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Detecting roundabout manoeuvres using OpenStreetMap and vehicle state

Master's Thesis in Systems, Control and Mechatronics

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Department of Applied Mechanics
Division of Vehicle Safety
CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
Aerial view of a roundabout in Sonnenberg Murschnitz, Germany by Aerial Photography
available at http://www.flickr.com/photos/leidorf/4997136347/

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Abstract

Naturalistic Driving Studies (NDS) is a recent research field used for the analysis of behaviour of road users in a natural setting. NDS provide large data sets containing numerous types of events such as manoeuvres, near crashes and crashes. Since we are dealing with a large database the analysis of those events can be hard due to the lack of information of where or when those events occur in the trips data. The identification of these events is typically done by a person manually reviewing the video footages. This is a tedious, time-consuming and ineffective way of identifying events in a large database. This project aims for the development of a method for an automatic identification of some car manoeuvres(i.e., left manoeuvre in a roundabout, right manoeuvre in a roundabout, and going straight in a roundabout) as well as a specific road structure(i.e., roundabouts). The data for this study comes from a Field Operation Test done in Gothenburg, as part of the euroFOT project. Some information from the OpenStreetMap project was also used. The labelling method developed here consists of the creation of a yaw rate profile for each manoeuvre under study that is then matched to the trip segment being analysed through the use of the Pearson's correlation parameter. The roundabout identification utilizes the results from the labelling method in order to gather the localization (GPS coordinates) of those roundabouts. The results obtained indicate that the method developed here has potential to be used for an automatic way of identifying specific roundabout manoeuvres that exist in a large database as well as the identification of the localization of roundabouts.

Contents

Preface

In this study a method for automatic labelling of car manoeuvres and road structure identification is developed using the data from a Field Operation Test database. The work has been carried out at the Department of Applied Mechanics, Division of Vehicle Safety Chalmers University of Technology, Sweden, with Fernando Jorge as student and Henrik Lind as supervisor from Volvo Car Corporation and Selpi as examiner from Applied Mechanics.

Göteborg October 2012
Fernando Jorge

1 Introduction

Each year tens of million people in the world are injured in traffic accidents [26]. Many active safety systems have been introduced on the market. The goal of these systems is to reduce the effect of collisions and sometimes even to avoid collisions.

Today's active safety systems mainly include the vehicle dynamics into the equation of when to activate the systems. Future systems will also take into account the driver behaviour into the equation but not at the expense of increased false and nuisance activations. The driver controls the vehicle based on the current situation. Thus, if an active safety system knows the situation, the system may be able to more accurately predict the driver behaviour.

Since 90% of the traffic accidents are thought to be caused by the driver [13] this creates a need to reduce the number of accidents by developing controllers and other functions embedded in the car. To minimize accidents and increase safety we first need to know how the manoeuvres are performed in order to adjust for example the parameters of the brakes and the engine.

The invention of motor vehicles has been a remarkable achievement that allowed the transportation of people and goods in a fast and easy way. This innovation of transport has brought some disadvantages mainly associated to pollution and human injuries. We can consider this work as one of the many steps that are needed to be taken to make the transportation more efficient and safer. The data used in this project was gathered from the OpenStreetMap (OSM) [24] as well as data collected from the Volvo cars partition of the euroFOT[8]. For details of the euroFOT project and the OSM see Appendix A.

1.1 Purpose

The aims of this Master's thesis are to:

- Investigate ways of labelling car manoeuvres using pre-recorded data from the Volvo car vehicles in the euroFOT database. In this case there is a ground truth available, that is, we have access to video footage where we can see what happened;

- Identify roundabouts with the same method that is developed to address the first aim.

1.2 Previous work

Throughout the literature review in this project we found several approaches for the detection of car manoeuvres either for labelling or predicting. The common methods used include Artificial Neural Networks (ANNs)[27], random forests [32, 33] and Hidden Markov Models (HMMs) [20, 19, 34, 10, 23, 15, 3, 13].

1.2.1 Artificial Neural Networks (ANNs)

Artificial Neural Networks are a learning method that has been greatly inspired by the structure of the human brain. The human brain is a complex structure that consists of approximately 10^{11} neurons that pass signals to each other via roughly 10^{15} synaptic connections [37]. This kind of organization where neurons are connected to each other is adopted in an ANN. The special thing about an ANN is that each individual neuron only computes a simple function, but combined they can compute complicated functions. To simplify the underlying mathematics an ANN is composed in several layers and each layer is only connected to its following one.

The general concept of how the biological neurons work has been adapted in the artificial neurons, although some modifications have been made. Each neuron is defined by its incoming connections and the weights associated with them. Each neuron has an activation function, which is usually the same for all neurons in one network. Integrated in this activation function there usually is, inspired by the biological neuron, also a threshold that determines whether the neuron *fires* or not.

The output the neuron gives is described by the activation function:

$$\sigma(b + \sum_i x_i \cdot \omega_i) \tag{1.1}$$

where x_i represent the input value of the i-th incoming connection, and ω_i the corresponding weight, b is a threshold value that is used in most activation functions[12]. Already a single neuron can be used as a classifier. An important question that always arises when dealing with a learning algorithm is the complexity to which this algorithm is able to learn. Specifically for the ANN's there is a great complexity involved in the structure of the network in itself as well as the algorithms used for the learning process. The specifics on the complexity and algorithms for the learning process are vast but will not be further discuss in this report.

1.2.2 Random Forests

Random Forests are a machine learning technique that utilizes a combination of decision trees in which each tree depends on the value of a random vector of features [31, 14, 38]. It has proven to run very efficiently on large databases as well as one of the most accurate learning algorithms [4].

1.2.3 Hidden Markov Models (HMMs)

A Hidden Markov Model(HMM) is a probabilistic technique which models a system that is assumed to be a Markov process[35, 28]. This Markov process is described as being a process where the future state of a system is solely dependent on the present state[36]. Specifically in a HMM the states of the system are not directly observable while the output of the system is observable. The use of HMM as been employed in the study of time series patterns such as speech recognition[29], coding theory [6] among other time dependent systems. We can find different types of HMMs on the papers reviewed, conventional[20], auto-regressive[13] and coupled[23] HMMs all of them showing good results.

From several papers that we have reviewed the method that showed to be more promising and had better results was the ones using HMMs. Even though the methods reviewed showed good results specially the HMMs we decided to be innovative and develop our own method. The intended new method should yield a high accuracy rate and be able to be employed in a large database.

1.3 Report Structure

In Chapter 2 we present the definition of driving and driving example as well as some of the manoeuvres that are subjected of automatic labelling found in the literature review. The result of a survey made at Volvo cars is also presented. Chapter 3 and Chapter 4 focus on the explanation of the methods developed for the labelling of manoeuvres and for the

method for the roundabout identification. We proceed to Chapter 5 with the results of the work followed by Chapter 6 with possible future improvements of the work developed on this project. We end the report in Chapter 7 with some conclusions and discussions.

2 Manoeuvres

In this section we present the manoeuvres that were subject to an automatic labelling process in the papers reviewed. A survey was also performed at Volvo Car Corporation in which the results are presented further in this chapter.

In the paper by Chan, Herrera and Andre[5], driving is defined as: "Driving is a control task that consists of controlling the vehicle's speed and position on the road. It is a driver and context dependent task which is greatly conditioned by the driver's habits and the surrounding environment (road, weather, traffic)."

And according to D. Mitrovic [19] a driving event is defined as :

"...any major change in vehicle attitude or speed."

According to McCall and Trivedi[18] there are three main parts that are active while driving:

- Environment

- Vehicle

- Driver

Each of these three parts has a complex behaviour by itself as well as the fact that they interact with each other which can be very hard to model and/or predict.

Here we list some of the most common manoeuvres executed by drivers as well as some of the most common manoeuvres that are subjected of automatic labelling in [20, 19, 23].

- Starting

- Braking

- Stopping

- U-turn

- Parking

- Overtaking a car

- Driving a vehicle along left curve

- Driving a vehicle along right curve

- Turning left on an intersection (with and without roundabouts)

- Turning right on an intersection (with and without roundabouts)

- Driving straight across an intersection with a roundabout

Survey

A survey was made in order to find out from the people in the industry (Volvo cars) what seemed to be the relevant manoeuvres and road structures to be identified(appendix I contains the survey format). The results from the survey were the following:

- Cutting-in vehicle

- Cutting-out vehicle

- Lead vehicle negotiating exit

- Closing up to crossing with traffic lights

- Closing up to crossing with stop sign

- Roundabout position and curvature

The reason behind the choice of these manoeuvres and structures are related mainly for a reaction for a semi-autonomous system like the ACC[1] (Adaptive Cruise Control) or in the case of the roundabouts for curve speed adaptation[2]. In this project we choose to focus on the identification of manoeuvres executed on intersections with an emphasis on roundabouts. This decision has two reasons, first of all there are previous works dealing with this kind of intersections as well as being one of the elements that appeared on the survey and secondly due to the fact of the relatively easy access to the data on roundabouts.

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[1]"Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment."[1]

[2]Adaptation of the vehicle speed regarding the curve angle.

3 Method for manoeuvre labelling

Section 3.4 will describe a method to label car manoeuvres. A manoeuvre can be described as a series of changes in the movement or direction of the vehicle in order to achieve a desired path. The idea of the method developed in this project was with a focus on simplicity. Rather than using various sensor signals we focused on using only one signal, i.e, the yaw rate. Our initial choice of manoeuvres were the ones executed in intersection with a focus on roundabouts.

3.1 Roundabout

A roundabout is a round physical road structure in which the traffic moves in one direction, in the case of right-hand traffic the direction is anti-clock wise while in a left-hand traffic the direction is clock wise. Figure 3.1 illustrates a typical roundabout configuration with four roads merging onto the roundabout structure. There are four possible manoeuvres that can be executed in this road structure: a U turn (figure 3.2), a left turn (figure 3.3), a right turn (figure 3.4) and going straight (figure 3.5). This project focuses on the left turn, right turn and the straight manoeuvres.
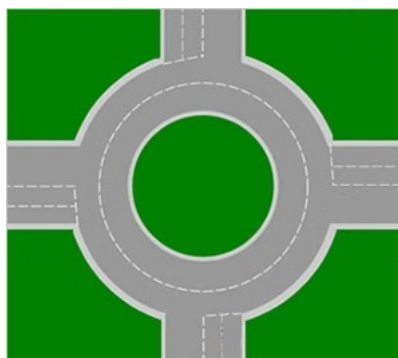

Figure 3.1: Roundabout configuration
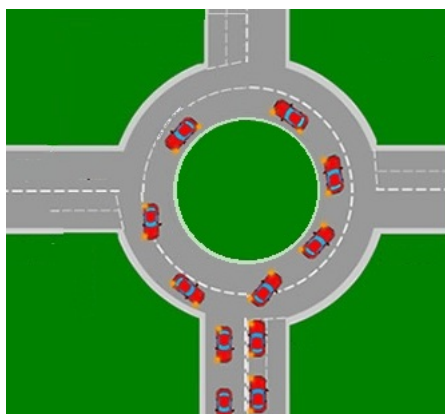

Figure 3.2: U turn in a roundabout

3.2 Yaw rate profile

The yaw rate is a measurement of an angular velocity of rotation in other words it measures the change in the heading angle. Some manoeuvres have a unique yaw rate profile that

can be clearly identified by looking at the display of the yaw rate data. It is this unique yaw rate profile that will be the basis of the labelling method developed in this project.

3.2.1 Yaw rate profile in a roundabout

In a roundabout the vehicle performs a circular movement around a circular object. This movement creates a change in the heading angle that can be measured using the yaw rate. Each of the different manoeuvres presented has a distinct yaw rate profile. Figures 3.3 to 3.5 show some of those manoeuvres and their respective general yaw rate profiles.
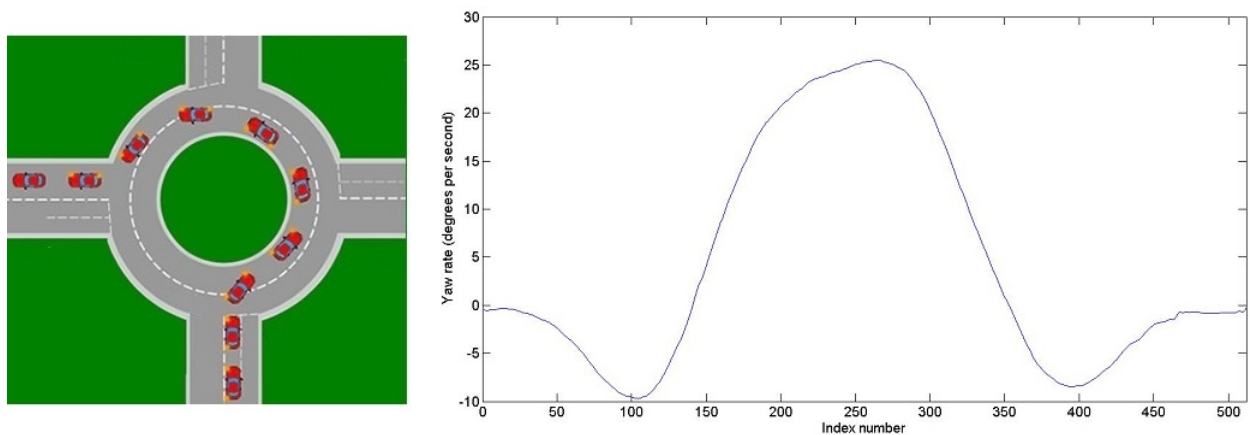
Figure 3.3: Turning left in a roundabout with the general yaw rate profile (factor 512)
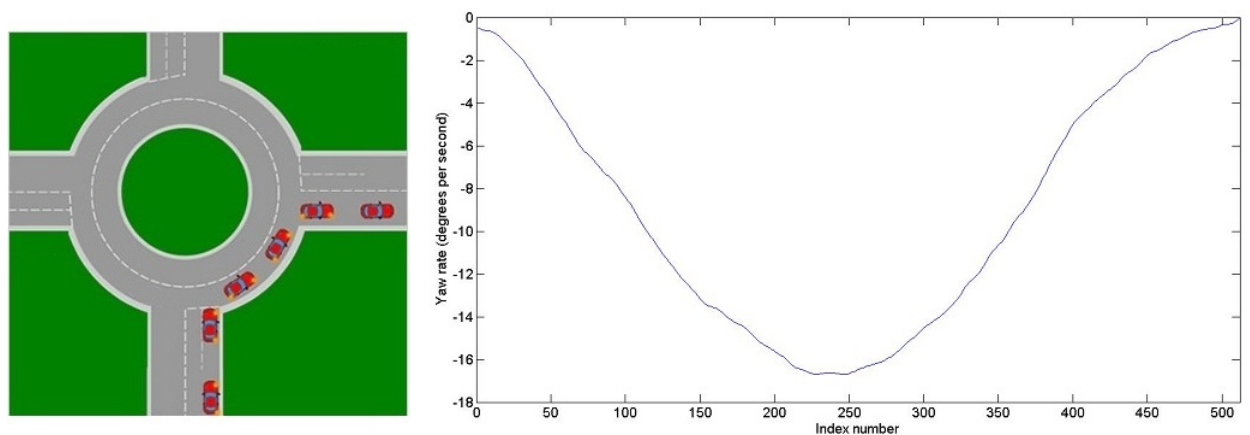
Figure 3.4: Turning right in a roundabout with the general yaw rate profile (factor 512)

3.3 Collecting instances of the roundabout manoeuvres

For the development and evaluation of the method we want to build here, two data sets are needed. One for creating the yaw rate profile and another one for the evaluation. These two data sets have to be independent from each other. In this work we chose the manoeuvres that are executed in roundabouts. The following steps were performed in order to create those two data sets:

- Gather GPS coordinates of roundabouts in the area of Gothenburg from the Open-StreetMap

Figure 3.5: Straight in a roundabout with the general yaw rate profile

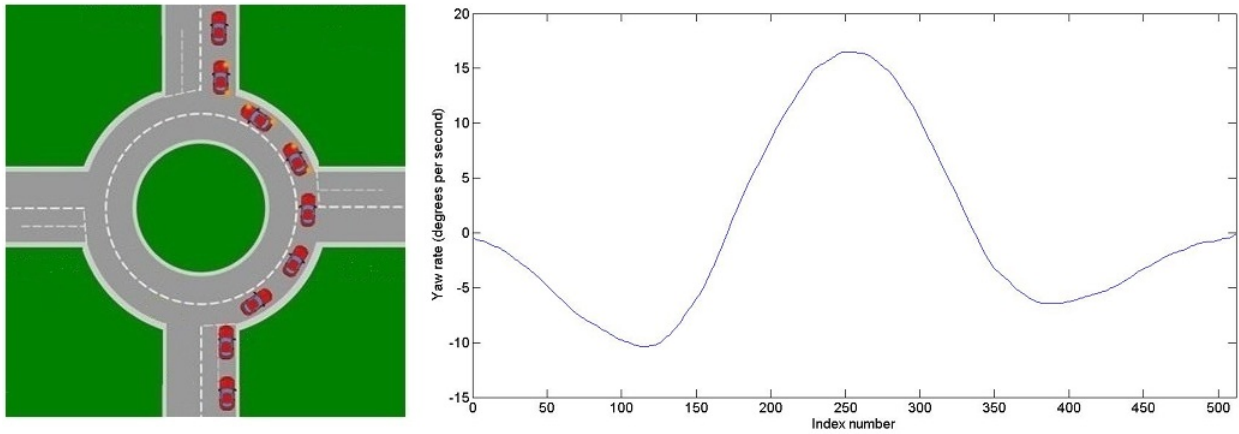- Find the segments of trips that pass these roundabouts

- Process the trips from the previous step

The process of gathering GPS coordinates is explained in Appendix C. With this information we created two files with the GPS coordinates (one for the latitudes and the other for the longitudes) of the roundabouts, matching row by row for each instance, which was used for finding segments of trips that pass through or nearby those coordinates. Figure 3.6 shows the localization of some roundabouts in the area of Gothenburg gathered from the OSM and displayed using the map display developed and explained in Appendix D.
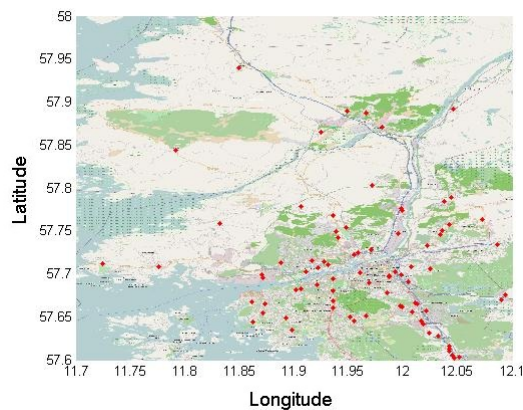
Figure 3.6: Roundabouts localization

One of the data accessed in the euroFOT database is the GPS coordinates of the trips. With both the GPS localization of the vehicle and the roundabouts a method was developed to find the segments of the trips where vehicles were driven near or inside the roundabouts. For this we created a box area around every roundabout to act as a trigger for the data collection. In appendix B a program developed (inspired by distributed system) is described which was implemented in this step of the creation of the data sets. Figure 3.7 shows a plot of the GPS coordinates of some of the trips found with the method above. Each blue line represents a trip segment found in the database.

Figure 3.7: Triggered trips

After finding the segments of the trips near or inside the roundabouts these segments of the trips were processed individually using the following steps:

- Classify each segment as being part of a roundabout manoeuvre or not

- Classify the roundabout manoeuvre into the turning left, turning right or going straight

- For each manoeuvre in a roundabout select the start and end of the manoeuvre

Even though a small box is chosen around each roundabout there were in fact trip segments that are found that did not belong to a roundabout manoeuvre so each individual segment found was observed using the video data and trip segments were analysed and classified as belonging or not to a roundabout manoeuvre. For each roundabout manoeuver analysed (left turn, right turn and going straight) 150 instances were obtained for each of these manoeuvres from several roundabouts, of these 100 were used for the creation of a yaw rate profile and the other 50 for the validation. For the negative part of the validation set there are 175 different instances composed of a mix of manoeuvres such as curves, turns and roundabout manoeuvres.

After the classification we treat each individual segment and define in a consistent way the start and end of the manoeuvre. This proved to be more complicated than initially thought since defining the start and end of the manoeuvre is very subjective. One can define it in various ways: the moment when the vehicle enters the roundabout, the moment when the car slows down when approaching the roundabout, threshold of the yaw rate. A decision had to be made concerning this issue so we decided to define the start of the manoeuvre 0.1 seconds before the vehicle enters the roundabout (indicated by a rapid change in the yaw rate). The same 0.1 seconds after the vehicle exits of the roundabout was used to define the end of the manoeuvre. Figure 3.8 shows an example of a manoeuvre executed in a roundabout where the selection of the start and end of the manoeuvre is showed.
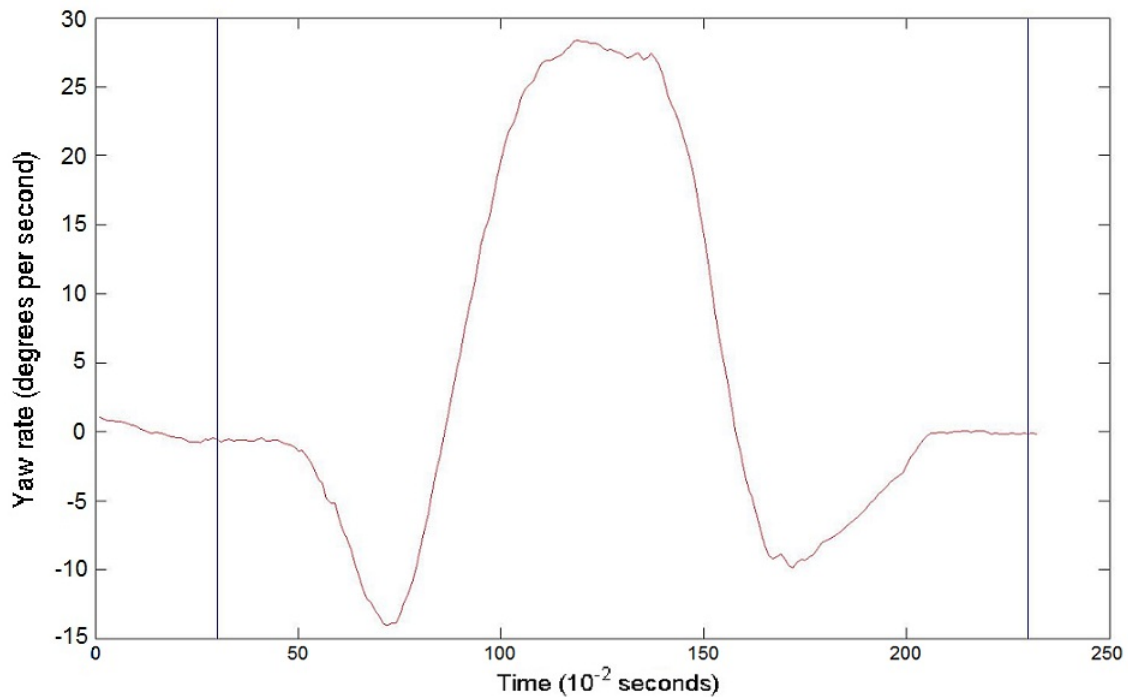
Figure 3.8: Example of a yaw rate profile of an instance with the selection of the start and end of the manoeuvre

3.4 Method explanation

This section describes a method developed for labelling manoeuvres in roundabouts. The method developed here uses yaw rate data to classify if a segment of a trip belongs to a given manoeuvre or not. In Section 3.3 we have described a method to obtain the positive instances of the roundabout manoeuvres. This method yields a number of instances which have different characteristics (different speed, different amount of traffic,...). So even though we are dealing with the same manoeuvre the data between trips are slightly different in terms of time and yaw rate profile. Figures 3.9 and 3.10 show two different yaw rate data of the same manoeuvre. We can see that the yaw rate profile on both instances have a rather similar shape.

This similar yaw rate profile is the base of the method developed here for the labelling of manoeuvres. Before the actual method can be applied we need to pre-process the positive instances in a systematic way. This pre-processing aims for the transformation of the data into a time and space invariant representation of the manoeuvre, i.e., each instance will be represented by a pre-defined vector size that is independent of the original size. We do this by re-sampling the yaw rate into a constant size vector of length 512. The re-sample function used was the one found in the Matlab library that uses a polyphase filter implementation[17]. The vector size was chosen because it was bigger than the instances found in the training set as well as being a power of 2. A size of 256 was tried and the results were the same as using a 512 vector size. Figure 3.11 shows two yaw rates profiles with different time length. Figure 3.12 shows the result of re-sampling the same two yaw rate profiles (shown in figure 3.11) to the same length.

The next step is to build a general profile out of the 100 instances of the same type of manoeuvre, this is done by averaging the yaw rate data of the re-sampled instances in each vector index. Figures 3.3 to 3.5 shows the profile of some manoeuvres executed in a roundabout obtained by the averaging process.
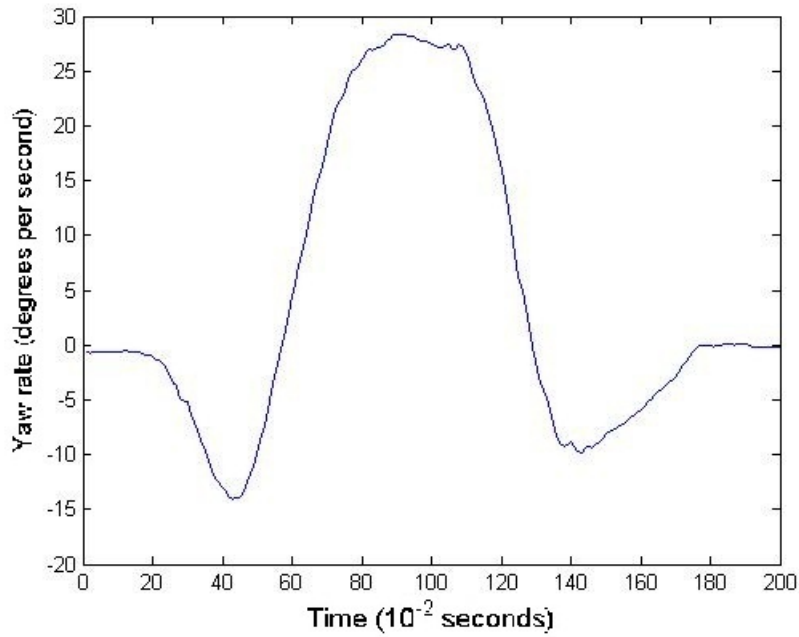
Figure 3.9: Example a yaw rate profile of an instance corresponding to a left manoeuvre
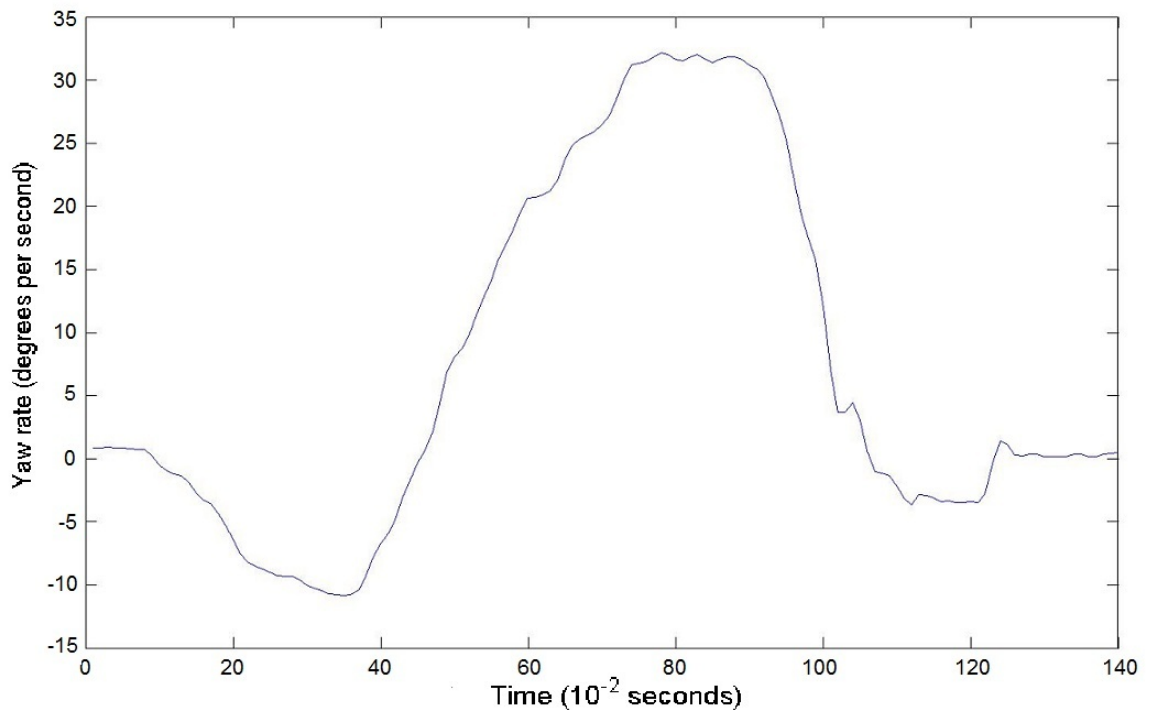
Figure 3.10: Example of another yaw rate profile of an instance corresponding to a left manoeuvre

Having this yaw rate profile of a manoeuvre we can now compare it with a yaw rate data of an unknown trip segment and determine how close the yaw rate data of that trip segment is to the profile. The way that is chosen to judge this similarity was by calculating the Pearson product-moment coefficient, which is a parameter that measures the correlation between two variables. It is calculated as follows:

$$\rho_{x,y} = \frac{cov(X,Y)}{\sigma_x \sigma_y},$$
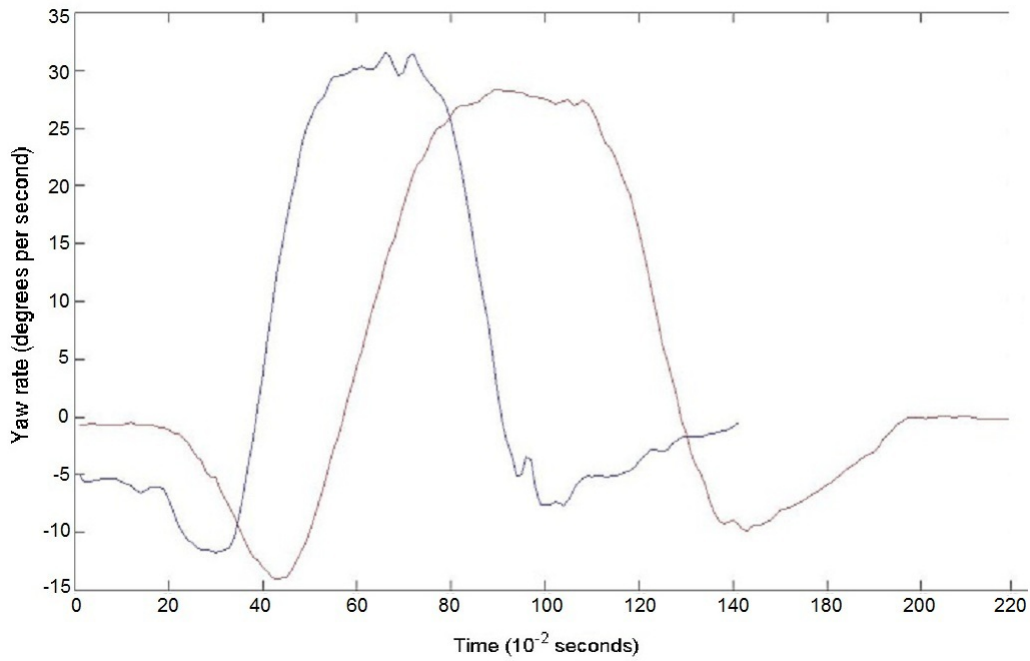
Figure 3.11: Example of the two yaw rate profiles instances
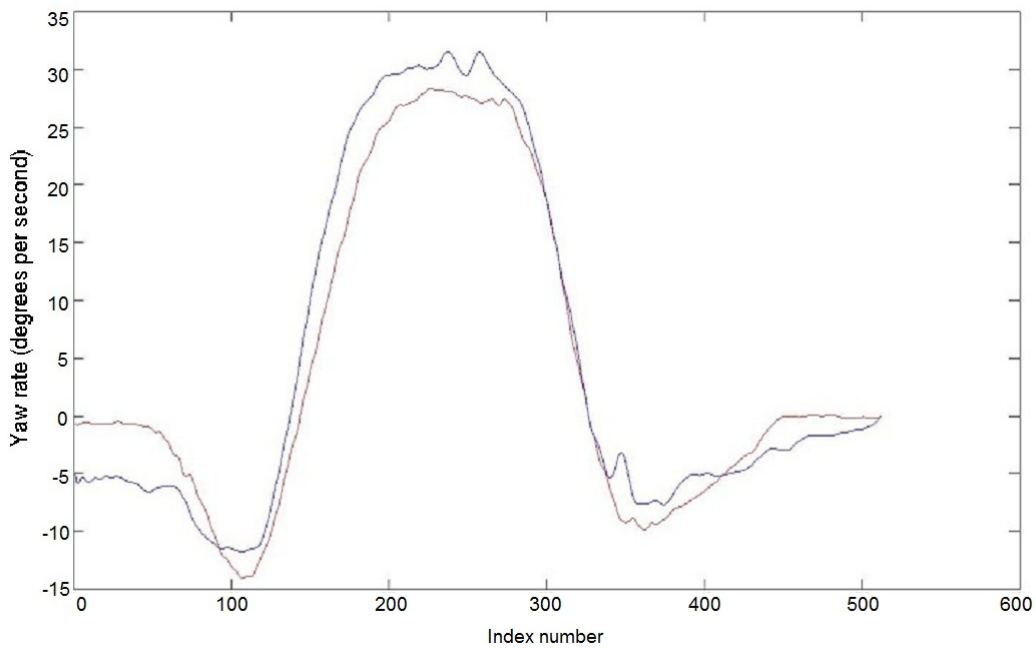
Figure 3.12: Example of the two yaw rate profiles instances re-sampled into a 512 vector

where cov is the covariance of the two variables and σ the standard deviation.

This parameter takes values between [-1,1] and the closest to one or minus 1 the more linearly correlated the variables are.

The Pearson correlation can be used as a cut-off parameter in order to determine if a manoeuvre belongs to a given class or not. Depending on the aim of the application we can tune this parameter to fit our purposes for example, to get a very accurate results with minimum error or to give us less accuracy but the inclusion of more positive instances.

This will be further discussed in Section 5.

The following steps are then used to process each trip segment:

- Define a maximum and minimum cumulative yaw rate integral for the manoeuvre being analysed

- Build a cumulative yaw rate vector

- Build a cumulative yaw rate matrix from the cumulative yaw rate vector

- Eliminate instances from the matrix that lies outside the lower and upper boundary defined

- Re-sample the instances

- Calculate the Pearson parameter

We will perform each step of the process with a small example. By integrating the yaw rate one can get the change (in degree) that the vehicle performed. The manoeuvres analysed in this project have a predictable degree change, for example the left turn in a roundabout has a change of around 270 degrees around the centre of the roundabout while the right turn in a roundabout has a change of around 90 degree. We choose to limit the range of left turns to 270 ± 50 degrees, 90 ± 50 degrees for right turns and 0 ± 20 degrees for straight manoeuvres. Figure 3.13 shows a made up example of a general profile. This profile has the following values as well as the sum of all index values:
a = [0 1 2 3 4 5 4 3 2 1 0 -1 -2 -3 -4 -5 -4 -3 -2 -1 0]

$$\sum_{i=1}^{21} a_i = 0$$

We define the maximum and minimum cumulative yaw rate for this example to be 1 and -1 respectively.
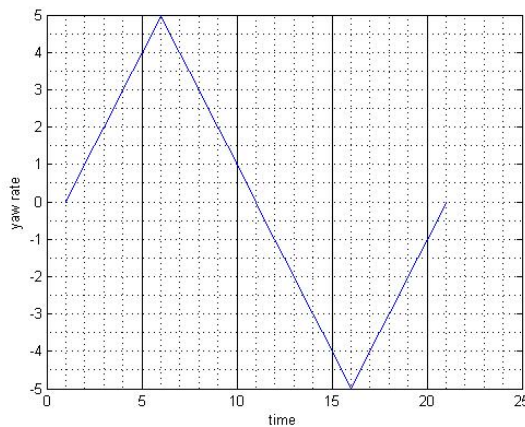

Figure 3.13: Example of general yaw rate profile

Figure 3.14 shows an example of an instance of yaw rate vector that is going to be used to apply the method described. The following vector corresponds to the values at each time instance of this instance:
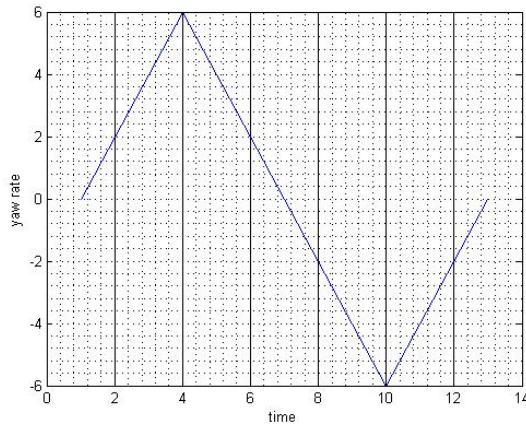b = [0 2 4 6 4 2 0 -2 -4 -6 -4 -2 0]

Figure 3.14: Example of an instance of yaw rate

A cumulative yaw rate vector is calculated, of the same size as the trip segment, in which each index corresponds to the discrete summation of each index of the yaw rate from the beginning until the corresponding index.

$cumulative\_yaw\_rate\_vector(i) = \sum_{k=1}^{i} yaw\_rate(k)$

The cumulative yaw rate vector for the example is the following:

$cumulative\_yaw\_rate\_vector\_b = [\ 0\ 2\ 6\ 12\ 16\ 18\ 18\ 16\ 12\ 6\ 2\ 0\ 0]$

A cumulative yaw rate matrix is then calculated where the position (x,y) of this matrix represents the difference of the cumulative yaw rate vector on the index x and y. We set a step of 0.1 seconds between each instance calculated. The number of columns and rows of this matrix is the same as the length of the trip segment.

$cumulative\_yaw\_rate\_matrix(x, y) = cumulative\_yaw\_rate\_vector(y) - cumulative\_yaw\_rate\_vector(x)$

This matrix is antisymmetric, that is:

$cumulative\_yaw\_rate\_matrix(x, y) = -cumulative\_yaw\_rate\_matrix(y, x)$

Figure 3.15 shows the cumulative matrix calculated from the values of the yaw rate vector. Since the values of the lower diagonal are antisymmetric to the upper values these are not calculated.

NaN	2	6	12	16	18	18	16	12	6	2	0	0
NaN	NaN	4	10	14	16	16	14	10	4	0	-2	-2
NaN	NaN	NaN	6	10	12	12	10	6	0	-4	-6	-6
NaN	NaN	NaN	NaN	4	6	6	4	0	-6	-10	-12	-12
NaN	NaN	NaN	NaN	NaN	2	2	0	-4	-10	-14	-16	-16
NaN	NaN	NaN	NaN	NaN	NaN	0	-2	-6	-12	-16	-18	-18
NaN	NaN	NaN	NaN	NaN	NaN	NaN	-2	-6	-12	-16	-18	-18
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-4	-10	-14	-16	-16
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-6	-10	-12	-12
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-4	-6	-6
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-2	-2
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Figure 3.15: Cumulative matrix

The next step is to eliminate the instances of the cumulative yaw rate matrix that have values outside the yaw rate integral defined according to the manoeuvre being labelled.

For example, for a left manoeuvre, if integral of the yaw rate lies outside the 270 ± 50 degrees the instance is eliminated.

For the example presented we will eliminate the instances of the matrix that lies outside the interval $[-1, 1]$. Figure 3.16 shows the resulting matrix after the elimination of the instances. The instances highlighted with a red circle will be further analysed on the next steps.

Figure 3.16: Eliminated instances on the cumulative matrix

After this elimination the yaw rate data of the trip segments on the cumulative yaw rate matrix are re-sampled to a 512 size which corresponds to the same size of the general profile calculated. The Pearson correlation parameter is calculated between the trip segment and the general yaw rate profile of the type of the manoeuvre being labelled.

The instances highlighted will be re-sampled to the same size as the general profile, in this case the vector size is 21. Figures 3.17 shows the instances before the re-sampling while figure 3.18 shows the re-sampled version of these instances.
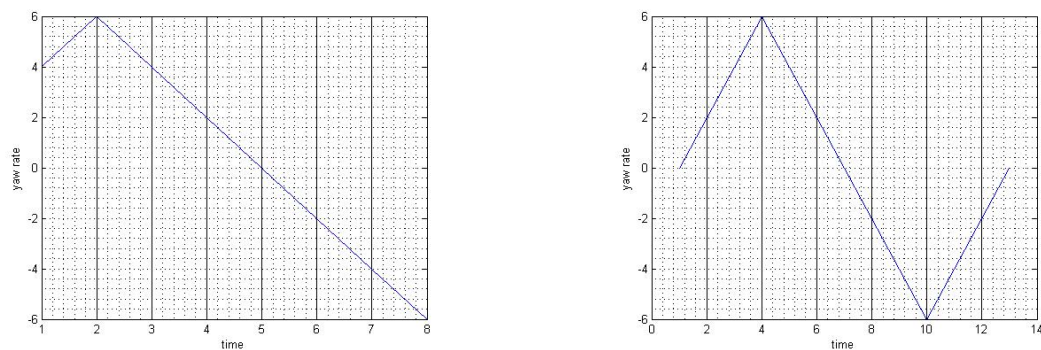
Figure 3.17: Yaw rate vector instances

The calculation of the Pearson correlation parameter is then calculated for these two instances which yields 0.84 for the first example and 0.98 for the second example.
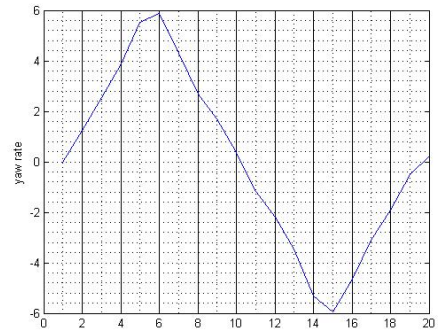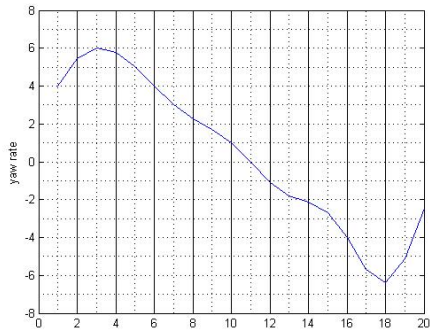
Figure 3.18: Yaw rate vector instances re-sampled

4 Roundabout identification

Roundabout identification have been a target of research in many papers [7, 2, 39, 21, 22]. Those papers used either aerial images [2, 39, 21, 22] or cameras installed in the car [7] in order to detect road junctions. The method described in this report can be used to identify roundabout using sensors instead of video images. In Chapter 3 a method for labelling manoeuvres was presented; this method can be slightly modified for the purpose of identifying roundabouts.

In the method for manoeuvres labelling we have the Pearson correlation parameter that can act as a cut-off parameter for classifying a given instance as belonging to a specific manoeuvre or not. A decision had to be made concerning the choice of this cut-off parameter for the purpose of identifying roundabouts so we decided to fix the parameter so the sensitivity would be 85%. From the validation set we get the value of the cut-off parameter.

The steps for the roundabout identification are the following:

- Run the method of the manoeuvres detection in the database with a selected cut-off parameter

- Collect GPS information

The first step of this method give us the start and end indexes of the segment trips that are found by the labelling method. With this information we can get the GPS coordinates of these segments and average the start and end positions in order to get a single GPS coordinate for each segment. An assumption was made regarding the maximum time to perform the manoeuvre which was set to be 5 seconds. Figure 4.1 shows the plot of several GPS coordinates of segments instances obtained without clustering them.
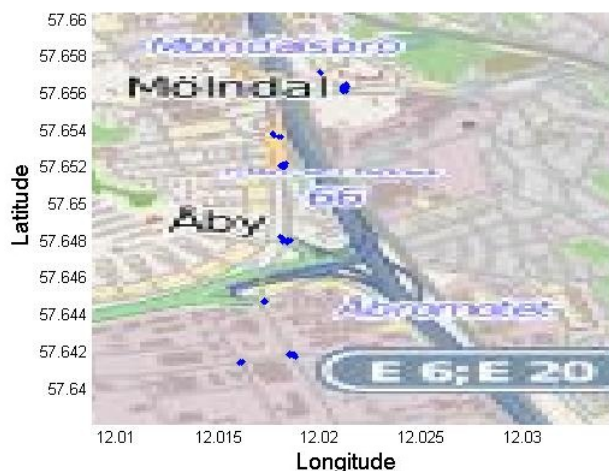
Figure 4.1: Small map area with instances of road structures

5 Results

5.1 Specificity and Sensitivity

When doing a binary classification we have four possible classifications: True Positives(TP), False Positives(FP), False Negatives(FN), True Negatives(TN). Table 5.1 shows the binary classification table.

		Actual Value	
		Positive	Negative
Prediction	Positive	TP	FP
	Negative	FN	TN

Table 5.1: Table of binary classification

From this four classifications the definition of sensitivity is as follows: $\frac{TruePositives}{TruePositives+FalseNegatives}$ and specificity: $\frac{TrueNegatives}{FalsePositives+TrueNegatives}$ Ideally we want those parameters to be as close to 1 as possible. Adjusting the parameters of the algorithm we have a compromise between TP and FN.

5.2 Receiver Operating Characteristic curves

The Receiver Operating Characteristic curves is a graphical representation for evaluating the performance of a given system. On the Y-Axis we have the Sensitivity (True Positive Rate) while on the X-Axis we have 1 - Specificity (False Positive Rate). Each point in this graph represents a different cut-off value. To evaluate the performance of the method we used the Area Under the Curve (AUC) which is a performance measure. It was chosen for its intuitive result interpretation as well as for the fact that it gives the overall performance of the method on all cut-off values. As a guide Hosmer and Lemeshow[11] suggest the following values to evaluate the method:

- .90-1 = outstanding discrimination

- .80-.90 = excellent discrimination

- .70-.80 = acceptable discrimination

- .50-.70 = poor discrimination

Figure 5.1 shows the representation of some ROC curves.

In the algorithm presented we have a parameter (correlation) that gives us information about how similar is the manoeuvre being analysed compared to the yaw rate profile built. Changing the threshold of this parameters yields different specificity and sensitivity which can be seen on the ROC plots.

5.3 Manoeuvres labelling

In this section we will present the results for the classification of roundabout manoeuvres. For validation purposes the negative instances of the validation set is composed of turns, curves, roundabout manoeuvres and straight driving. Furthermore we set the proportion
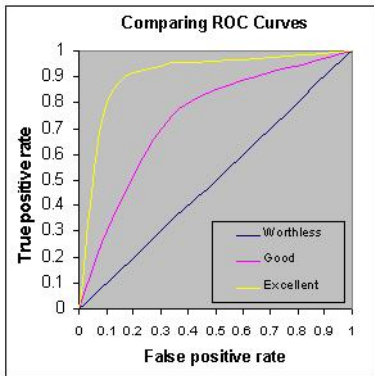
Figure 5.1: The Area Under an ROC curve. Picture originally from [30]

of roundabout manoeuvres to be around $\frac{1}{3}$ of the negative part of the validation set. We will present the ROC curves for each manoeuvre for the data set that was used to create the yaw rate profile as well as for the validation set.

5.3.1 Left manoeuvre in a roundabout

The data set for creating the yaw rate profile is composed of 100 instances and the validation set is composed of 50 positive instances and 175 negative instances. The positive instances consists of left manoeuvres in several roundabouts under different traffic conditions, different speeds and with variable length of time.

Figure 5.2 shows the ROC for the validation set.
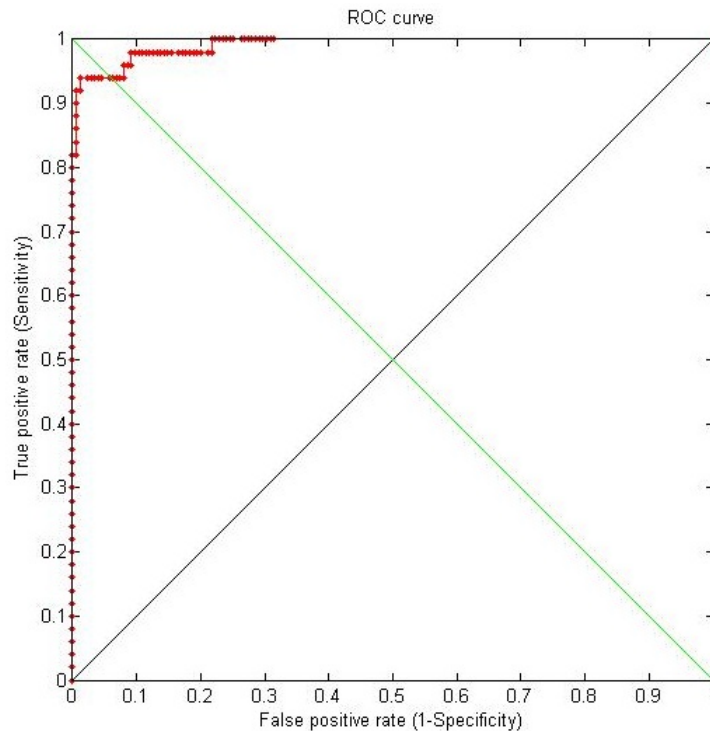
Figure 5.2: ROC curve of the validation set of the left manoeuvre in a roundabout

The AUC is 0.99143 with a confidence level of 95% in the interval [0.9733 1].

5.3.2 Right manoeuvre in a roundabout

The data set for creating the yaw rate profile is composed of 100 instances and the validation set is composed of 50 positive instances and 175 negative instances. The positive instances consists of right manoeuvres in several roundabouts under different traffic conditions, different speeds and with variable time.

Figure 5.3 shows the ROC for the validation set.
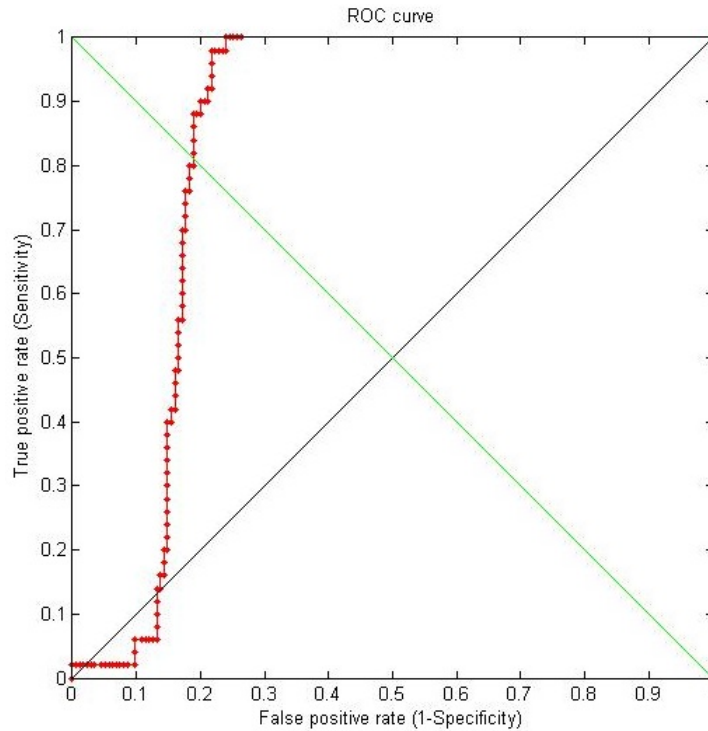
Figure 5.3: ROC curve of the validation set of the right manoeuvre in a roundabout

The AUC is 0.83840 with a confidence level of 95% in the interval [0.76639 0.91041].

5.3.3 Going straight in a roundabout

The data set for creating the yaw rate profile is composed of 100 instances and the validation set is composed of 50 positive instances and 175 negative instances. The positive instances consists of going straight in several roundabouts under different traffic conditions, different speeds and with variable time.

Figure 5.4 shows the ROC for the validation set.

The AUC is 0.95851 with a confidence level of 95% in the interval [0.91929 0.99773].

5.4 Roundabout identification

For the roundabout identification we used the part of the available database in order to identify roundabouts. We choose the going straight in a roundabout due to it's high AUC. A decision of the value of the cut-off had to be chosen for the purpose of identifying roundabouts. The point chosen had a specificity of 85%. The result of this method will be expressed in a positive prediction value (PPV) defined as:
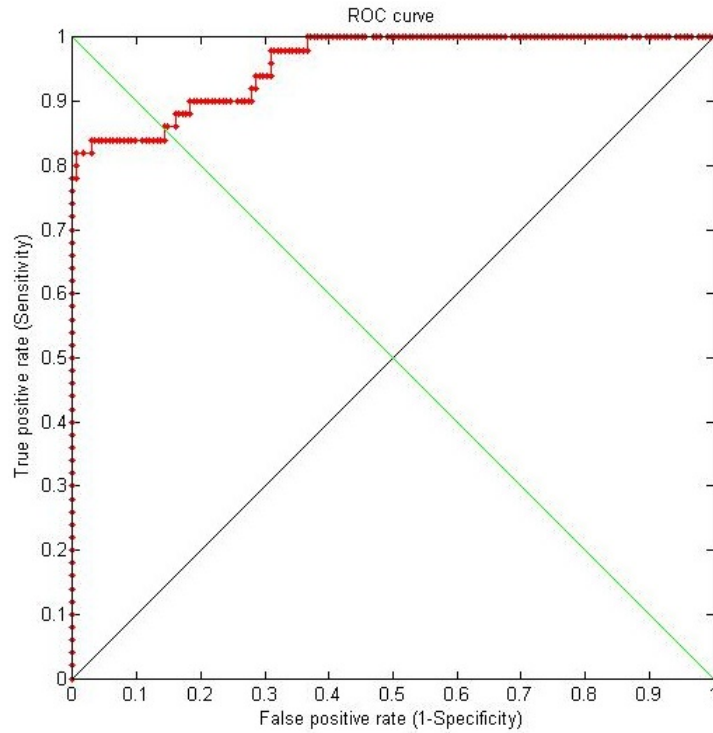
Figure 5.4: ROC curve of the validation set of the front manoeuvre in a roundabout

$$PPV = \frac{TruePositives}{TruePositives + FalsePositives}$$

Running the method on part of the euroFOT database we obtained a total number of 4759 instances detected by the method from which 4165 were positive, i.e., these instances correspond to actual localization of roundabouts. This result yields a PPV of 87.5%.

6 Future Work

In this project we developed a method for labelling roundabout manoeuvres as well as identifying roundabout localization. On the course of doing this work a programme, inspired by distributed system was developed as well as an off-line map display. In those two systems there is room for improvement which was not necessary for the scope of this thesis.

6.1 Program inspired by Distributed System

The program developed has room for some improvements. As it is now the system does not automatically recover from a crash meaning that the crashed batch has to be manually executed. The batch size of the file system is not done evenly according to the trip length but rather by the number of trips. This implies that some batches contains long trips and others very short trips. The user interface can be further developed to show an estimate of the time for the full processing as well as other kind of statistics useful for the user.

6.2 Map Display

The images for the map display only contain files with the same zoom level which for displaying large areas is an issue. This can be overcome by having different databases for different zoom levels. Another approach for the displaying task can be by extracting the images from the OpenStreetMap directly. The drawback of this approach would be the necessary internet connection that had to be available.

6.3 Manoeuvres

In this project the manoeuvres analysed were composed of roundabout manoeuvres. The method developed could be extended in order to identify other manoeuvres such turns and following curves as well as the use of other signals besides the yaw rate.

6.4 Road Structures

Similar to the manoeuvres we can extend the method to find roundabouts to be able to find other road structures such as intersections, curves, exits on highways, etc.

7 Conclusions and discussions

The basics of the method developed in this thesis were the use of a single signal, i.e., the yaw rate, and the use of the correlation coefficient. With this we managed to develop a method for manoeuvres identification. The method consists of building a yaw rate profile for each manoeuvre and then find the correlation between this profile and the segment trip that is being analysed. We have to note that some of the negative instances of the data sets do not pass through the first stage of the method, i.e., the yaw rate integration is not in the set range of the manoeuvre being tested. In the case where a whole trip would be fed to the method the number of false positives would be very small compared to the number of true negatives. The reason for this lies in the way the method works when given a trip or a segment of a trip. The algorithm will split the trip or segment trip into various lengths and different starting and end points yielding a vast number of different segments from the original one which are then individually evaluated.

In the papers analysed the methods described always assume that either a segment of a trip is selected or that the segment feed to the system will always be one of the manoeuvres trained by the method. In the method developed the trip segment being analysed does not have belong to one of the manoeuvres being classified as well as the segment does not have to only contain the manoeuvre. This means that the method is robust enough to be able to find the specific manoeuvre given a larger size of a trip.

The method developed in this project is very simple and the results showed potential and there is the potential of applying the method in a large database where a the manual classification would be very difficult.

Regarding the roundabout identification we notice a relatively high positive prediction value (87.5%) for the roundabout identification. Some of the localizations regarded as roundabouts are in fact road constructions that mimic part of an actual roundabouts which yield several false positive instances.

Some of the problems encounter with the method developed here was the similarity of some manoeuvres since they have a similar yaw rate profile giving a high correlation value. We think that even with the use of more signals to try to differentiate the manoeuvres would not give better results due to the fact that the cars' behaviour is rather identical. Another issue is the computational issue when dealing with large segments of trips. Since the method developed here splits the original segment into several segments and each one of them is individually tested this yields a large number of computational operations.

To do a fair comparison between methods the same evaluation scheme should be used. The method developed in this project can classify each trip segment in a binary form, whether it belongs to a specific manoeuvre or not by setting a threshold. Since we have control of the threshold parameter we can decide the balance between sensitivity and specificity yielding different results. Due to the difference of methods a direct comparison of the results from the method developed here and the results from the papers reviewed is not possible. Regarding the AUC of the ROC plots of the manoeuvres we find that the range of this result is between 0.8 and 0.9 corresponding to an excellent discrimination. Further on we notice that in the papers analysed we find a large set of signals used such as: average speed, average lateral acceleration, average longitudinal acceleration, lateral acceleration slope, longitudinal acceleration slope, among other whereas in our case we only use a single signal, the yaw rate.

Regarding the roundabout identification the method developed here obtained a high positive prediction value (87.5%). Considering a rather simple method used here, our results showed that the method could perform rather well.

The work done in this project aimed for the development of a new method of labelling

manoeuvres and roundabout identification which was achieved with fairly good results.

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A   Data description

This project relies on the availability of data in order to construct methods for the automatic labelling of roundabout manoeuvres. The data for this project comes from a Field Operational Test(FOT) as well as from the OpenStreetMap [25]. It will be mainly the combination of the data acquired from both the FOT and OpenStreetMap that will be used to develop a method to label manoeuvres as well as the identify roundabouts.

A.1   Field Operation Test

According to FESTA handbook a FOT is defined as: "A study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi-experimental methods." [9]. Figure A.1 gives the generic steps taken for conducting a FOT.
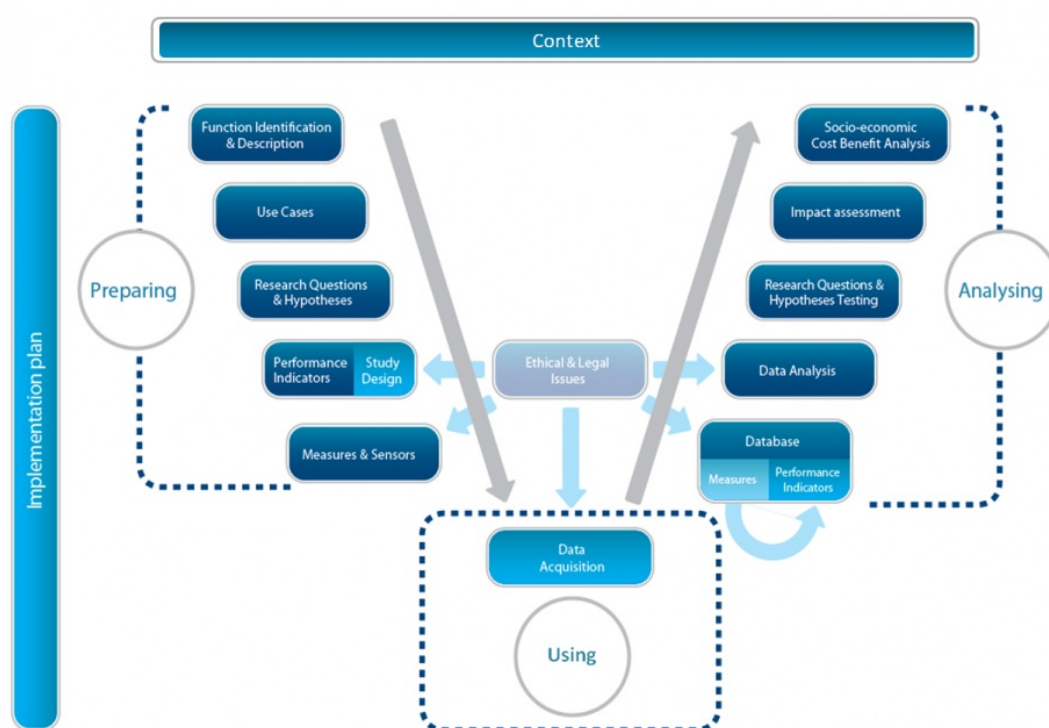
Figure A.1: The steps that typically have to be considered when conducting an FOT. The large arrows indicate the time line. Adapted by euroFOT project from the FESTA handbook.

FOT have been executed in several countries such as Japan, USA as well as in Europe either nationally or regionally.

Besides the use of the FOT database some data was also collected and used from the OpenStreetMap.

A.1.1   EuroFOT

The database used for this project comes from the euroFOT[8] project, more specifically the Volvo cars data of euroFOT. This research project, involving 28 partner-organisations, is the first large-scale European field operational test on active safety systems.

There are various signals that can be accessed in the database. In this project we will focus mainly on following data: GPS position, yaw rate, video recordings and speed.

A.2 OpenStreetMap project

The OpenStreetMap project[25] is an open source service that provides information and data concerning geographic data such as road map information, localization of ATMs, banks, roundabouts and public places.

On the website of the OpenStreetMap there is the possibility of exporting an XML file of a given area of the map containing information of the GPS coordinates, user id, different node tags, timestamps, etc. Besides the XML file we can also download the map image on JPEG format. For an example of part of an XML as well as the corresponding image see appendix C.

B   Program (inspired by Distributed System)

Dealing with massive amount of data generally means massive amount of computation. To overcome this problem either we restrict ourself to a small portion of the data or we have to design a system that can handle the amount of data available such as a distributed system. To be able to apply a distributed system to a problem there are some requirements that are needed to be fulfilled:

- The problem can be divided into sub-problems

- Access to shared memory

- Fault tolerance

The first requirement can be seen as the most important issue arising from the possibility to implement a distributed system. The task must have a decomposing property, this means that a sub set of the problem can be solved that is not dependent on the results of other problems. The achievement of the final solution is independent of the order in which the sub-problems are solved. For the system to work there has to be a shared memory accessible by the systems involved in the distributed system in order to be able to coordinate the problem solving task. In case of part of the system fails the distributed system has to be able to recover from the failure without affecting the final solution.

B.1   Program implementation

The program was implemented on five of the department computers with the objective of making the process of collecting specific data from the entire database faster. For the development of this program, Matlab scripts and GUI were created. One of the requirements for the system to work is access to a shared memory zone for the purpose of coordination of all of the elements. In the computers used the local network access is blocked so a direct communication between the elements of the system was not possible such as seen in the Figure B.1. To overcome this issue the use of common folders, accessed by all the elements of the system, was chosen as a communication platform (Figure B.2).
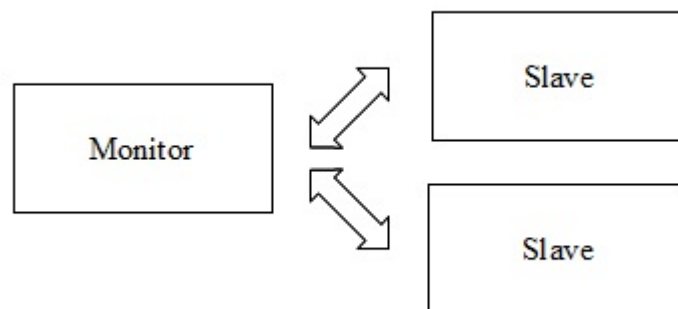
Figure B.1: Monitor/Slaves direct communication

The euroFOT data available for this project consists of many independent trips which are organized into folders. By getting the directory list of the database we can then divide it into batches which enables us to divide our problem into smaller ones. This assumes that the problem in hand is trip independent and the solution of a trip is not needed as an input for another trip.
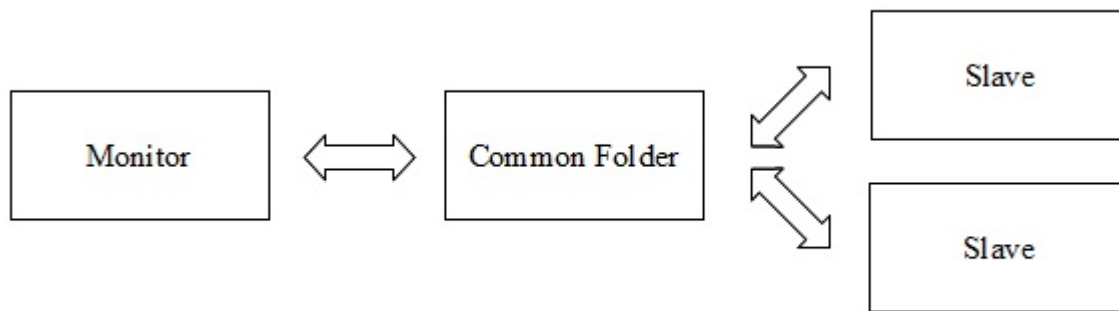
Figure B.2: Monitor/Slaves communication with common folder

For the coordination of the system a monitor was developed which assigns individual batches to specific computers. Besides the assignment of batches to the computers the monitor is responsible for keeping track of the batches that have been processed and the ones that still need to be processed.

B.2 Analysis, problems and further work

For the use of this system the algorithm developed has to be constructed in a way that is only batch dependent which in some applications it might not be possible. The requirement of fault tolerance was not fully fulfilled. At the stage where this report was written in the case of one of the computers crash the results of the associated batch are lost. Typically the main reason for failure was a Matlab crash due to lack of memory. The program can be further improved to accommodate those failures and minimize the overhead introduced when assigning individual batches to the computers.

C   Information extraction from the OpenStreetMap

Like mention before the OpenStreetMap (OSM) provides a lot of information that can be extracted using different methods depending on the type of data that we want. In this section the extraction and handling of specific information and data from the OSM will be explained.

C.1   The XML file

The XML(eXtensible Markup Language) files obtained have many different tags such as: highway, junction, public_transport, amenity, cycleway, etc. On all of the tags (key) there are subtags (values) associated with them. Table C.1 shows some of the tags and subtags that can be found in the XML files of OSM [24].

Key	Value
highway	motorway
highway	service
junction	roundabout
public_transport	platform
amenity	car_rental
amenity	fuel
cycleway	lane
cycleway	shared_lane

Table C.1: Map Features

C.2   Xapi

Besides the standard OpenStreetMap website there is an extended API (Application Programming Interface) called Xapi [40]. In the Xapi wikipedia page [41] we can find the following definition: "The OSM Extended API (or xapi, pronounced zappy) is a read-only API, based on a modified version of the standard API, that provides enhanced search and querying capabilities."

This API enables us to query the OpenStreetMap for specific data such as the GPS coordinates of roundabouts, hotels, bus stops, specific highways, etc. To make a query to the database there are two ways: either a manual selection of the type of data and area using the Xapi webpage [40] or by constructing a custom made URL. To construct the URL there are 3 elements that we need to define: type, tag and bbox. The element type can take three different values: way, node and relation; the tag element is formed by a key and a value like the ones shown on Table C.1; the bbox corresponds to the area where we want the information to be obtained.
Example:
http://open.mapquestapi.com/xapi/api/0.6/way[public_transport=platform][bbox=11.9722,57.70,12.00,57.71]
The example above gets the information about the public transport platforms in the limiting area of latitude [57.70, 57.71] and longitude [11.9722,12.00]. Figure C.1 shows the reply from the server.

```
<osm version="0.6" generator="Osmosis SNAPSHOT-r26564">
<bound box="57.70000,11.97220,57.71000,12.00000" origin="Osmosis SNAPSHOT-
r26564"/>
<node id="1309380155" version="3" timestamp="2011-11-27T14:02:19Z" uid="35601" use
r="magol" changeset="9967122" lat="57.709815" lon="11.9721202"/>
<node id="1309380193" version="2" timestamp="2011-06-02T18:51:09Z" uid="447982" us
er="D@niel" changeset="8323093" lat="57.7098544" lon="11.9723123"/>
<node id="1309380217" version="3" timestamp="2011-11-27T14:02:20Z" uid="35601" use
r="magol" changeset="9967122" lat="57.7097023" lon="11.9721901"/>
<node id="1309380255" version="2" timestamp="2011-06-02T18:51:09Z" uid="447982" us
er="D@niel" changeset="8323093" lat="57.7099032" lon="11.9722815"/>
<node id="1309380288" version="3" timestamp="2011-11-27T14:02:20Z" uid="35601" use
r="magol" changeset="9967122" lat="57.7098714" lon="11.9720852"/>
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r="magol" changeset="9967122" lat="57.7097597" lon="11.9721545"/>
<node id="1309380371" version="3" timestamp="2011-11-27T14:02:20Z" uid="35601" use
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<node id="1309380411" version="2" timestamp="2011-06-02T18:51:09Z" uid="447982" us
er="D@niel" changeset="8323093" lat="57.7097984" lon="11.9723473"/>
<node id="1309380425" version="2" timestamp="2011-06-02T18:51:09Z" uid="447982" us
er="D@niel" changeset="8323093" lat="57.7100189" lon="11.9722089"/>
<node id="1309380429" version="2" timestamp="2011-06-02T18:51:10Z" uid="447982" us
er="D@niel" changeset="8323093" lat="57.7099612" lon="11.9722453"/>
<way id="116023687" version="2" timestamp="2011-06-02T18:51:11Z" uid="447982" user="D@
niel" changeset="8323093">
<nd ref="1309380429"/>
<nd ref="1309380288"/>
<tag k="ref" v="24"/>
<tag k="public_transport" v="platform"/>
<tag k="highway" v="platform"/>
<tag k="operator" v="Västtrafik"/>
<tag k="covered" v="yes"/>
</way>
<way id="116023718" version="2" timestamp="2011-06-02T18:51:14Z" uid="447982" user
="D@niel" changeset="8323093">
<nd ref="1309380193"/>
<nd ref="1309380292"/>
<tag k="ref" v="22"/>
<tag k="public_transport" v="platform"/>
<tag k="highway" v="platform"/>
<tag k="operator" v="Västtrafik"/>
<tag k="covered" v="yes"/>
</way>
<way id="116023723" version="2" timestamp="2011-06-02T18:51:15Z" uid="447982" user
="D@niel" changeset="8323093">
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<nd ref="1309380371"/>
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<nd ref="1309380411"/>
<tag k="ref" v="21"/>
<tag k="public_transport" v="platform"/>
<tag k="highway" v="platform"/>
<tag k="operator" v="Västtrafik"/>
<tag k="covered" v="yes"/>
</way>
<way id="116023739" version="2" timestamp="2011-06-02T18:51:18Z" uid="447982" user
="D@niel" changeset="8323093">
```

Figure C.1: Xapi query reply

The Xapi allows the query to return a maximum of 10 000 000 elements or a maximum area of 100 square degrees. To overcome this restriction a Matlab[16] script was written

to automatise the process of gathering GPS coordinates in which we have a area box of 9 square degrees which is small enough to fulfil the restrictions of the Xapi query. The script written (see appendix F) was designed to obtain the GPS coordinates of roundabouts in the area of Sweden but it can be modified to obtain different information from different areas of interest. Figure C.2 shows an extraction of one of the obtained files.

Sheet1

```
<node id="767154323" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230709" lon="12.6401761"/>
<node id="767154324" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0231093" lon="12.6402128"/>
<node id="767154325" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0231502" lon="12.6402152"/>
<node id="767154326" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0231893" lon="12.6401828"/>
<node id="767154327" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0232293" lon="12.6400953"/>
<node id="767154328" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0232469" lon="12.6400037"/>
<node id="767154329" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0232488" lon="12.6398689"/>
<node id="767154330" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0232338" lon="12.6397745"/>
<node id="767154331" version="1" timestamp="2010-06-08T11:21:25Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0231974" lon="12.639682"/>
<node id="767154333" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0231595" lon="12.6396421"/>
<node id="767154335" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0231203" lon="12.639636"/>
<node id="767154336" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230807" lon="12.6396637"/>
<node id="767154337" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230473" lon="12.6397231"/>
<node id="767154338" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230288" lon="12.6397843"/>
<node id="767154339" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230153" lon="12.6398801"/>
<node id="767154340" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230144" lon="12.6399551"/>
<node id="767154341" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230255" lon="12.6400527"/>
<node id="767154342" version="1" timestamp="2010-06-08T11:21:26Z" uid="46971" user="Stefan Rothe" changeset="4936339" lat="66.0230495" lon="12.6401351"/>
<node id="836649884" version="2" timestamp="2010-09-02T14:22:48Z" uid="110639" user="aighes" changeset="5662723" lat="66.017915" lon="12.6321064"/>
<node id="836649887" version="2" timestamp="2010-09-02T14:23:13Z" uid="110639" user="aighes" changeset="5662723" lat="66.0179124" lon="12.6315806"/>
<node id="836649890" version="2" timestamp="2010-09-02T14:22:52Z" uid="110639" user="aighes" changeset="5662723" lat="66.0177541" lon="12.631906"/>
<node id="893013386" version="1" timestamp="2010-09-02T14:22:10Z" uid="110639" user="aighes" changeset="5662723" lat="66.0179651" lon="12.6320016"/>
<node id="893013478" version="1" timestamp="2010-09-02T14:22:15Z" uid="110639" user="aighes" changeset="5662723" lat="66.0177584" lon="12.6317468"/>
<node id="893013538" version="1" timestamp="2010-09-02T14:22:18Z" uid="110639" user="aighes" changeset="5662723" lat="66.0179663" lon="12.631693"/>
<node id="893013591" version="1" timestamp="2010-09-02T14:22:21Z" uid="110639" user="aighes" changeset="5662723" lat="66.017771" lon="12.6320038"/>
<node id="893013621" version="1" timestamp="2010-09-02T14:22:23Z" uid="110639" user="aighes" changeset="5662723" lat="66.0178531" lon="12.6321288"/>
<node id="893013649" version="1" timestamp="2010-09-02T14:22:24Z" uid="110639" user="aighes" changeset="5662723" lat="66.0178486" lon="12.6315625"/>
<way id="25155096" version="8" timestamp="2010-09-02T14:23:14Z" uid="110639" user="aighes" changeset="5662723">
```

Page 1

Figure C.2: Sample of XML file with roundabout localization

C.3   Processing of XML file

Making a query to the Xapi server yields a XML file that needs to be parsed if one wants to extract specific information from it (for example GPS coordinates). In the XML files of the queries of the elements such as roundabouts, fuel stations, parks, etc there are information that is not needed if the intention is to only get the GPS coordinates. There are XML parsers that can extract specific information but in this project the use of a spreadsheet was preferred because of its simplicity.

The Matlab script written (appendix F) yields multiple XML files that needs to be processed in order to get only the GPS coordinates. Even though a script could be developed to process all the files automatically and extract the GPS coordinates this was not done due to the small number of files needed to be processed. Instead the file was opened in a spreadsheet and the information rearranged into columns that allowed an easy extraction of the GPS coordinates. The information of the roundabouts extracted from the OSM contains multiple coordinates for the same roundabout which for the aim of this project was not needed so a reduction of information was made. The reason for this multiple GPS coordinate lies on the fact that the roundabout is represented as a collection of several road

segments. The reduction was made by averaging the GPS coordinates of each roundabout yielding a single coordinate. By doing this to the several roundabouts in the XML files obtained a list of latitudes and longitudes coordinates were obtained and two files were created one with latitudes and the other with longitudes, matching row by row for each instance.

D Map display

Beside allowing users to export data as XML files, OpenStreetMap also allows users to export map tiles. With this possibility we can build an offline database with the extraction of tiles of small size covering an area of interest.

D.1 Image format and scale

The OSM gives us the possibility of choosing the format of the image that we want to export (PNG, JPEG, SVG, PDF and Postscript) as well as the scale of the image (from a scale of 1:95000000 to 1:1) which correlates with the 18 different zoom levels which have different details of the map. Figure D.1 shows an area with the maximum zoom allowed by OSM while Figure D.2 shows an area with minimum zoom.

Figure D.1: Example of image with maximum zoom

D.2 Image database

When dealing with a massive amount of data, often one encounters the problem of storing the data, maintaining the data and accessing the data. When getting the images from the OpenStreetMap there is a limit area that one can extract if we want a high zoom. This means a massive amount of files are needed to be downloaded to make up the whole map. For the purpose of this project we decided to obtain the map images of the area around Gothenburg with a zoom level of 5 (out of 18, level 1 being the highest zoom possible). Since it is not possible to download a big area with the intended zoom a script had to be developed to automatise the extraction of the map tiles (see Appendix G).

One of the limitations encountered when trying to download a large amount of data continuously from OpenStreetMap is that the server often denies the request. A possible solution to overcome this was to introduce a pause in each loop of the script but this proved to be very inefficient. The solution adopted here to run the script until the server denied the request and restart the script from the last longitude obtained. Figure D.3 shows an example of one of the tiles extracted from the OSM database.
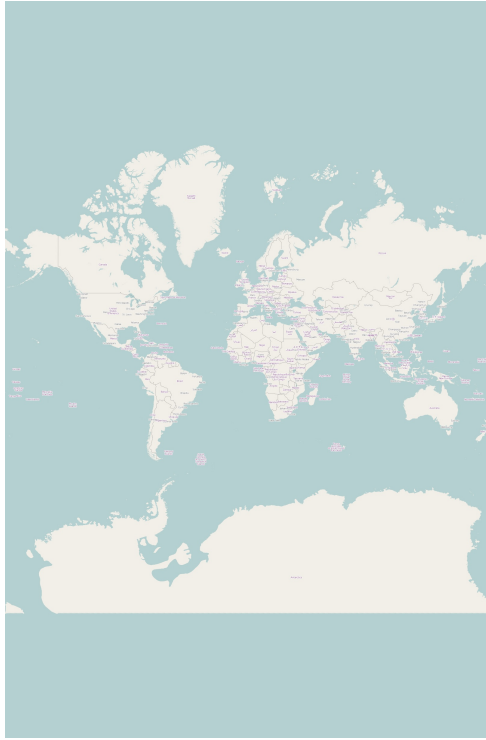
Figure D.2: Example of image with minimum zoom

D.3   Hashing the database

After downloading the images and naming the files as an aggregation of the GPS coordinates the next step was to organize the files (around 140 000 files) in an easy and fast way to be accessed. The naming of the files consists of GPS coordinates of the bottom left and upper right separated by a comma followed by the image extension e.g., 10.051,60.459,10.102,60.51.jpg. Hash tables are a good solution for this problem since they divide the data into different folders and if a good hash function is used a uniform distribution is achieved.

The division of the data into folders allows a faster way to access the data since it reduces the number of collisions and comparisons. The size of the hash table depends on the application purpose. For this project a hash size of 7040 was chosen. With this hash size and a uniform distribution we would have a number of tiles around 20 in each folder.

D.4   Hash function

The solution implemented to create the hash function was to obtain the latitude and longitude of the bottom left corner of the tile and apply the following formula:

$$mod(floor(latitude * 100) + floor(longitude * 100), 7039)$$

The result of the formula will be the folder into which the file will be transferred.

Appendix H shows the Matlab script that organises the image files into the respective folders.
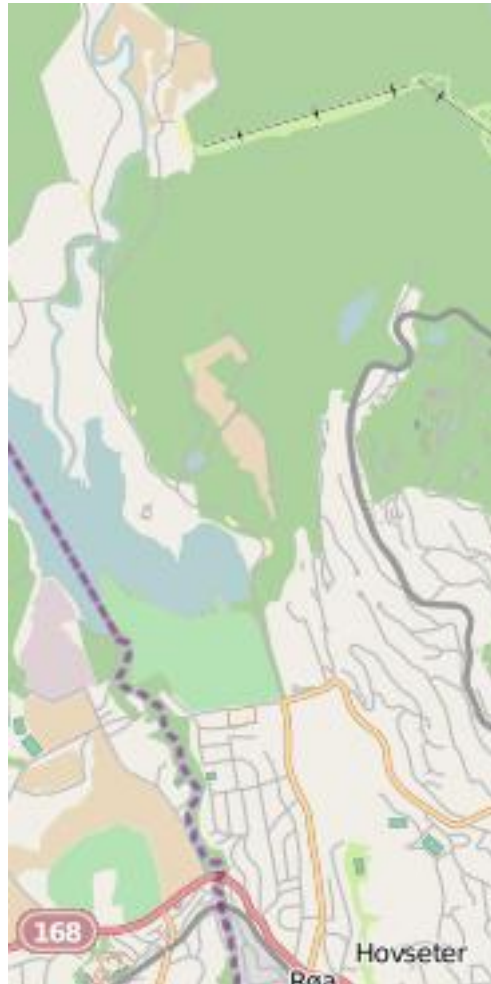
Figure D.3: Example of one tile from the OSM database

D.5 Graphical User Interface (GUI)

With the availability of a database with images of an area we designed a GUI to display a smaller area of interest by introducing the GPS coordinates. Figure D.4 shows the GUI developed for this application as well as a map section. The first pair of coordinates corresponds to the lower left corner of the map while the second corresponds to the upper right corner of the map. The directional keys ($\leftarrow, \rightarrow, \uparrow, \downarrow$) allow us to move around the map while the '+' and '-' buttons zooms in and out, respectively.

Figure D.4 shows an example of a plot of an area around Gothenburg using the program developed.
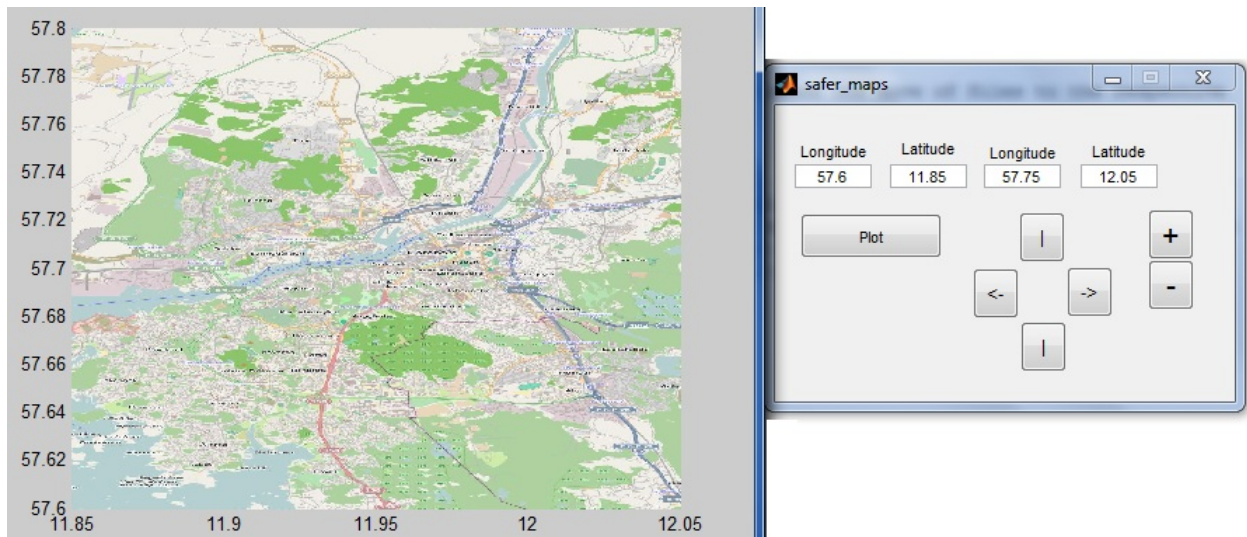
Figure D.4: Map and GUI

E Sample of XML file from the OpenStreetMap

```
 <way id="120796107" user="magol" uid="35601" visible="true"
version="2" changeset="8664701" timestamp="2011-07-
08T10:39:33Z">
  <nd ref="1353647930"/>
  <nd ref="1353647921"/>
  <nd ref="1353647924"/>
  <nd ref="1353647920"/>
  <tag k="highway" v="unclassified"/>
  <tag k="name" v="Kruthusgatan"/>
 </way>
 <way id="26612612" user="magol" uid="35601" visible="true"
version="7" changeset="8950490" timestamp="2011-08-
07T18:46:28Z">
  <nd ref="265793086"/>
  <nd ref="265794089"/>
  <nd ref="1390025402"/>
  <nd ref="1021143672"/>
  <nd ref="1390025233"/>
  <nd ref="1353680177"/>
  <nd ref="1353680144"/>
  <nd ref="302999062"/>
  <nd ref="302999149"/>
  <tag k="highway" v="tertiary"/>
  <tag k="name" v="Södra Sjöfarten"/>
  <tag k="oneway" v="yes"/>
 </way>
 <way id="138574359" user="magol" uid="35601" visible="true"
version="1" changeset="9967122" timestamp="2011-11-
27T14:02:11Z">
  <nd ref="1519518001"/>
  <nd ref="1519517990"/>
  <tag k="access" v="no"/>
  <tag k="highway" v="service"/>
  <tag k="psv" v="yes"/>
  <tag k="service" v="bus"/>
 </way>
 <way id="120796105" user="magol" uid="35601" visible="true"
version="2" changeset="9635436" timestamp="2011-10-
23T16:45:30Z">
  <nd ref="1353647920"/>
  <nd ref="247323296"/>
  <tag k="highway" v="unclassified"/>
  <tag k="name" v="Kruthusgatan"/>
 </way>
 <way id="116023694" user="D@niel" uid="447982"
visible="true" version="2" changeset="8323093"
timestamp="2011-06-02T18:51:14Z">
  <nd ref="1309380410"/>
  <nd ref="1309380241"/>
  <tag k="covered" v="yes"/>
  <tag k="highway" v="platform"/>
  <tag k="operator" v="Västtrafik"/>
  <tag k="public_transport" v="platform"/>
  <tag k="ref" v="39"/>
 </way>
 <way id="116023689" user="D@niel" uid="447982"
visible="true" version="2" changeset="8323093"
timestamp="2011-06-02T18:51:12Z">
                      1
```

Figure E.1: Sample XML file

F Matlab code for extraction of XML files

```matlab
min_long = 54;
max_long = 70;
min_lat = 7;
max_lat = 28;
sliding_window = 3;

for i=min_long:sliding_window:max_long
    for j=min_lat:sliding_window:max_lat

        url_maker= strcat('http://open.mapquestapi.com/xapi/api/0.6/' ...
            'way[junction=roundabout][bbox=' , num2str(j) , ',' ,...
            num2str(i) , ',' , num2str(j+sliding_window) , ',' ,...
            num2str(i+sliding_window),']');

        filename = strcat('sweden',num2str(j),num2str(j+sliding_window),.
            num2str(i),num2str(i+sliding_window),'.xml');

        fp=fopen(filename,'w');
        fwrite(fp,urlread(url_maker));
        fclose(fp);

    end
end
```

G   Matlab script for image extraction

```
1   log_step = 0.051
2   lat_step = 0.051
3
4   cd('C:\Users\Funas\Desktop\map_images\the_world')
5
6   max_log = 70;
7   min_log = 66.426;
8   max_lat = 30;
9   min_lat = 20;
10
11  delta_log = max_log-min_log;
12  steps_log = floor(delta_log/log_step);
13
14  delta_lat = max_lat-min_lat;
15  steps_lat = floor(delta_lat/lat_step);
16
17  total_steps = steps_lat * steps_log;
18
19  h = waitbar(0,'Please wait...');
20
21  k=1;
22  l=1;
23
24  for i = min_log:log_step:max_log
25
26      k=k+1;
27
28      for j = min_lat:lat_step:max_lat
29          l=l+1;
30
31          url = strcat ('http://tile.openstreetmap.org/cgi-bin/export?' ...
32              ,'bbox=' ,num2str(j),',',num2str(i) ,...
33              ',',num2str(j+lat_step), ',', num2str(i+log_step),...
34              '&scale=110000&format=png');
35
36          img=imread(url);
37          image_name = strcat(num2str(j), ',',num2str(i) ,',',...
38              num2str(j+lat_step), ',', num2str(i+log_step),'.jpg');
39
40          imwrite(img,image_name,'jpg');
41
42          waitbar(l /total_steps,h)
43
44      end
45  end
46
47
```

H   Script for hash table

```matlab
1   cd('C:\Users\Funas\Desktop\map_images\the_world')
2
3   while (1)
4       clear all
5       close force all
6       list_of_files = dir;
7
8       nr_files = size(list_of_files,1);
9       for i = 1:nr_files
10          indexes_of_files(i) = (list_of_files(i).isdir == 0);
11      end
12
13      list_of_files = list_of_files(indexes_of_files)
14      nr_files = size(list_of_files,1)
15      h = waitbar(0,'Please wait...');
16      for i = 1 : nr_files
17
18          waitbar(i /nr_files,h)
19          name_file = list_of_files(i).name
20
21          positions = findstr(name_file, ',')
22
23
24          lat = str2num(name_file(1:positions(1)-1))
25          log = str2num(name_file(positions(1)+1:positions(2)-1))
26
27          hash_indexe = hash_table (lat,log)
28
29          movefile(list_of_files(i).name,[cd , '\',num2str(hash_indexe),...
30              '\',list_of_files(i).name])
31
32      end
33
34      pause(2)
35  end
```

```
function table_indexe = hash_table (lat,log)

prime  = 7039;
lat_temp = floor(lat * 100);
log_temp = floor(log * 100);

mod_number = lat_temp + log_temp;

table_indexe = mod(mod_number,prime);

end
```

I Survey

Survey

Student: Fernando Jorge	
Volvo Cars Supervisor: Henrik Lind	

Aim:	The aim of this thesis is to use pre-recorded data from FOT studies EuroFOT and SemiFOT and develop a machine learning algorithm so that it can label maneuvers in an automatic way. In a second stage of the master thesis a predicting algorithm will be develop based on the conclusions and results of the automatic labelling stage. Perdiction will be made in Matlab.

Scope of survey:	Review needs for real time and post annotation of log data collected during product development of active safety systems. The prediction will be based on CAN data and GPS data.

(personal information might not be filled if you don't want)

Name:	
Department:	
Contact:	

Manouvre

Why?

What other maneuvers that could be not of much relevant but still would be interesting to label/predict?

Opinions/Comments:

Please return this survey to Henrik Lind (hlind1@volvocars.com) or to me (fjfernandojorge@hotmail.com) with your comments/ideas

Thank you for your collaboration,
Fernando Jorge