyes. Head detection should with current technologies also be able to work when the person is wearing sunglasses. The issue with head detection is accuracy an whether the mirror will adjust itself according to the position of the head based on the detection. Considering all these factors the system could work optimal by only detecting the head.

8.1.3 Template Matching

Template Matching is an image processing method that compares the input image with templates in a database [Robotics & Inc., 2004] [Moeslund, 2009, p. 40-42]. Template matching also looks for the templates when they are rotated and scaled. The seat can be adjusted back and forth, meaning that the persons head will scale either up or down and it will be of no concern if the driver tilts the head. Whenever the system is able to find a template the system will be aware of the head placement and the mirrors will be adjusted accordingly. With template matching the camera can be placed in a variable position e.g. in the mirror, without causing problems for the system.

The issues with template matching is like with simple camera vision that the weather variable will impact the system just as much as described in the simple camera vision example. Although template matching focuses on shapes in the picture, the amount of light emitted by the sun is able to make them undetectable. Using template matching will also require a large sample database from a broad variation of people to ensure that as many people as possible would be able to use the system.

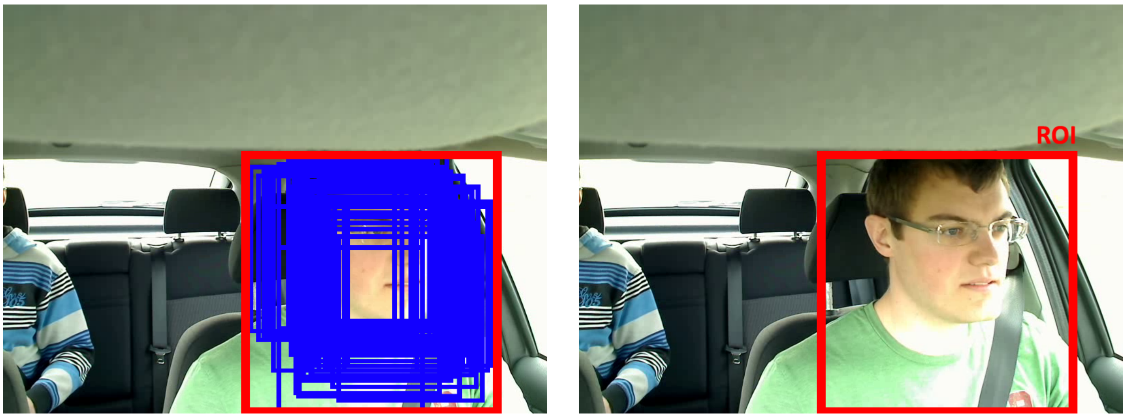
8.1.4 Haar Classifier

For the next iteration head detection is a desire to implement for system control. This can be achieved through the use of OpenCV [OpenCV, 2011], since these C++ tools uses the same libraries and therefore makes for easy communication. OpenCV has a built in system to detect the head through facial features. This is called the Haar Feature-Based Cascade Classifier for Object Detection [OpenCV, 2004a] [OpenCV, 2004b]. The Haar classifier is looking for features within a region of interest (ROI) that has the same size used in the training data in the input image. The classifier outputs 1 when it is able to detect a sample from the training data, allowing the system to determine whether or not a head is in the input image.

8.1.5 Region Of Interest

It is possible to define the ROI to a specific area of the image input, meaning that the system only looks for changes in this area and thereby require less computational power [Moeslund, 2009, p. 17-18]. By observing the users as in the User Observation chapter, the result was a definition of the ROI area of a 800x600 input image from the camera where the mirror have been mounted on the top-center of the mirror. The ROI can be seen in Figure 8.1. The figure illustrates the combined results of the regions of interest. They are based on screen shots from the user observations. Each screen shot has been made after adjusting the mirror.

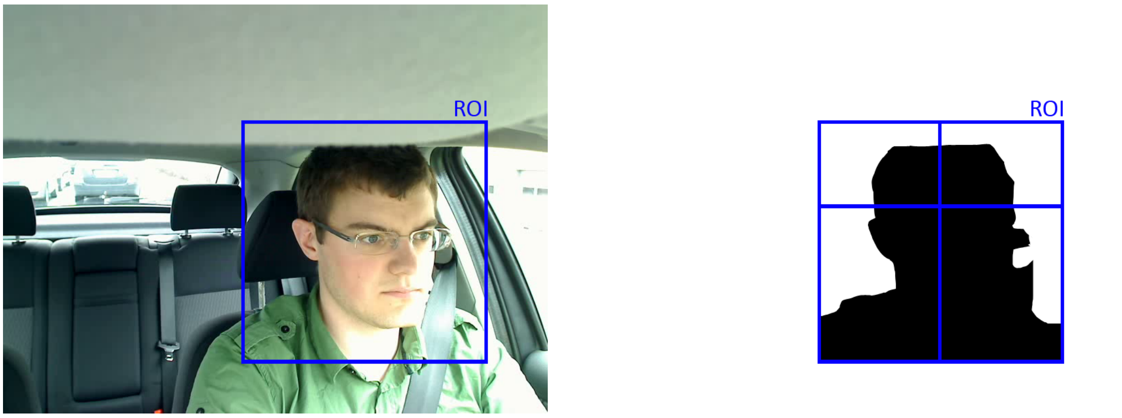
The definition of the ROI means that the system only needs to detect within the defined area. The rear view mirror will then adjust itself according to the hight of the person and



(a) (b)

Figure 8.1: Combined ROI: (a) Every blue square represents a sample of a test person's head, the red square represent the combined ROI for all the test participants (b) Illustration of the final ROI.

to the horizontal placement of the head as illustrated in Figure 8.2.



(a) (b)

Figure 8.2: (a)Region Of Interest in a car (b)Binary input, to find height and horizontal placement

8.2 Mirror Control Improvements

The current prototype works in accordance to the initial thoughts that describe how the system should be implemented. There is however a need to continue improving the system to provide more accurate positioning for the driver. To improve the accuracy of the current system the positioning would need different parameters that determines movement in the horizontal direction. The reason why this was not implemented in the Laboratory Test is based on results in the User Observations, showing that people are less sensitive to changes in the horizontal direction. Furthermore when the driver is on the road, it is rare that the horizontal positioning of the head changes very much. This is due to the physical conditions, like a seat belt that keeps the driver "locked" in the same position, horizontally. The vertical positioning was of higher importance because the driver had some degrees of freedom, meaning that over time the driver will start to slouch.

Because the purpose of the system is to increase comfort and safety it would be advantageous to continue further improvements of the mirror positioning in the horizontal direction. A method for accomplishing this would be to test the effect on the driver, when the sensitivity of the mirror is not equally reactive in both the vertical- and horizontal direction. The technical considerations for a solution regarding the horizontal direction will consist of a implementation which takes into account the further towards the middle of the car that the head moves, the minor the angle of reflection will be. Therefore the mirror must position itself with a gradually decreasing angle towards the middle position as seen in Figure 8.3.

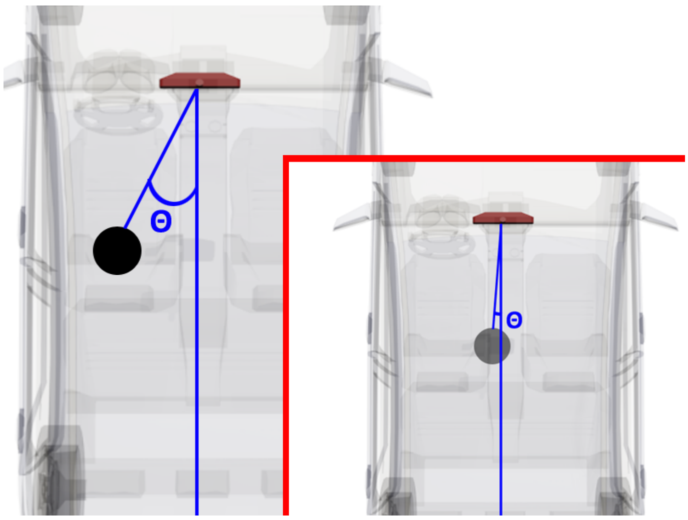


Figure 8.3: If the users head (black circle) moves towards the middle of the car the angle of reflection gets smaller (blue illustrations).

While the solution for the horizontal inaccuracy can be solved in the software, the vertical solution could benefit more by trying out alternatives to the servo motors. The alternatives would be evaluated by whether or not they provide more accurate positioning of the mirror. The accuracy of the system would be confirmed by forwarding the same values to the motors repeatedly. After each repetition the physical position of the system would be measured for comparison. The differences between the sampled values will then indicate the inaccuracy that exist within the version of the system, that is put to the test.

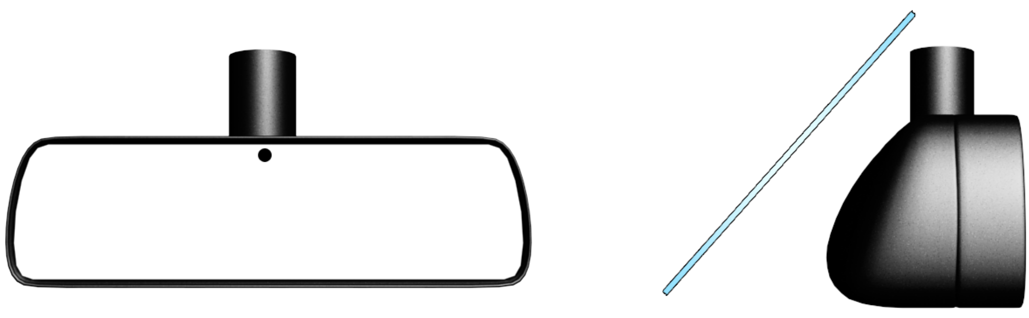
8.3 Additional Considerations

8.3.1 Integrated Camera

Cameras come in many shapes and sizes, and nowadays the images of build-in cameras in smart phones produces high resolution and high quality images and video. This makes it possible to install a camera in the mirror, that does not steal attention from the driver and delivers sufficient images for processing. The camera would consist of a small black dot in the top center of the mirror as depicted in Figure 8.4 (a). An essential part of the next iteration will be to implement attention reducing components wherever the possibility presents itself, and a camera on top of the mirror can be assumed to demand more attention than a integrated camera in the mirror. It can be assumed that a small camera with an acceptable resolution replaced with the visible camera would be able to reduce unnecessary attention directed towards the camera. This applies both to having the camera integrated into the mirror or integrated as part of the cabin interior.

8.3.2 Space Limitations

The first iteration prototype was not concerned with the space requirements because the development of the functionalities was prioritized for the first iteration. In the next iteration the space requirements are of concern, because the prototype should be tested in a car, whether or not it will be in a parked car to get the surroundings as realistic as possible or a test on the reads. The space behind the mirror is limited which means that the different components are limited in the space they can occupy, and an example of available space in the housing behind the mirror for containing the electronics can be seen in Figure 8.4 (b). The design and shape of the housing has been made with respect to still representing a mirror which will meet the visual requirements for being implemented in a car.



(a) (b)

Figure 8.4: 3D model of rear view mirror: (a) Mirror seen from the front looking like an ordinary mirror (b) Mirror seen from the side.

In the next iteration the Arduino should not necessarily be placed along with the servos behind the mirror since it takes up too much space. The devices handling the electronic devices could instead be placed with the main computer of the vehicle or as an integrated part of it. This should influence the final prototype to fit within the limits of the space available behind the mirror in most modern cars.

8.3.3 Suggestion for Implementation

The mirror used for development and prototype testing during the project has been an ordinary mirror as seen in Figure 8.5 (a) mounted in a fixed structure to restrict the movement. The mirror in Figure 8.5 (b) is mounted in a way that is better suited for implementing motor control in the mirror. The implementation could be hidden in the housing below the ceiling of the car, which has the mirror mounted on a cylinder.

(a) (b)

Figure 8.5: Different mirrors. (a) showing an ordinary mirror, which is mounted directly onto the windshield on a knob, and (b) showing a mirror that is mounted in a casing below the ceiling of the car, which allows enough space for an implementation of the mirror control.

8.3.4 Automating all Mirrors of a Vehicle

This project focused only on the interior rear view mirror, but for future solutions it will be interesting to have all three mirrors of the car adjust automatically. It could also be beneficial to transfer the technology to trucks, since the law dictates how their mirrors must be positioned. The benefits by an automated mirror in trucks will aid in terms of safety but also physically because it can be challenging to reach and adjust the mirrors on a truck.

8.3.5 Share Information with Saab Driver Attention Warning System

Using a system like the Saab Driver Warning Attention System to detect in which direction the driver is looking, could possibly be combined with our solution. Having determined the direction of driver's gaze by using the Saab-system, the image processing is already accomplished. The results of the image analysis could be transferred to the mirror control and thereby only make use of a single surveillance system in the car.

8.4 Summary

For the iterations to come there are a wide range of possibilities for further prototype development. All the ideas could potentially end up with different outcomes, and the best solution could be mixing some of them together. Making a prototype that fulfill all requirements can be a time consuming task on its own. Therefore the choice of disregarding variables for the first iteration, in order to re-include them at a later stage can provide faster results. Some requirements could even be out of reach for developers that are not a part of the car manufacturers development department, like including the system with the rest of the car equipment.

Trying out the different possibilities would surely be a time consuming task, however the gain from conducting these iterations could result in the optimal product solution, that could one day end up on the market. Extensive testing would also offer a more fail-safe product, which is necessary as a sales argument. Both when presenting the research for eventual car producers and for their users.

9. Conclusion

The purpose of this project is to investigate the necessary conditions for developing an automated rear view mirror. This idea originates in the automation process, which has been developed and improving cars during the last decade.

Since their inception the car has always served as a means of transportation to aid people in their daily lives. Today people decide where to live without regard for the distance to their work, because the range of the car also has increased the range of our living space. The car is used for many tasks, but unfortunately it is not always that we take the time to adjust the settings of the car, which can increase the risk of dangerous situations. Along with the mirror serving as a safety feature, it is more comfortable and time saving to people who are sharing the same car, because it means that the mirror adjusts itself to suit the needs of the driver without his or her involvement.

Because this mirror has not been implemented by any car companies, the system had to be developed from its beginning. To do that the research areas had to be defined. The subjects of interest when making a new product are functionality and the physical installation. These can be further split into driver's behavior, system requirements, and the hard- and software requirements. Since the possibilities are many, the best solution will also be found through many iterations.

Observing users in a live car scenario has provided data regarding their behavior when driving. The results showed that the average orientation time was 0,42 seconds, the average number of times looked in the mirror was approximately once a minute. When adjusting the mirror into position, the time used amounts to an average of 9 seconds. The interesting result derived from the test is that the mirror can be positioned with a wide difference, and still be satisfying for the user, even when the same user is doing the adjustment. This information is all relevant for designing the automated mirror and defining the functionalities that is required of it, since it will be replacing the existing non-automated mirror.

The approach for creating an automated mirror during this project has been to limit the variables until a working prototype has been made. The following steps for development will then be adding them into the solution one at a time. Because this is a time consuming procedure the results gained from the prototype were kept at a conceptual level. They did however confirm that an automated mirror would be a possible addition for the cars of today. Of course assuming that the product keeps the promises made and have been documented as a stable and fail-safe product.

If this product were to be developed from prototype towards final product the next necessary steps include:

Task	**Deadline**
Computer Vision of the system. A single camera is able to detect the driver in spite of sunlight conditions.	October 2011
Fine-tuning and tests of different types of motors to find the optimal choice.	December 2011
The physical components of the mirror is implemented in a real car.	January 2012
Improvements of the software handling the motors.	April 2012
The product is undergone extensive usability testing to ensure and document the functionality of the product and the safety of the users.	August 2012

These steps provide an overview that we as developers estimate to be realistic in terms of time required for the next iterations.

The coming iterations definitely have a lot of research areas to cover. Although it would be time consuming, the gain from conducting these iterations will result in a better prototype and thereby a better product. The users require a fail-safe product as their necessary argument of purchase, and this can only be done through continued development and testing.

Appendices

A. Car Manufacturers & Equipment

This list includes the best-known solutions and systems when it comes to new technology and equipment, and it is believed by the project group that it will give a thorough and satisfying overview of the equipment on the market.

The research of new technologies is focused around the European market. Several of the solutions has been introduced several years ago, but has taken time to develop before being part of the end-product and included in the comfort and safety packages by the manufacturers.

Equipment List

Adaptive Cruise Control

The system measures the distance to the vehicle ahead by means of a special radar sensor and controls the speed, ensuring it does not exceed the set value. In addition, adaptive cruise control automatically maintains a constant distance to the vehicle ahead. If the driver's intervention is required to sufficiently brake the vehicle, a signal is automatically given. The driver can adjust the desired distance to the vehicle in front [Audi, 2011] [BMW, 2011a] [Volvo, 2011] [VW, 2011].

Adaptive Light

Adaptive light helps the driver to see further and see objects earlier in poor light conditions and especially in bends. The dynamic cornering light swivels the headlights in the direction of travel, following the degree of turn of the steering wheel. It thus effectively illuminates the path of the road ahead with respect to the turn of the steering wheel [Audi, 2011] [Ford, 2011].

Advanced Key

The advanced key is an electronic access and authorization system. To unlock and start the vehicle, the driver only has to have the key in close proximity to the car. As soon as the driver carrying the key is within approximately 1.5 meters of the vehicle and moves a hand towards the door handle, the key is identified by means of a proximity sensor in the vehicle door and a radio pulse generator in the key housing. The vehicle is automatically unlocked when the door handle is pulled. For unlocking and starting the vehicle, the advanced key can stay in the driver's pocket [Audi, 2011] [Mercedes-Benz, 2011] [VW, 2011] [Saab, 2011].

Automatic Anti-glare

Automatic anti-glare exterior mirrors protect the driver from headlight dazzle by automatically and progressively dimming when the light coming from behind is too bright. This prevents dangerous situations arising from glaring light reflections in the mirrors. Automatic anti-glare mirrors measure the light intensity by sensor and darken dependently in response to excessively strong light. An electronic control unit varies the darkening effect quickly and continuously according to the current ambient light conditions [Audi, 2011] [VW, 2011].

Collision Warning with Auto Brake

Collision Warning helps the driver avoid the sort of low-speed collisions that are common in urban traffic and in slow-moving traffic queues. At speeds of up to 30 km/h a laser-based technology detects if a vehicle within 6-8 meters in front of the car is stationary or traveling at lower speed. If the system detects an imminent collision, the brakes are prepared, so they respond faster and if the driver do not brake, the system automatically brakes and disconnect the fuel supply to reduce the impact of a collision [Volvo, 2011] [Ford, 2011].

Driver Attention Alert

Driver Attention Alert systems alerts the driver if tiredness or loss of focus is detected. Based on signals from a digital camera that monitors the road ahead and data on steering wheel movements the system registers error responses in relation to the normal driving style. A status indicator shows how aware the driver is. If the system detects that the driving style is showing signs of sleepiness or inattention a warning sound will be activated and a display will show a message on the dashboard which tells the driver it is time for a break [Mercedes-Benz, 2011] [Ford, 2011] [Volvo, 2011] [Saab, 2011].

Driver's Seat With Memory Function

Electric seat adjustment with memory function stores the individual seat settings and the mirror positions. The settings for the exterior mirrors are also retrieved from the memory. The driver-specific seat position is stored to a personal key. In some models this function is also optionally available for the front passenger seat. [Audi, 2011] [Saab, 2011].

Electric Folding Mirrors

Electrically folding exterior mirrors prove especially useful when taking the vehicle through the car wash or parking in narrow garages or tight spaces where every inch of space counts [Audi, 2011] [Saab, 2011].

Heating

The exterior mirror heating responds automatically depending on the weather conditions and humidity. The system heats as necessary depending on the temperature and the vehicle speed, making sure the driver has a clear view [Audi, 2011].

Lane Assist

Lane assist detects lane markings by means of a camera on the front of the vehicle. The system is operational as soon as the camera detects road markings on both sides of the vehicle. If the vehicle starts to drift towards one of the detected lane markings, vibrations in the steering wheel warn the driver that the vehicle is moving out of its lane and the system is also capable of keeping the car in the right lane. No warning is given if the driver is indicating with the turn signal. The system is designed for driving on motorways and main roads.[Audi, 2011] [BMW, 2011a] [Ford, 2011] [Mercedes-Benz, 2011] [VW, 2011].

Level Sensor - Car Theft Prevention

If someone tries to steal the rims or tow the car, this will activate the alarm by use of the level sensor, which will detect the movement of the car and alert the owner [Volvo, 2011] [Saab, 2011].

Light and Rain Sensor

The light and rain sensor automatically controls the windshield wipers and the headlights. It independently activates the appropriate lights in poor weather or when driving in darkness. The rain sensor adjusts the wipe interval to match the strength of the rain. LEDs inside the windshield emit invisible infrared light which is reflected at the outer surface of the windsshield only where it is free of raindrops. The reflected light is continuously measured by photo diodes. As the quantity of water hitting the windshield increases, less infrared light is reflected, thus allowing an exact regulation of the wipe interval. [Audi, 2011] [BMW, 2011a] [Mercedes-Benz, 2011] [VW, 2011] [Saab, 2011].

Memory Function

Various settings are stored together with the seat position and associated with the respective driver's key. In addition, the memory function automatically tilts the mirror face of the passenger side exterior mirror downwards when reverse gear is engaged, providing the driver with a better view of the curb an objects on the ground [Audi, 2011] [BMW, 2011a] [Saab, 2011].

Highway Beam

A vehicle electronics component continually analyses the vehicle speed via sensors. After a brief interval of traveling at highway speed, the system determines this to be a highway drive and automatically switches from the dipped beam mode to the highway mode. By specially positioning the shield in the xenon plus headlights, additional light can be focused by an aluminum reflector and projected far in advance of the vehicle, but without dazzling any other drivers. This extends visibility more than twofold: from 70 m in the dipped beam mode to 150 m in the highway beam mode. Thanks to this increased visibility, at a speed of 130 km/h, two additional seconds are gained in which to react to objects or occurrences ahead of the vehicle. Consequently, the highway beam considerably increases driving safety [Audi, 2011] [Mercedes-Benz, 2011].

Parking System

The parking system provides all-round assistance for parking and maneuvering. The system detects obstacles the driver cannot see, gives reliable warnings and even helps looking for a suitable parking space. The parking system makes parking easier whatever the traffic, and warns the driver of unseen obstacles close to the vehicle. Depending on the chosen specification, the system monitors the area behind the vehicle or both in front of and behind it. If the car approaches an object during maneuvering, a auditory feedback to the driver tells that the vehicle is heading towards an obstacle [Audi, 2011] [BMW, 2011a] [Ford, 2011] [Mercedes-Benz, 2011] [VW, 2011].

Pedestrian Detection with Auto Brake

The Pedestrian Detection system detects if a pedestrian is to be hit by the car. The front of the car is fitted with a soft bumper which will absorb most of the energy in the case a pedestrian is hit by the car, making less damage to the pedestrian [Volvo, 2011].

Queue Assist

Automatically adjusts the speed after the vehicle ahead. When the car sets off, by pushing the queue button or pressing the throttle will make the car ”follow” the car in front automatically with the specified spacing. When the speed exceeds 30 km/h, simply set the desired speed and the smallest temporal distance to the car in front. When the radar sensor detects a slower car ahead, the speed adjusts automatically to this car and when there is no longer is a car in front, the car accelerates to the chosen speed [Volvo, 2011].

Side Assist

The lane change assistant aids the driver when changing lane. With its radar sensors in the rear bumper, the system monitors traffic in the driver's blind spot. When a vehicle approaches from behind, a LED warning signal lights up. The area beside and behind the vehicle is monitored by radar sensors at speeds above 30 km/h. When there is a vehicle in the blind spot or a vehicle is approaching rapidly from behind, the LED signal in the respective exterior mirror is continuously illuminated as a warning to the driver. If the turn signal is operated in this situation, the lights in the exterior mirror flash to alert the driver to the danger of a collision. The Side Assist does not actively intervene in the controlling of the vehicle and the driver may deactivate it at any time by pressing a button on the driver door [Audi, 2011] [Mercedes-Benz, 2011].

Speech Dialogue System

With the speech dialogue system, the car phone, radio, CD player, CD changer, TV tuner and all the main functions of the navigation system can be controlled. An electronic noise reduction feature filters out unwanted distortion noise. The system is also capable of processing dialects, individual pronunciations and fast speech. The central operating element for the voice control system is the push-to-talk button on the multifunction steering wheel. When this button is pressed, the first voice command by the driver selects the unit to be operated. Which options are then available depends on the selected unit. This prevents unintentional activation of other units and ensures intuitively correct operation [Audi, 2011].

Traffic Sign Recognition

Traffic Sign Recognition automatically reads the signs and displays the speed limit, overtaking rules, or other appropriate symbol on the information display to help the driver being alert in traffic [Ford, 2011].

Figure A.1: Car Manufacturer Logos for the researched brands

B. Mail Correspondence with Driving Instructors

In connection with researching the use of the mirror, it was investigated to what degree mirror adjustment is instructed as part of the basic training for achieving a drivers license in Denmark and the following mail was sent to Driving Academy and Jysk Trafikskole by Claus, both situated in Aalborg. We only got a reply from Driving Academy.

Mail Sent to Driving Instructor - Original Danish Version

Hej

Vi er to specialestuderende fra Aalborg Universitet der er ved at skrive projekt om brugen af spejle i personbiler, og i den forbindelse kunne vi godt tænke os at høre i hvor høj grad der bliver lagt vægt på indstillingen af bilens spejle i forbindelse med teoriundervisning, og efterfølgende i den praktiske brug på vejene.

Hvilke retningslinier bruges der i undervisningen i forbindelse med indstilling af bilens spejle, for henholdsvis sidespejle og bakspejlet?

Vi håber i vil være behjælpelige med information, da det vil hjælpe os i den videre udvikling med vores system til indstilling af bilen spejle.

Venlig Hilsen
/Svend Emil Mosbæk & Morten Elkjær
Medialogi, 10. Semester, Aalborg Universitet.

Mail Sent to Driving Instructor - English Version

Hi

We are two graduate students from Aalborg University who is writing a project with focus on the use of mirrors in cars, and in this regard we will like to hear to what extent there is an emphasis on the setting of car mirrors in connection with teaching theory and in the practical use on the roads.

What guidelines are used in teaching in the setting of car mirrors, respectively side mirrors and rear view mirror?

We hope you will help us with information as it will help us in the further development of our system to adjust car mirrors.

Best regards,
/Svend Emil Mosbæk & Morten Elkjær
Medialogy, 10th Semester, Aalborg University.

B.0.1 Reply from Driving Academy - Original Danish Version

Hej!

Der er ikke nogle decideret retningslinier for, hvordan spejle skal indstilles på en bil eller køretøjer generelt. Det færdselsloven siger er, at man ikke må være til fare eller ulempe for andre bilister og derfor er det jo nødvendigt at indstille sine spejle korrekt. Derudover er det ikke lovpligtigt at højre sidespejl forefindes på bilen, men kan man ikke orientere sig tilstrækkeligt skal højre sidespejl være monteret.

I vores undervisning, både teoretisk og praktisk, lægger vi stor vægt på brugen af spejlene, men i kombination med hoveddrejning for at afdække evt. blinde vinkler. Det er simpelthen nødvendigt at kombinere disse, da man ellers vil dumpe sin køreprøve. De prøvesagkyndige accepterer ikke, at eleverne udelukkende bruger spejlene til at orientere sig i. Vi er af samme mening, da man ved hoveddrejning og brug af spejle orienterer sig bedst muligt og derved nedsætter risikoen for ulykker i alle manøvrer. Det må jo være det alle helst vil undgå.

Jeg håber I har fået svar på jeres spørgsmål ellers er I velkomne til at henvender jer igen, enten på mail eller tlf. 222 700 75.

Mvh Morten
Driving Academy

B.0.2 Reply from Driving Academy - English Version

Hi!

There are no definite guidelines as to how mirrors must be adjusted on a car or vehicle in general. The traffic regulations says that one may not be a danger or inconvenience to other motorists and therefore it's necessary to adjust the mirrors correctly. Furthermore, it is not mandatory to have a right side mirror on the car, but if the driver can't orient sufficiently then a right side mirror must be mounted.

In our teaching, both theoretically and practically, we emphasize the use of mirrors, but in combination with head rotation to identify any blind spots. It is simply necessary to combine these, else you will not pass the driving test. The examiner do not accept that students only use the mirrors to orient themselves. We are of the same opinion, as it is by head turning and use of mirrors you oriented properly, and thereby reduces risk of accidents in all maneuvers. It must be in everybody's interest.

I hope I have got answers to your questions, otherwise you are welcome to contact me again, either by mail or phone.

Kindly, Morten
Driving Academy

C. Results for User Observations - Number and Duration

Test Person	Seconds to Adjust	Average	Estimated duration	Number of looks
1. - adjustment 1	9	15,5	5,5	11
1. - adjustment 2	23			
1. - adjustment 3	15			
1. - adjustment 4	15			
2. - adjustment 1	7	8	2,5	9
2. - adjustment 2	5			
2. - adjustment 3	9			
2. - adjustment 4	11			
3. - adjustment 1	5	4,75	3	8
3. - adjustment 2	5			
3. - adjustment 3	3			
3. - adjustment 4	6			
4. - adjustment 1	5	7,75	7	16
4. - adjustment 2	9			
4. - adjustment 3	7			
4. - adjustment 4	10			
5. - adjustment 1	10	7,25	5	11
5. - adjustment 2	5			
5. - adjustment 3	7			
5. - adjustment 4	7			
6. - adjustment 1	5	4,5	2,5	5
6. - adjustment 2	6			
6. - adjustment 3	4			
6. - adjustment 4	3			
7. - adjustment 1	22	14,5	7	16
7. - adjustment 2	16			
7. - adjustment 3	12			
7. - adjustment 4	8			
8. - adjustment 1	5	9,5	1,5	5
8. - adjustment 2	9			
8. - adjustment 3	18			
8. - adjustment 4	6			
9. - adjustment 1	6	5,25	12	25
9. - adjustment 2	4			
9. - adjustment 3	6			
9. - adjustment 4	5			
10. - adjustment 1	8	9,5	1,5	7
10. - adjustment 2	12			
10. - adjustment 3	10			
10. - adjustment 4	8			
	346		47,5	113
Average	8,65	8,65	4,75	11,3
Minimum	3	4,5	1,5	5
Maximum	23	15,5	12	25

D. Results for User Observations - Accuracy

Test Person	X center	Y center	X reference	Y reference
1. - adjustment 1	400	300	259	343
1. - adjustment 2	400	300	274	342
1. - adjustment 3	400	300	271	342
1. - adjustment 4	400	300	267	343
Mean			267,75	342,50
Std			6,50	0,58
2. - adjustment 1	400	300	250	346
2. - adjustment 2	400	300	256	338
2. - adjustment 3	400	300	261	347
2. - adjustment 4	400	300	266	343
Mean			258,25	343,50
Std			6,85	4,04
3. - adjustment 1	400	300	266	342
3. - adjustment 2	400	300	266	318
3. - adjustment 3	400	300	242	310
3. - adjustment 4	400	300	281	309
Mean			263,75	319,75
Std			16,13	15,37
4. - adjustment 1	400	300	281	345
4. - adjustment 2	400	300	285	343
4. - adjustment 3	400	300	302	335
4. - adjustment 4	400	300	287	343
Mean			288,75	341,50
Std			9,18	4,43
5. - adjustment 1	400	300	251	327
5. - adjustment 2	400	300	257	301
5. - adjustment 3	400	300	287	291
5. - adjustment 4	400	300	294	283
Mean			272,25	300,50
Std			21,41	19,14
6. - adjustment 1	400	300	236	280
6. - adjustment 2	400	300	262	279
6. - adjustment 3	400	300	251	269
6. - adjustment 4	400	300	257	273
Mean			251,50	275,25
Std			11,27	5,19
7. - adjustment 1	400	300	267	308
7. - adjustment 2	400	300	273	301
7. - adjustment 3	400	300	248	307
7. - adjustment 4	400	300	262	309
Mean			262,50	306,25
Std			10,66	3,59
8. - adjustment 1	400	300	284	321
8. - adjustment 2	400	300	269	319
8. - adjustment 3	400	300	289	327
8. - adjustment 4	400	300	284	315
Mean			281,50	320,50
Std			8,66	5,00
9. - adjustment 1	400	300	239	321

9. - adjustment 2	400	300	230	338
9. - adjustment 3	400	300	240	332
9. - adjustment 4	400	300	228	330
Mean			234,25	330,25
Std			6,13	7,04
10. - adjustment 1	400	300	247	338
10. - adjustment 2	400	300	261	324
10. - adjustment 3	400	300	276	324
10. - adjustment 4	400	300	261	318
Mean			261,25	326,00
Std			11,84	8,49
Additional Test Participants				
11. - adjustment 1	400	300	237	335
11. - adjustment 2	400	300	248	321
11. - adjustment 3	400	300	266	325
11. - adjustment 4	400	300	274	332
Mean			256,25	328,25
Std			16,82	6,40
12. - adjustment 1	400	300	238	347
12. - adjustment 2	400	300	260	345
12. - adjustment 3	400	300	253	343
12. - adjustment 4	400	300	266	341
Mean			254,25	344,00
Std			12,07	2,58
13. - adjustment 1	400	300	243	331
13. - adjustment 2	400	300	253	325
13. - adjustment 3	400	300	240	334
13. - adjustment 4	400	300	238	334
Mean			243,50	331,00
Std			6,66	4,24
14. - adjustment 1	400	300	233	328
14. - adjustment 2	400	300	244	310
14. - adjustment 3	400	300	258	307
14. - adjustment 4	400	300	260	313
Mean			248,75	314,50
Std			12,69	9,33
Over All				
Mean			260,32	323,13
Std			17,51	20,23
Standard deviations				
Mean			10,86	7,29
Minimum			6,13	0,58
Maximum			21,41	19,14

E. Questions used for The Laboratory Prototype Test

Which <u>positive</u> elements do you see in the concept just presented to you?

Which <u>negative</u> elements do you see in the concept just presented to you?

Would you find this automation uncomfortable? Why/Why not?

How would you categorize such a system? Comfort or Safety? Why?

Would you like it installed in your car? What would the requirements then be? Which functionalities would you expect?

F. DVD

Bibliography

[Almén, 2002] Almén, Lisbeth (2002). *Driver attention control*, p. p. 1–2. The Graduate School for Human-Machine Interaction (HMI) Linköping and Stockholm.

[Articlebase.com, 2007] Articlebase.com (2007). *Saab's Driver Attention Warning System*. ArticlesBase.com - Free Articles Directory Free Online Articles Directory. http://www.articlesbase.com/automotive-articles/saabs-driver-attention-warning-system-257973.html [date: 11.03.2011].

[ASP, 2011a] ASP (2011a). *Anti Sleep Pilot*. APS. http://www.antisleeppilot.com/media/presentation/Web-site%20DK/Produkt/Design_I%20kabine_S.jpg [date: 04.05.2011].

[ASP, 2011b] ASP (2011b). *Anti Sleep Pilot*. APS. http://www.antisleeppilot.com/en/product/Introduction [date: 07.04.2011].

[ASP, 2011c] ASP (2011c). *State-of-the-art science*. APS. http://www.antisleeppilot.com/en/product/the-science [date: 07.04.2011].

[Audi, 2011] Audi (2011). *Glossary - Vorsprung durch Technik in Detail*. Audi. http://www.audi.com/com/brand/en/tools/advice/glossary.html [date: 12.04.2011].

[BMW, 2011a] BMW (2011a). *BMW Technology Guide*. BMW. http://www.bmw.com/com/en/insights/technology/technology_guide/start.html [date: 12.04.2011].

[BMW, 2011b] BMW (2011b). *Keyless lock in BMW*. BMW. http://www.bmw.com/com/en/insights/technology/technology_guide/articles/comfort_access_system.html [date: 16.03.2011].

[Broy, 2010] Broy, Manfred (2010). *Automotive Software and Systems Engineering*, p. 1–7. ACM.

[Caranddriver.com, 2011] Caranddriver.com (2011). *Car and Driver*. Car and Driver. http://www.caranddriver.com/ [date: 12.04.2011].

[Cowan, 2000] Cowan, Nelson (2000). *The magical number 4 in short-term memory: A reconsideration of mental storage capacity*, p. 87–185. Cambridge University Press.

[DealExtreme, 2011a] DealExtreme (2011a). *MG946R Metal Gear Digital Torque Servos with Gears and Parts*. DealExtreme. `http://www.dealextreme.com/p/mg946r-metal-gear-digital-torque-servos-with-gears-and-parts-35761` [date: 25.05.2011].

[DealExtreme, 2011b] DealExtreme (2011b). *SG90 Mini Servo with Gears and Parts (2Kg Torque)*. DealExtreme. `http://www.dealextreme.com/p/sg90-mini-servo-with-gears-and-parts-2kg-torque-35764` [date: 25.05.2011].

[Driving-Academy, 2011] Driving-Academy (2011). *Driving Academy*. Driving Academy ApS. `http://www.driving-academy.dk` [date: 23.03.2011].

[DrowsyDriving.org, 2011] DrowsyDriving.org (2011). *Facts and Stats*. National Sleep Foundation. `http://drowsydriving.org/about/facts-and-stats/` [date: 07.04.2011].

[DST, 2011a] DST (2011a). *Danmarks Statistik*. Danmarks Statistik. `http://www.dst.dk/pukora/epub/Nyt/2010/NR288.pdf` [date: 23.03.2011].

[DST, 2011b] DST (2011b). *Danmarks Statistik*. Danmarks Statistik. `http://www.dst.dk/pukora/epub/upload/15197/saa2010.pdf` [date: 24.03.2011].

[DTA, 2010] DTA (2010). *Lempede regler for sideafskærmning (cyklistværn)*. Danish Transport Authority. `http://trafikstyrelsen.dk/DA/Presse/Nyhedsarkiv/Nyhedsarkiv_SYN/2009/10/Lempede-regler-for-sideafskrmning-cyklistvrn.aspx` [date: 05.04.2011].

[DTA, 2011] DTA (2011). *Sensorteknik*. Danish Transport Authority. `http://www.trafikstyrelsen.dk/DA/Syn-og-K%C3%B8ret%C3%B8jer/Regler-om-k%C3%B8ret%C3%B8jer/Hoejresvingsulykker/Sensorteknik.aspx` [date: 05.04.2011].

[eHow, 2011] eHow (2011). *How a Keyless Car Lock Works*. eHow. `http://www.ehow.com/how-does_5589615_keyless-car-lock-works.html` [date: 11.03.2011].

[ErgonomicsSimplified.com, 2011] ErgonomicsSimplified.com (2011). *Driving Ergonomics - Prober Adjustment*. ErgonomicsSimplified LLC. `http://www.ergonomicssimplified.com/tips/driving` [date: 03.05.2011].

[Ford, 2011] Ford (2011). *Intelligent teknologi lige ved hånden*. Ford. `http://www.ford.dk/Nyheder&omtale/Kommendebiler/NyFocus/Teknologi` [date: 27.04.2011].

[Færdselsstyrelsen, 2004] Færdselsstyrelsen (2004). *Meddelelse om køretøjers indretning og udstyr mv. nr. 1837. Nye spejle på alle lastbiler fra 1. oktober 2004.* retsinformation.dk. `https://www.retsinformation.dk/Forms/R0710.aspx?id=22320` [date: 05.04.2011].

[Færdselsstyrelsen, 2011] Færdselsstyrelsen (2011). *Bekendtgørelse om detailforeskrifter for køretøjers indretning og udstyr, sektion 10.03.021 Personbil M 1.* Færdselsstyrelsen. `https://www.retsinformation.dk/Forms/R0710.aspx?id=22683` [date: 11.03.2011].

[Garcia & Quintana-Domeque, 2007] Garcia, Jaume & Quintana-Domeque, Climent (2007). *The evolution of adult height in Europe: A brief note*, p. 343. Elsevier.

[Group1034, 2011a] Group1034 (2011a). *Drive from Aalborg to Svenstrup - Front View.* YouTube. `http://www.youtube.com/watch?v=o21yLKVkOGs` [date: 09.05.2011].

[Group1034, 2011b] Group1034 (2011b). *Drive from Aalborg to Svenstrup - Rear View.* YouTube. `http://www.youtube.com/watch?v=nLoLLe0jaXE` [date: 09.05.2011].

[HVU, 2006] HVU (2006). *Ulykker mellem højresvingede lastbiler og ligeudkørende cyklister.* Havarikommissionen for Vejtrafikulykker. `http://www.hvu.dk/pdf/Tema04UlykkerHoejrevingende.pdf` [date: 05.04.2011].

[Ideafinder.com, 2011] Ideafinder.com (2011). *The Great Idea Finder.* The Great Idea Finder. `http://www.ideafinder.com/history/inventions/automobile.htm` [date: 11.04.2011].

[Instructables.com, 2011] Instructables.com (2011). *CarPuter.* Instructables.com. `http://www.instructables.com/id/Adding-a-computer-to-your-car-CarPuter/` [date: 24.04.2011].

[Justitsministeriet, 2009] Justitsministeriet (2009). *Bekendtgørelse om undervisningsplan for køreuddannelsen til kategori B (almindelig bil).* Ministry of Justice. `https://www.retsinformation.dk/Forms/R0710.aspx?id=123766` [date: 18.03.2011].

[Kar, 2011] Kar, Meena (2011). *Bored Drivers More Likely To Have Accidents.* Thaindian News. `http://www.thaindian.com/newsportal/world/bored-drivers-more-likely-to-have-accidents_100484976.html` [date: 11.03.2011].

[Khawaja *et al.*, 2010] Khawaja, M. Asif, Chen, Fang, & Marcus, Nadine (2010). *Using Language Complexity to Measure Cognitive Load for Adaptive Interaction Design*, p. 333–336. ACM.

[Krug, 2006] Krug, Steve (2006). *Don't Make Me Think! - A Common Sense Approach to Web Usability*. New Riders Publishing.

[Larson, 2011] Larson, Aaron (2011). *Distracted Drivers and Auto Accidents*. ExpertLaw.com. http://www.expertlaw.com/library/car-accidents/distracted-driver.html [date: 11.03.2011].

[LivOgTrafik, 2011] LivOgTrafik (2011). *Liv og Trafik*. LivOgTrafik. http://www.livogtrafik.dk/vision-100.htm [date: 24.05.2011].

[Mercedes-Benz, 2011] Mercedes-Benz (2011). *Mercedes Techcenter*. Mercedes-Benz. http://www3.mercedes-benz.com/mbcom_v4/xx/techcenter2009/en.html#/home [date: 12.04.2011].

[MichaelPines, 2011] MichaelPines (2011). *Top 25 Causes of Car Accidents*. Law Offices of Michael Pines. http://seriousaccidents.com/legal-advice/top-causes-of-car-accidents/ [date: 11.03.2011].

[Miller, 1955] Miller, George A. (1955). *The Magical Number Seven, Plus or Minus Two Some Limits on Our Capacity for Processing Information*, p. 343–352. American Psychological Association.

[Moeslund, 2009] Moeslund, Thomas B. (2009). *Image and Video Processing, 2nd Edition*, p. 135. DTU Informatics.

[Mysteries, 2011] Mysteries, Everyday (2011). *cugnot*. 'Everyday Mysteries'. http://www.loc.gov/rr/scitech/mysteries/auto.html [date: 01.03.2011].

[NSW-Government, 2011] NSW-Government (2011). *RTA*. Transport, Roads and Traffic Authority. http://www.rta.nsw.gov.au/roadsafety/speedandspeedcameras/index.html [date: 23.03.2011].

[OpenCV, 2004a] OpenCV (2004a). *Face Detection using OpenCV*. OpenCV. http://opencv.willowgarage.com/documentation/object_detection.html [date: 28.04.2011].

[OpenCV, 2004b] OpenCV (2004b). *Face Detection using OpenCV*. OpenCV. http://opencv.willowgarage.com/wiki/FaceDetection [date: 28.04.2011].

[OpenCV, 2011] OpenCV (2011). *OpenCV*. OpenCV. http://opencv.willowgarage.com/wiki/ [date: 09.05.2011].

[openFrameworks, 2011] openFrameworks (2011). *openFrameworks*. openFrameworks. http://www.openframeworks.cc/ [date: 18.05.2011].

[Oviatt, 2006] Oviatt, Sharon (2006). *Human-Centered Design Meets Cognitive Load Theory: Designing Interfaces that Help People Think*, p. 871–880. ACM.

[Platzer, 2011] Platzer, George (2011). *Car Mirror Safety by George Platzer*. SAE International. http://www.northstarbmw.org/forms/blindzone.pdf [date: 12.04.2011].

[Politiken.dk, 2004] Politiken.dk (2004). *Stadig dødsulykker trods nye spejle på lastbiler*. Politiken.dk. http://politiken.dk/indland/ECE101207/stadig-doedsulykker-trods-nye-spejle-paa-lastbiler/ [date: 05.04.2011].

[Quiroga, 2010] Quiroga, Tony (2010). *How To: Adjust Your Mirrors to Avoid Blind Spots*. CarAndDriver.com. http://www.caranddriver.com/features/10q1/how_to_adjust_your_mirrors_to_avoid_blind_spots-feature [date: 11.03.2011].

[Robotics & Inc., 2004] Robotics, Australian & Inc., Automation Association (2004). *Visual Object Recognition using Template Matching*. ARAA. http://www.araa.asn.au/acra/acra2004/papers/cole.pdf [date: 25.04.2011].

[Rockwell, 1972] Rockwell, T.H. (1972). *Skills, judgment, and information acquisition in driving*. T.W. Forbes.

[Saab, 2011] Saab (2011). *Saab Innovation*. Saab. http://www.saab.dk/dk/dk/start#/world/innovation/safety/safety-features/ [date: 12.04.2011].

[saabnetwork.com, 2007] saabnetwork.com (2007). *Saab Driver Attention Warning System*. The Saab Network. http://www.saabnet.com/tsn/press/071102.html [date: 11.03.2011].

[SAE, 1995] SAE (1995). *Society of Automotive Engineers*. Society of Automotive Engineers. http://www.sae.org/ [date: 18.03.2011].

[Sharp *et al.*, 2006] Sharp, Helen, Rogers, Yvonne, & Preece, Jenny (2006). *Interaction Design - Beyond Human-Computer Interaction, 2nd Edition*, p. 591. John Wiley & Sons, Ltd.

[sikkertrafik.dk, 2010] sikkertrafik.dk (2010). *Statistik om højresvingsulykker*. sikkertrafik.dk. http://www.sikkertrafik.dk/Paa%20cykel/Undgaa_hoejresvingsulykker/statistik_om_hoejresvingsulykker [date: 05.04.2011].

[SikkerTrafik.dk, 2011] SikkerTrafik.dk (2011). *Kampagnearkiv*. Rådet for Sikker Trafik. http://www.sikkertrafik.dk/Aktuelt/Kampagner/Kampagnearkiv [date: 05.04.2011].

[SST, 2011] SST (2011). *Sundhedsstyrelsen*. Sundhedsstyrelsen. http://www.sst.dk/publ/publ2000/10aarmedgst/inde0002.htm [date: 24.03.2011].

[Statoil, 2011] Statoil (2011). *Sådan indstiller du dine højre sidespejle korrekt!* Statoil. http://www.statoil.dk/FrontServlet?ds=OmStatoil&state=OmStatoil_dynamic&viewid=1880646 [date: 05.04.2011].

[Truckernet.dk, 2011] Truckernet.dk (2011). *Indstilling af spejle.* Truckernet.dk. http://www.truckernet.dk/spejl.asp [date: 05.04.2011].

[Volvo, 2011] Volvo (2011). *Volvo V60 Equipment.* Volvo. http://www.volvocars.com/intl/all-cars/volvo-s60/details/pages/features.aspx [date: 12.04.2011].

[VW, 2011] VW (2011). *Volvo V60 Equipment.* VW. http://www.volkswagen.dk/content/medialib/vwd4/dk/trimlevel_pdf/passat_cc/_jcr_content/renditions/rendition.file/passatcc_2011.pdf [date: 12.04.2011].

[Wierville, 1993] Wierville, Walter W. (1993). *Demands on driver resources associated with introducing advanced technology into the vehicle*, p. 133–142. Pergamon Press Ltd.