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Development of Software to Predict Road Information using Map Data

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Development of Software to Predict Road Information using Map Data

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Resumo

Este relatório é resultado do trabalho realizado como projeto final de curso do curso de Engenharia de Controle e Automação na empresa Adam Opel AG na planta principal da empresa em Rüsselsheim, na Alemanha.

A Adam Opel é uma empresa que pertence ao grupo General Motors (GM) e sempre se destacou no mercado europeu por sua influência e inovação. Além disso, a Opel aparece em outros continentes através do fornecimento de projetos para outras empresas do grupo GM.

Durante o período de 6 meses, o autor trabalho no setor de Engenharia Avançada e esteve envolvido em um projeto novo, mas que há muito é discutido no setor. Com os avanços cada vez maiores das tecnologias relacionadas a automóveis fica claro o intuito das empresas do setor automotivo em aumentar o conforto e a segurança de motorista e passageiros. Dentro deste contexto, o projeto pode ser resumido no acesso e tratamento de dados de autoestradas encontrados em mapas virtuais para o uso em um aplicativo para smartphones com o objetivo de auxiliar o motorista, com e sem o uso de rotas pré-determinadas.

Este auxílio se dá na forma de predição de indicadores, como, por exemplo, cruzamentos, semáforos e limites de velocidade – este último sendo o foco do trabalho – para antecipar o comportamento do motorista. Com o conhecimento prévio da necessidade da tomada de ação, o motorista consegue a seu favor a redução do número de acidentes, a redução do consumo de combustível e a durabilidade prolongada de alguns componentes do veículo.

Para isso foi necessário no início um estudo sobre o funcionamento de mapas virtuais envolvendo desde os provedores até a facilidade de trabalho. Tudo foi discutido com alguns funcionários do departamento que possuíam conhecimento prévio. Além disso, a escolha da ferramenta e plataforma de trabalho foi muito debatida, uma vez que o tempo de realização das atividades era fundamental, tanto para o autor quanto para a empresa apesar de ser um projeto de longa duração.

Em um primeiro momento pensou-se em usar o General Motors System Development Kit (GMSDK), que é o kit de desenvolvimento para a nova plataforma embarcada nos automóveis da GM. Por se tratar de uma ferramenta nova esta foi descartada nesta etapa do projeto macro. Decidiu-se assim, desenvolver o projeto para smartphones com sistema operacional Android e para isso foi utilizada a linguagem JAVA e o Android System Development Kit (AndroidSDK) usando a ferramenta Eclipse, escolhida por sua fácil compreensão.

Outro tópico de decisão foi a questão de qual mapa utilizar. A escolha foi pelo OpenStreet Map (OSM), um mapa Open Source que se encontra online e offline, e que possui uma gama de dados considerável para a abordagem que seria dada pelo autor. Foi utilizado como base um código já existente que integra o aplicativo OsmAnd, que também é Open Source.

A grande dificuldade surgiu quando se trabalhou sem o uso de rota determinada, uma vez que se torna complicado prever os indicadores quando existem várias opções de escolha de vias.

Levando em conta estes fatores, o relatório apresenta os passos do desenvolvimento do projeto, bem como o seu embasamento teórico. São apresentados também os testes experimentais juntamente com a implementação dos algoritmos necessários. A validação foi feita por pessoas do departamento que fazem parte do projeto macro e que acompanharam o desenvolvimento.

Abstract

This report is the result of the work done as final project of the course of Control and Automation Engineering, in the main plant of Adam Opel AG in Rüsselsheim, Germany.

Adam Opel is a company that belongs to General Motors (GM) and always stood out in the European market for their innovation and influence. In addition, Opel appears in other continents by providing projects for other companies in the GM group.

During the period of 6 months, the author has worked in the sector of Advanced Engineering and was involved in a new project, but that has long been discussed in the industry. With technological advances of automobiles, is clear the intention of the companies in the automotive sector to increase the comfort and safety of driver and passengers. Within this context, the project can be summarized in accessing and processing data from highways found on virtual maps to use in an application for smartphones with the goal of assisting the driver with and without the use of pre-determined routes.

This assistance takes the form of predicting indicators, for example, intersections, traffic lights and speed limits - the last one being the focus of the work - to anticipate driver behavior. With prior knowledge of the necessity about taking action, the driver is able to avoid and reduce the number of accidents, reduce fuel consumption and extend the useful life of some vehicle components.

For this, it was required at the beginning a study about the operation of virtual maps involving from the providers to the ease of work. Everything was discussed with some employees of the department who had prior knowledge. Furthermore, the choice of the tool and work platform was much debated, since the time to conclusion of activities was essential for both, the author and the company, although been a long-term project.

At first, it was thought to use General Motors System Development Kit (GMSDK), which is the development kit for the new embedded platform in GM cars.

Because it is a new tool, was discarded at this stage of the macro-project. It was decided therefore to develop the application for smartphones with Android operational system. It was implemented in JAVA language with the Android System Development Kit (AndroidSDK) using the Eclipse tool, chosen for its easy understanding.

Another decision topic was the issue about which map to use. The choice was the OpenStreetMap (OSM), an Open Source map with online and offline versions, which has a considerable range of data for the approach that would be given by the author. It was used a code base that composes the existing application OsmAnd, that is also Open Source.

The biggest difficulty arose when working without the use of a given route, since it becomes difficult to predict the indicators when there are several options of choosing routes.

Taking into account these factors, the report presents the steps of project development, as well as its theoretical fundamentals. The experimental tests, with the implementation of the algorithm needed, are also described. The validation was done by people in the department who are part of the project.

Summary

Simbology

GPS – Global Positioning System

OSM – OpenStreetMap

SDK – Software Development Kit

GM – General Motors

GMSDK – General Motors Software Development Kit

ADAS - Advanced Driver Assistance Systems

ADASIS - Advanced Driver Assistance Systems Interface Specification

1. Introduction

When the inventors and investors of automotive segment in the end of the 19^{th} century, as Karl Benz and Henry Ford, worked to produce the first combustive cars with internal combustion engines and start the first companies, they probably could not have imagined the evolution that would take place in the automotive industry. The thoughts about the concept of a car changed during the all last century. Nowadays, we can resume two important searches in two ‘S’: safety and sustainability, of course, together with a good engine sytem.

The safety topic is related with the physical integrity. In other words, the safety guarantee is the ability to avoid some event that can affect in some way the car or the people in the environment, i.e., people in or outside of the vehicle. Independently of the size of the accident, the developers know that the consequences are almost unpredictable. About this, the main companies perform, in partnership with specialized research centers, a lot of studies and tests to find always the best technology and release a safer vehicle, categorizing the items in:

- Active safety items that prevent accidents such as ABS or third brake light;
- Passive safety items which reduce the impact of an accident, such as seat belts, airbags and side protection bars;
- Equity safety items which preserve the vehicle ownership, such as anti-theft alarm. [1]

In the first category, it is possible to find fairly new items: the computers and electronic devices which are able to preview and warn about road caution events. This category is directly related with this project.

The other topic, the sustainability, become a point in the companies “agenda” around 20 years ago, when the greenhouse phenomenon appeared massively in the media and was related with the gases emission, more precisely, the CO2. The truth behind this information is not clear and the discussion is complex and involves a lot of other questions. Anyway, the automotive sector “heard” the public opinion and many studies have been done to minimize the gases emission from cars, from fuel changes to electric engines.

Called Fuel-Efficiency Technologies, the tools and components used to get the car efficiency higher with low fuel consume are increasingly common. The most of the companies created a specific department only to study and project features related to this subject. Chevrolet, for example, has been pushing the limits of fuel efficiency for years with vehicles getting the most out of fuel, from Eco models, to hybrids and an electric vehicle with a range-extending gas generator.

Despite, the technical progress achieved in the vehicles, the influence of the driver’s behavior, actions and decisions play an important role in the energy efficiency scenario. In this case, the possibility to give a feedback to the driver about the way he is driving is a great feature to improve the efficiency. The explanation is simple: with predicted actions it is possible to avoid unnecessary behaviors that consume more fuel, as high acceleration or abrupt break actuation. Moreover, it is a mode to reduce the wear of the car parts, increasing the component time and providing money saving the owner.

The Adam Opel has as an objective, to follow the concepts presented above, proposing solutions to ensure safety, comfort and economy to the customer. These solutions come to add to the companies, a versatile form of intensifying and accelerating the way he delivers it to the customer, since the market is competitive and these technologies become almost mandatory.

In this context appears the subject of the project described in this document. Between numerous projects and after some discussions, the responsible sector in Advanced Engineering Department proposed a tool using road data through virtual maps to warn the driver about some indicators and preview actions. The usage of maps to provide information is one of the crucial topics in this case. The work developed by the author is a part of a macro and long-term project.

1.1: Project Overview

The main goal of author project is to create an application with access to some online map and repository, to get road data, as speed limits and traffic signals, and help the driver about next actions that he must take.

The idea of extract road data not used often from virtual maps and process them is new and not too much common yet. Moreover, this tool is an alternative to an existing feature onboard of some Opel cars that uses local database to foretell speed limits, to show information and to suggest actions for driver, as could be seen in Figure 1. This interface design will be used as model to the current project. So, beyond safety and sustainability, this project will provide money save to company and clients.

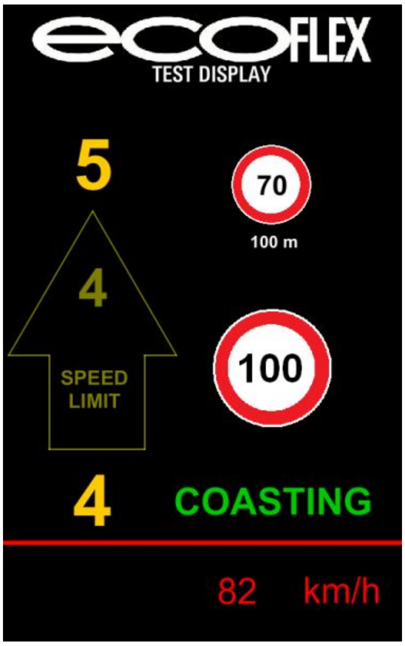

Figure 1- Existent interface used as model

The work includes the study of the subjects, the choice of best development tools and sources and the implementations of the application. It is important to stress that it is a prototype and a first idea for a future commercial product.

To reach the objective, some features are proposed as small goals:

- Predicting road indicators, such as speed limits and the distance to be traveled until it is reached by the vehicle;
- Show information clearly;
- Communicate the application with the car system
- Actions indicate to the driver according to the indicator shown.

The author prioritized the first two requirements. As can be observed later on this document, the prediction without a predefined route was the biggest challenge for the author due the complexity to find next possible roads and collect the related data. Thus, a long part of the internship time was in the development of code that accesses and processes the information to be used.

During this report it is possible to observe that, by request of the project leaders, the emphasis is the speed limit. Because of this, the author project is informally called “Speed Limit's Preview”.

1.2: Report Overview

This report is divided as follows:

Chapter 2: It presents the study of digital maps, giving emphasis to the structures of information systems that compose the map data part and that assist applications in geo-location.

Chapter 3: Are described the influences, in drivability, of applications that works with data prediction, based on two topics: safety and sustainability.

Chapter 4: This chapter presents the goals and planning for possible access to map data.

Chapter 5: Provides information about software specification and implementation, as well as structures to access data and prediction them when using methods two different modes of navigation.

Chapter 6: Presents information and analysis on the tests and results obtained during development.

1.3: Company Overview

1.3.1: Adam Opel AG

Celebrating the 150th anniversary in 2012, Adam Opel AG, was founded 1862 in Rüsselsheim, Hessen, Germany, by Adam Opel. The beginning of the company was producing sewing machines and bicycles. In a short period, Adam Opel became very successful for his attention to detail and the quality of the products. In 1929, Opel became a subsidiary of the American General Motors Corporation, which incorporates all the german company in 1931.

With the headquarter in Rüsselsheim, the company has 11 plants and four development and test centers in seven European countries. It employs around 40,000 people, with more than 22,000 of them in Germany. Opel and its British sister brand Vauxhall are present in over 40 countries. In 2011, over 1.2 million passenger cars and light commercial vehicles were sold, reflecting a 6.1 percent market share in Europe.

The company has established a new segment in the European car market with the Ampera, thus underlining its role as a trendsetter in progressive mobility solutions. [2]

Figure 2 – Opel sites in Europe

2. **Maps Studies**

The history of maps started around 8000 years ago. But, the contemporary cartography is based in the first maps drawn in the sixth century BC by the Greeks who, due to their military expeditions and navigation, created the main center of geographical knowledge of the Western world. The making of a map usually starts from the Earth's surface reduction in its size. On Earth maps contained entirely on a small scale, the world is presented as the only way to exact representation. The transformation of a spherical surface on a flat surface it is called cartographic projection.

Today, the mapping is done by modern means such as aerial photographs and satellite remote sensing. Moreover, with the capabilities of computers, geographers can achieve greater accuracy in calculations, creating maps that have up to 1 meter accuracy. Aerial photographs are made so that overlapping two images from the same place, there is obtained printing a single image in relief. Then, the surveyor completes the work on the ground, revealing the details barely visible in the photographs.[10]

2.1: Geographic Information System

Geographic Information Systems (GIS) are systems that can store, capture, manage, analyze, and display geo-spatial data. The Geographic Information System enables create a database of geographic information which is associated with the graphical components of a digital map by a common identifier. Thus, marking an object can know the value of their attributes, and conversely, selecting a record from the database you can know your location and point it on a map. [3]

There are two types of data used in GIS: Tabular and Graphics. The first is in the form of databases containing descriptive information, usually in alphanumeric format, and can be linked with data graphs. The graph data are visual representations of tabular data in maps. We can sub-divide the data in Vector and Raster Graphics (Pictures). These divisions are explained in later topic. [4]

When speaking of GIS operations, takes in mind these have five fundamental elements [3]:

- Acquisition of data: This element refers to the process of identifying and collecting the data required by application.
- Preprocessing: This process is used to convert the data format suitable for entry into the system. This is an essential step.
- Data Management: The controller database allows GIS to define the contents of the information base, inserting or deleting data.
- Analysis: this is the step of data manipulation. Many analyzes can be made in this case, from mathematical combinations of layers to use external programs.
- Generation Product: here is the software that will show the graphs and tabular data.

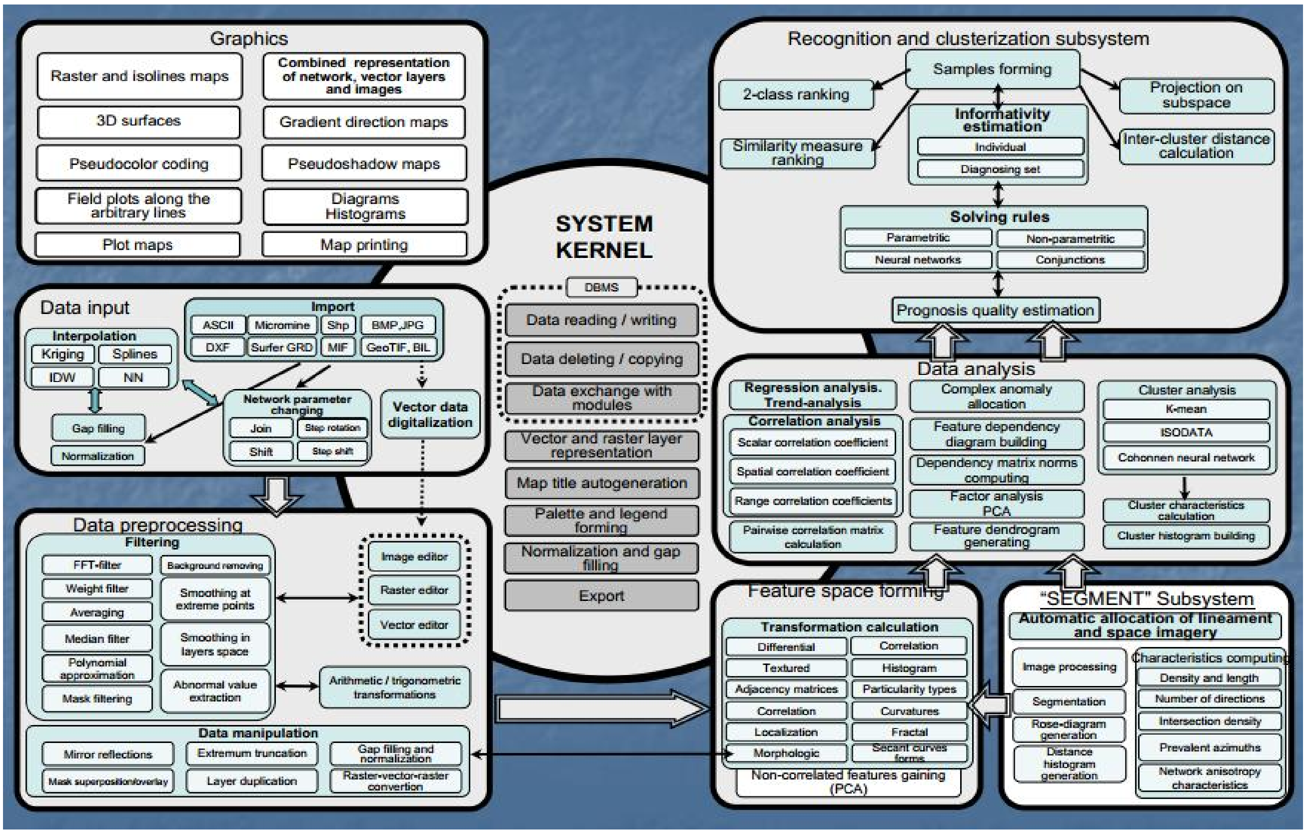

Figure 3 – GIS Architecture

The GIS separates the information contained in different layers according to the type and stores them independently. This lets you work with them in a simple and agile, allowing the user to interact with related information through the position of objects.

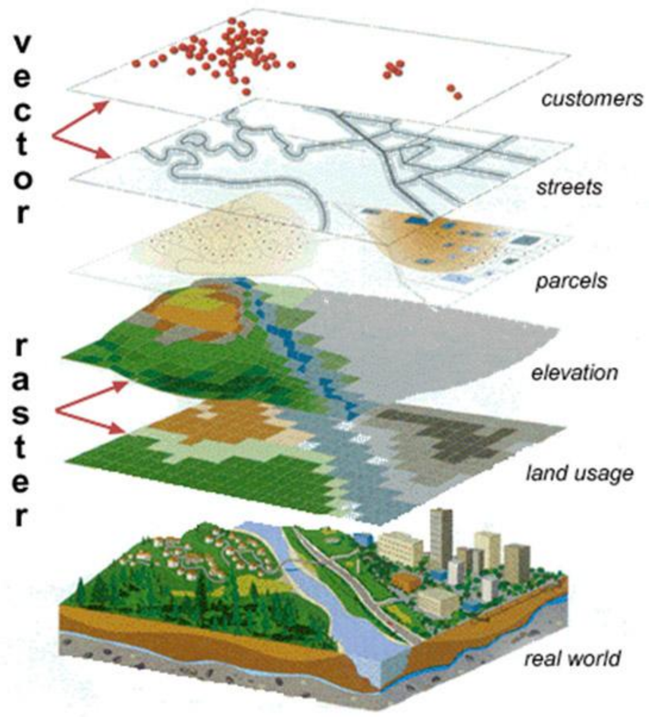

Figure 4 – Example of layers division

2.1.1: Raster-Based

In raster system, the selected area is divided into cells called pixels and each pixel has a single value for each layer in the database. Therefore, a spatial location may present different values in each layer.

The map image is composed by a grid of pixels. Then, raster maps are basically scans of a normal paper map. That means that the information in the map are only available all together. [3]

Since each point must be represented on the map with a pixel and the color, such maps require very much memory on the hard disk.

2.1.2: Vector-Based

The vectors refer to lines, dots, polygons with coordinates “X, Y” that allow the placement of these objects on maps.

With a vector maps there is no image in the database. Instead an image is created by using information from a database. The database consists of coordinates defining points and information on how to connect these points together to form lines and other objects. In addition, labels attached to the object can provide text to be displayed along with the object when an image is created.

Considering streets in a map, it consists of an ordered set of waypoints. Each waypoint is defined with a name and location and the order is used to draw a line connecting them all together, called segment. This is a vector representation of the street.

Since a GPS receiver computes a location it is easy to integrate its location within the locations of other objects from the database. This is essentially how a vector mapping program works. It can use mathematics to compare GPS locations with database locations and collect information about it. [3]

2.2: Map Data

The information stored in the data base can be accessed in two ways: with a XML file and Binary Serialization.

2.2.1: XML Format

XML is a format to provide human readable data interexchange formats. Basically it is a list of instances of data primitives (nodes, ways, and relations) that are the architecture of some map providers model. The structure of a XML file containing map information is seen in the Figure 5. [7]

```xml
<?xml version="1.0" encoding="UTF-8"?>
<osm version="0.6" generator="CGImap 0.0.2">
 <bounds minlat="54.0889580" minlon="12.2487570" maxlat=
 <node id="298884269" lat="54.0901746" lon="12.2482632"
 <node id="261728686" lat="54.0906309" lon="12.2441924"
 <node id="1831881213" version="1" changeset="12370172"
  <tag k="name" v="Neu Broderstorf"/>
  <tag k="traffic_sign" v="city_limit"/>
 </node>
 ...
 <node id="298884272" lat="54.0901447" lon="12.2516513"
 <way id="26659127" user="Masch" uid="55988" visible="tr
  <nd ref="292403538"/>
  <nd ref="298884289"/>
  ...
  <nd ref="261728686"/>
  <tag k="highway" v="unclassified"/>
  <tag k="name" v="Pastower Straße"/>
 </way>
 <relation id="56688" user="kmvar" uid="56190" visible="
  <member type="node" ref="294942404" role=""/>
  ...
  <member type="node" ref="364933006" role=""/>
  <member type="way" ref="4579143" role=""/>
  ...
  <member type="node" ref="249673494" role=""/>
  <tag k="name" v="Küstenbus Linie 123"/>
  <tag k="network" v="VVW"/>
  <tag k="operator" v="Regionalverkehr Küste"/>
  <tag k="ref" v="123"/>
  <tag k="route" v="bus"/>
  <tag k="type" v="route"/>
 </relation>
 ...
</osm>
```


Figure 5 – XML file structure

To use the format, the user saves a data file. It is both a storage format and a change file format, so in addition to storing data downloaded from the server it can also represent changes made by the user since downloading.

The pro and con of this format is presented in Table 1.

PRO	CON
• Clear structure; • Machine independent due to exact definitions; • Ready to use parsers;	• Huge files; • Might need to decompress before; • Parsing takes a lot of time;

Table 1 – Pro and con of XML file

2.2.2: Binary Format

This is an alternative to the XML format commonly used for distribution of map data. Binary serialization is a sequence of bytes, a set of binary digits (bits), grouped in eights. In case of map representation, the binary base structure is a series of binary blocks, which specify their length followed by a type followed by encoded data.

The use of set of information is good to increase the processing speed. Because this, the binary map format is good for rendering on devices with limited resources like mobile phones, because it allows storage of geographical information, fast tile-based access and filtering of map objects by zoom level. [7]

For example, a set in some digital map systems, called “Ways”, reduce the data needed to be transmitted by only sending the positions of nodes as longitude-latitude pairs. If the bits needed between two pairs is too big then, it fakes nodes filling the gap are given. In Table 2 it is observed the required number of bytes for some map information. [8]

Bytes	**Information**
20	Configuration byte
2	Tile size
Variable	Projection
8	Map start position
1	Start zoom level
Variable	Way tags

Table 2 – Number of bytes

2.3: Tiled Maps Data

A tiled projection is that one divided in square bitmap graphics displayed in a grid arrangement to show a map.

The tiled map data is a geo-data indexing strategy. The idea is to store a geo-database such that data for a specific location can be retrieved quickly, by dividing the data up by location, partitioning the spatial area into tiles.

It is important not be confused with this different ideas.

In the tiled map data, the user specifies a bounding box for an area that he wants to view. This then finds the nodes, finds the segments related to those nodes, then any missing nodes (where the other end of the segment lies outside the bounding box). This will miss any segment that totally traverses the area, and is even harder to work out for enclosed areas. [9]

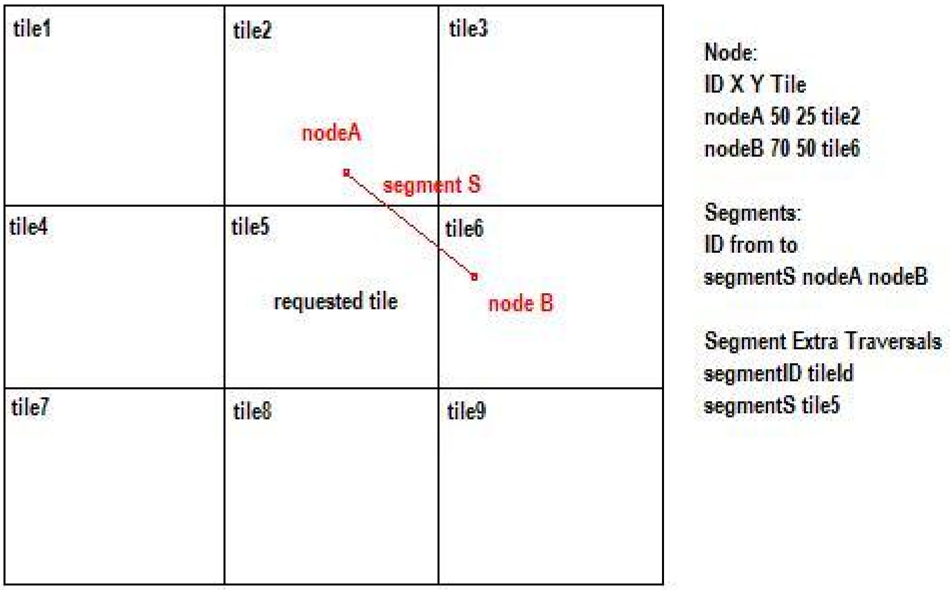

Figure 6 – Illustration of Tile Map Data

2.4: Global Positioning System

The Global Positioning System (GPS) is a set of 27 satellites orbiting the earth 24 is in operation and three extras in case of a failure. The U.S. military developed this satellite network as a military navigation system, but soon opened up for public use.

The GPS position is based on measuring distances to the satellites of the system. The GPS satellites act as reference points in space whose position is known accurately. Then, a GPS receiver, based on measurement interval of elapsed time between transmission of signals from satellites and their reception determines its distance from three satellites in space, using such distances as radii three circumferences, each having a satellite as a center. The GPS position will be the point common intersection of three spheres with the earth's surface. This operation is a mathematical principle called trilateration, show in the Figure 7. [5]

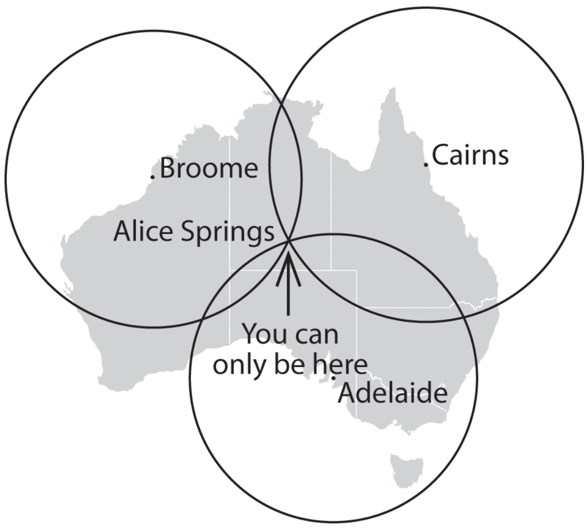

Figure 7-GPS Triateration

However, to determine the length of the signal path, the GPS receiver needs to know the exact moment when the signal was delivered by satellite to power measuring the time difference between transmission and reception.

So, the GPS system is based on the principle that the receiver and the satellite must be synchronized so that generates the same code at exactly the same instant. Thus, simply equipment, by receiving the code transmitted by a satellite, measuring the time difference between the instant of reception and the time that the receiver generated the same code. [6]

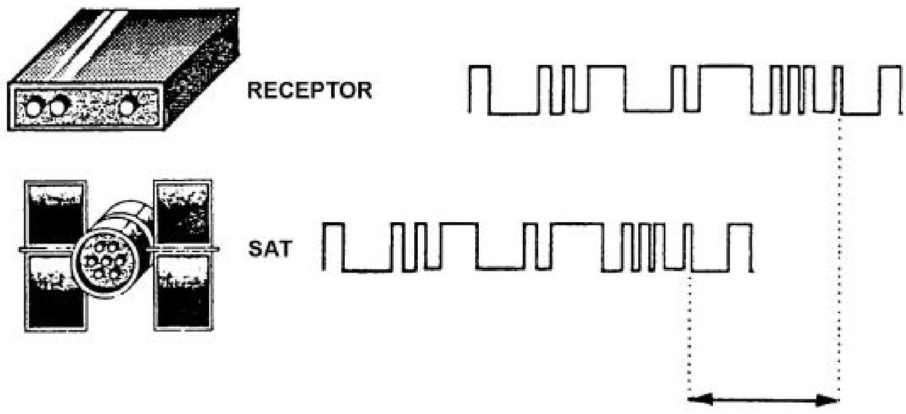

Figure 8 – Time difference between signals

The delay value is equal to the travel time of the signal. The receiver multiplies this time by the light speed and with this is able to determinate how far the signal traveled. Assuming that the signal traveled in a straight line, it is the distance between the satellite and the receiver.

3. Prediction Applications

The automotive industry is constantly on the move. And to accompany the changes, new technologies are always studied to ensure driver comfort. Among this comfort are two issues that have gained strength and grew in public opinion: safety and sustainability.

As the future potential of passive safety measures is limited, new active safety measures are needed to open the additional safety potential needed on preventing accidents. The sustainability is mainly related with efficient cars. A car with a good performance has increased their lifespan and reduces environmental impacts

The development of any kind of tool that ensures the integrity of the driver and the vehicle or provides a better performance is always on the agenda. For example, to keep mobility in future the European Commission has initiated a number of research and development programs to contribute to reduction of road fatalities and further improve the efficiency and ecology of road traffic.

3.1: Driver Behavior

To talk about how the driver behavior influences the in the safety and sustainability factors, each one will be pointed separately.

Influence in Safety:

This condition is obvious. Cause not control itself completely alone, the vehicle “follows” the actions of the driver. The laws disrespect or driver inattention, even for fractions of seconds, can cause an accident and jeopardize the physical integrity of things - people and objects – in the environment.

The data prediction in this case can aid the driver in planning the next action to take.

Influence in Sustainability:

In this case, it should be thought that different drivers have different behaviors in traffic. Thus, most aggressive drivers tend to consume more fuel and require more of the car without.

Another issue is related to the wear of car parts. By inattention, for example, a driver must step on the brake sharply and this speeds up the time of disposal of the piece, creating a "junk" parts.

With the prediction data it is possible indicate to the driver the next action without compromising efficiency.

3.2: Road Indicators Prediction

The prediction of highway indicators, as speed limits and traffic signals, can help the driver to anticipate a decision and, then, get many advantages already mentioned.

Some projects were or are developed about this subject. Following are described two of them, to contextualize the problem.

3.2.1: “Car 2 Car” Consortium

The Car 2 Car Communication Consortium is a non-profit industrial driven organization initiated by European vehicle manufacturers supported by equipment suppliers, research organizations and other partners. The Consortium is dedicated to the objective of further increasing road traffic safety and efficiency by means of cooperative Intelligent Transport Systems with Inter-Vehicle Communications. It means the communication between cars. [12]

The exchange of information between cars allows that one "tell" to other if it is near about obstacles or events that alter the normal vehicle drivability. This idea is so strong that the Consortium supports the creation of a European standard for future communicating vehicles spanning all brands.

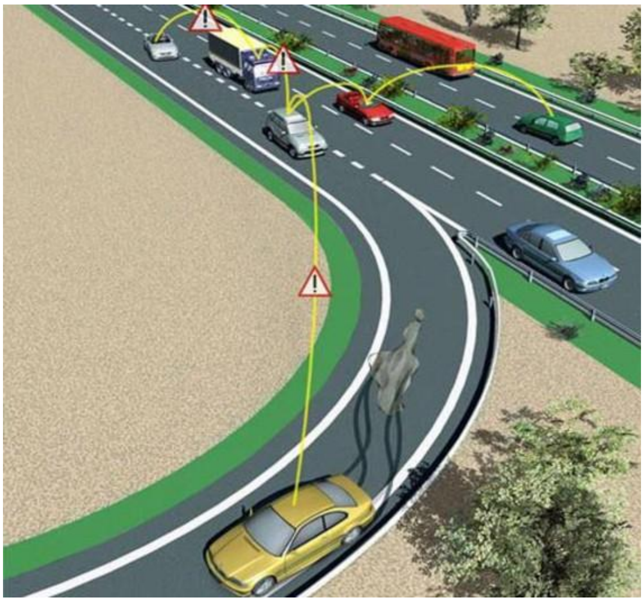

Figure 9 – The Idea of Car2Car Communication

3.2.2: Existing embedded tool

Nowadays, there are some tools to alert the driver about the road signal, but in the most, this information are stored into a local database. It is the example of the tool embedded in Opel cars with the "stamp" ECOFlex. The tool enables, for example, to anticipate some road indicators. The tool uses the ADAS system. ADAS is a system developed by a joint of automotive companies with the goal to have a standard system to help the driver in the driving process. [13]

The workflow of the tool is a little complex. The map data is extracted by the ADAS Horizon Provider and delivered on a vehicle bus system. Therefore an ADASIS CAN protocol has been defined. The Horizon data contains vehicle position data as well as road segment attributes from the map. The flowchart of the tool is showed below in Figure 10.

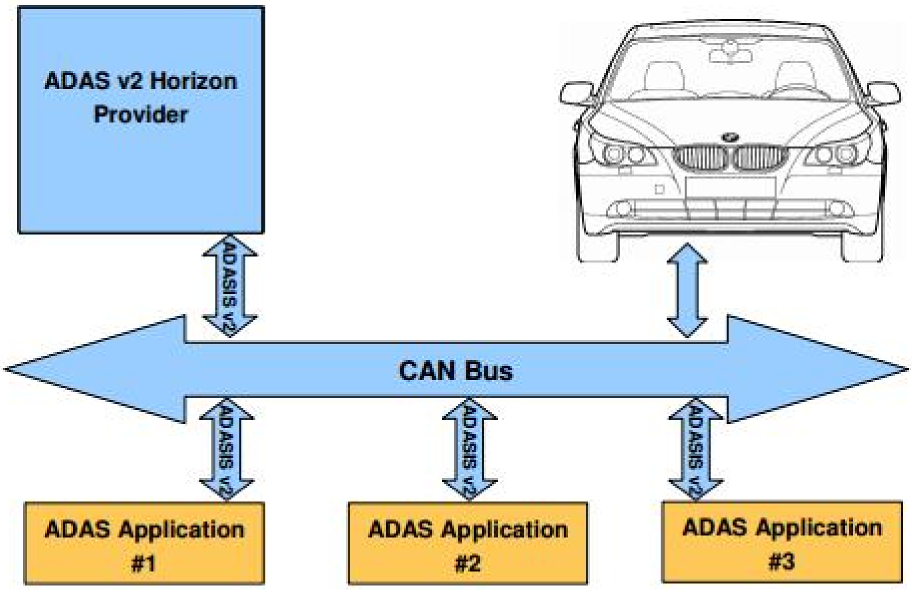

Figure 10 – ADAS Appication Flowchart

As showed, the ADAS is a powerful tool to applications related to navigation. But, the use of a local database is one of the main negative points in this case. It can be resumed in three reasons:

- Outsourced Data Company: automotive companies work in partnership with other companies in the industry to provide database information.
- Outdated Info: it is not usual to change an indicator in the road, for example, a speed limit. However, if it occurs the database will not be update "by itself".
- High Cost: this database costs around tens of dollars per car. But, a company produces millions of cars per year and it is possible to imagine how big the sum is.

Taking these facts rise the proposal of an alternative method to work with highway data. One of these proposals is to use online repositories, in specific, a map with an own database.

3.3: Proposed Solution

Analyzing the problems mentioned in the previous sections, it is necessary to study a new way of approaching the subject of prediction data.

Then, some company departments began to think about the proposal to use up repositories that are not embedded in the vehicle. From this idea, is created in the department of Advanced Engineering Opel a project to study the feasibility of accessing data allocated on maps.

Because it is a relatively new subject, the research part is a key-point. After studying the matter and usability of resources proposes the creation of a prototypical software format initially, i.e., no need for future commercialization.

The proposal is formalized as follows:

Plan and develop a navigation application with remote access to an external data repository. The application should be able to:

- Show horizon and path to the driver with actual speed limit and upcoming speed limit, traffic signs and crossings subscribed by the distance to;
- Show if it is over speed limit;
- Access data from different sources – access data from the maps and internet for vehicle functions and features;
- Generate appropriate HMI, intuitive, helpful, not distracting;

Some goals considered secondary are propose but the relevance is low and it only requires attention in case of time available that does not compromise the above:

- Notify shift indication when it is necessary;
- Development of a data protocol for the transmission of vehicle CANbus data over WiFi/WLAN/Bluetooth interface;

4. The Road Signals Project

As commented previous, it is not common to use virtual maps to storage and provide data about highways. The researches in this area will open new ways to work with this information.

4.1: Road Information

4.1.1: OpenStreetMap

OpenStreetMap (OSM) is a collaborative project, based in the UK, to create a free editable map of the world. The restrictions on the use or availability of information maps in much of the world and the advent of inexpensive portable navigation devices, motivate collaborators to collect and update the map data. [15]

The generated data are made available for use since applications such as Foursquare to less common applications such as the replacement of data with GPS receivers.

According the OSM official wiki site [15]:

“OpenStreetMap uses a topological data structure, with four core elements (also known as data primitives):

Nodes: are points with a geographic position, stored as coordinates (pairs of latitude and longitude). Outside of their usage in ways, they are used to represent map features without a size, such as points of interest or mountain peaks.

Ways: are ordered lists of nodes, representing a line, or possibly a polygon if they form a closed loop. They are used both for representing linear features such as streets and rivers, and areas, like forests, parks, parking areas and lakes.

Relations: are ordered lists of nodes and ways (together called "members"), where each member can optionally have a "role" (a string). Relations are used for representing the relationship of existing nodes and ways. Examples include turn restrictions on roads, routes that span several existing ways (for instance, a long-distance motorway), and areas with holes.

Tags: are key-value pairs (both arbitrary strings). They are used to store metadata about the map objects (such as their type, their name and their physical properties). Tags are not free-standing, but are always attached to an object: to a node, a way, a relation, or to a member of an relation. A recommended ontology of map features (the meaning of tags) is maintained on a wiki."

4.1.2: Map Data Access

The OSM has the facility about contain a good range of different kind of data. Further, it is possible to edit the value of the variables since it is an open source platform. The reliability of the data, as well as the guaranteed existence of them, is not considered given that it is not important in this phase.

How the data will be used in real-time during the navigation, it is indispensable that the connection with the map does not be lost. The author has two options: use the infotainment system of the car, developing an application based on the GMSDK and connecting to the internet through a Wi-Fi connection adapted in a test car or use a smartphone with access to 3G connection. The choice by the smartphone is commented on the next chapter.

The information about roads can be found in an independent XML file generated by a tool in the OSM webpage. However, the size of the file is directly proportional to the map area selected what can be too big for the processors.

Then, to access the data, in this case, it is better to access the map. It means that the usage of memory can be higher than desirable too. Therefore, the workflow of the software must be planned. The Figure 11 represents a simplification of the expected working cycle.

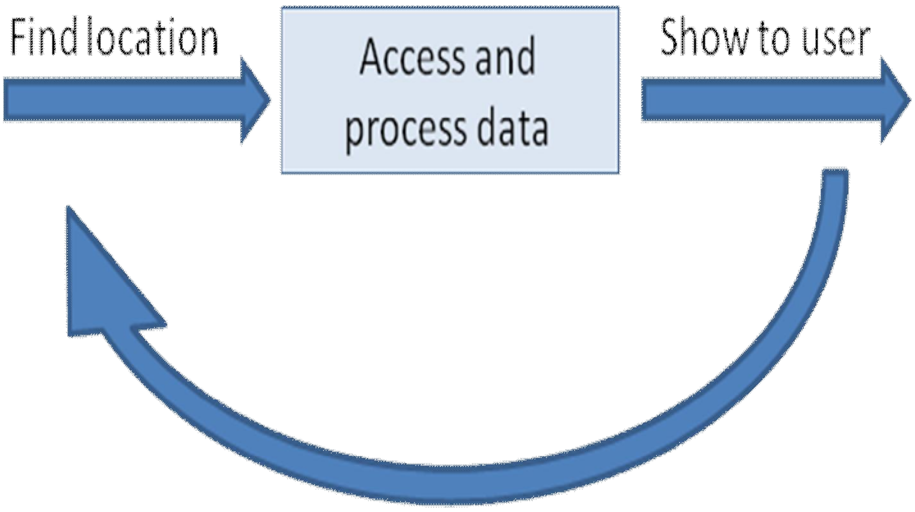

Figure 11 – Software work cycle

4.1.3: Relevant Data to the Process

As mentioned in the chapter 3, the OSM works with structural elements complemented by tags. A tag consists in a key and a related value. These elements and tags are the data to access and process. Follow, are listed the main ones.

4.1.3.1: Road ID

To find the information about the current location is necessary to look for the values related with the current road. Each road has an unique identification number (ID) which it is possible to read the information for more than a segment that composes it. It must be careful to not confuse, because a highway can contain more than one road.

4.1.3.2: Nodes

A node is one of the core elements in the OpenStreetMap data model. It consists of a single geospatial point using a latitude and longitude. Nodes have an unique ID and can be used to define standalone point features or be used to define the path of a way. In the current project, the second option is the necessary one.

4.1.3.3: Highway Name and Reference

It is used to provide details of the name for a feature. This tag fits not only to street, but also to points, places and other ways. Furthermore, this tag has some variations to permit the use in diverse situations.

4.1.3.4: Maximum Speed

The tag that the key called “maxspeed” is used to define the maximum legal speed limit for general traffic. By default, values will be interpreted in kilometres per hour. This tag can be combined with other keys to precise the information.

In the project scope are declared three upcoming variables to show to the driver: speed limits, crossings and traffic signals. For convenience and relevance to the project, the speed limit value is adopted as the main one.

4.1.3.5: Highway Type

The “highway” tag is the main one for highways. It defines the kind of the road. In the most of the countries in Europe, the road type carries some standard values. It is showed below, on Figure 12.

Minding it, this tag is a way to associate data and display to the driver.

	Maxspeed in km/h, driving a motorcar											
	Motorway		Trunk		Primary		Secondary		Tertiary		Unclassified	
Country		link	outside place=	inside place=	outside place=	inside place=	outside place=	inside place=	outside place=	inside place=	outside place=	inside place=
Armenia	110	90	90	60	90	60	90	60	90	60	90	60
Austria	130	130	100 (*7)		100 (*7)		100 (*7)		100 (*7)		100 (*7)	
Azerbaijan	110	80	80	50	80	50	80	50	80	50	70	50
Belgium	120		90	50	90	50	90	50	90	50	90	50
Bulgaria	140		120	50	90	50	90	50	90	50	90	50
Czech Republic	130		90	50	90	50	90	50	90	50	90	50
Denmark	130		80	80	80	50	80	50	80	50	80	50
Estonia	90	90	90	50	90	50	90	50	90	50	90	50
Finland	120	80	100	60	80	50	80	50	60	50	80	50
France	130		110	110	90	50	90	50	90	50	90	50
Germany	130 (*1)	80	130 (*1)	50	100	50	100	50	100	50	100	50
Hungary	130		110	110	90	50	90	50	90	50	90	50
India	180	120	80	50	80	50	80	50	80	50	80	50
Iran	120	90	110	70	100	50	100	50	100	50	100	50
Ireland	120	120	100	100 (*3)	100	100 (*3)	80	80 (*3)	80	80 (*3)	80	80 (*3)
Flag of Isle of Man Isle of Man, United Kingdom	UL (*6)	UL (*6)	UL (*6)	50	UL (*6)	50	UL (*6)	50	UL (*6)	50	UL (*6)	50

Figure 12 – Standard maximum speed according the highway

4.1.3.6: Traffic Signals

Traffic signals are automated mechanisms for instructing road users to wait or to proceed at an intersection or section of a road. The default value is the traffic light. Nevertheless, it is possible to set other signals as value.

4.1.3.7: Crossings

This tag is used for more accurately describing specific types of pedestrian crossings across roads, and other types of crossing over road or rail. The crossing tag is set for the node where the both ways are crossing

4.2: Navigation

The navigation mode is related with movement, i.e., the idea to follow a track. Differently to the static mode, that one which the user only generate a route but does not navigate on in, a good navigation depends from:

- GPS Signal: the first step is to ensure a good GPS hardware to not lose the track, or at least, a quickly correction whether it happens.
- Projection: A not clear projection can confuse the driver and cause an accident.
- Accuracy: To show the current position in the right location is fundamental. If the precision is not well calculated, the device can put driver on the wrong lane, for example. The practical work showed errors between 5 and 15 meters.

The choice of the navigation mode is important to. In this case, the type of transportation is the first thing to decide. In the project case, of course, it is a car. But, the main decision it is about a route: use or not use one?

The approach is different in these two cases.

4.2.1: Route Mode

In this method, a final location, or a “target point” as is called, is defined. The specific algorithm in each device calculates a route and traces it to guide the driver. Not always is the best or the short way. It depends from the mathematic tool used. Anyway, the route is a joint of segments. In this case, it is easier to find an intersection, for example.

4.2.2: No Route Mode

The navigation without a route, or “free driving”, is more complex to work with. A problem, for example, is to snap the current position in the road. Sometimes, it can vary the enough to show the driver out of the lane, for example, over a building.

Other factor is the update delay. When this method is used, it does not know if the user change the highway in the exactly. The common is to use probability calculus to show the current position. Thus, if the user takes a highway exit, the device will note it with some seconds later and then correct the position.

The challenge surges when the user is inside a city with many options of roads. The amount of data is big and the process to find, to read and to treat them can be slowed about to lose information.

4.3: Software Architecture

The software architecture is structured to attend the follow points:

- Process speed: it indicates how fast a loop is. To guarantee that the data showed are from the right position or are not delayed, this condition is fundamental.
- Accuracy: the position from where the data are caught must be close to the real one. The initial tolerance is 10 meters.
- Memory usage: for the devices proposed to use is advisable to use less memory as possible.

Despite the two methods existents for navigation, with a pre-defined route and free driving, the software will follow a basic structure, showed on Figure 13. It is clear during the planning that the development will be different between both and it is discussed in the implementation step.

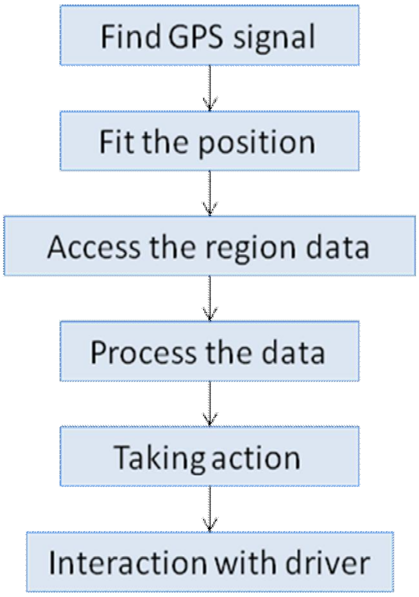

Figure 13 – Basic software structure

The work concentration will be in the last four blocks. The first two are important, but they are not the focus of the problem and there are some known codes in the engineering department.

Then the blocks can be briefed in:

- Access: consists in to catch the tags related with the established position. This part must be able to read the road information in advance to predict the decision of the driver.
- Process: the processing is the structure which prepares the data before the action. Here, the conditions are implemented to ensure the provision of road indicators values.
- Act: with the data processed, the software will use them to decide how and what to show to the driver.
- Interact: the display of information and the suggestion to driver about the next driving decision.

4.4: The Helpful Interface

This feature has more attention than imagined in Opel. As the researches show, the distraction during the driving can increase the chances of an accident. A study conducted by the Governors Highway Safety Association (GHSA) according through the data of 350 scientific papers on the subject and has that smartphone distractions account for between 15% and 25% of all crashes, which range from minor fender-benders to accidents involving fatalities. [14]

To avoid this, a helpful and easy-use screen has to be implemented. The idea is to create an interface without too much information, trying to keep it clear. The other point is to implement an application that the user does not need many manipulations. In other words, an application that the driver configures one time and it is not needed to touch during the driving.

5. The Smartphone Application

The study about a structure to access the map data and the development of it were the main activity in this project. Knowing this, the author should plan carefully each approach, because the time was a little bit short for the implementation of the code and wrong choices could cause the invalidation of the entire project.

The first step in the project was to decide in which platform to develop. There were two possibilities: infotainment system or a mobile device. The listed pros and con are presented in the Table 3**.**

Platform	Advantages	Disadvantage
Infotainment System	• Embedded in the car • Exclusive • Standard operational system on all the Opel cars.	• Fairly new system without much references and informations. • Development tools are not robust. • Access by the final user to system car to updates is more difficult
Mobile Device	• Mobility • Robust system • Large amount of features possibilities in development tools • Facility to find sources and development information.	• Necessity of a device • Different settings between devices.

Table 3 – Pros and con of the platforms

After some analyses, the author opted to use a smartphone type device.

5.1: Development Tools

5.1.1: Operational System: Android

Android is an operating system based on Linux for mobile devices. It is developed by companies that work in partnership form, led by Google.

The decision to work with this operational system was based on the facility to find information and references about the development on it.

Other important point was the “openness” that it provides. It means that the application can run in many devices from various brands, differently to others operational systems, as the exclusive iOS from Apple.

The Android applications are implemented in JAVA programming language, through a group of tools disposed by the Android System Development Kit (Android SDK).

5.1.2: Eclipse

The Eclipse software was chosen due:

- Easy configuration to Android SDK;
- Simplicity to communicate with mobile devices during tests;
- Previous experience of the author;

5.1.3: OsmAnd

OsmAnd is an open source navigation application with access to a wide variety of OpenStreetMap data. The application offers offline and online routing functionality. All map data, vector or tile maps, can be stored on the phone memory card for offline usage.

This source code was used as the base of the author code. Due to the short time and the specific focus of the project – collect and predict data – the open code of OsmAnd had an important role, permitting to skip the development of basic functions related with positioning in the map.

5.1.4: OSM Editors: Merkaartor and Potlach2

Merkaartor is an OpenStreetMap editor. With this software is possible to generate a new map or select a region from OSM and edit the data. The edited map can be downloaded into a device to be used by another application. On the report project, this tool was used simply to find and confirm some road data.

To update data in the map road was needed to use the Potlach2. This editor is found in the on the OpenStreetMap homepage, and permit to edit the information online. The advantage is that the new information is available on the map for all user and developers. This is one of the explanations to use OpenStreetMap.

Of course, to edit online information in the map, it is necessary to be sure about the value. In parts, it is ensured by post verification by the OSM team.

5.2: Road Data Access

In the beginning, after discover where and how to find the map data, the idea was to use a XML file generated from the OpenStreetMap. However, it was discarded because the file size was big and it would be heavy to process.

Then, the choice was the binary serialization. The binary format is designed for map rendering on devices with limited resources like mobile phones. Cause this, the application to be implemented could run together with a map view. This proposal could help in the condition of low memory usage.

The structure to read the binary serialization was ready in the OsmAnd application code. Thus, to the author remained the task to find and get the road data.

The choice between maps online or offline influences and also differs somewhat in problem approach. However, only a few adjustments are necessary to adapt to each other, which was disregarded by author.

5.2.1: Data Search

To find the data, it was necessary to implement a code that read the map information. The parser structure used, responsible to investigate the correspondent tile data file and split the tag information, was also in the OsmAnd. The connection between the parser and the information to be caught was adapted by the author.

Thus, some functions were created to find specific tags. To find the tags, it was necessary the follow workflow:

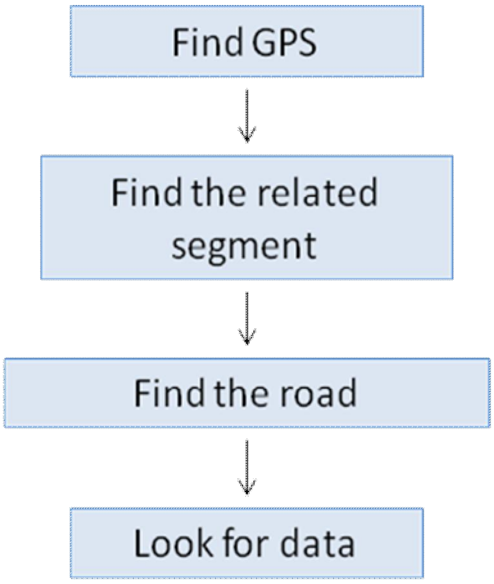

Figure 14 – Flow to find the data.

The first three blocks depend on the information contained in the binary file. It is from there that it is possible to correlate the information from the GPS to display on the map. With the information about the segment, you can read the data contained on the highway, remembering that each road is a part of the highway and has a unique ID that guarantees the uniqueness of the value.

Access to data was done through the search for key-value. The key that indicates the maximum speed, for example, is called "maxspeed". The key is accompanied by a value in string form or numerically. If there is any restriction or sub-information in the tag, it follows the key.

The concentration of a long part of the internship time was in the development of code that accesses and processes the tags to be used.

5.2.2: The Location Algorithm

The search for the current segment or the nearest segment of the GPS location is performed by a mathematical algorithm that defines a certain region on the map with a zoom level conducive. In this bounded region, on the calculation in the form of loop, restricts the possibilities of occurrence until reaching the segment in the shortest distance. The formula used is similar to the follow one in Figure 15, where “d” is the distance between a GPS point “Q” to a road segment “AB”. The “Q’ ” is the projection of the point in the segment and “de” is the Euclidean distance. The visualization can be seen in the Figure 16. [16]

$$d(Q, AB) = \begin{cases} d_e(Q, Q') & \text{if } Q' \in [AB] \\ \min\{d_e(Q, A), d_e(Q, B)\} & \text{elsewhere} \end{cases},$$

Figure 15 – Calculus of the distance between a point and a road segment

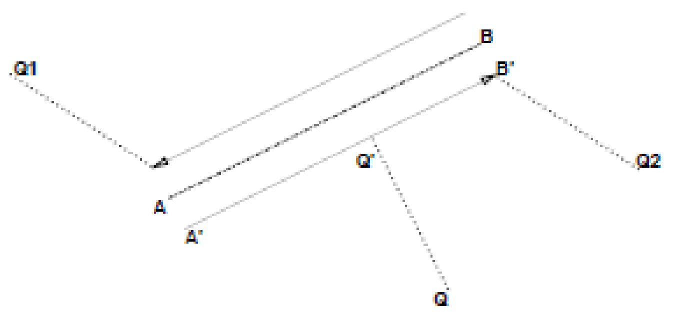

Figure 16 – Visualization of the calculus projections

The calculation used and implemented formulas were already done. It was left to the author to make the necessary modifications and adapt to the code.

Tag	Text
myTag	mDist-->276361.03262321436
myTag	-->Am Fort Gonsenheim
myTag	mDist-->270266.0598982224
myTag	-->Am Fort Gonsenheim
myTag	mDist-->264675.81401462556
myTag	-->Am Fort Gonsenheim
myTag	mDist-->264365.3079858256
myTag	-->John-F.-Kennedy-Straße
myTag	mDist-->218378.9312971344
myTag	-->John-F.-Kennedy-Straße
myTag	mDist-->209125.09348158241
myTag	-->John-F.-Kennedy-Straße
myTag	mDist-->167236.0467946576
myTag	-->Thomas-Jefferson-Straße
myTag	mDist-->165400.7942495824
myTag	-->Paul-Denis-Straße
myTag	mDist-->139234.86177076
myTag	-->Paul-Denis-Straße
myTag	mDist-->132411.0019894864
myTag	-->Paul-Denis-Straße
myTag	mDist-->127315.92178857759
myTag	-->Am Fort Gonsenheim
myTag	mDist-->123462.96806928157
myTag	-->Am Fort Gonsenheim
myTag	mDist-->120777.18820112161
myTag	-->Am Fort Gonsenheim
myTag	mDist-->42993.501240942394
myTag	-->Josefsstraße
myTag	mDist-->8651.7477162576
myTag	-->Mombacher Straße
myTag	mDist-->6007.7048520784
myTag	-->Mombacher Straße
myTag	mDist-->3919.3985737296
myTag	-->Mombacher Straße
myTag	mDist-->19.786632483600002
myTag	-->Mombacher Straße
myTag	--------------->ENDE

Figure 17 – Result of algorithm to find segment

The Figure 17 illustrates the result of the algorithm to find a segment. As can be seen in the image, the algorithm selects an area with a level of zoom using the tile mode based in the current position provided by the GPS receptor of the device. Then, the algorithm starts to investigate the road segment nodes present in the selected area and calculates de distance to the GPS position indicated. This distance is considered a straight line. The looping algorithm runs until to find the shortest distance between the segment and the received location from GPS.

5.2.2.1: Snap the Road

The function known as "snap the road" is used to match the visual position indicator, usually an arrow or a circle, in the middle of the highway on the display. Thus, it can help for a better visualization and avoids the indicator appears at places where it will not move, as sidewalks or buildings places. Moreover, this feature can assist in finding the exact route when there are parallel roads very close.

The author tried to develop the code for this function when the method was working with no route, but the work in this topic was interrupted because it was not a primary goal. Anyway, a small structure was suggested, by the author, for a future work.

When the route exists, the indicator generally follows the line drawn on the road. The problem here is that the feature only snaps to the road that the driver needs to follow, so it cannot be wrong direction.

5.2.3: Data Prediction

The indicators prediction was related with to find the next segment connected to the current one and then take the necessary data. For an initial version, were considered only the speed limits values. Thus expedite the work, because, as these data belong to a road, could facilitate the prediction, since a road is a set of segments and for having a unique ID, also has a single speed limit.

There are roads with varying speed limits according the lane, but it is marked with the tag sub-keys, and can be easily identified. This case needed a new solution. Other case is the highways where there are no speed limits, as the Autobahns in Germany. This marked with a sub-key too. It is necessary do not confuse: this tag is not to be used for situations where there is a limit but it is not known. The missing data is described in a next sub-topic.

The code implemented to access and take the data allows it to be possible to predict data from other segments connected by nodes that connect each other, in the same road or another highway through an intersection.

Thus, was planned the programming code that would predict the next data. The data previewed would be analyzed and if there were changes, it would indicate the value. So, it would be possible to know when a speed limit changed and in which distance that change would occurs. After this, the upcoming indicators are showed to the driver and he can decide what to do.

However, in this part appears the biggest challenge in the project. During development it was realized that using the method with route would be easier to predict changes, since it knows the next segment to be traveled. The bigger problem came when the prediction should be implemented without the use of route, since the algorithm does not know what the next destination of the driver when you have more than one choice of paths.

For this reason, the development was separated in two parts: with route and without route.

5.2.3.1: Route Mode

After the user sets up an endpoint and an algorithm calculates a probable route that will guide him. This route comprises a list of connected segments and follows the order according to the flow must be traversed. As a basic algorithm to generate the route was already implemented, the author adapted it for his use.

Thus, with access to the list of segments, it has been developed some functions to read the data from next segment, according to the vehicle's current position.

Other feature to the route mode is a routing context using. This context works like an informative about the “real environment” where the route is created. This context receives some information from the map, from the device and from the routing points. Based on it, the route is generated and drawn. A difficult here was to store and refresh the list if some track change occurs, but it was discarded and can be evaluated in the future.

5.2.3.2: No-Route Mode

The initial code developed for this method had a constant reading of data according to the current location. Thus, it was possible to update the position data values in accordance with the cycle time of processing.

The chosen cycle time was calculated from the system time and then there was no loss of data. The issue of delay information was also considered. This means that the difference between the time of transmission of GPS information and the time it takes to update the information from pathway would respect the tolerance, of no more than 3 seconds.

As mentioned in the previous section, the challenge of navigating without the use of a pre-established route is find the possible directions when there are new options for change. As the number of paths increases, the more complicated it is to investigate the data.

The solution adopted was to take data segments belonging to the same road on which the vehicle is traveling. Then the idea was to take the data of possible intersections using probabilities, i.e., calculating the possible chance that the driver switch highway.

5.2.4: Problem of Missing Data

Another topic addressed is the lack of data on some highways. Because it is a map of open use, the OpenStreetMap group expects that users and developers fill the blank data fields of highways. Thus, many streets and roads do not provide information in the database.

To compensate for this, some data fields were supplemented within the bounded region of tests, by using editors.

In the code developed, some conditions were also implemented to solve the problem. Noting that the highway does not have the desired tag, another tag should be used to try to relate with the value. In the case of speed limits, if not found, these are related to the type of road. If this tag also does not exist, is given a value that indicates the absence of such. If the value is of type string is returned the is a string "null". In the case of numeric values, returns the value "0.0".

Taking into account the data collected, it was possible to have a good grasp of the difficulties and possible usability of the application in the future. Emphasizing again that the greatest goal is to provide the data without the use of pre-defined route, the lack of a reference because it is a subject rarely discussed hindered project implementation. Anyway, the results achieved are of great value and will be discussed in the next chapter.

6. Tests and Results

To guarantee the usability and strength of the software, it was submitted to some tests. These tests were done sometimes with the collaboration of other person, to that validation was more effective. The maps used were offline, i.e., they were downloaded in the smatphone, but the usability is similar to online maps. The usage of offline maps is explained for the lack of data in the available online maps.

6.1: Simulations and Tests-drives

To run the tests some during the development process were used computer simulations and test-drives. They are divides in two categories, according the navigation methods, i.e., with route or free driving mode.

6.1.1: With routes

The use of a route enables the generation of a list of segments where the data can be taken. With the list generated was possible to observe some relevant information to the project's goal, the prediction of information. The first information was the tag values. To test, a random route (Figure 18) was created.

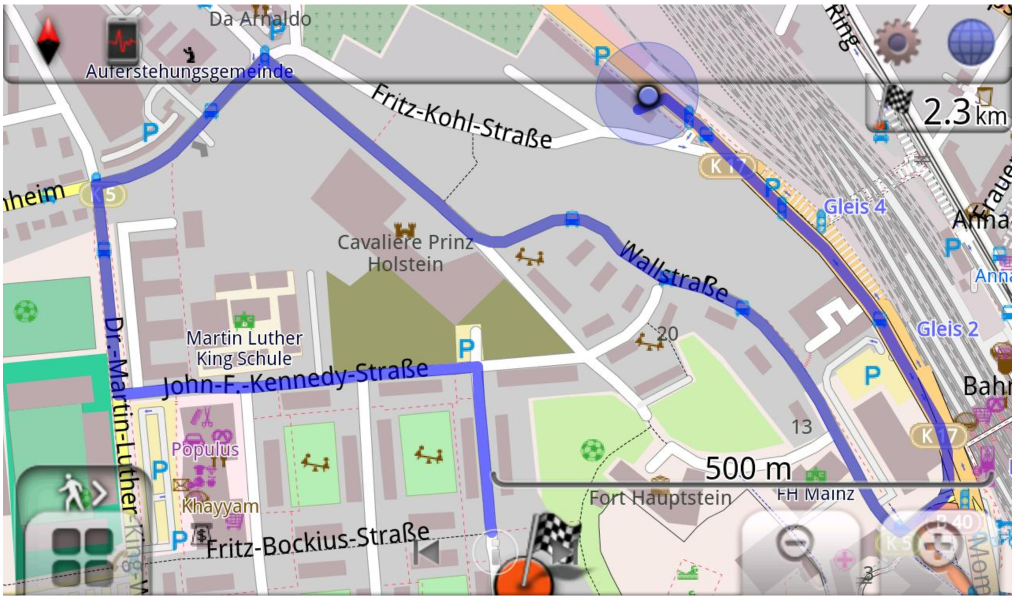

Figure 18 – Example route generated

```
PREPARE        Mombacher Straße
PREPARE        13.888889
PREPARE        Mombacher Straße
PREPARE        0.0
PREPARE        Mombacher Straße
PREPARE        0.0
PREPARE        Mombacher Straße
PREPARE        0.0
PREPARE        Wallstraße
PREPARE        0.0
PREPARE        Wallstraße
PREPARE        8.333333
PREPARE        Am Fort Gonsenheim
PREPARE        0.0
PREPARE        Am Fort Gonsenheim
PREPARE        0.0
PREPARE        Dr.-Martin-Luther-King-Weg
PREPARE        13.888889
PREPARE        John-F.-Kennedy-Straße
PREPARE        8.333333
PREPARE        null
PREPARE        8.333333
```

Figure 19– List with name and speed limit of the segments that compose a route

We can observe in the Figure 19 the list with the ordered segments that compose the route from' Figure 18**.** In this case, are showed the value of the keys “name” and “maxspeed”, i.e., the name of the road that contains the segment and “float” numbers representing the speed limits, in meters per second, from each segment. The values “null” and “0.0” indicates that the related segment have no key data filled in the database. The label “PREPARE” was created for the author and does not have a specific meaning.

Some road's name appears more than one time. It indicates that there are different segments from the same road in the route. Thus, the correct process of the data is showed. The distance between segments could be reached too.

After this, was possible to find the attached segments in the route, i.e., the roads segments that are not in the route, but are connected and could be an optional way.

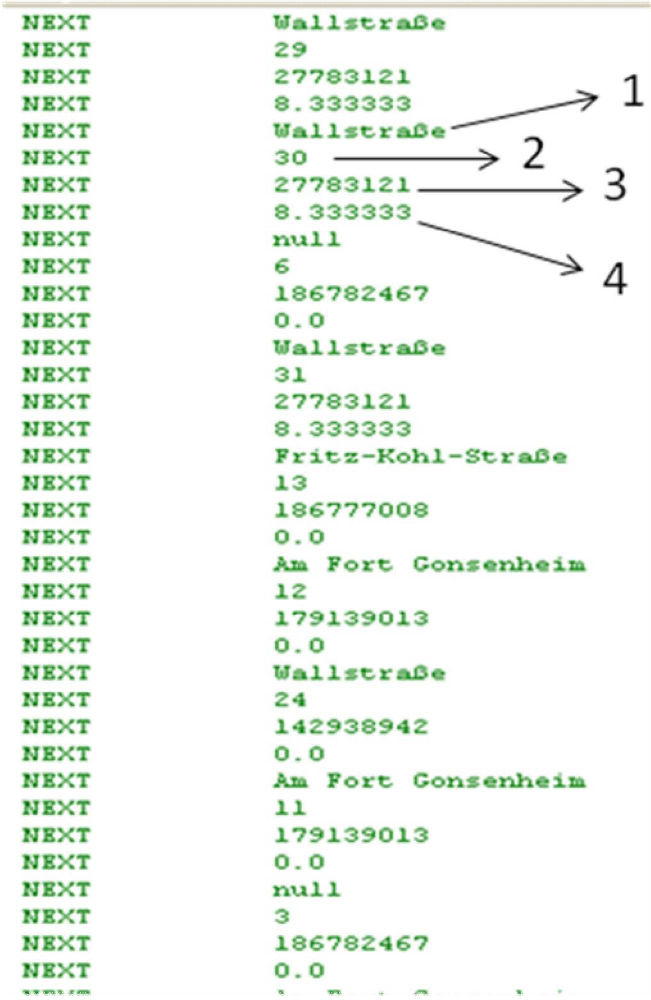

Figure 20 – Attached segments in the route

The list with attached segments (Figure 20) shows some important data for the project goal: the name(1) and ID number(3), both related to the road where is located the segment, a node number(2) indicating the start point of connection from the segment, and the road's speed limit(4).

The values above were caught using static mode. During the navigation mode it was possible to get the data from the current segment where the vehicle was. The problem appears to access the data from the next connected segment from the list, because the stored list did not permit the access to the next segment. After some attempts, it was reached, but the data display not.

6.1.2: Without routes

The first test trying to access the data from current position was realized with the static mode. This because the goal were only to verify if the information were been read cyclically. This was confirmed by the test (Figure 21) and work time of the software was considered good. Again, the speed limit value “0.0” indicates the lack of this value for this road in the database.

Tag	Text
RS	Name Faulbruchstraße
RS	ID 35067555
RS	Points 3
RS	MaxSpeed 0.0
RS	Location[mProvider=network,mTime=1360933433102,mLatitude=49.9954096,mLongitude=8.4105117,mHasAltitude=false,mAltitude=0.0,mHasSpeed=false,mSpeed=0.0,mHasBearing=false,mBearing=0.0,mHasAccuracy=true,mAccuracy=1103.0,mExtras=Bundle[mParcelledData.dataSize=148]]

Figure 21 – Static data access without route

Then, it was run in real test-drive. During the driving, the software updated the information correctly. The result can be seen in the Figure 22. It is possible to note the tag “highway:type” with the value “secondary”. This tag was used to associate a speed limit to the road when there is no value recorded in the tag “maxspeed” in database.

The update time was considered good, ranging between 1 and 1.6 seconds. Comparing with a driver decision time, it is enough to guarantee the time to the driver take an action.

This update action is also related with the position changing. It means, each time the GPS position changes, the data from current location are read and displayed to the user.

```
                      ParcelledData.dataSize=148]]
L:39:45...  RS        Mombacher Straße
L:39:45...  RS        50.0
L:39:45...  RS        secondary
L:39:45...  RS        122570773
L:39:47...  RS        Location[mProvider=network,mTime=1359938384611,mLatitude=50.0 □
                      0436856666667,mLongitude=8.253901483333333,mHasAltitude=false □
                      ,mAltitude=0.0,mHasSpeed=false,mSpeed=0.0,mHasBearing=false,m □
                      Bearing=0.0,mHasAccuracy=true,mAccuracy=50.0,mExtras=Bundle[m □
                      ParcelledData.dataSize=148]]
L:39:47...  RS        Mombacher Straße
L:39:47...  RS        50.0
L:39:47...  RS        secondary
L:39:47...  RS        122570773
L:39:47...  RS        Location[mProvider=network,mTime=1359938384611,mLatitude=50.0 □
                      0436856666667,mLongitude=8.253901483333333,mHasAltitude=false □
                      ,mAltitude=0.0,mHasSpeed=false,mSpeed=0.0,mHasBearing=false,m □
                      Bearing=0.0,mHasAccuracy=true,mAccuracy=50.0,mExtras=Bundle[m □
                      ParcelledData.dataSize=148]]
L:39:47...  RS        Mombacher Straße
L:39:47...  RS        50.0
L:39:47...  RS        secondary
L:39:47...  RS        122570773
L:39:48...  RS        Location[mProvider=network,mTime=1359938384611,mLatitude=50.0 □
                      0436856666667,mLongitude=8.253901483333333,mHasAltitude=false □
                      ,mAltitude=0.0,mHasSpeed=false,mSpeed=0.0,mHasBearing=false,m □
                      Bearing=0.0,mHasAccuracy=true,mAccuracy=50.0,mExtras=Bundle[m □
                      ParcelledData.dataSize=148]]
L:39:48...  RS        Mombacher Straße
L:39:48...  RS        50.0
L:39:48...  RS        secondary
L:39:48...  RS        122570773
L:39:48...  RS        Location[mProvider=network,mTime=1359938384611,mLatitude=50.0 □
                      0436856666667,mLongitude=8.253901483333333,mHasAltitude=false □
                      ,mAltitude=0.0,mHasSpeed=false,mSpeed=0.0,mHasBearing=false,m □
                      Bearing=0.0,mHasAccuracy=true,mAccuracy=50.0,mExtras=Bundle[m □
                      ParcelledData.dataSize=148]]
```

Figure 22 – Cycling data access during driving mode without route

However, two problems were found. The first one was the matching of the location indicator in the road. Sometimes, for problems with GPS signal, it was displayed out of the road. Some conditions were created in the code and this error was corrected in parts. Anyway, it invalidates this feature.

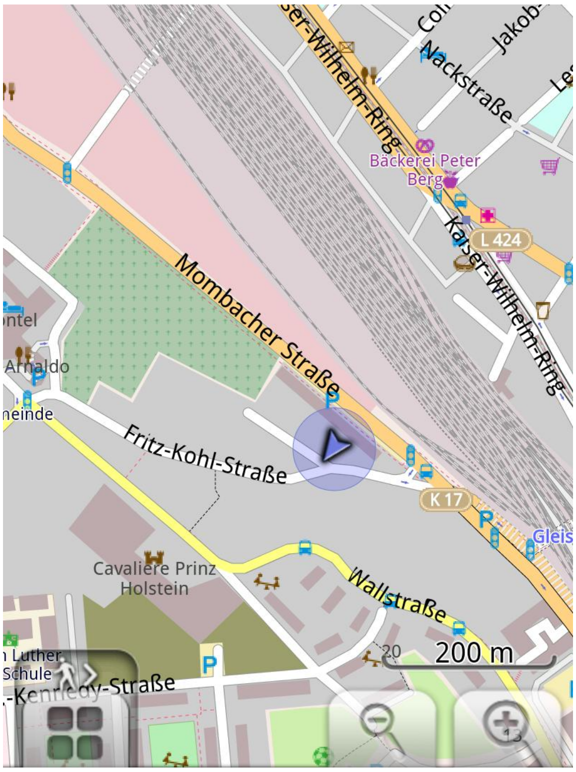

Figure 23 – Indicator matched out of the road

Another error occurred when the position indicator went through highways that crossed either by actual intersection, either by intersection projection map. The value caught in this case could be from any road in the crossing. In this way, the software could get information about the wrong road. The author tried to be correct this error using a conditional function to get the information only about the current highway, but there were not enough tests for some specific situations to validate this.

The big goal in this method, which was to provide data from other roads, was not achieved despite countless efforts. What has been achieved was the finding of some roads nearby, but without obtaining data. The segments found are out of order, what make difficult the choice of next route. The author proposed some conditions, as find shared nodes, to minimize this problem.

6.2: Memory Usage

Memory usage was considered satisfactory for both cases. However, it is believed that this number may increase in long periods of use of the application in the navigation pre-defined route.

6.3: Interface

The initial idea was to create a separate interface to display only the data. However, during the development project, it was decided that the interface could present a mix of map data for tests that were made.

The data visualization occurs on screen display of the map, as observed in Figure 24. The data showed are: road name, road reference, speed limit recorded in the database, in kilometers per hour, and speed limit imposed according the highway type. In the Figure 24, the last information is a random value for maximum speed associated with the highway type, in this case, a “secondary road”.

In the future, the map will run in the background and the screen will separate information.

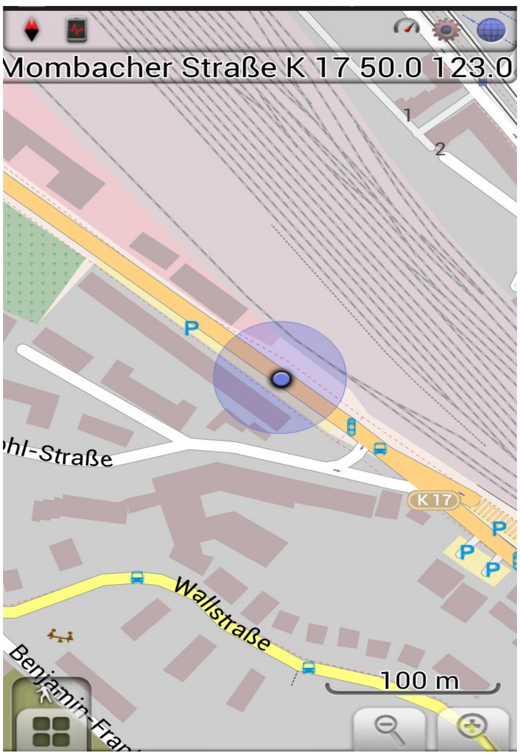

Figure 24 - Inteface

7. Conclusions and Perspectives

The growing searches of automotive companies for tools that increase the rates of safety and sustainability makes new technologies are studied. The reflection of this can be seen in the decreasing number of negative indicators related to these indices, as many accidents and emission levels.

Thus, tools that assist in predicting information of highways can avoid events that affect the normal traffic, contributing positively to ensure driver comfort and benefit the environment.

What was seen in the course of development is that this prediction is not always easy to achieve. The existing projects seeking to predict events and data work with complex structures of hardware and software. In the case of the project developed by the author, the complexity of algorithms to locate neighboring segments, while ran a without route track through the map, was considered high and surprised the project staff. The factor of being a little depth study and without many references also contributed.

Even not reaching all the goals expected, the results were considered satisfactory by the team involved in the project since it was discovered and presented tools and frameworks, so far with a superficial study.

Results of access to data and prediction method with the use of pre-established routes were very satisfactory, facing the project objective.

In the method of free direction, the results were considered good. Despite not display the predicted values in the smartphone, the code structure and left studies were of great value to the company. The values displayed in the current position without the use of route was considered, in certain way, an innovation, as it is not very applied in existing devices.

For the future, it will be continued the development and the application programming by another person in department, putting the focus on the method without navigation route. This indicates the keen interest of the company in this matter. It is clear that this tool will benefit both, drivers and the company.

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