NTNU
Norwegian University of
Science and Technology

Pervasive Games for Vehicle Drivers

Amr Ellafy

Master in Information Systems
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Supervisor: Alf Inge Wang, IDI

Norwegian University of Science and Technology
Department of Computer and Information Science

Abstract

Pervasive games are a new gender of games that is gaining popularity in recent years. The potential of pervasive games is their ability of mixing real-life physical objects in the gameplay, creating a thrilling experience for players.

This thesis work researches the possibility of engaging vehicle drivers in pervasive games with road safety as the primary concern. First a research of main causes of traffic accidents is conducted though available statistics. The statistics shows that the human-factor contributes to the top five causes of traffic accidents. The statistics also concluded that the driver psychophysiological state is vital for road safety.

Factors conditioning human's psycho physiological state are analyzed from computer games perspective. Affective Gaming, a gender of gaming highly dependent on player psychophysiological state, is further studied in terms of its applicability for in-vehicle use. The study includes researching various methods of capturing human psychophysiological state. Furthermore, different types of pervasive games are discussed including state of the art games available for vehicles.

A research is conducted to cover available driver support systems and show how they work and contribute to road safety. Heads-up Display are also discussed as a method of displaying information to the driver with minimal distraction from driving.

Relevant concepts and technologies in relation to pervasive games, driver support systems and road safety were defined and utilized as a basis for the conceptual framework which was developed in this thesis work. The framework shows how pervasive games can be used to contribute to road safety using various driver support systems. The idea is illustrated in a set of example game scenarios. A simulation software is used to demonstrate a part of the conceptual framework as a proof of concept.

An important outcome of this thesis includes a conceptual framework for pervasive game implementation. The guidelines and relevant technologies are indispensable not only for pervasive games, but also for other multimedia (infotainment) application development and integration in the vehicle environment in terms of road safety and driving quality.

Acknowledgements

First and foremost I would like to express my sincere gratitude to my advisor Audrius Jurgelionis for his continuous support, enthusiasm, and vast knowledge. I would like also to thank my supervisor prof. Alf Wang for his support and effort in reviewing my work. Also I would like to thank Jo Skjermo at Statens vegvesen for his help in running the driver simulator.

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Part I

Introduction

Chapter 1

Introduction

Pervasive games have become popular in recent years. The ability of mixing physical and virtual reality has made pervasive games come with new ideas of games offering a thrilling gameplay experience.

In this thesis work I research the possibilities of developing an interactive pervasive game in vehicles connected to Intelligent Transportation Systems (ITS) infrastructure to improve road safety and traffic efficiency using technologies such as Car-to-X, Global Position Systems (GPS), head-up display (HUD) and facial expression recognition. The main idea is to entertain the driver while adjusting the gameplay according to vehicle driver psychophysiological state (Drowsy, stressed, high/low heartbeat rate, etc.), the driver destination, and road conditions. The research will include studying state-of-the-art projects as well as other similar systems. The outcome of the project will provide user and infrastructure requirements for such games and will analyze the feasibility of technologies proposed.

1.1 Motivation

Pervasive games will offer vehicle drivers a better driving experience along the travel route. However the motivation is not only entertaining vehicle drivers, but also assuring a safer trip. Gameplay can change the driver psychophysiological state from a negative to a positive affect. For example, gameplay can keep drivers excited and focused on the road rather than drowsy and distracted.

1.2 Problem Definition

This project researches the possibilities of developing pervasive game in vehicles which uses Intelligent transportation systems to improve road safety and traffic efficiency using relevant supporting technologies.

1.3 Reader's Guide

Part I - Introduction explains the motivation behind the project, the problem definition, and the research methods and questions.

Part II - Prestudy includes traffic accidents statistics, traffic psychology, human psychophysiology, and the linkage between them. This part also discusses the state of the art drivers supporting technologies and how they can be used to develop pervasive games for vehicle drivers. The last chapter in this part discusses pervasive games and effect of games on players' psychophysiological states. Finally state of the art similar pervasive games are illustrated.

Part III - Own Contribution explains the conceptual framework, example scenarios, and illustration of how simulation can be used to make use of the framework.

Part IV - Evaluation contain the evaluation of the project. This part includes discussions on problems encountered and evaluation of research methods.

Part V - Summary contains thesis conclusion, future work, and recommendations for game developers whom are interested in implementing pervasive games for vehicle drivers.

Chapter 2

Research Methods & Questions

Qualitative and Quantitative research are the two main research paradigms.[45] describes quantitative research as research which focuses on gathering numerical data and generalizing it across a group of people. It is also noted that statistics is the most widely used branch of mathematics in qualitative search. In this thesis work I start by collecting numerical data and statistics on traffic accidents, their main causes, as well as the current available technologies in assuring traffic safety.

However, I also pursue answers in the effect on drivers' psychophysiological state in safety on road. Quantitative methods are insufficient on their own in explaining the phenomenon they wish to study [37] and thus I also use qualitative research. The strength of qualitative research [33] is its ability to provide information about the "human" side of an research question. This includes studies of human behaviors and emotions (psychophysiology) and its effect of different aspects of life. Therefore qualitative research dominates most of this thesis work in regard to studying driver psychophysiology.

Conceptual framework , as defined in[30], is a tool that enables researchers to find links between the existing literature and one own research goals. Therefore a conceptual framework is needed to identify relevant issue and frame research questions. Concept mapping is used to reflect a personal understanding of the problem and define the research questions. ([52] defines concept maps as follows " a concept map present a the relationships among a set of connected concepts and ideas"). Figure 2.1 illustrates the concept mapping for this thesis work.

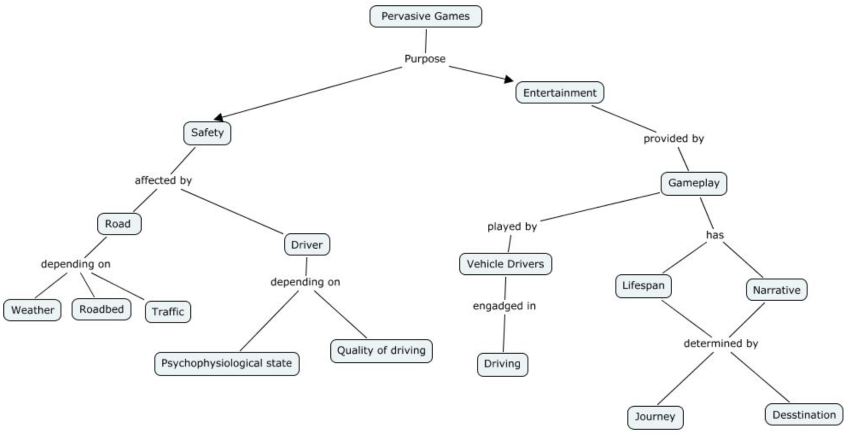


Figure 2.1: Concept Map

From the concept map the research questions are deduced. This thesis work is pursuing answers for the following questions:

Q1:What types of pervasive games are available for vehicles?
To answer this question I will look what both academia and industry products in the field of pervasive games, specifically for vehicles.

Q2:How can pervasive games be developed for vehicle drivers?
There are different ways of presenting pervasive games for vehicle drivers. To answer this question i research available technologies which facilitates developing pervasive games for vehicle drivers.

Q3:What is the linkage between gameplay and road safety?
The gameplay effect on player's psychophysiological state has been studied in various researches. The statistics also confirm that driver psychophysiological state is vital for road safety. To answer this question i research the effect of game play on players psychophysiological state and illustrate the traffic statistics link between driver psychophysiological state and traffic accidents.

Q4:How can pervasive games for vehicles utilized for better road safety?
Various technologies can be used by pervasive games to contribute to road safety. To answer this question I research available technologies which support road safety and describe how these technologies can be used by pervasive games.

Q5:Which applications are feasible to be used in pervasive games context?
Among available technologies for road safety there are some of them feasible to be used in pervasive games context. To answer this question I describe a conceptual framework which assist in spotting out feasible technologies.A set of game scenarios are explained to illustrate the usage of these technologies.

2.1 Game Research

Games research involves other research fields such as graphics and game design, film and theater studies, psychology and cognitive science and other research fields. [12] have suggested two general areas in game research, theoretically-oriented game research and design-oriented game research.

Designed-oriented research in general is defined by [20] as research which involves studies, design, and construction and of novel kinds of information and interaction technology to gain new knowledge. In this thesis designed-oriented game research is performed. Technologies such as Intelligent Transportation Systems, Head-up Display, facial expressions recognition and other relevant technologies which make it possible to develop pervasive games for vehicles in general ,and for drivers in particular, are researched.

Theory-oriented game research is defined as the researchers approach to understand and analyze the impact of games and game-play [12]. In this type of research, other range of research fields is involved to draw a frame of knowledge to study a certain effect of games and game-play. Therefore theory-oriented game research may also involve psychology, cognitive science, sociology, and other fields. Moreover, for the past few years digital games have become a theoretical research topic. For example, psychologists research the relation between game-play and behavioral effects. In this thesis, research on the effect of games in player psychological and emotional state, specifically vehicle drivers, is performed. The aim of this part of the research is to improve the safety in the road by tuning drivers' psychological state to a positive affect.

2.2 Validation of Technologies

In addition to the methods used to answer the defined research question a technology validation is performed. [51] illustrates three general categories for technologies validation, each includes four methods as shown in table 2.2

Observational	**Historical**	**Controlled**
Project Monitoring	Literature search	Replicated Experiment
Case Study	Legacy Data	Synthetic environment experiments
Assertion	Lessons learned	Dynamic analysis
Field study	Static analysis	Simulation

Table 2.1: Technology validation methods

for this thesis work, two methods are relevant:

- *Literature search;* this method is used by performing analysis on related research work. the outcome is to confirm an existing hypothesis. This thesis work evaluates relevant existing pervasive games ,driving support systems, and research on human psychophysiology.

- *Simulation;* this method is used to simulate real environments. This method is used to test the feasibility of a few parts in the game framework. It can also be considered as a guideline for researchers interested in simulation on relevant projects.

The validation results are discussed later in Chapter 10.

Part II

Prestudy

Chapter 3

Traffic Accidents

3.1 Statistics

Referred as "road traffic injury" by World Health Organization [34] ,"motor vehicle accidents" by U.S.A census bureau [13] and "motor traffic vehicle traffic collision" by transport Canada [14], traffic accidents have a remarkable contribution in human life losses ,permanent disabilities, and serious injuries every year all over the globe. In the year 2006 42,642 people lost their lives in traffic accidents in the U.S and 38,600 in the EU zone which makes traffic accidents share approximately 2.1 % of deaths every year worldwide and entitled to be the fifth leading cause of death by the year 2030 [36].

3.1.1 Main Causes

Causes of traffic accidents are ranged from human-factor, inappropriate roads, weather conditions and manufacturing defects in vehicles. However, the human-factor occupies the top five causes of car accidents. This section discusses those causes in details and how they take place.

Distracted Driving

Ranging between 20 to 25 percent, distracted driving is the top cause of traffic accidents. Distracted driving can be defined as any activity performed by a vehicle driver rather than driving while on the road. Distracting activities include [35] : rubbernecking, looking towards a scenery, adjusting entertainment devices such radio and music players, reading newspapers, magazines or documents, using communication devices such as mobile phone or pagers, and communicating or paying attention to other passengers in the vehicle.

Driver Fatigue

Fatigue drivers are the second leading cause for traffic accidents. Driver fatigue can be caused by lengthy travel periods, driving at night, or various activities performed by the driver before driving the vehicle. Driver fatigue is not limited only to drowsiness but also include irritable, bored and feeling fidgety. Fatigue drivers can easily be diagnosed by the appearance of one or more of symptoms [35] such as miss-judging traffic situations, slow response to irregular traffic incidents, unreasonable driving speed, drifting from one road line to another without reasons, and driver's yawning and heavy eyelids.

Drunk Driving

According to NHTSA [34], drunk drivers are estimated to be responsible of one third of fatal traffic accidents during the week. The percentage rises during the weekend to more than 50% during the weekends. Drunk drivers usually cannot perform regular tasks such driving, obeying road signs and traffic light, and handling unexpected traffic situations. However, blood alcohol concentration level is a key indicator of driver ability to drive safely and therefor some traffic regulations control this aspect.

Speeding

Speeding is the classic, or the de-facto, cause of traffic accidents. Speeding crashes are more severe than others. Also speeding decrease the amount of time needed for the driver to take an action to avoid a crash or overcome a thread in the road. According to IIHS [35] increasing speed from 64 km/h to 97 km/h (40 to 60 mph) doubles the amount of energy produced by a crash.

Aggressive Driving

Aggressive driving is a driver inappropriate manner towards other vehicles in the road. Aggressive drivers are characterized by pushy manner, boldness, selfishness and various behaviors during driving such as: flashing lights at other drivers to show irritation, rude and inappropriate gestures, preventing other drivers on the road from moving or speeding, unsafely changing lanes during driving.

The human-factor occupies the top five causes for traffic accidents. According to [50] 95% of all traffic accidents take place due to human error involvement. [50] categorize human error in traffic accidents into three categories: operation errors, judgment errors, and cognitive errors. Operation errors, 13% of human error in traffic accidents, are errors the cause accidents by an appropriate operation. Judgment error, 40% of human error in traffic accidents, is which drivers' misjudgment of the situation and led to an accident. Cognitive errors, 47% of human errors in traffic accidents, are errors that cause accidents by cognitive mistakes such as lack of drivers' attention or other inappropriate behavior by the driver.

Psychophysiological state of a vehicle driver has a key role in driver's safety. For example, Anger and frustration is the main cause of aggressive driving. In the U.S only, Aggressive driving costs 450,000 fidelities and 35 million injuries per year. Many other emotional and physiological states can seriously danger the drivers' safety.

Sleepiness and fatigue, known as Drowsy driving, is also one of the top contributors to the most fatal traffic accidents. Drowsy driving can be as serious as drunk driving and can lead to severe injuries, if not death, in most of the cases. A study by the NSC [7] stated that 37% of drivers admitted falling asleep behind the wheel at some point during their driving career.

Excitement seeking (also known as sensation seeking) is another important emotional state that contributes to human-factor causes of traffic accidents. Prof. Zuckerman defines excitement seeking in [53] as "a trait defined by the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, and financial risks for the sake of such experiences". Excitement seeking, especially with young drivers, is the main motivation for speeding and close-range driving.

3.2 Traffic Psychology

Traffic psychology is a new and expanding field in psychology that studies the behavior of road users, including vehicle drivers, and the psychological processes underlying that behavior. Traffic psychology is a wide research field and underlays other studies such as cognitive, motivational, and emotional determinants of traffic behavior. [43] have distinguished six areas in Traffic psychology: Behavior and accident research, Accident Prevention and improvement of traffic safety, Research in mobility and transport economy and engineering, Vehicle construction and design, Psychological assessment and rehabilitation, and Rails and flight psychology. Two among these areas are most relevant to this thesis:

(I) Behavior and accident research; studies road users' behavior and the role of human factor, especially driver performance, in road safety. The research area include:

  (a) Attentiveness and perception when driving.

  (b) The driver's psychophysiological state such as alertness and fatigue.

(II) Accident Prevention and improvement of traffic safety; studies how influencing and modifying behavior of drivers promote safety on the road.

This thesis work propose pervasive games to be used to assist vehicle drivers by:

- Keeping the driver attention to the road while driving.
- Observing the driver psychophysiological state and switch it from negative to positive affect.
- Improving the traffic safety using information collected from driver support systems (Discussed in Chapter 5).

Chapter 4

Human Psychophysiology

One can easily identify that driver behavior is the main contributor in the top cause of traffic accidents as discussed in the pervious Chapter .[16] states that driver inability to manage own emotions is identified as one of the major causes of traffic accidents. This chapter discusses the human emotional and psychophysiological state and how they can be observed and contribute to traffic psychology.

4.1 Human Moods and Emotional State

"Moods" is commonly used term by individuals to express their current emotional state. However, Thayer Robert distinguishes between moods and emotions in [48] that moods are less specific and less likely to be triggered by a particular stimulus.[49] describes moods as biopsychological in nature, which means that they do exist by the influence of various biological and psychological happenings. Thus human moods are not only subject of events but also body's rhythms and conditions. While moods are conscious, which means that humans can evaluate their current mood, the human bodies are unconsciously trying to improve their current mood which is scientifically referred to self-regulation of moods.

Human moods can be inferred by various signs such as [49] behavior, posture, tone of voice, slowness of response, slumped shoulders, and other signs. Psychology speaking, behavioral science refers to mood as Affect. [49] states that: "Affect has a certain surface quality or immediacy associated with it". Practitioners refer to affect variation using the term affect level. Affect levels can be observed by visible emotional reactions.Affect has both positive and negative dimensions. Positive affects are moods that come in favor of human beings in specific situations such as focus while driving. To the contrary, negative affects are moods that have a negative outcome on human beings such as drowsiness while driving.

A mathematical approach, based on numerical analysis, was introduced in 1985 by two American psychologists [17]. In their study, they used factor analysis to combine findings on several studies in self-reported mood to group common factors among large number of mood indicators. Mood indicators were categorized in various studies in psychology by physical indicators such as facial and vocal emotional expressions. Such expressions can be evaluated by computational analysis of face and speech recognition.

4.2 Biofeedback and Neurofeedback

Association for Applied Psychophysiology and Biofeedback (AAPB) [4] defines Biofeedback as "the process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance. Precise instruments measure physiological activity such as brain waves, heart function, breathing, muscle activity, and skin temperature."

Biofeedback helps individuals to improve their health by understanding the signals their own bodies emit [41]. There are various medical instruments that are used to study Biofeedback. These tools mainly used sensors attached to certain parts to the human body where the biofeedback is active. For example, the feedback thermometer (illustrated in Figure 4.1) is attached to the patient finger in order to detect the current body temperature. Therapists use temperature biofeedback measured to diagnose temperature-related diseases such as anxiety and stress.

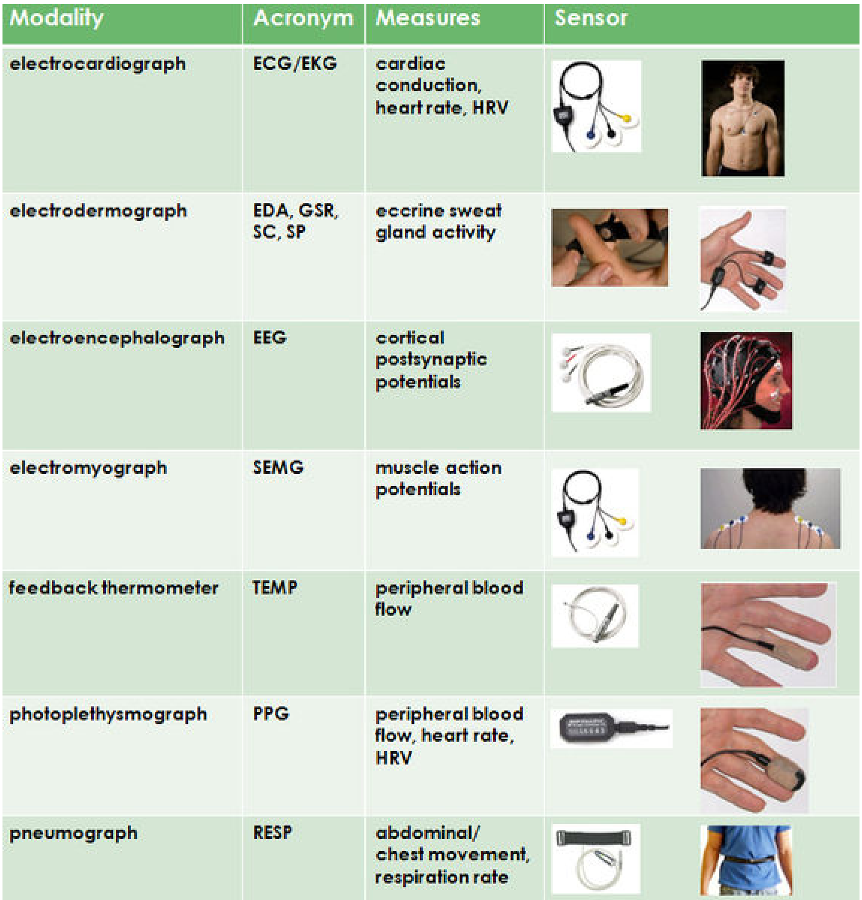
Neurofeedback is a branch of biofeedback that uses Electroencephalography (also known as EEG, a technique to record the brain electronic activity through the scalp) to receive a feedback of human brain activity in a given type while the patient is performing a certain action. Neurofeedback is often used for controlling the central nervous system activity.

Figure 4.2 illustrates the different parts of the human brain and how each functions. There are different parts in the brains that are responsible for various skills such as memorizing, emotional reaction and visual abilities. Figure 4.3 shows how neurofeedback affects the brain functions. For example, Occipital lobes, a section in the brain, can be targeted by neurofeedback technology to improve visual processing.

4.3 Affective Gaming

[28] describes affective gaming as "games where the player's current emotional state is used to manipulate gameplay". Affective games do not mainly depend on regular game input that involve physical action from the player such as gamepad, however, the game controller can be the current emotional state the player is going through. The concept of affective gaming appeared in the 1980s [28] with a text-based game called "Planetfall". In Planetfall, the game narrative changes according to the player emotional state deduced from what is typed during the gameplay.

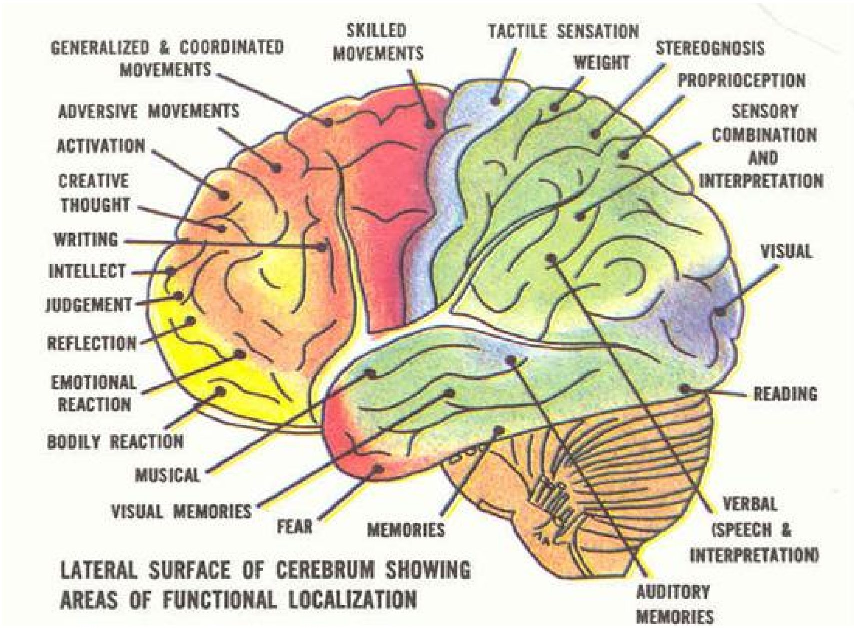
Biofeedback is also used by game developers to orchestrate an affective game. Some games use it as an additional input from the player and other games depend mainly on the player emotional state as a controller to the game dynamics. Games in which regular input is replaced with biofeedback are known as biofeedback



Modality	Acronym	Measures	Sensor
electrocardiograph	ECG/EKG	cardiac conduction, heart rate, HRV	
electrodermograph	EDA, GSR, SC, SP	eccrine sweat gland activity	
electroencephalograph	EEG	cortical postsynaptic potentials	
electromyograph	SEMG	muscle action potentials	
feedback thermometer	TEMP	peripheral blood flow	
photoplethysmograph	PPG	peripheral blood flow, heart rate, HRV	
pneumograph	RESP	abdominal/ chest movement, respiration rate	

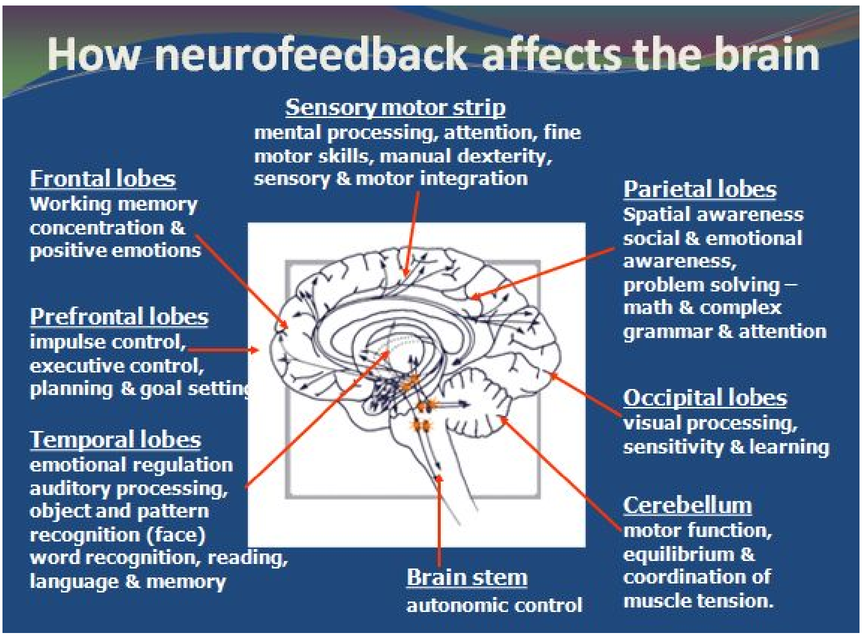
(Source: Wikipedia)

Figure 4.1: Biofeedback Modalities



[24]

Figure 4.2: Brain functions



[24]

Figure 4.3: How Neurofeedback affects the brain

games[28]. Biofeedback games demand the player to maintain a desired emotional state to keep control of the gameplay.

[27] proposes what affective state of players can do to improve gaming experience, including dynamically generating the game content with respect to the affective state of the player. [5] defined two features needed to support development of affect-adaptive games:

1. To be able to recognize a broad range of player's emotional state in real-time.

2. To adapt to player's emotional state, including changing the gameplay rewarding scheme, the game content, and even the colors of the items in the game.

4.3.1 Affective Games Controllers

SmartBrain Technologies [10] is a US-based company that develops highly interactive devices that leverage the power of the brain analysis as an input for different applications such as brain performance improvement and interactive games. The company uses neurofeedback technology developed and researched in NASA labs to improve pilot attention while flying [11].

SmartBrain offers a set of game controllers for game consoles such as Xbox and PlayStation. The game controllers include an EEG which analyze the player brain waves to help the player maintaining a desired brain state [15]. For example, the desired brain state can be gaining focus. If the player kept a desired focus level the game will proceed and the player is continuously winning. On the other hand, if the player focus decreases, the ground will be lost.

A case study conducted by the National Center for Technology Innovation (NCTI) [19] to recognize the potential of neurofeedback technology in improving of attention-related disabilities and patients with focus problems. The study used a car racing game with SmartBrain game controllers to test the effect of neurofeedback on children with attention-related disabilities. Smart Box (EEG neurofeedback acquisition device included in the controller kit as illustrated in Figure 4.4) is used to measure the brain activity and sends the signal to gamepad controller. The brain activity feedback received from the EEG device is mainly what decides how effective the gamepad is. For example, if the brain activity shows a positive focus level the gamepad become more efficient and car can reach top speed. Otherwise, if a negative focus level is reported, the gamepad become less efficient.

[10]

Figure 4.4: SmartBrain game controllers kit

However, there are other approaches of recognizing psychophysiological state more suitable for in-vehicle context. The next Section illustrates another approach, facial expression recognition, which is less distracting and more suitable for vehicle drivers.

4.4 Recognition of Psychophysiological States

There are various methods of recognizing emotional and psychological states. Body temperature, vocal and speech tone, and facial expression are the most commonly used method to detect emotional and psychological states. Facial expressions are one of the primary sources of recognizing emotional and psychological state. Face Action Coding System, FACS, is a proven method of recognizing Psychophysiological state using facial expressions.

4.4.1 Face Action Coding System

Developed by P. Ekman and Wallace V. [38] , Face Action Coding System (FACS) is a method of recognizing emotional and psychological states from facial expressions. Each emotional state is combined with distinguished facial expressions and characterized by a combination of one or more facial muscle(s) that produce them. FACS defines a unit, called Action Unit (AU), to measure specific muscles movements. A FACS coder dissects an observable facial expression and decompose it to a set of specific Action Units that infers an emotional state, each set of AUs are defined as FACS score. Accordingly, a database of AUs has been developed by the authors of FACS, namely "Facial Action Coding System Affect Interpretation Dictionary" or FACSAID .

Facial Action Coding System Affect Interpretation Dictionary (FACSAID) [38] is a project that links facial expressions with their psychological interpretations. FACSAID holds FACS scores in a database. Each FACS score infers an emotion state such as happiness, anger; sadness...Etc.Table 4.4.1 shows FACS score for common emotional states.

Emotion	Action Units
Happiness	6+12
Sadness	1+4+15
Surprise	1+2+5B+26
Fear	1+2+4+5
Anger	4+5+7+23
Disgust	9+15+16
Contempt	R12A+R14A

Table 4.1: FACS scores for common emotional states

4.4.2 Facial Expression Recognition

In order to computerize the expression process a set of procedures are followed for maximum accuracy of emotional and psychological state. CERT [23] is a software toolkit for automating the process of real-time facial expression recognition. CERT makes use of a FACSAID database, and distinguishes between 19 different facial expressions using FACS scores.

CERT goes through 6 stages to identify the emotional facial expression:

1. *Face Detection:* In this stage each frame in the processed video clip is analyzed and large face found is segmented for further processing later on.

2. *Face Feature Detection:* After the face detection stage the system need to identify key face features. In this stage, a set of 10 facial features are detected in the face region using specific detecting mechanized for each feature. The key face features are: The inner and outer eye corners, eye centers, tip of the nose, inner and outer mouth corners, and center of the mouth, are detected within the face region using feature-specific detectors.

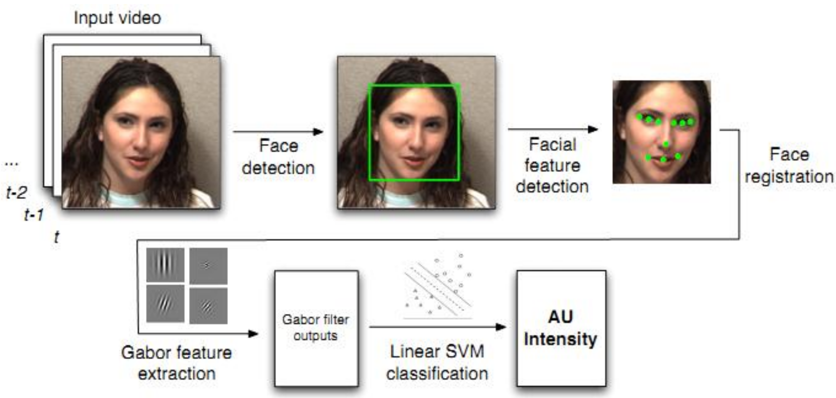
3. *Face Registration:* In this stage the identified face features are used to register the face position into a frame. This frame becomes the center of focus and outer area is ignored.

4. *Feature Extraction:* Detected features are extracted in this stage using specific image processing filters. Each feature, in a given time, is stored in a single feature vector.

5. *Action Unit Recognition:* Each computed feature vector is compared to Action Units stored on several databases using linear support vector machines (SVM).(SVM are defined as "a set of related supervised learning methods that analyze data and recognize patterns, used for classification and regression analysis."). For maximum accuracy, CERT compares the computed feature vector against several databases including FACSAID.

6. *Expression Intensity and Dynamics:* In this stage the intensity of the facial expression is measured by evaluating the distance between the computed feature vectors against SVM of different Action Units. Frame-by-frame intensity processing takes place giving information about the dynamics of facial expressions.

Figure 4.5 illustrates CERT processing staging, starting from face detection until the facial expression intensity is measured.



[23]

Figure 4.5: CERT processing stages

Chapter 5

Supporting Technologies

5.1 Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) is a general term defining research and industry institutes efforts to integrate information and communication technologies to support transport infrastructure and vehicles.Traffic control systems (traffic signal control, speed control, number plate recognition), parking guidance, collision avoidance and road condition advice is an example of variety of vehicle support systems. Such systems either use an in-road advanced transport infrastructure to be supplied with such information, or by communicating with other vehicles in the road. Both technologies are known as Car-to-Infrastructure (C2I) and Car-to-Car (C2C) respectively, and both technologies are Car-to-X communication technologies.

5.1.1 Driver Support Systems

Driver Support Systems help driver taking right decision while road journey to assure maximum road safety. [32] distinguish between two driver support systems: *Active Safety Applications (ASA)* and *Passive Safety Applications (PSA).* Passive Safety Applications react when the system detect an accident will definitely, or already, took place and works to reduce the number of fatalities but cannot prevent the accident. Active Safety Applications is however try to prevent accident from taking place. Active Safety Application systems such as Advanced Driver Assistant Systems (ADAS) exist today to support drivers. ADAS include Lane Departure Warning Systems, Lane Change Assistance, Adaptive Cruise Control, Forward Collision Warning, and Driver Fatigue Warning Systems.

In this thesis work Active Safety Application is used to develop a conceptual game framework. The conceptual framework has an underlying driver support system that controls the game content to reduce vehicle drivers' human errors (discussed in Chapter 3).

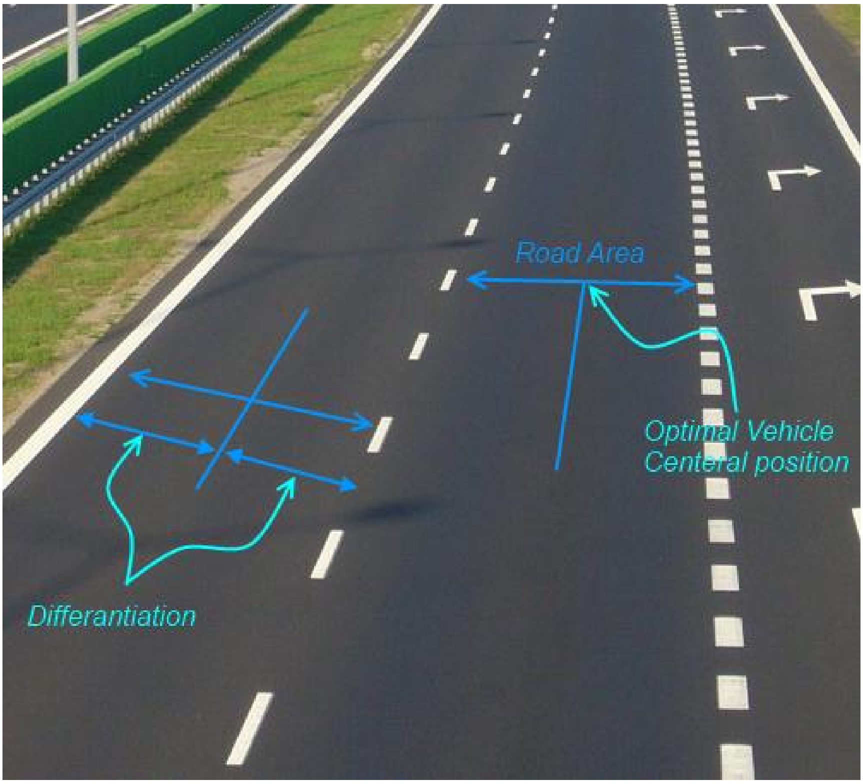


Figure 5.1: Detection of white lines

Quality of Driving

There are plenty of aspects which determine quality of driving which keep both driver and other vehicles safe in road. [1] defines three measures to evaluate the Quality of Driving (QOD):

1. **Degree of Meandering;** To calculate degree of meandering, recognition of the roadway white line of the lanes is required. This can be achieved by installing color-sensitive camera on the front center of the vehicle and a processing unit. The color sensitivity of the camera allows the processing unit to differentiate between solid/stripped white lines and asphalt.

   In order to detect a vehicle meandering we compare the degree of shifting of the ongoing vehicle position against the average position the vehicle maintained in a period of time before then [1]. Figure 5.2 illustrates how degree of meandering is calculated.

   The vehicle ongoing position between the lanes is calculated using the following equation:

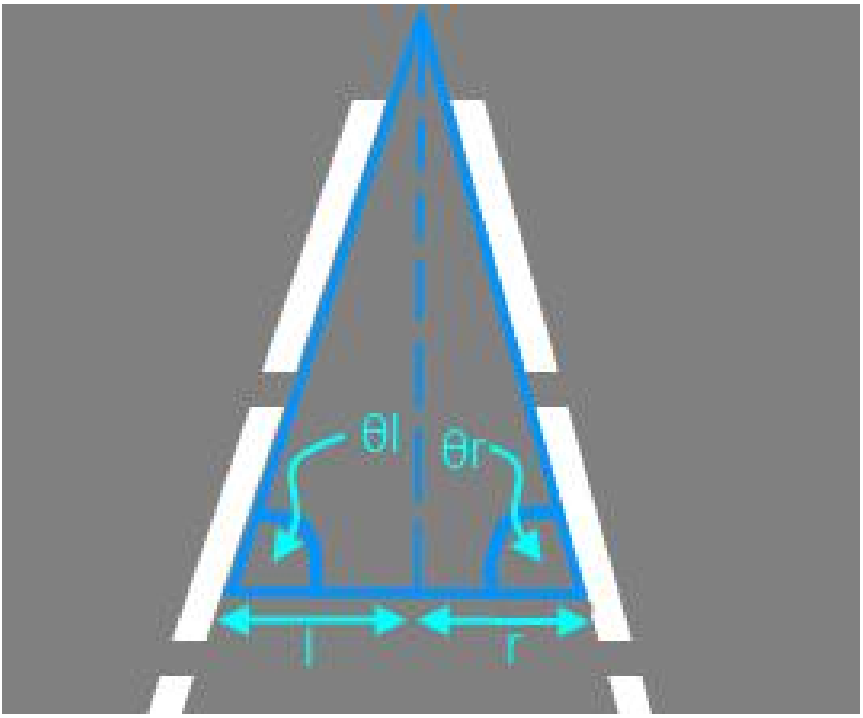


Figure 5.2: Calculating Degree of Meandering

$$l\colon r = \frac{1}{\tan\theta l}\colon\frac{1}{\tan\theta r} \quad (5.1)$$

The value is calculated in a given time interval, 20 seconds for example. Every time the value is calculated a comparison is made to the average of previously computed values. Therefor the higher the value indicates that the vehicle in meandering.

2. **Rightness of Velocity;** The velocity rightness is determined by various parameters. In this thesis we used the Norwegian traffic guidelines. The guidelines recommend driving three seconds apart from the vehicle ahead. In other words, it should take your vehicle more than three seconds to reach where the vehicle ahead is. In order to compute such value the color-sensitive camera (installed in the vehicle front) is used to determine the distance between the vehicle front and vehicle ahead, the vehicle velocity then determines the amount of time to reach the vehicle ahead.

3. **Maintaining proper distance with other vehicles;** Maintaining a reasonable distance between your own vehicle and other vehicles in the roadway helps avoiding accidents such as forward collision.

   To detect the distance between the vehicle front and the vehicle ahead we use the same color-sensitive camera. The light reflection makes vehicles ahead horizontal and vertical edges distinguishable from the environment and thus easy to recognize. The distance is calculated by measuring the distance between the cameras optical axis and the lower part of the vehicle ahead.

   The following mathematical equation is used

$$\frac{F * H}{X} \quad (5.2)$$

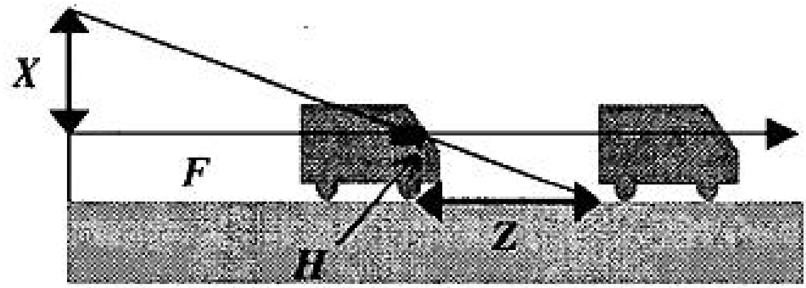
   where F is the focal of the camera, H is the height of the camera installation location, and X is the length between the camera optical axis and lower part of the vehicle ahead.

Weather and Road Surface Detection

Weather conditions have influence on road safety. A study by the Dutch national state [6] showed that accidents increased between 25% and 182% while rainy weather. The same study also showed that ice forming on roadbed increased accidents between 77% and 245%.

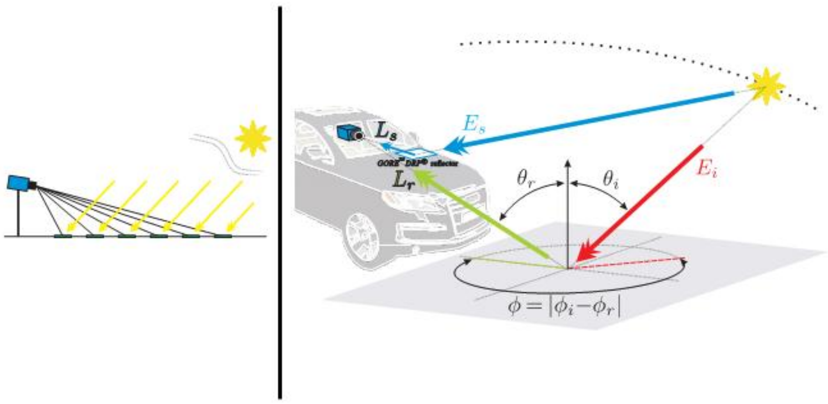
Though weather conditions effects drivers' visibility, it also decreases the driver control of the vehicle. Heavy rain and ice decreases the friction between the vehicle wheels and the road surface leading to too smooth road surface.

[31] describes a system for the road surface detection. The system process images from a camera to detect whether the road surface is covered by reflected substance such as ice or water. Using Bidirectional reflectance distribution function (BRDF). BRDF defines how light is reflected on opaque surface.[31] states that,



[1]

Figure 5.3: Distance between forward vehicles



[31]

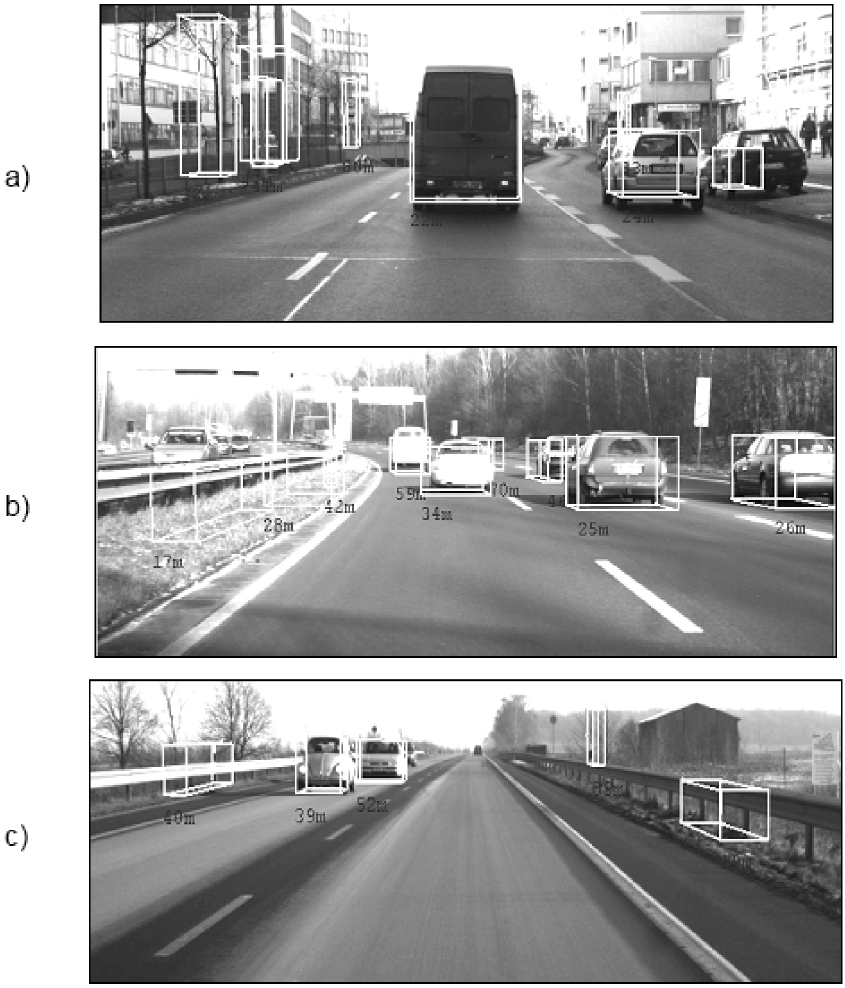
Figure 5.4: BRDF setup in vehicles

in principle, single images taken from a camera provide sufficient information for BRDF to detect reflective road surfaces. Figure 5.4 , left section, shows how a single camera cam be used to measure reliable BRDF. The right section illustrates the mathematical equation used to compute the degree of reflection on the road surface and therefor obtaining the road surface conditions.

Obstacles Detection

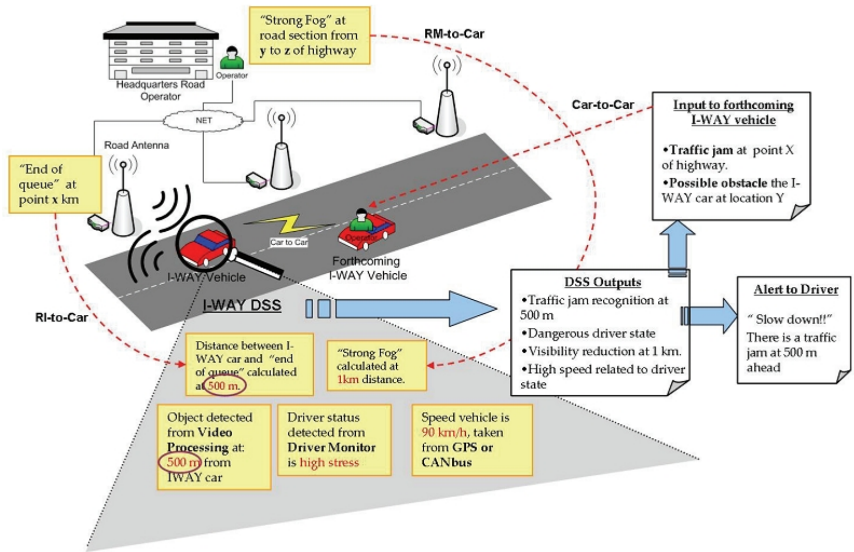
Road obstacles can be a threat to the driver safety especially if the drivers are not instantly aware of them. For example, motor vehicles, pedestrians, or static such as irregular objects in the road surface. [44] developed a system that uses stereovision based detection of obstacles (stereovision detection uses two or more cameras for detection).

5.5 illustrates the various views of obstacles detection. The system detects obstacles ahead and the obstacles on country road as shown in c) section. The



[44]

Figure 5.5: Stereovision approach for Obstacle detection



[22]

Figure 5.6: I-WAY DSS showcase

system also estimate the distance between your vehicle and other obstacles as shown in the figure.

Decision Support Systems

Most of driver support systems include risk evaluation to prevent traffic accidents from taking place, or at least decrease the chances of "probable cause" of happening. According to [18] "probable cause" in a condition or event such that if the condition of event been prevented, the accident would not occur. [22] developed a probabilistic framework for their driver support system, called I-WAY, based on Dynamic Influence diagrams (DID). [22] describes DID as "temporal extensions of Influence Diagrams which are in turn extensions of Bayesian Networks". In I-WAY implementation they considered three criteria to calculate the overall risk of an accident to take place. The three criteria are:

1. Information collected about the road conditions.

2. Vehicle Data.

3. Driver State.

Figure 5.6 shows how I-WAY DSS works. The system detects a few threats in the road that risks driver safety. The system then generate a report (illustrated as DSS outputs) with current threats and alert the driver to take a certain action to avoid these threats.

5.1.2 Car-to-X Communication

Car To Car Communication Consortium [2] defines Car-to-X communication as "interactions among cars, between cars and infrastructure and vice versa." The consortium have studied the most valuable use cases and defined a set of scenarios were which Car-to-X communication can be best used, and three general categories are proposed: Security, Traffic Efficiency and Infotainment.

Security

Car-to-X communication can offer a lot for the security of the driver. Example of security usage scenarios are:

1. Cooperative Forward Collision Warning;
   One of the typical traffic accidents is the rear-end collision. This type of collisions takes place due to driver distraction or sudden braking of vehicles in front. Cooperative Forward Collision Warning Systems are technologies that can be integrated into vehicles to prevent rear-end collision traffic accidents. The equipped vehicles share information together, using Car-to-Car communication, such as heading, speed and position [2] (The system also uses object recognition if the nearby vehicles do not have similar technology). The system in each vehicle analysis the vehicle position and actions taken by its own driver to predict a possible collision. If the probability of a collision becomes critical, the system warns the driver visually or auditory so that the driver will have time to take action to avoid the crash.

2. Pre-Crash Sensing/Warning;
   Few of collisions cannot be avoided and a crash is likely to take place. In such scenario involved vehicles start exchanging information such as speed, position and acceleration. This information will help each vehicle calibrating its own safety system such as airbags, pre-tensioners level of seatbelts and extendable bumpers.

3. Hazardous Location V2V Notification;
   In this scenario a network of vehicles share information related to roadway. Vehicles notify each other with hazardous locations such as dangerous conditions in the roadway: slippery, potholes or other abnormal road conditions. The equipped vehicles will either notify the driver, visually or auditory, or perform automatic optimization of safety and chassis systems.

Traffic Efficiency

Improving the efficiency of the transportation network is another aspect Car-to-X communication can improve. The following scenarios are proposed by Car To Car consortium [2]:

1. Enhanced Route Guidance and Navigation;
   Car-to-Infrastructure technologies are used in to improve route guidance and

navigation. The infrastructure unit is continuously collection relative information to predicate traffic congestion points on roadway in a large region. The unit informs equipped vehicles current and forecasted traffic conditions which by it inform the driver with expected delays or recommend better routes.

2. Green Light Optimal Speed Advisory;
   This system helps the driver to have smoother and non-stop driving experience. In road intersections, Traffic signals have a time interval between turnings from red to green. This time interval is sent to equipped vehicles to optimize the vehicle acceleration between the vehicle current location and the next intersection and thus achieving optimal speed. Beside better driving experience, this system also traffic flow and reduce fuel usage.

3. V2V Merging Assistance;
   Car To Car Communication Consortium [2] defines V2V Merging Assistance as "allows merging vehicles to join flowing traffic without disrupting the flow of the traffic." In this scenario, each vehicle request maneuvering recommendations from other equipped nearby vehicles. The main purpose of this scenario is to allow safer and non-disruptive merge of traffic.

Infotainment

The infotainment category contains three scenarios: Internet Access in Vehicle, Point of Interest Notification and Remote Diagnostics [2]. The first two scenarios focus mainly on driver entertainment. Remote Diagnostics, on the other hand, focuses on the physical state of the vehicle and how it can be remotely diagnosed and keeps the driver aware of it.

5.2 Heads-up Display

Heads-up Display, or HUD, is a visual displaying technology that represents data on the same viewpoint the user currently using. HUDs are transparent to assure fewer disturbances and display consistency. HUDs were originally developed for military aviation generally and jet flights in particular. Jet flights have a limited viewpoint and thus a transparent embedded display is integrated into the windshield. HUDs have been also used in automobile industry since the late 80s . Figure 5.7 shows a HUD in a BMW vehicle already in production [8]. Drivers can get information about navigation direction, speed and variety of other information.

Other independent manufacturers offer installable HUD. An interesting prototype of Laser-based HUD display introduced in CES 2011 show by Pioneer [47], the HUD can be connected to smart phone and allow driver to display interactive content such as GPS or games. Figure 5.8 illustrates Pioneer Laser-based HUD displaying GPS data, information and other graphic illustrations.

[8]

Figure 5.7: HUD in modern vehicles

[47]

Figure 5.8: Laser-based HUD

Chapter 6

Pervasive Games

6.1 Pervasive Games

Computer games have introduced new dimensions to games since they started to appear in 1950s. The imaginative virtual world created by the help of computer graphics and sound effects [15] made computer games a popular interest for children and adults.

In the past decade [12] game researchers have been researching the possibility of mixing the game experience with real-life physical objects in the player environment to increase human-computer interactivity.[12] defines different terminologies related to these type of games; *Pervasive Games*, *Location-based Games*, *Tangible Games*, *Augmented Reality Games*, and *Mixed Reality Games.* Among these, three terminologies are relevant to this thesis work:*Mixed Reality Games*, *Augmented Reality Games*, and *Location-based Games.*

Mixed Reality Games are games that mix between virtual entities in the game-play and real-life physical entities. In other words Mixed Reality games exist between really and virtual reality. [12] states that the term "mixed really" is a general term and not explicitly associated with any specific technology. However, other subfields of Mixed Reality depend on specific technology to match reality with virtual world, Augmented Reality Games are among them.

Augmented Reality Games lay objects and characters in game-play directly in the player's real world environment. To achieve such game experience the player use certain display technologies such as head-mounted displays, a mobile display device, or a regular display screen.

Augmented reality games have been used by industries in the past few years. Figure 6.1 shows EyePet Move Edition, developed by Sony. EyePet display players on a display screen and allow them to interact with imaginary character using motion controller.

Others have used augmented reality games for another purposes beside entertainment. For example, Microsoft developed a virtual fitting room to allow customers to tryout different dresses virtually. Figure 6.2 shows Microsoft Kinect

[42]

Figure 6.1: EyePet Move Edition

augmented really fitting room powered.

Figure 6.3 shows another types of augmented reality games. The player on the left is wearing the head-mounted display and the laptop on his back is displaying a virtual character, which he is currently seeing.

Location-based Games involve player geographical location in the game play. The player position is determined by a positioning system such as GPS. The game-play depends on the player's current location and thus the physical movement of the player is real world determines what will happen next in the game.

6.2 In-vehicle Gaming

In this Section various approaches of pervasive games for in-vehicle gaming is discussed. The focus of this section is illustrating other projects involving games in vehicle environment and how are they related to this thesis.

6.3 Backseat Playgrounds

Location-based pervasive games have been actively research in the past few years. One of the notable research projects is backseat playgrounds [26] at Microsoft research labs in Cambridge and Swedish Interactive Institute. As the name infers, backseat playground researched the development of a pervasive games for children on the drivers' backseats to involve them in the journey experience. The main input that scales the game dynamics is geographical information, using Geographical Information systems (GIS). The game interacts with players using a communication device, such as walkie talkie, where which a conversation between the player and the system take place using text-to-speech, and a pocket pc.

[39]

Figure 6.2: Kinect-Powered virtual fitting room

[21]

Figure 6.3: Augmented Reality Game-play

[26]

Figure 6.4: Children players interacting with Backseat Playgrounds

The logic that generates the game narrative is the Game Event Manager module and a set of predefined game story scripts. The Game Event Manager receives a list of surrounding objects in the roadside from the GIS module and then asks the story scripts to rate their priorities according to the pervasive of the current surrounding world. The Game Event Manager picks the story script with the highest rating and plots it.

The GIS module provides three key steps: path prediction, extraction of visually available information and production of journey. The path prediction step predicts where the car is heading to in the near future thus informing the Game Event Manager to pre-match the narrative to the surrounding geography. The extraction of the visually available information step provides information about the surrounding objects (such as roads, buildings, houses, forests etc.) to the system so that these objects can participate in the game narrative. The third step, production of journey, maps the objects to the journey experience by combing the predicted paths and the extracted geographical objects. This combination defines journey event list which generate important visual events in the narrative.

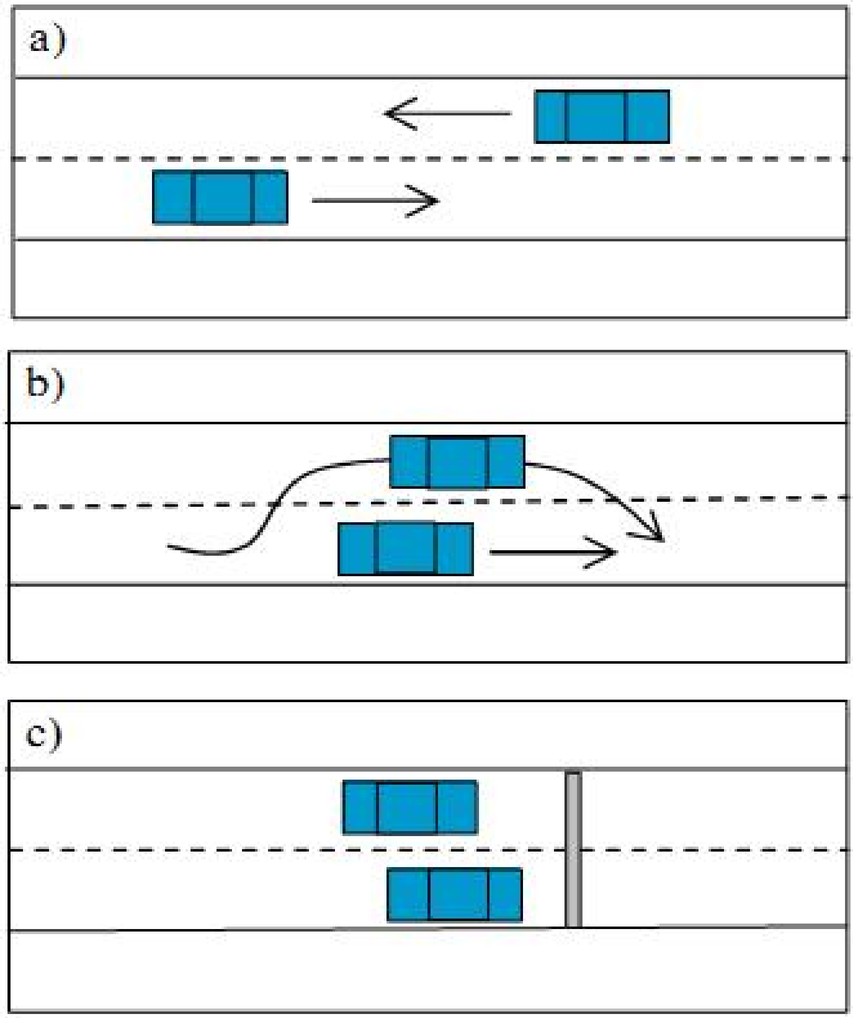
6.4 The Road Rager

The Road Rager in another research project by the Swedish Interactive Institute [29]. The game is described as a multi-player game which allows passengers in different vehicles to play against each other during meeting in traffic. Road Rager takes advantage of the rapid change of scenes and the sense of motion along the road during the journey, generating a dynamic and interesting gaming experience.

The game concept is to automatically trigger the game start when the players approximating each other in road whilst in different vehicles. The game controller is PDA device connecter to a GPS service which allows the player to aim to the opponent and collect an asset (such as a star in Road Rager) and increase the score accordingly. The game has three encounters, when a) opponents' vehicles meet in opposite lanes, b) one vehicle overtake the other, or c) meet in a traffic light accumulation.

Though the game tests did not meet all the researchers' expectations but the project showed an interesting use of technologies such as WLAN and GPS in a very dynamic game encounters.

Though the current state-of-the-art games covers similar topics to this thesis such as pervasive gaming, (specifically location-based pervasive games), in-vehicle games, and biofeedback games, it has been noted the lack of research on in-vehicle games targeting the driver and not the passengers. It is also obvious that the represented equipment, like EEG, is not suitable for the driver and will have negative effect such as disturbing the driver and the safety of such electronic device in case of accident.



[29]

Figure 6.5: Road Ragers game encounters

Part III

Own Contribution

In this thesis work I present a conceptual game framework. This framework is used to illustrate how supporting technologies can be used to deliver pervasive games for vehicle drivers. Chapter 8 shows example game scenarios. Each game scenario shows how supporting technologies (Discussed in Chapter 5) are utilized.

Chapter 7

Conceptual Framework

This chapter describes a conceptual framework which assist pervasive game developers to build pervasive games for vehicle drivers and recognize supporting technologies to be used to deliver such games. Chapter 8 illustrates different game scenarios and shows how the framework is used to devise supporting technologies and their usages.

The conceptual framework consists of three main components (Figure 7.1):

- Observers
- Assessment of Situation
- Actions

The *Observers* component use sensors technologies such as light-sensitive cameras or infrastructure information systems such as Intelligent Transportation Systems. Observers component consist of various types of observers to observe in-road situations where which the driver has to take action. Examples of such situation can be the vehicle is too close from the vehicle ahead, sudden obstacle, the driver have to turn or slowdown, or other situations.

The *Assessment of Situation* component assesses the situation reported by one of the observers. The Assessment generates a report of how serious in the situation and ways of avoiding or overcoming it and sends it to the *Actions* component.

The *Actions* component receives the report and advice the driver in different ways.The main difference between regular driver support systems and the Actions component is that advise in not represented directly to the driver but it is represented indirectly in changing the gameplay.

7.1 Observers

Observers are used to detect events in the journey that risk driver safety. Risks are categorized in domains so that each risk belongs to a domain of risk. The domains of risk fall into two categories: Driver-related and Road-related. The driver-related

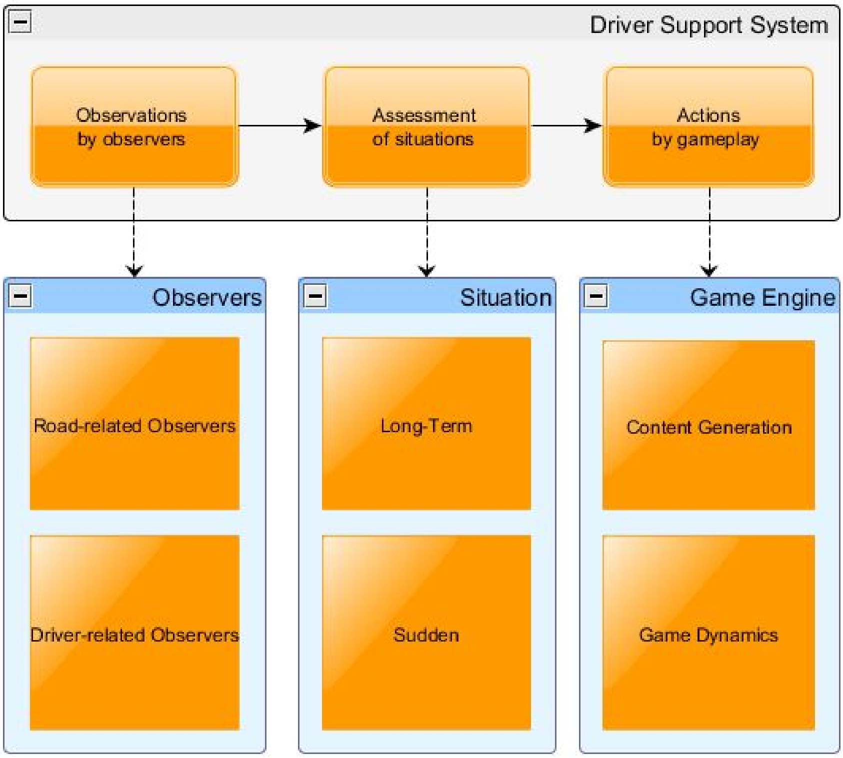


Figure 7.1: Driver Support System components

Domain of Risk	**Example of risk events**
Driver psychophysiological State	Stressed, Distracted, Drowsy, Fatigue
Quality of Driving	Degree of Meandering,Rightness of Velocity, Maintaining proper distance from vehicles ahead.
Road Obstacles	Approaching vehicle ahead,traffic jam, static obstacle
Road surface conditions	slippery, non-smooth asphalt
Weather conditions	Heavy rain, fog, Rainfall, wind, snowing

Table 7.1: Domains of Risks

domains of risks are affected by the driver psychophysiological state and quality of driving. Other domain of risks such as obstacles, road surface conditions, and weather are road-related. Table 7.1 shows five domains that threats the driver safety in the road journey.

Thus there are two types of observers required: *Road Observers* and *Driver Observers*.

7.1.1 Driver Observers

Driver observers detects risks related to the driver such as driver psychophysiological state, and the quality of driving.

The driver psychophysiological state , as discussed in Chapter 4, is very vital for the road safety. Section 4.4 discuses how the driver psychophysiological state can be recognized using facial expressions. The observed psychophysiological state triggers a risk if it is a negative affect such as stressed, Distracted, or drowsy. Table 7.1.1 shows driver observers supporting technologies that are suitable for pervasive games in vehicles, and which domain of risk they cover.

Supporting Technology	Usage	Domain of risk
Facial expressions recognition	detects driver psychophysiological state such as stressed, fatigue, or distracted	Driver psychophysiological State
Quality of Driving module	recognizing driver quality of driving such as degree of meandering, rightness of velocity and maintaining proper distance from vehicles ahead	Quality of Driving

Table 7.2: Driver observers supporting technologies

7.1.2 Road Observers

Road observers detects conditions in the road the can threat driver's safety. Here, supporting technologies such as road surface detection, obstacles detection, and other technologies discussed in Chapter 5 are used. Table 7.1.2 shows different technologies suitable for supporting road observers.

Supporting Technology	Usage	Domain of risk
Road surface detection	detects road surface unsafe conditions such as slippery or non-smooth surface	Road surface conditions
Obstacles	detects road obstacles such as approaching vehicles, traffic jams or static obstacles	Road Obstacles

Table 7.3: Road observers supporting technologies

7.2 Assessment of Situations

Assessment of Situations component is used to evaluate the risk of events observed by the observers. Risk evaluation main purpose is to prevent traffic accidents from taking place, or at least decreasing the chances of "probable cause" of happening. According to [18] "probable cause" in a condition or event such that if the condition of event been prevented, the accident would not occur.

Decision support systems (as discussed in Section 5.1.1) are used to evaluate the risk and propose actions to be taken. These actions are the send to the *Actions* component. Decision support systems are a wide area of research, however I-WAY DSS approach discussed in Chapter 5 is the most suitable for assessment of situation component.

7.3 Actions

After *Assessment of Situations* component evaluates the risk, the *Actions* component role is to generate and control the gameplay to prevent the risk or decrease the possibility of it happening (thus actions are to be considered as advises from the system to the driver). The key difference between the Actions component and present driving support system is that actions are neither represented directly to the driver nor the system take the action itself (for example, braking or turning the vehicle direction automatically).

The Actions component role is to indirectly present the actions to the driver in the gameplay by changing the game content and game dynamics to prevent the risk. For instance, the game content generation component generates obstacles in the gameplay inline with real obstacles existing in the road. The game dynamics component controls the gameplay so that actions taken in the games will assist the driver to avoid a risk. Chapter 8 describes different scenarios and illustrates how actions are presented to the driver during the gameplay to prevent risks observed in the road.

Chapter 8

Game Scenarios

This chapter explains different game scenario. Each scenario describes how supporting technologies are used to change the game content to support the safety of the driver.

8.1 Scenario 1

Imagine that a vehicle driver has no longer to feel bored by long travels and play a pervasive game until reaching her/his destination. Figure 8.1 illustrates how a pervasive game for vehicle drivers can look like. Here a shoot'em up game mockup is presented. [46] describe shoot'em up game as "Action game with extreme focus in shooting down enemies".

The figure shows a vehicle interior view with the required equipment for pervasive games in vehicles installed, a GPS system, a transparent HUD where which the game is being displayed, a camera for facial expression recognition, and game controller at the fingertips of the driver on the steering wheel. The GPS system will provide information of the driver's directions and final destination so that the gameplay will adjust to it. The transparent HUD is used to display the game content without keeping the driver sight away from the road. The HUD is positioned in the middle of the windshield as a way assuring broader view. The camera is used for recognizing the driver facial expression as a method of psychophysiological data acquisition. The psychophysiological state of the driver will determine the game content and narrative.

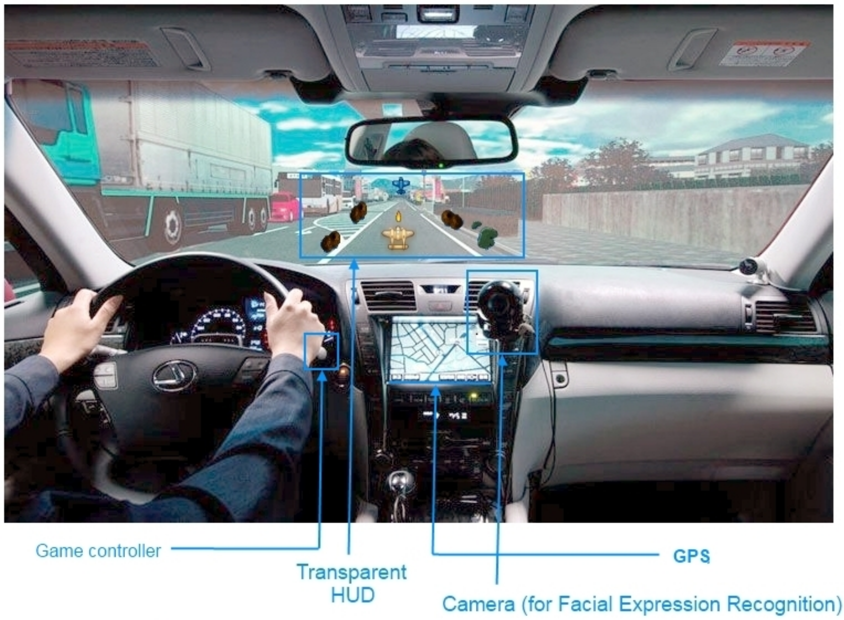


Figure 8.1: Driver view with game scenario 1

Figure 8.2: Zoomed-in Driver view in game scenario 1

Let's have an in-depth look into the game displayed.Figure 8.2 shows a zoomed-in view of the windshield, specifically where the game is displayed. The underlying game driver support system assesses all the measures such as the traffic conditions, driver destination, and driver psychophysiological state. The system finds out that a shoot'em up game will be the best for the current scenario.

Let's again have a look into Figure 8.2, specifically the road. To the left side of the vehicle there is the contrary road, and sidewalk to the right side of the vehicle. Accordingly, the game engine renders obstacles within the game content, such as rocks and islands, to force the player moving his jet flight in the right direction to avoid crashing into the obstacles and thus lining with the road the

Component	Technologies/Methods	Usages
Game engine	HUD GPS	Displaying game content Used to define the road journey to the game engine
Road observers	Obstacles detection	used to inline obstacles in gameplay with real obstacle in the road
Driver Observers	Facial Expression recognition	detecting driver psychophysiological state and changing game dynamics accordingly

Table 8.1: Observations in Scenario 1 using the Framework

vehicle is traveling, a practical use of obstacles detection systems. (discussed in Section 5.1.1).

Driver support system can also infer the optimal speed for the vehicle in the current scenario. Though the road is empty and open for the vehicle to speed up, there is still a speed limit for this road and the vehicle still need to maintain a certain speed that won't risk the driver safety. The game engine then renders and another jet flight in the game narrative so that if the driver speeded up his/her own jet flight will be in risk of crash into the jet ahead.

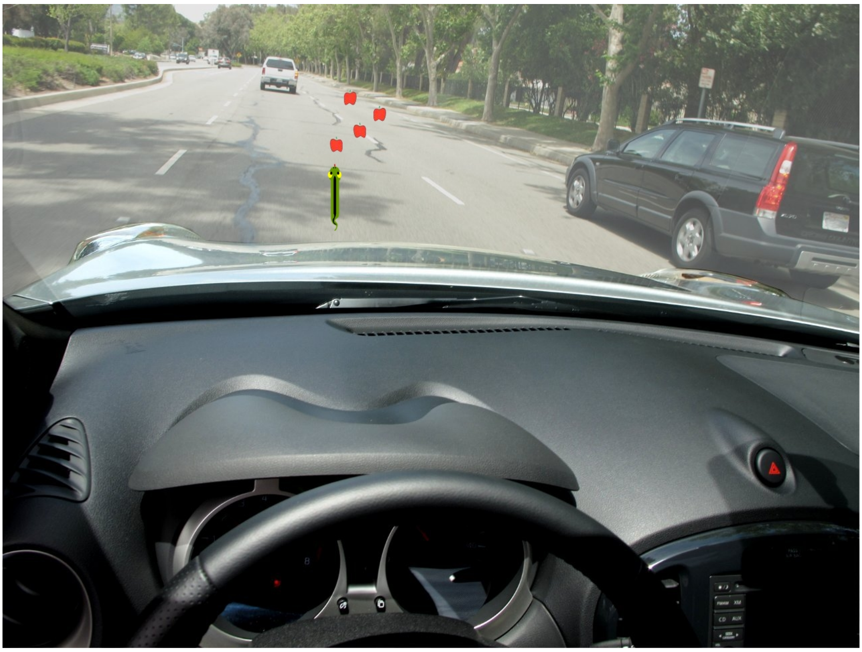
The facial expression recognition system detects that the driver is a little drowsy. The underlying driver support system decides to switch the driver psychophysiological state from negative affect, drowsiness, to alertness which is considered a positive affect in this situation. The game engine then changes the other jet flight color so that it will appear as an enemy and the driver will shoot it using an attached controller just behind the driver fingertips on the steering wheel.

Table 8.1 show the usage of the framework to observe required technologies from this scenario.

8.2 Scenario 2

In example scenario 2 (shown in Figure 8.4) another game type is presented. The infamous snake game [25], where the player have to eat fruits to keep his snake alive.

In this scenario the system detected two vehicles in the road, one to the right and the another is ahead. The obstacles observer component detect two other vehicle ahead and the driver need to meander between these two vehicles. The game engine puts apple in a certain order so that the driver can safely meander.



Background image source: about.com

Figure 8.3: Driver view with game scenario 2

Table 8.2 show the required technologies for this scenario deduced using the Framework. The game, as mostly all cases, will be displayed using HUD in front of the driver. The road obstacles detection is used to detect other vehicle in the road, and thus plotting apples ,as shown in the figure, on the right path the driver should be driving. The Quality of Driving (discussed in Section 5.1.1) is used here to enforce the driver to maintain the right velocity and the proper distance between own vehicle and the vehicle ahead.Accordingly, the apples will be plotted on the screen in the right positions where which manoeuvering between vehicles will be safe.

Component	**Technologies/Methods**	**Usages**
Game engine	HUD	Displaying game content
Driver observers	Quality of driving	Used by the game engine to enforce the driver to maintain the right velocity and distance between vehicle ahead
Road observers	Obstacles detection	Used to plot objects in gameplay

Table 8.2: Observations in Scenario 2 using the Framework

Component	**Technologies/Methods**	**Usages**
Game engine	HUD	Displaying game content
Driver observers	Quality of driving	Used by the game engine to enforce the driver to maintain proper distance from vehicle ahead
Road observers	Road surface detection	Used to control the speed of gameplay in order to keep the vehicle in a safe speed and position

Table 8.3: Observations in Scenario 3 using the Framework

8.3 Scenario 3

Example game scenario 3 presents another scenario where which the driver is engaged in fly-safe game. The player has to keep his shuttle from crashing into alien ufos by slowing down until they pass. In this scenario, weather conditions is the dominating risk. As a result of snow the roadbed is slippy and driving need to slowdown and keep a reasonable distance from vehicles ahead. The game engine plots alien ufos in the gameplay so that the driver will slowdown to save the shuttle.

Figure 8.4: Driver view with game scenario 3

Road surface detection ,discussed is Section 5.1.1, is one of the supporting technologies that can be used in this scenario. Table 8.3 shows the required support technologies for this scenario.

Chapter 9

Simulation

Running field tests in a specialized track and require expensive resources. Also due to safety regulations, testing such pervasive games in real vehicle is difficult until it is approved to be stable and reliable. This Chapter demonstrates how simulation is used to simulate the driving environment. Simulation provides safe, easily accessible and easily controllable environment for validating and testing the conceptual framework.In this Chapter, a single observer, Quality of Driving observer, is demonstrated as a proof of concept.

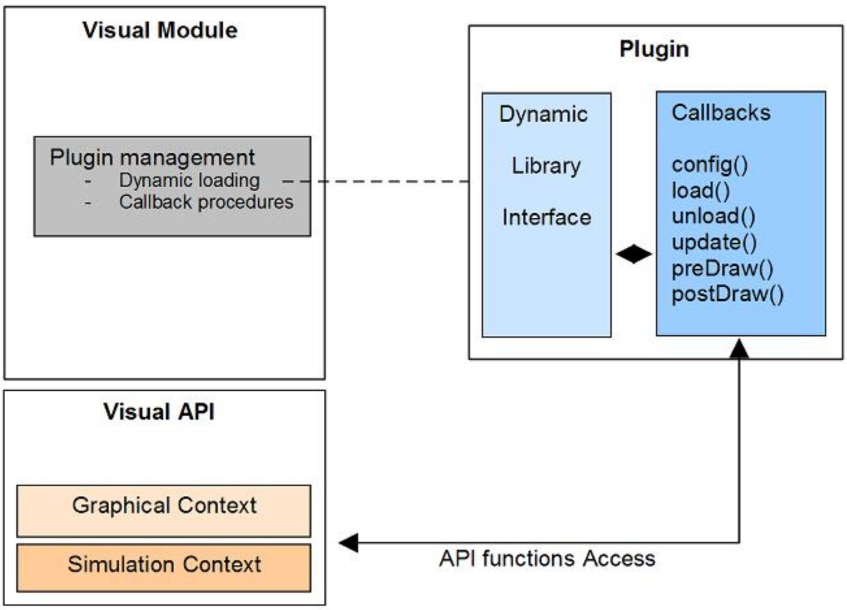
Computer Simulation is software program, runs across single or multiple computers, to attempt simulation of an abstract model of a particular system or environment . Using high computational power of today's computers, simulation of complicated systems became possible.

Driving simulation engines are specialized type of computer simulation software. Driver simulation engine simulates most of the surrounding environment such as traffic, road physics and mechanics of vehicles. Driving simulation engines are also used for training of drivers in educational institutes and car industry In order to evaluate the framework a driving simulation has been used. SCANeR [9] software is an advanced driving simulation engine used mainly for research and training purposes. SCANeR also provides researchers high flexibility to control the road environment such as simulation of trip details, road conditions, weather conditions and extensible programming framework.

The simulation took place in Statens Vegvesen, ITS sector, in Trondheim. The simulator uses SCANeR simulation software for developing and testing research projects. Figure 9.1 shows the simulator setup: two workstation computers for developer and running the simulator, high resolution screen for display, and specialized steering wheel and driver seat.

SCANeR simulation engine provide developers with a set of programmable interfaces (Application Programming Interface, or API) to allow researchers to extend the simulated environment such as road environment and traffic. The API also allows querying information about driving behavior. The system is shipped with a plug-in architecture [40] which allows software developers to extend the system. Figure 9.2 illustrates SCANeR studio visual plugin architecture.

Figure 9.1: Simulator at Statens Vegvesen, Trondheim



[9]

Figure 9.2: SCANeR Plug-in Architecture

The simulation engine provides a scripting language to create driving experiences, or scenarios. A scenario contains elements which altogether create a desired driving experience. These elements can be of the following:

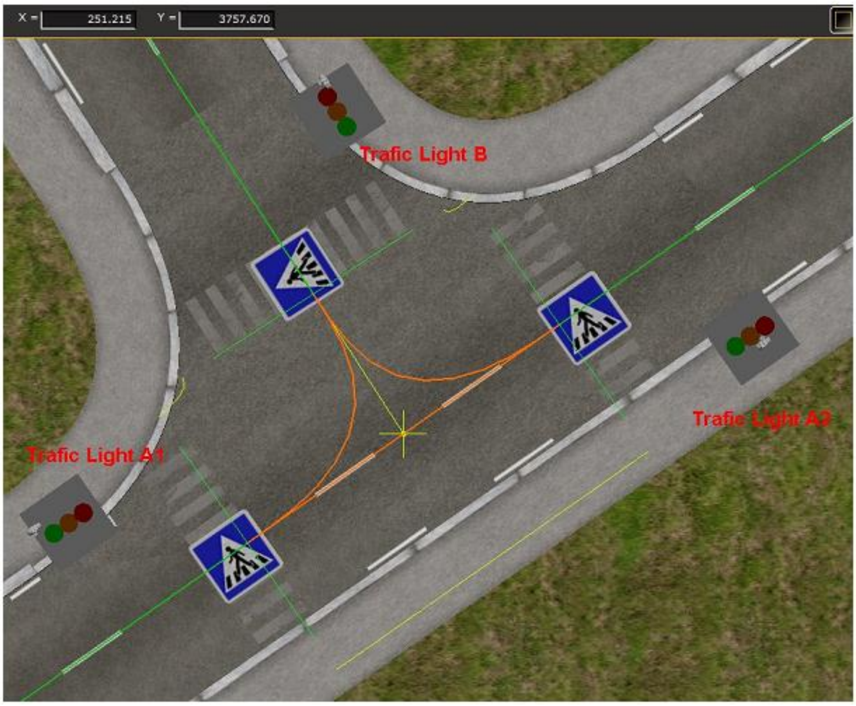


Figure 9.3: Sample traffic lights on intersections

1. **Terrains;**A terrain includes the physical static details of the road. A terrain will include traffic details such as: traffic lights, intersections, walk lanes, or road details such as: trees, houses, or parking vehicles. Figure 9.3 illustrates a sample model of a terrain.

2. **Resources;** Resources are moving objects in the road such as vehicles, pedestrians and other road objects. These objects can be dynamically generated during the scenario. Figure 9.4 illustrates a generated traffic in a scenario.

3. **Parameters;** Parameters are record settings or initial conditions such as the position of a vehicle at the beginning of the scenario, the simulated day and time, or the simulated atmosphere conditions. Figure 9.5 shows the environment setting panel where which weather conditions are set.

4. **Scripts;** Script is the code of the scenario that makes elements interacts together during the simulation. A script is composed of a set of Includes, Variables, Rules, Tasks, and Subtasks. Includes are pre-made scripts which can be reused. Contrary to scenarios, includes do not contain terrain, neither resources nor set of parameters, therefore it still needs a main scenario to be used. Variables are symbolic name associated with a value and whose associated values may be changed. Rules are combination of conditions and

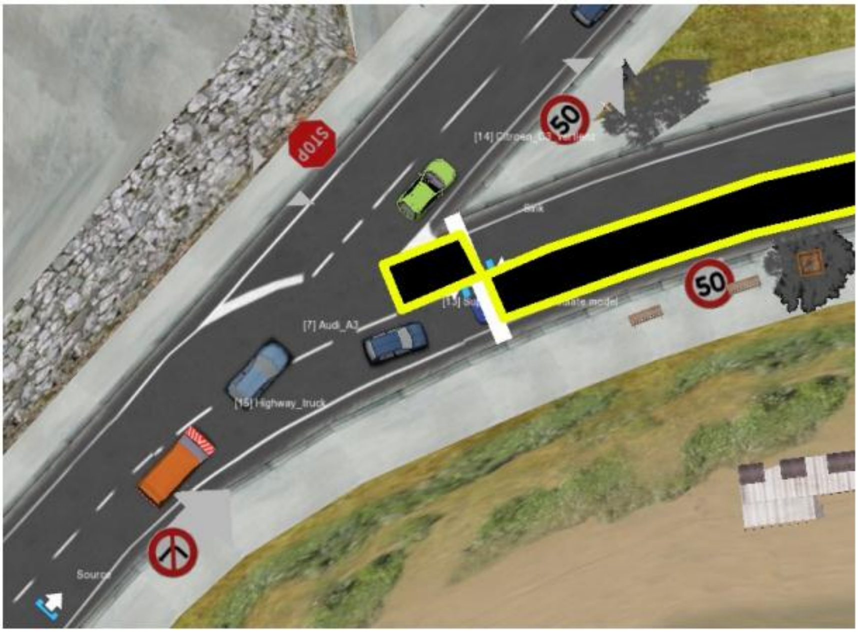


Figure 9.4: Resources in SCANeR Studio

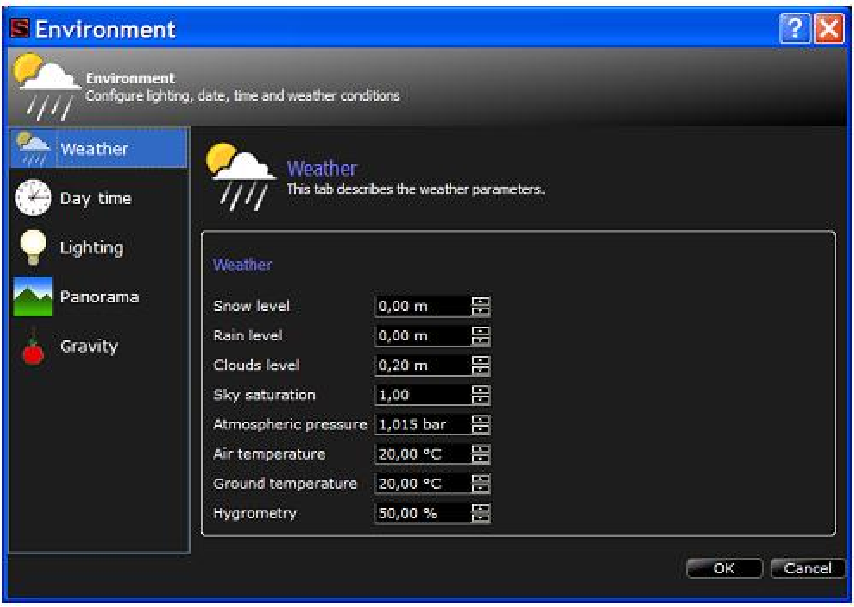


Figure 9.5: Resources in SCANeR Studio

Figure 9.6: Quality of Driving Module

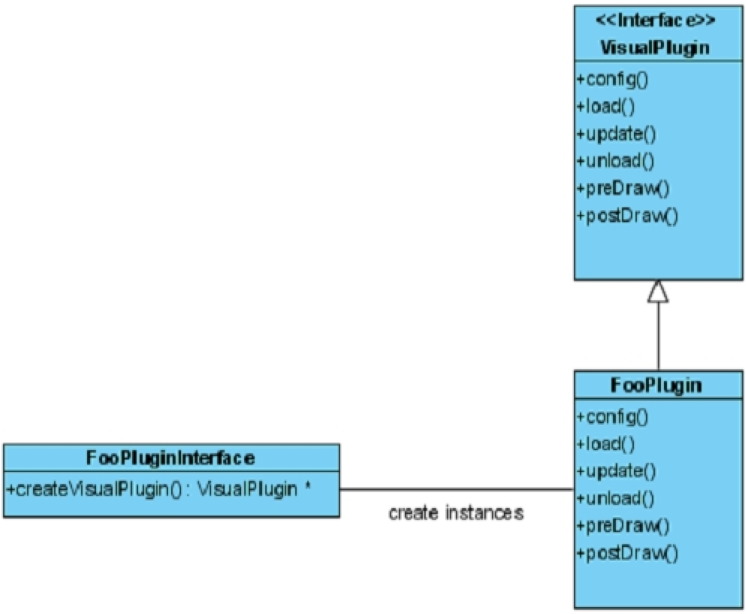
actions taken if these conditions were met. Tasks are method of grouping rules for readability and logical association of rules. Subtasks are used to create logical sub-sequences in the task by grouping rules.

9.1 Demonstration of the Simulation Engine

The simulation environment is used to demonstrate how events and observers (discussed in Chapter 7) can be simulated.However, The Quality of Driving (QoD) module is demonstrated as a proof of concept.

QoD module measure three inputs: Degree of Meandering, Rightness of Velocity, and maintaining proper distance from other vehicles. For measuring the later, a three-seconds rule is used. This means that it should take the vehicle three seconds or more to reach where the first vehicle ahead, otherwise it is considered unsafe. Figure 9.6 shows the Quality Of Driving module. The simulator displays the measured values for testing purposes. The vehicle average speed is display in the top line, followed by degree of meandering in the middle and the three-seconds rule. The three-seconds rule displays the distance the vehicle with travel in the next three seconds.

The top right line display the current distance between the vehicle and first vehicle ahead. The distance shown in more than the three-seconds rule distance and therefore no distance need to be avoided in the current time (distance to be avoid is shown in the bottom left line.).



[9]

Figure 9.7: SCANeR visual plug-in class diagram

9.2 Game Development guidelines

The simulation engine, SCANeR, allow developers to extend the core graphics engine using plug-ins. Plug-in architecture is a design pattern which allow Third-party developers to extend additional functionalities to meet their specific needs [40]. Figure 9.7 shows SCANeR visual plug-in which allow developers low-level access to the core graphics engine.

The *VisualPlugin* interface provide the developer with six methods to add graphics :

config This method allow developers make user defined configurations and initializations values. For example, game developers extending the visual plug-in can use this method to initialize the game graphics and save its components into the memory for faster response.

load This method load directly after the configuration phase performed by **config** method.At this point the game instructions can be displayed. (game instructions to be displayed in a distracting manner so that it will not risk the driver safety)

update This method is used to update graphics each time a frame is rendered by the simulation engine. This method is used to mainly for the game content presentation.

unload This method is used to unload all graphics presented by the plugin. For example, this method can be used to unload the game and display other important information to the driver.

preDraw This methods is called before each frame is presented using the update method. This method is where the game content is changed according to actions taken by the driver,or other conditions in the environment such as approaching obstacle or adapting the gameplay to road conditions

postDraw This method is called after each frame is presented using the update method. This method works as a receiver which receive player action in gameplay.

Listing 9.1 illustrates a sample C++ code that implements *VisualPlugin*. The code is for illustration purposes to guide game developers in implementing games plugins for SCANeR. Each method contains comments on how it is to be used.

Listing 9.1: implementing the visual plugin

```
\label {lst:samplevisualplugin}
#include "VisualPlugin.h"
class GraphicalContext;
class SimulationContext;
class AnimatedBillboard;
class GamePlugin  : public VisualPlugin
{
  public:
  GamePlugin ();
  virtual ~ GamePlugin () {}
  virtual void config();
  virtual void load(GraphicalContext * p_visualContext, SimulationContext↩
      * p_simulationContext);
  virtual void unload();
  virtual void update();
  virtual void preDraw(VisualPlugin_Chanel* chan);
  virtual void postDraw(VisualPlugin_Chanel* chan);
};
/********** GamePlugin.cpp *********/
#include "GamePlugin.h"
GamePlugin:: GamePlugin ()
{
    m_name = "GamePlugin";
    m_description = "game sample";
}
void GamePlugin::config()
{
    // Configure that game according to the available installed ↩
        supporting technologies
}
void GamePlugin::load(GraphicalContext * p_visualContext, ↩
    SimulationContext * p_simulationContext)
{
    // Use simulationContext pointer to check the most suitable way to ↩
        display instructions without
    // distracting the driver.
}
void GamePlugin::unload()
{
    // The game is being unloaded. here you can save statistics data ↩
        about the gameplay for further // improvements.
```

```
}
void GamePlugin::update()
{
    // Draw the game sprites and display the game.
}
void GamePlugin::preDraw(VisualPlugin_Chanel* chan)
{
    // Receive driver action against the gameplay and prepare the action ↩
        to be taken.
    // Check with Assessment of Situations component implementation
    // to take actions according to the observations from driver and road↩
        observers
    // and prepare gameplay changes.
}
void GamePlugin::postDraw(VisualPlugin_Chanel* chan)
{
    // Display gameplay changes prepared by the preDraw method.
}
```

This sample code is a starting point for game development on SCANeR simulation engine.

Part IV

Evaluation

Chapter 10

Method Evaluation

In this thesis work, i have used different research methods for answering my research questions.This chapter evaluates these methods, and the outcome of choosing them. The research methods and question are discussed in Chapter 2.

1. **Qualitative and Quantitative Research**
   Both qualitative and quantitative research have been a help for this project. Quantitative search contribution was the dominant in this thesis work, contradicting me expectations on the beginning of the project.

2. **Theory-oriented Game Research**
   The main goal behind Theory-oriented game research is to find linkage of gameplay with other fields of research. Theory-oriented game research focus is the effect of games in players psychophysiological state. The players here are vehicle drivers and their psychophysiological state is altered by gameplay to assure better road safety. However, theory-based game research projects will work best if they involves more than a researcher with different backgrounds such as ludology and psychology.

3. **Literature Search**
   In this thesis I researched state-of-the-art games and what they offer.Literature search used in finding the linkage between psychophysiology, road safety, and gameplay on the other side. Literature search have made it possible to answer Q1 (*What types of pervasive games are available for vehicles?*). In addition it contributed in answering other questions, specifically Q2 and Q3.

4. **Simulation**
   The simulation was useful in simulating one of the observers as a proof of concept. This method helped in answering question Q4 (*How can pervasive games for vehicles utilized for better road safety?*) and proved that regardless the game itself, pervasive games for vehicle drivers can contribute to road safety as long as driver support systems are used by the game engine to assist the driver in taking safer decisions in the road and prevent risks.

Chapter 11

Problems Encountered

During this thesis work, i ran into several problems related to different aspects in this project. This chapter presents the most significant problems.

11.1 Literature

Throughout this project i came across relatively many research materials either in a form of papers, reports, or purely industrial projects. Pervasive games related search is quite mature compared to the age of pervasive games itself. However, pervasive games for vehicles research is still lagging compared to other pervasive games. The cost and the complexity of implementing pervasive games in vehicle may be one of the reasons, but also the feasibility of such games to industry is properly the main reason most of the research effort moves toward theory and not practice.

Psychophysiology in game design was the most interesting part in this thesis work. The regulation of human Psychophysiological state using games are actively researched for variety of purposes. However, most of the literature is more focused in kids and negative affects of gaming such as violence(Although it's worth mentioning the research effort in assisting people with disabilities using games). Throughout this thesis work, lack of research in affect of games in specific psychophysiological states was an obstacle, specifically psychophysiological states vital to the road safety such as drowsiness and distraction.

11.2 Technology

The available simulation software have plenty of features. However the lack of open-source implementations of vehicle simulation software is notable. Most of the simulation software is commercial and does not offer free licensing to researchers and students.It is also noted that most of simulation software is tailored for driver training schools explicitly.

SCANeR, the simulation software used in this work, was also not available all the time due to licensing and copyright issues. The used simulation engine, SCANeR, graphical context is not designed for graphics intensive modules such as games.

There is also lack of open source affective gaming software libraries. Though the commercial offers are satisfactory if the researcher is willing to invest in. I recommend emotiv (`http://www.emotiv.com/`) software offerings.

Part V

Summary

Chapter 12

Answering Research Questions

This chapter present answers to research questions in Chapter 2

12.1 Q1:What types of pervasive games are available for vehicles?

This question was answered in Chapter 6. Most of the pervasive games in vehicles focus on the passengers, and not the driver. Location-based pervasive games (Discussed in Chapter 6) is the dominant game gender for such games. The idea of pervasive games specifically for vehicle driver is considered to be unique.

12.2 Q2:How can pervasive games be developed for vehicle drivers?

The answer of this question is represented in Chapter 7. The main goal for these type of games is road safety, in addition to entertainment. Game scenarios and the conceptual game framework ,discussed in Chapter 8 & 7 respectively, can be a valuable starting point for game developers.

12.3 Q3:What is the linkage between gameplay and road safety?

To answer this question first the linkage between driver psychophysiological state and traffic accidents is observed by the available statistics.Secondly, Affective gaming (discussed in Chapter 6) shows how player psychophysiological state are used to manipulate the gameplay. Thirdly, Facial expression recognition (discussed in Chapter 4) is found to be suitable way of recognizing driver psychophysiological state. and Finally the example games scenarios show how affective games in vehicles is used.

12.4 Q4:How can pervasive games for vehicles utilized for better road safety?

Chapter 5 discussed driver supporting technologies such as obstacles detection, road surface detection, Heads-up display, and Quality of Driving. Chapter 7 and Chapter 8 described the conceptual framework and game scenarios where which these supporting technologies used to control the game dynamics and showing how pervasive games can be used for road safety.

12.5 Q5:Which applications are feasible to be used in pervasive games context?

Among all supporting technologies discussed in Chapter 5 there are specific applications of use feasible for pervasive games. In Chapter 8, the example game scenarios illustrated the usages of such technologies. However, devising more game scenarios can demonstrate other feasible supporting technologies.

Chapter 13

Conclusion

In this master thesis, I researched the possibilities of pervasive games usage for vehicle drivers for safety and entertainment purposes. I started my thesis with statistics of traffic accidents and their main causes. The statistics concluded that the driver psychophysiological state occupies the top five main causes for traffic accidents.

I then researched the effect of gaming on the player's psychophysiological state. This research included methods of capturing player's psychophysiological state such as biofeedback and neurofeedback. The research also covered Affective Gaming, a gender of gaming where which the player psychophysiological state orchestrate the game.

Furthermore, I researched different driver support systems that can be used by pervasive games for safety purposes. The research included technologies that assist drivers in observing obstacles in the road, weather effect on road surface, and driver own quality of driving. The research also included Heads-up Display, a method of displaying the game without distracting the driver from the road.

The main outcome of the thesis is a conceptual framework that shows how these technologies can be used in pervasive games.A set of game scenarios were devised to illustrate the idea of engaging vehicle drivers in games, not only for entertaining but also for their own safety. The use of driver simulators was described.

The idea of pervasive games engaging vehicle drivers may seem unrealistic at the beginning, especially when it is claimed to bring safety to the road. However, with the available technologies such as driver support systems, it is possible to engage vehicle drivers in gameplay for safety and entertainment purposes. The conceptual framework provides a good starting point for other in-vehicle applications development, capable of bringing entertainment and safety to the road journey.

Chapter 14

Further Work

This chapter discusses possible further work and research. This chapter also includes suggestions on different aspects that can improve further work.

14.1 Research

Throughout this thesis work i found lack of research on games effect in certain psychophysiological states such as drowsiness, fatigue and other states relevant to drivers. With the availability of technologies such as facial expression recognition it would be easy to run qualitative research on psychophysiological effects of games.

Field studies [51] is another validation method where often several projects are simultaneously studied by external group so the subject under study is not disturbed. Therefore field studies on games, or ludology, will be beneficial for further research of gameplay in the context of driving without being disturbed with other studies.

There are also other relevant research directions should be considered for future work. For instance, Ergonomics in vehicles is a research field which is concerned with the effect of driving on driver's physical conditions such as neck and back pain [3]. By adding driver physical conditions observers to the conceptual framework, pervasive games can contribute to vehicle ergonomics.

14.2 Technology

The available technologies used in this thesis work (discussed in Chapter 5) have been satisfactory. However, there is a lack of open source projects in Driving simulation software, facial expression recognition, and affective gaming engines. Though the commercial offerings are robust,however the lack of open source software covering these area was an obstacle.

Technological future work should include developing:

- Driver simulation engine which allow developers to extend the core functionality of the engine.
- Facial expression recognition library specifically for game developers to assist in future affective gaming research.

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