CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Electronics have become a vital part of humanity, not only in highly developed countries, but throughout the globe. Therefore it is not so surprising that new disciplines are emerging up from the application of computer concepts. The joint work created by such association is proving more and more successful every day. Road surface images are the most significant ones among the other available data sources. The field of study of this thesis falls into the multidisciplinary category and particularly contributes towards the area known as computer vision.

There are more than 1 billion vehicles on the roads throughout the world and many people have been killed in car accidents because of the failure to follow a road or stay on a road. Driving a long distance is also a challenge for individuals. As a result driver assistance systems and even unmanned vehicles have been researched for many years to help drivers to drive safely and comfortably. The first requirement of such a system is to detect other vehicles, obstacles, and road surface. Many former driver assistance systems are gradually appearing in new vehicles. Recently, luxury cars have been equipped with front and rear facing radars for detecting objects in front of and behind the vehicle. The new vehicles have Blind Spot Detectors which use cameras positioned in both side rear view mirrors. This system can detect vehicles in the blind spot which humans cannot detect when
driving and is crucial to safe lane changes. The next step in driving system development is to track and follow other vehicles and the road. The ultimate goal is autonomous vehicles which can operate in all environments without drivers.

Statistics show that the number of fatal traffic accidents is directly proportional to the total travelling distance independent of the season, which is surprising since one might think more accidents would occur during the winter when road conditions are worse. The fact that accidents are evenly distributed over the year is believed to be closely connected to average speed which is 10-25% lower during winter season since drivers adapt to changes in road conditions as described by Trafikverket (2010).

According to Johan Strandroth et al (2012), 68% of all fatal accidents during the 2009-2010 winter seasons in Sweden occurred either on snow or ice. The study shows that a fatal accident is at least three times more likely caused by the driver losing control of vehicle on the snow or ice covered roads compared with the same scenario on dry or wet road conditions during the winter season.

The conclusion is that snow and ice covered parts of the road have big impact on traffic safety since drivers apparently do not take proper precautions when driving during these road conditions. This shows the need for safety systems that inform drivers and road maintenance about current road surface conditions in order to prevent this type of accidents.

Slippery Road Information System (SRIS) was a research project involving several private actors and the Swedish Road Administration. SRIS aimed to map and distribute information about local critical road surface conditions, which vary over time. Weather stations are used to determine the road condition. However, the issue is to get an accurate estimation between
the stations. This is why SRIS uses the vehicle built-in sensors to complete information from the weather stations in order to make better estimation of the road conditions further away from the stations. The vehicle data is gathered by accessing vehicle’s Controller Area Network (CAN) and logging signals and messages to see if certain automotive subsystems are active or not at a certain position. Two types of information are gathered, “Event data” and “Background data”. Information about windshield wipers, temperature and position is a part of the background data and is collected every 30 seconds. Other information, such as ABS, Traction Control is sent only upon its activation and belongs to event data, as per Per-Olof Sjölander (2008).

Background and event data is gathered from a large number of cars on the roads. The data from the vehicles is compared with information from nearby weather stations that has been processed through a “Weather model”, which estimates the climate situation of the specific location. The data sets are then evaluated by processing both data through an analyse model and a road condition is estimated and categorized into any of the three following grades:

- Grade 1 – Very slippery
- Grade 2 – Slippery
- Grade 3 – Not slippery

This way SRIS can map which certain parts of the roads are in a “Risk zone” of causing accidents due to slippery road surface conditions, as suggested by Per-Olof Sjölander (2008).

Further on, the information is used to both notify drivers out on the road and the road administration about critical road sections. Proper measures can be taken to avoid accidents e.g. speed reduction, redirect road
maintenance resources respectively. This project has been proved to be a very successful method in preventing traffic accidents as mentioned by Per-Olof Sjölander (2008).

Field tests of SRIS were carried out twice. The first test in 2006/2007 involved 80 weather stations and 20 vehicles. The second field test in 2007/2008 involved 80 weather stations and 100 vehicles. According to Pär Ekström, research engineer deeply involved in the SRIS project, ABS activation showed to be the best indication of a slippery road surface.

SRIS is currently not an active system. The issues are mainly political, in the industrial politics where the OEMs are reluctant to share signal databases which is one of the reasons why the system has not been commercialized yet.

The disadvantage with SRIS is that each vehicle (manufacturer or even car model) uses different designations to code messages on the CAN-bus and requires a library to be interpreted. The consequence is that a custom solution is needed for most car models, which limits the flexibility of the system, as mentioned by Per-Olof Sjölander (2008).

Intelligent machines have been engineered by humans since the appearance of early civilizations. For example, the first programmable machines have been dated back in Ancient Greece in the 1st century BCE as per Sharkey (2007). It is said that human-sized automata were built in ancient China in the previous centuries as mentioned by Needham (1954). Furthermore, from the Renaissance until the 20th century, machines like calculators and chess-playing automata were increasingly researched as described by McCorduck (2004). The formalization of Artificial Intelligence around the 1950s brought intelligent machines to a new dimension, in which their role in human lives has progressively gained importance. At this
moment, humans are assisted everywhere: from hazard alarms, medical technology, communications, transportation, etc. The research in this thesis is focused on the role of Computer Vision for driver assistance, which not only represents a hot research topic nowadays but also is of crucial importance for human societies, as it is argued along this chapter.

There are more than 200 million vehicles on the roads of North America and many people have been killed in car accidents because of the failure to follow a road or stay on a road. Driving a long distance is also a challenge for individuals. As a result driver assistance systems and even unmanned vehicles have been researched for many years to help drivers drive safely and comfortably. The first requirement of such a system is to detect other vehicles and obstacles. Many former driver assistance systems are gradually appearing in new vehicles. Recently, luxury cars have been equipped with front and rear facing radars for detecting objects in front of and behind the vehicle. The new VolvoS80 has Blind Spot Detectors which use cameras positioned in both side rear view mirrors. This system can detect vehicles in the blind spot when humans encounter when driving and is crucial to safe lane changes. The next step in driving system development is to track and follow other vehicles and the road. The ultimate goal is autonomous vehicles which can operate in all environments without drivers.

Transportation is crucial to the development and defense of societies and nations. This is the reason why many countries are developing unmanned systems such as unmanned fighter jets to replace piloted fighter jets, robots to replace human soldiers and autonomous vehicles to transport materials.

Carnegie Mellon University has been a leader in autonomous vehicle research. Their most famous unmanned vehicle is ALVINN which is a vision-only based autonomous driving vehicle. ALVINN (25) used relatively
primitive vision technology (30*32 pixels) images processed by a neural network to control vehicle steering. This system worked very well in spite of the low resolution image used.

In November 2007, Defense Advanced Research Projects Agency (DARPA) held a competition called the DARPA Urban Challenge to select the autonomous vehicle which could best navigate urban streets. Unlike the DARPA Grand Challenge which was set in the desert, this competition was held in an urban environment containing asphalt and concrete road surfaces with many other vehicles also using the same roads. The environment in which vehicles had to operate for the Urban Challenge was much more complex than that of the Grand Challenge. The vehicle was required to drive roads bordered by concrete walls or grass fields. The vehicle had to properly recognize stop signs and navigate intersections. The vehicle had to park in a parking lot and perform a U-Turn when the road was blocked. Although the competition was complicated, many teams competed in this event including Team Case. In this competition, Team Case placed in the top 15 out of 55 teams.

Most teams used LIDAR to measure the distance to surrounding obstacles for the Urban Challenge. But LIDAR has its limitations; the measured distance cannot be larger than 30 meters when the vehicle is driving more than 40mph was said by Gary (2005). A powerful LIDAR which can detect objects at larger distances costs many times the cost of a SICK LIDAR which costs only 3000 dollars. And the data from a powerful LIDAR needs a more powerful computer system to process it. That means that a LIDAR system to detect distant obstacles might cost more than 100 thousand dollars, but a good camera for image detection might only cost 500.00 dollars.

Because the cost of a camera is much cheaper than LIDAR, many methods for driver assistance based upon vision have been developed in the
past 20 years. Recent vision-based road vehicle detection system typically use cameras mounted on the front, rear or both sides of a vehicle. Processing these images is a challenging task because the camera has to operate in an environment where there may be dirt on the lens, water on the lens when it is raining and glare in the image when the lens faces the sun. There is no simple method to deal with all these situations. The outdoor environment is very complex and traffic situations are hard to predict. These facts make vehicle systems hard to design. And the biggest issue of an automatic vehicle system is that it must operate in real-time. The system must operate faster than the speed of the vehicle. For example, the camera might take 30 images per second when the vehicle is driving 20 meters per second. A slow-moving car 10 meters ahead requires a system that can detect the car ahead and stop the vehicle in less than a half second. This means the system must detect the car in less than one fifth of a second. This requires a system which can process at least 5 images per second, and for safety reasons, 10 images per second would be better.

Currently, the normal image size from a camera is 640 * 480 = 307200 pixels. This is too large for real-time processing using common computers. This is the reason why much research in this field focuses on object detection such as vehicle detection, road sign, traffic signal detection, etc. Because these objects occupy only a small region of a large image, the calculation time for image processing can be reduced considerably, allowing more complicated and precise algorithms to be used.

cameras are typically used: single lens cameras, infrared cameras and stereo cameras. Many vision-based autonomous vehicle systems have been developed based upon detecting objects on the road. Only a few systems have been developed which detect the drivable surface of a road.

Chapuis et al (2002) developed a system to reconstruct a 3-D shape of a road based upon fine edge detection and statistical testing. But this system only finds the two side edges of a road and not the drivable surface of a road. And the computation time was 150ms using a HP workstation which is not fast enough for real-time applications. Nuchter et al (2003) developed a system called 6D SLAM which uses a 3-D laser scanner to build a 3-D environment around the vehicle. Then it checks this environment for drivable areas. This system works well. But the 3-D laser scanner and onboard computers are far more expensive than a camera-based vision system.

1.2 ADVANCED DRIVER ASSISTANCE SYSTEMS

Automobiles represent one of the key technologies for human development in the modern era. Since their popularization during the 20th century, automobiles have changed societies in many aspects: demographic distribution, urbanism, social interactions, industry growth, environmental alterations, economy development, etc. Moreover, their potential to provide independent, flexible and fast movement to people has lead to new trends in city planning, traveling and employment. According to Organisation Internationale des Constructeurs (2012), around 50 million passenger cars and 20 million commercial vehicles are being produced worldwide every year. At this rate, in the next years the number of auto-mobiles in the world will reach one billion units, especially due to emerging economies like India and China.

Unfortunately, together with the many benefits, such a technology has also carried a dark side since the very beginning: traffic accidents. The
first death by a motor vehicle was registered in Ireland on 31st August, 1869 as described by Fallon & O’neill (2005). Obviously, in 19th century the number of existing automobiles was low so fatalities were rare. Nowadays, according to the World Health Organization, road accidents represent the 6th cause of death in high-income countries and the 11th worldwide as mentioned by Peden et al (2004). Every year almost 1.2 million people are killed in traffic crashes while the number of injured rises to 50 million as shown in Figure 1.1. Furthermore, these numbers are expected to increase a 65% between 2000 and 2020, especially in low and middle-income countries.

![Figure 1.1 Information panels in highways states the accumulated number of deaths and injuries](image)

In order to improve safety, the automobile industry has been developing special technology of increasing complexity and performance through the time. First electric headlamps were introduced in 1898 in the Columbia Electric Car, while turn signal lights were devised in 1907. In the 1920s, physicians advocated the use of seat belts in cars to protect vehicle passengers, but it was not until 1955 when Ford included them as optional equipment and 1958 when Saab made them standard. Later, Volvo patented
the well-known three-point belt, the one used at present time. Safety cage and padded dashboard were incorporated in 1949. Airbag was developed by various researchers in late 1960s, although it would take two decades to become standard in the United States and three decades in Europe. In 1978, Bosch and Mercedes- Benz commercialized the antilock braking system (ABS) technology on trucks and sedans, although the technology had been first engineered for aircrafts, like seat belts. Electronic stability control (ESC) was first introduced by Mercedes-Benz in 1995 (co-developed with Bosch and trademarked as Electronic Stability Programme) followed by BMW and Volvo. This technology provides automatic individual wheel braking when it detects vehicle skids. As can be seen, since the invention of vehicle and until 1990s the technological advances in security relied mostly in physical devices focused on providing safety when accidents were happening.

In the last twenty years, research has moved toward intelligent systems able to predict dangerous situations and anticipate the accidents. They are referred as advanced driver assistance systems (ADAS), in the sense that they help the driver by providing warnings, assisting to take decisions and even taking automatic evasive actions in extreme cases. They differ from the previous safety technologies in the sense that they do not only rely on physical/mechanical cues from the host vehicle (e.g., ABS or ESC) but in addition they understand the exterior world up to some extent. As will be devised during this thesis, Artificial Intelligence plays a key role when pursuing this understanding of the vehicle surroundings. In addition, efforts in other research areas such as sensors, human machine interfaces, and even aspects like psychology and law have to be made when developing these systems.
The first stone in the area of ADAS was put by Dickmanns group in 1986 with an autonomous highway driving system. They presented a system able to drive through closed highways at speeds of up to 96 km/h by exploiting cameras, rudimentary image processors and Kalman filtering. This research would later lead to the first European project on autonomous vehicles: Prometheus. Nowadays many ADAS have already been commercialized and can be found in the market. For example, the first adaptive cruise control (ACC) systems were introduced in high-end Lexus, Mercedes and Jaguar in the late 1990s. ACC keeps a constant distance to the front vehicle by slowing or accelerating the host one. Lane Departure warning systems warn the driver when the vehicle moves out of its lane, unless the corresponding direction turn signal is on.

This technology was first included in trucks in 2000 and later in sedans. This technology is currently being improved by assisting the steering action or warning/intervening in lane changing in case of danger. One of the currently hot research topics are advanced front lighting (AFL) systems, which control the headlight parameters so that the beam is optimized for different conditions like driving speed and direction as referred by Vlacic et al (2001) and Bishop (2005).

1.3 MOTIVATION

ITS are believed to have big potential for improving the coexistence and cooperation between different road users and other means of transportation. Consider the system envisioned by the European Telecommunications Standards Institute (ETSI) illustrated in Figure 1.2.
There, it is proposed that large parts of the transportation vehicles are linked together, mutually providing useful information. But not only the vehicles are able to communicate to each other, also the infrastructure is thought to be part of this all-covering network, providing, for example, trip and connection information.

Focusing on road transport, the infrastructure can provide information for different functions. Obvious applications are adaptive trip planning where the proposed travel route is automatically updated based on the current transport situation on the road as indicated above or improving cruise control systems by communicating the driving behavior between vehicles. Another important application is novel safety systems that complement and enhance the existing safety systems of vehicles. Modern cars...
are already well equipped when it comes to safety features: seat belts and airbags mitigate the effects of a collision, anti-lock breaking systems (ABS) and electronic stability programs help to keep the vehicle controllable under adverse conditions, and recently developed functions such as lane keeping assistants or driver drowsiness detectors are finding their way into cars as described by Rose (1999) and Hostettler et al (2012).

Considering the statistics of the manner of collision versus the number of lanes for the USA for the year 2010 illustrated in Table 1.1 given by Zhou et al (2007), one can note that almost 3/4 of accidents are related to two-lane roads. The majority of accidents between motor vehicles within that segment are rear-end collisions, head-on collisions, and angular collisions (side impacts). These types of collisions can be mainly attributed to inattentive drivers as mentioned by Hostettler & Birk (2011) or an obstructed field of view at the collision site. In such cases, a collision avoidance system as described by Rothenberg (1971) would greatly benefit from information about the vehicles within the larger surroundings.

Table 1.1  Manner of collision versus number of lanes for the USA for 2010

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not with motor vehicle</td>
<td>431</td>
<td>14,835</td>
<td>1,465</td>
<td>2,583</td>
<td>285</td>
<td>297</td>
<td>198</td>
<td>20,194</td>
</tr>
<tr>
<td>Front-to-Rear</td>
<td>61</td>
<td>2,265</td>
<td>617</td>
<td>889</td>
<td>166</td>
<td>140</td>
<td>41</td>
<td>4,179</td>
</tr>
<tr>
<td>Font-to-Front</td>
<td>28</td>
<td>4,929</td>
<td>244</td>
<td>728</td>
<td>59</td>
<td>46</td>
<td>29</td>
<td>6,063</td>
</tr>
<tr>
<td>Sidewipe – Same Direction</td>
<td>8</td>
<td>508</td>
<td>203</td>
<td>250</td>
<td>45</td>
<td>62</td>
<td>9</td>
<td>1,085</td>
</tr>
<tr>
<td>Sidewipe – Opposite Direction</td>
<td>3</td>
<td>795</td>
<td>52</td>
<td>123</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>992</td>
</tr>
<tr>
<td>Rear-to-Side</td>
<td>2</td>
<td>29</td>
<td>23</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>68</td>
</tr>
<tr>
<td>Rear-to-Rear</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Unknown / Other</td>
<td>4</td>
<td>112</td>
<td>22</td>
<td>32</td>
<td>2</td>
<td>5</td>
<td>19</td>
<td>186</td>
</tr>
<tr>
<td>Total</td>
<td>630</td>
<td>31,644</td>
<td>3,474</td>
<td>6,873</td>
<td>745</td>
<td>780</td>
<td>567</td>
<td>44,713</td>
</tr>
</tbody>
</table>
One way of achieving this is by installing communication-enabled roadside sensors at critical spots such as dangerous intersections or road strips. These sensors would then constantly monitor traffic and communicate the current traffic situation (location and intentions of other road users, ambient conditions, etc.) to the individual vehicles. Using that information, collision avoidance algorithms such as proposed by Brannstrom et al.(1971) could take better decisions based on more and spatially wider information. However, for this to become reality, one piece in the architecture in Figure 1.1 is missing: low-cost, high-accuracy sensors that can be deployed in large numbers.

Note that not only traffic safety benefits from such a system. For example, also, traffic monitoring and control could be improved to enhance traffic efficiency or to detect incidents based on the analysis of traffic flow Kay (1993).

1.4 PROBLEM STATEMENT

As mentioned above there are lots of developments happening in the transport system. But still there is lag in some of the area. The research is going this direction to fulfill the need and increase safety. This will help us to ensure the safety.

One such area is the braking system. There are lots of improvements done in the braking system like Anti-lock Braking system, Traction control system, Electronic Stability program, etc., The surface based braking is done only in Anti-lock Braking system. In this also the braking is done based on the surface which it travels. The surface detection is done based on the slip only when the vehicle is travelling on the surface.

So the time taken by the braking system to react to the surface information is increased and the efficiency of the Anti-lock braking system is
reduced. To increase the efficiency of the Anti-lock braking system, several methods has been proposed. But none of them is based on the surface detection.

1.5 OBJECTIVES OF THE RESEARCH WORK

As there are lots of areas of improvement available in the area of braking based on the surface detection, I have chosen this as research area. This will help to improve the efficiency of Anti-lock braking system. For this the surface detection has to done as early as possible in a predictive manner.

To solve this issue and increase the efficiency of Anti-lock braking system, a method of camera based surface is proposed. In this method, a camera is fitted in front of the car or the driver assistance system camera can be used to detect the surface in front of the car. This surface information is available well in advance before entering the road surface.

The road surface can be classified into the following:

i) Asphalt
ii) Cement
iii) Sand
iv) Grass
v) Rough Road

The available above information before entering into the surface is given to the safety system such as Antilock Braking System (ABS), Traction Control System (TCS), Electronic stability System (ESP), etc., and improves its reaction time and stability.
1.6 ORGANIZATION OF THESIS

The thesis is organized in seven chapters. Chapter 1 presents an overview of the transport system and its current scenario. Also deals with the issues faced by the current transport system and introduce the proposed system to solve it. Chapter 2 forms a review of the wider literature survey and scope of the present study, which deals with the existing system for the performance analysis. Chapter 3 presents an overview about different vehicle safety system available in the market and its importance to save life. Chapter 4 deals with different algorithm existing and proposed to detect the road surface condition. Chapter 5 explains the proposed algorithm for classification of road surface. It also explains how the performance of active safety system is improved with the help of proposed algorithm. Conclusion of the thesis and scope for the future research work are presented in chapter 7.