

Fault code positioning

Exploring the environment of DTCs creation

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Abstract

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Scania's vehicles are market leaders when it comes to quality. Despite this, more or less serious errors occasionally occur in the vehicles. These errors generate the so called fault codes. The more you know about the errors the easier it is to prevent them and fix them. It would therefore be an advantage to know the position of the vehicles when the fault codes (DTCs) are created.

The purpose of this master thesis is to create a method to determine the position of DTCs and then use these positions to present information about the environment in which the DTCs are created. This is then visualized in a demonstrator.

DTCs and positions are gathered from two separate systems which are used by different departments at Scania. The two closest positions are taken for a chosen fault code. Linear interpolation is used to determine the DTC's position from these positions. However, some complement cases were used due to the lack of data and bad matching in data, in addition to the interpolation method. Data were collected from both internal (Scania) and external sources. The data includes operational data from the vehicles, weather and traffic data, UV and altitude data. A demonstrator was created in form of two interfaces. One focuses on a specific occurrence of a DTC and presents it in form of a geographical plot. The other one focuses on all occurrences of a DTC and presents them in form of data tables and statistics.

Whether the method for determining the position of a DTC is accurate enough depends on how and for what purpose the position is used. A more accurate determination of DTCs positions requires better map data and a more sophisticated interpolation method. However, the used environmental data and created demonstrator are to be considered as a good start for the usage of fault code positioning. There are possibilities to continue with this thesis work, yet again depending on what the purpose is. Some approaches for future work are suggested.

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Populärvetenskaplig beskrivning

Scantias fordon är marknadsledande beträffande kvalitet. Trots detta uppstår emellanåt mer eller mindre allvarliga fel i fordonen. Dessa fel genererar så kallade felkoder. Ju mer som är känt om ett fel desto enklare är det att förebygga och åtgärda felet. Det är därför en fördel att ta reda på var fordonet befunnit sig då felet inträffade.

Syftet med detta examensarbete är att skapa en metod för att positionsbestämma felkoder. Och vidare, givet en felkodsposition, utreda vilken omvärldsdata som kan vara intressant att visa för att presentera omgivningen i vilken felkoden har uppstått. Detta visualiserades slutligen i form av en demonstrator (ett program).

Felkoder och positioner hämtades från två olika system. För en vald felkod valdes de två, i tiden, närmaste positionerna ut. Linjär interpolation användes sedan för att positionsbestämma felkoden utifrån dessa två positioner. Dock gjorde bristande och dålig matchning i datan att några kompletterande fall användes utöver interpolering. Omvärldsdata hämtades från interna (Scania) och externa källor. Datan bestod bland annat av driftdata från fordonen, väder- och trafikdata, UV och höjddata. Demonstratorn bestod av två gränssnitt; ett där en specifik upplaga av en felkod ritades ut på en karta och ett där statistik för en viss felkod presenterades.

Huruvida felkodspositionen bestäms på ett tillräckligt noggrant sätt beror på vad den skall användas till. En mer exakt metod skulle kräva bättre kartdata och en mer komplex interpolering. Omvärldsdatan som användes och demonstratorn som skapades skall ses som ett första exempel på hur felkodspositionering kan användas. Det är möjligt att utveckla detta vidare beroende på syfte. Några ideer för framtida arbete föreslås.

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Södertälje, 2010-12-23

Joakim Fennö

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Definitions

CAN	Controller Area Network. Serial and wired digital communication between control unit. CAN is commonly used for embedded systems. (Scania inline, 2010)
DTC	Diagnostic Trouble Code. A code indicating a discrepancy in an electronic control system (ECU) and provides information about why the code has been created. (Scania inline, 2010)
ECU	Electronic Control Unit. A device for controlling one or more systems or functions of a vehicle. (Scania inline, 2010)
FMS	Fleet Management System. A system that comprises computer and communication related products and services for planning, monitoring and following up shipments, individual vehicles and vehicle fleets. (Scania, 2010)
ICL	Instrument Cluster. A set of devices in the instrument panel that displays vehicle information to the driver. (Scania inline, 2010)
RESD	A department working with tools, components, principles and services for diagnoses and operational data.
SDP3	Scania Diagnos and Programmer 3. A PC tool used to ease troubleshooting and reparation of vehicles.
STEP	Scania FieldTest EcuData Portal. An application installed to the on board-computer which reads diagnostic data from the vehicle and send it via GPRS.

Disposition and instructions to the reader

The objective of the thesis was divided into three steps, these are described in chapter 1. The method used to obtain each of the steps is given in chapter 2. Chapter 3 consists of the theoretical background. The results of each of the steps are then presented in chapter 4-6. Finally a general discussion about the results is finally given in chapter 7.

A short description of each chapter is presented below to help the reader find useful information faster.

1. Introduction

This chapter gives an introduction and a background to the thesis, a short description of Scania, and the objective of the thesis and chosen delimitations.

2. Method

This chapter presents the method used during the development of this thesis. That is, how and why things are done and why. Some notations about the used data are also mentioned.

3. Diagnosis and creation of fault codes

This chapter gives a short description of diagnosis and an introduction to diagnostic trouble codes and how these codes are created.

4. Determining the position of DTCs

This chapter gives a description of the different data sources and the method used to determine fault code positions.

5. Environmental data

This chapter presents the different environmental data sources which were used and an explanation of why that data was interesting for the purpose of the thesis.

6. Demonstrator

This chapter presents the demonstrator created for the thesis.

7. Discussion

This chapter contains a discussion about the results of the thesis as well as some ideas for future work.

1. Introduction

This chapter gives an introduction to the thesis, states the objective and chosen limitations.

Scania's vehicles are market leaders when it comes to quality. The vehicles are expensive to buy, however the customers demand them since the superior quality makes them profitable in the long run. Despite this, more or less serious errors occasionally occur in the vehicles. These errors generate so-called fault codes. The fault codes are used to determine what errors the vehicle suffers from. There are different ways to collect fault codes from vehicles, either in connection to workshop visits using a PC-tool or by reports that Scania receive from vehicles on the run.

Diagnosis is used by Scania during Research and Development (R&D) to enforce the quality of their products before they are released to the market. Fault codes are central in this task. RESD is a department at Scania which develops diagnosis tools which are used to debug vehicles.¹

Fault codes are created by numerous reasons. For instance, the brakes might be broken, a valve could be blocked or a memory leakage might have occurred in the software. However, the more you know about an error the easier it is to prevent it or fix it. In order to facilitate troubleshooting and the understanding of why an error has occurred, it would be an advantage to know the position of the vehicle when the fault code was created. Further, what environmental information can be found given a specific time and position of a fault code that is relevant for understanding the creation of the fault code.

1.1 About Scania

Scania is an automotive industry manufacturer of heavy trucks, busses, and marine and industry engines. Founded in Södertälje in 1891, Scania is one of the oldest actors on the market. Scania is today a global player with production facilities in seven countries including Brazil and Russia, and operates in about 100 countries. Scania is today majority owned by Volkswagen, however the headquarter and most of the R&D are still located in Södertälje. Scania employs more than 35 000 people of which 2400 work with R&D.

Scania uses a modular product system where the vehicles are built up by a number of standardized components. This makes it possible for Scania to produce different vehicles which are optimized for different kinds of uses but also to keep manufacturing costs at a lower level. (Scania, 2010)

The components (engine, brakes, gearbox etc.) are controlled by electrical control units (ECUs). An ECU is an embedded computer system used to control algorithms and optimize the hardware in the vehicle. This can for example be done by reading sensors or setting control signals. Each ECU has a more or less limited task to control; the ABS ECU controls the ABS-system and so on. The different ECUs communicate via controller-area-network

¹ Refers to Scania's field test (FT) vehicles which are used by R&D.

(CAN) which is a communication bus. A CAN is a broadcast type serial protocol and has become the standard for ECU communication in the automotive industry.

1.2 Objective

The objective of the thesis is to create a method to determine the position of fault codes. And further to create an example of how fault code position can be used to present information about the environment in which the fault codes were created.

The objective of the thesis is divided into three steps:

1. Determining position of fault codes

Scania stores both the fault codes and the positions for vehicles. However this is not done in the same system. The first step consists of using Scania's internal information to determine fault code positions as accurate as possible.

2. Finding relevant data given fault code position

What environmental data might be relevant to present together with a fault code in order to give information about the environment in which the fault code was created. This step includes a research to find interesting and accessible data from both internal (Scania) and external data sources.

3. Presenting fault code positioning in a demonstrator

The result of step one and two is presented in form of a demonstrator to give an example of how fault code positioning can be used in the future at Scania. This step includes figuring out how to present fault code and belonging data in a useful way.

1.3 Delimitations

Given that the objective is to present an example for future implementation, rather than creating a product, some restrictions were made according to the used data.

1.3.1 Fault codes

The fault codes comes from a selected group of vehicles and a selected time period. This is explained more in detail in *4.3 Selection group and time period*.

1.3.2 Data sources

Some environmental data has been identified as interesting, however no suitable or available data source has been found. This aspect is further discussed in *5.8. Interesting but unused data*.

The environmental data used are restricted mostly to Swedish data. This is explained more in detail in chapter *Environmental data*.

2. Method

This chapter describes the method used for the development of the thesis as well as some notations which were general for the data used.

The method of the thesis has been iterative where the focus has been shifting among the three steps. The background information and sources used consist mostly of internal Scania documentation and meetings with Scania employees.

2.1 Feedback meetings

The method of the thesis was carried out in discussion with Joakim Drott, supervisor, at Scania through weekly meetings with the following structure:

- *What did I do last week*
- *What do I plan to do this week*
- *What problems do I have/What can the supervisor help me with*

The meetings have been used to discuss the progress of the thesis including new ideas and confirm that the objective of the thesis agrees with Scania's expectations.

2.2 Step by step

The method used for fulfilling each of the three steps, that were presented in *1.2 Objective*, are presented below.

1. Determining position of fault codes

This was done by using Scania's internal databases. The STEP database has reports containing the fault codes while the FMS database contains the GPS-position. This is explained in more detail in chapter *Determining the position of DTC*.

2. Examining relevant environmental data

To get an idea about what data that might be interesting to present together with a fault code the following steps were performed:

- a study was made, by looking at internet resources and internal Scania documentation.
- a small survey was done in form of an excel-document where system affected employees could come up with ideas.
- employees working at related departments were interviewed.

See chapter *Environmental data* for further reading.

3. Creating a demonstrator

The demonstrator was created in the .NET developing environment: C#, Visual Studio 2008 and MSSQL 2005. The demonstrator is presented in chapter *Demonstrator*.

2.3 Collecting and harmonizing data

A lot of data has been used for the purpose of this thesis. Both for determining DTC-positions and for adding environmental data. Most of the data were gathered and stored physically in SQL database tables, see chapter *Environmental data*. However, some data (UV and altitude) were gathered in real-time from online databases using web scraping. That is timestamp and GPS coordinates were passed as parameters to set the right web address and the wanted data were then gathered from the resulting web page.

Local time zones and different GPS reference systems cause problems to the consistency of the data. Therefore, all data that was used was also harmonized, so that everything was given comparable times and positions. Harmonized means that UTC-times (which are commonly internationally used) and WGS84-references were chosen. The conversion from SWEREF99 to WGS84 was done by using *Translate coordinates between RT90, WGS84 and SWEREF99 using .NET*. (Sållarp, 2010)

2.4 Distance formula

A common task in the thesis is to search through a list of positions (for example positions of weather stations) to see which one is closest to a specific position. In order to do that a distance formula is used which compares two positions and gives the distance in kilometers between them. (SpiderWorks Technologies, 2010)

2.5 Developing demonstrator

The demonstrator was created in form of a web application developed in Visual Studio. The demonstrator contains a number of controls (such as dropdown lists, buttons, tables etc.). Data from the (SQL and online) databases are then presented according to the users choices. That is, the buttons triggers the respective methods such as *determiningPosition*, *addWeatherData*, *drawStatisticTable* and so on. For more details see chapter *Demonstrator*.

3. Diagnosis and creation of fault codes

This chapter gives a short theoretical description of diagnosis, DTCs and how they are created.

Diagnosis, in a Scania context, refers to error and repair related information for troubleshooting, regulation, legislative demands, quality control and security. Diagnosis is further divided into an on-board and an off-board part. The on-board part consists of the vehicle's ECUs. The ECUs runs diagnostic (electrical, threshold and plausibility) tests continuously, store diagnostic data and correct smaller faults (for example by giving replacement values to functions). The off-board part consists of collecting diagnostic data from the vehicle via a computer. This can be done in many ways. One way is by getting readouts using the STEP-application (see 4.1 STEP) and another way is via Scania Diagnos and Programmer (SDP3) which is a PC-tool used in workshops for troubleshooting and reparation. Fault codes are used to register different kinds of errors that might occur in the vehicle. Examples of errors that can be represented with fault codes are signal from monitoring units, short circuit, operators errors, signals with abnormal values and so on. (Dahlen, 2010)

3.1 DTC

Throughout this report, the term fault code has been used. What fault code really refers to in the context of this thesis is DTC² which stands for *Diagnostic Trouble Code* and according to Scania Lexicon is defined as:

A code indicating a discrepancy in an electronic control system [ECU] and providing information about why the code has been created.

System and function owners chose and define DTCs. There are some principles according to creation of DTCs; they should only be created when there is a risk for a function degradation, they should not indicate an unknown fault, and they should not be false (DTCs should only warn when necessary).

Each DTC is given a id number which is unique for each ECU and specification (see table Table 3-1 for an example).

² Fault code and DTC are used interchangeably in this report.

Table 3-1: Table with an example of a DTC specification.

Attribute	Description	Example
Heading	DTC number and diagnostic area	0x0052, Pressure in the AC system.
Detection	Description of how the diagnostic test works and when it reacts. The description shall include criterion and threshold values if available.	The pressure switch which monitors the pressure in the AC system has registered an implausible value. The voltage in the circuit has been too low or too high.
Cause	Possible causes of the failure. Should describe the technical cause of the failure.	Short circuit or open circuit in the pressure switch circuit of the AC system. There may also be a fault in the pressure switch itself.
System reactions	How the fault can be recognised by the driver or mechanic; the consequences of the fault.	The AC compressor cannot be activated as long as the fault is active.
Actions	How to locate the faulty component and if necessary some short advice on how to repair it.	Check the AC system pressure switch including wiring and connectors.

All DTCs also have some properties including a status (whether the DTC is active, validated or pending), a counter (number of times the DTC has been active), a time stamp (date and time when the DTC was created) and a freeze frame (a snapshot with operational data for the vehicle at the time when the DTC was created).

DTCs are used in workshops by mechanics for troubleshooting and reparation, and by R&D (such as RESD) for quality control and statistics. There are more DTCs defined for the FT-vehicles (which are used during R&D) than for the after market-vehicles. That is because the mechanics at workshops are only interested in DTCs that are related to real errors. This means for example that after market-vehicles has DTCs defined which indicates that an ECU is broke, however they do not have any DTCs defined representing internal errors in ECUs. (Dahlen, 2010)

3.2 DTC creation

A DTC indicates that and when an error has occurred. The diagnostic tests that runs in the ECUs creates DTCs. This method used for the DTC creation is called isolation.

When a diagnostic test runs they are given result values depending on whether the corresponding test specification is fulfilled, for example when a threshold value is reached. However, a test result does not tell what the real error is, that is specified by the DTC. One or a combination of two or more test results has to be created to trigger the creation of a DTC – the error is isolated. Which tests that triggers the creation of what DTC is specified in a table. A short example will give a better understanding of the isolation method:

A tailpipe has a catalyst, used to filter the pressure, in the middle, one sensor at the opening and one sensor at the end. One test is used for each sensor (test1 and test2) to test if the pressure is too low, normal or too high. Depending on the results of the tests different errors

are likely to have occurred hence different DTCs are created, see table Table 3-2. (Dahlen, 2010)

Table 3-2: Table illustrating the tests and DTCs in tailpipe example

	Test1	Test2
DTC1 Incoming pressure to high.	Too high	Normal
DTC2 Stop in pipe.	Normal	Too low
DTC3 Catalyst broke.	Too high	Too high

4. Determining the position of DTCs

This chapter describes the sources, selection group and the method used to determine the fault code position.

Two sources were used when determining the position of the DTC. STEP for getting the DTC and FMS for getting the position. Data were gathered from STEP and FMS:s belonging databases (STEP Test and OP Test) for this objective. The DTCs were taken from a selected group of vehicles and a given time period. Interpolation was used to determine the DTC-position, however some additional cases were used as well.

4.1 STEP

Scania FieldTest Ecudata Portal (STEP) is an application in the on board-computer (the vehicle computer) which reads diagnostic data from the vehicle and sends it to Scania via GPRS. STEP is installed to the interactor and speaks to the vehicle through the CAN-network. Since all ECUs are connected to CAN, STEP reads data, including DTCs, from all ECUs. Each vehicle has between 7 and 27 ECUs. However some ECUs has no or only a few DTCs defined. All FT-vehicles have STEP installed in order to give Scania an understanding of the fault code situation before production but also to troubleshoot fault codes from distance. (Salonen, 2009)

STEP has three main objectives which mainly revolve around the data of the FT-vehicles:

- 1. Wirelessly retrieve the data from the field test vehicles. The data includes fault codes, Freeze frames, ECU-info, milage, operational time, adaptation data and other diagnostic messages.*
- 2. Helping system owners to classify [giving them one of the following descriptions: unknown, development, real fault, irrelevant, information] fault codes.*
- 3. Helping system owners and decision makers to produce statistics for the field test vehicles.*

STEP reads data from the vehicles in a given interval (normally every 24 hour) or by requesting a readout from a vehicle (using a push method). The readout time period is defined as the time since the last readout was made. One readout might contain an infinite number of DTCs. Each DTC has a belonging time stamp which represent the time when the DTC was created. The time is set by the Instrument cluster (ICL) and is given in UTC-time.

STEPs data storage has a big coverage since it do not wash (i.e. delete part of) the data, however some data needs to be modified or translated before usage. A readout does not contain multiples of a DTC even though a DTC occurred more than once for the time period of the readout. If the DTC was created more than once during the time period for a readout only the last one is used (which means that operational data such as time stamps are stored for that occurrence of the DTC). However the readout contains a counter with the number of occurrences for the DTC. (Drott, 2010)

4.1.1 STEP Test

STEP Test is a database that contains a copy of the STEP production database (which it is updated regularly from). STEP Test is used for developing and testing. Four tables in STEP Test has been used for the purpose of this thesis, see Figure 1.³

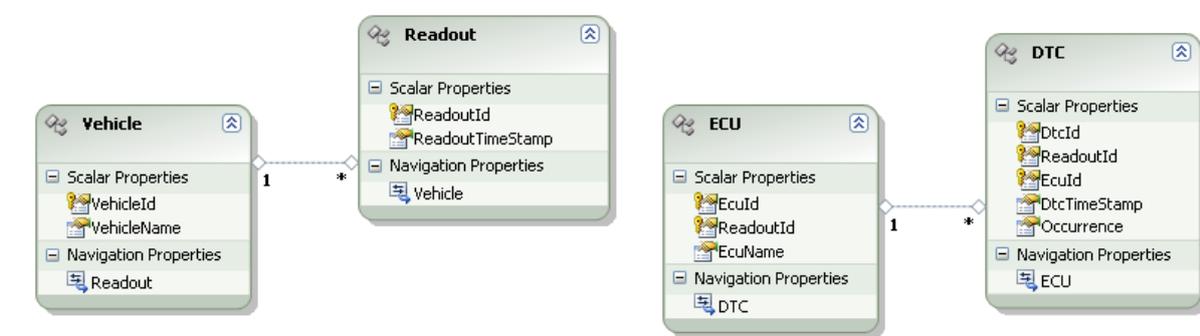


Figure 1: Figure showing the tables from STEP Test that were used.

Table Readout

The readout table is central to the database. A row is added to this table each time a readout is created (automatically or by request). The table contains information about the readout including the id for the readout, the belonging vehicle and a time stamp for the readout. *ReadoutId* uniquely identifies each row and links the table to most of the other tables in the STEP Test database.

Table 4.1: Attributes for table Readout.

Attribute	Description
ReadoutId	Id number.
ReadoutTimeStamp	Time stamp for the readout.

Table Vehicle

This table contains information about the vehicle including id and name of the vehicle. *VehicleId* uniquely identifies each row.

Table 4.2: Attributes for table Vehicle.

Attribute	Description
VehicleId	Id number.
VehicleName	Vehicle name.

³ The database tables do not contain all the attributes thought only attributes that were used for the thesis are included.

Table ECU

Table ECU stores data about the ECUs which has occurred in readouts. This table contains information about the ECUs including id and name belonging to each readout. *ReadoutId* and *EcuId* uniquely identifies each row.

Table 4.3: Attributes for table ECU.

Attribute	Description
ReadoutId	Id number.
EcuId	Id number.
EcuName	ECU name.

Table DTC

Table DTC stores data about the DTCs which has occurred in readouts. This table contains information about the DTC including id, time stamp, the number of times the DTC occurred for the readout, belonging ECU and readout. *ReadoutId*, *EcuId* and *DtcId* together uniquely identifies each row.

Table 4.4: Attributes for table DTC.

Attribute	Description
ReadoutId	Id number for the belonging readout.
EcuId	Id number.
DtcId	Id number.
DtcTimeStamp	The time when the DTC was created.
Occurrence	The number of times the DTC occurred for the readout.

4.2 Scania Fleet Management

Scania Fleet management (FMS) is a service used to track and collect data from vehicles via an office computer. It is possible to get data such as position, fuel consumption, how the vehicle is driven and potential mechanical problems. Data is collected automatically via GPS in a given interval or by making a request. Operational data including GPS data is stored. The GPS is located on the roof in the front of the vehicle and has coverage all over the world, however the signal vary in strength. (Burman, 2010)

4.2.1 OP Test

OP Test is a production database containing data used for FMS purposes. OP Test stores data every fifth minute as long as the vehicle has GPRS and GPS-reception. A plausibility test is used for the time stamp to check if the time stamp is set to an abnormal value. All data belonging to such time stamp is thrown. The time stamp is set by the GPS and is given in UTC time. The time stamp is rounded to nearest minute. Multiple tables from OP test were joined to create one table (FMS positions) used for the purpose of the thesis.

FMS positions

This table includes information about position and position related information including belonging vehicle, time stamp for the coordinates and coordinates. *VehicleId* and *TimeStamp* uniquely identifies each row.

Table 4.5: Table with attributes for table FMS positions.

Attribute	Description
VehicleId	Vehicle id.
FmsTimeStamp	Position time stamp.
Lat	Latitude.
Long	Longitude.

4.3 Selection group and time period

As mentioned before the main objective of the thesis is to create an example of how fault code positioning can be used. This implies that the requirements for the amount of data used as a base is not the most important. Rather it is an advantage to work with smaller sets of data since it makes it faster.

The DTCs which were used were from a selected group of vehicles and from specified time period. There were around 38 000 occurrences of DTCs in total.

The selected group of vehicles are all FT-vehicles. These are the only vehicles which has STEP installed. The FT-vehicles also got more DTCs defined than the after market-vehicles. This is because diagnostic departments such as RESD are interested in DTCs that might not be caused by real errors (i.e. some DTCs are created for R&D purposes). The FT-vehicles runs all over the world; an estimate is that of 100 vehicles, 80 runs in Sweden, 10 in the rest of Europe, 5 in South America, and 5 in the rest of the world. (Drott, 2010)

The time period is limited to January – September 2010. This is because the data had to be limited in some way, especially since it was hard to find free weather data etc. The time period covers seasonal weather changes.

All vehicles that had readouts (8662 readouts in total) in STEP for the selected time period were selected, which were 108 vehicles. 97 of them had data in FMS and those vehicles makes the selection group. The difference between STEP and FMS exist because STEP has some vehicles used for long milage testing which only runs at the test track, data for these vehicles are not stored in FMS.

4.4 Determining position

Each created DTC gets a belonging time stamp (DTC-time stamp) which then is stored in the STEP Test database. The DTC-time stamp is used together with the *vehicleId* to determine the position of the DTC using the data from OP test. This is described in the function given below:

Function(DTC-time stamp, vehicleId)=DTC-position

As mentioned before STEP Test has good data coverage, however a disadvantage with it is that STEP Test contains data with abnormal values. If the ECU does not have access to the time when DTC is created the DTC-time stamp is set to fault code value. The DTCs with these time stamps cannot be given a position and are therefore omitted since the method requires a valid time stamp.

The DTC-time stamp is compared with all time stamps in the OP test database (the FMS-time stamps) for the given vehicle. That is the time difference in seconds between the DTC-time stamps and all FMS-time stamps are calculated. The FMS-time stamps are then ordered from lowest to highest time difference and the first two rows are returned. The position of the DTC is then calculated from the two positions (called base positions) corresponding to the two FMS-time stamps. The way the DTC-position is calculated depends on the values of the FMS-time stamps and base positions. However, each DTC gets a position information-tag which explains the method used to calculate the DTC-position. This also gives an indication of the quality of the calculated position. See table Table 4-1 for a description of the positions and time stamps used.

Table 4-1: Table of position and time stamp notation.

Position	Time stamp	Description
Base position1	FMS-time stamp1	The position and time stamp from OP test belonging to the first position in time.
Base position2	FMS-time stamp2	The position and time stamp from OP test belonging to the second position in time.
DTC-position	DTC-time stamp	The position and time stamp of the DTC.

4.4.1 Position information tags

Five different cases were used for determining fault code positions, resulting in five different position information tags.

Case1: One FMS-time stamp before and after the DTC-time stamp.

This is the normal case. Assuming that the OP test database has full coverage (a position is stored at-least every fifth minute) the DTC-position is calculated from two base position belonging to one FMS-time stamp that comes before and one that comes after the DTC-time stamp in time. Interpolation (described in 4.4.2 *Interpolation*) is used to determine the DTC-position.

Position info = [Interpolated position]

Case2: One FMS-time stamp before and after the DTC-time stamp & the base positions are equal

This is an extension to the normal case. The same method is used to calculate the DTC-position. However since the position of the two base positions are equal the vehicle is assumed to be standing still when the DTC was created. It is possible that the vehicle have been driving away and then back to its initial position. However since the coordinates are given with 5 decimals in precision that is very unlikely. A warning is added to the position information-tag.

Position info = [Interpolated position (Warning vehicle is probable standing still)]

Case3: Both FMS-time stamps are either before or after the DTC-time stamp.

The fact that both the FMS-time stamps are either before or after the DTC-time stamp in time indicates that there are some lack of data in the OP test database. To do an interpolation for this case might result in very inaccurate positions since the second base position used for the interpolation might differ much in time from the DTC-time stamp. The solution is instead to take the position belonging to the closest FMS-time stamp and use it as DTC-position.

Position info = [Based on closest position]

Case4: Both FMS-time stamps are either before or after the DTC-time stamp & FMS-time stamp1 differ by more than 900 seconds from the DTC-time stamp.

This is an extension to case4. Since there is no guarantee that the closest FMS-time stamp actually is close in time to the DTC-times tamp a warning is added to the position information-tag if the time between the DTC-time stamp and the closest FMS-time stamp differ by more than 900 seconds (15 minutes).

Position info = [Based on closest position (Warning, time stamp differ by more than 15 minutes)]

Case5: Only one base position was found in OP Test.

This is a special case used if only one FMS-position is found for the given vehicle. This is the case when there are a big lack of data in the OP Test database, which could be a vehicle with bad GPS-reception. The DTC-position is given the FMS-position and a warning is added to the position info-tag.

Position info = [Based on closest position (Warning, only one position was found)]

4.4.2 Interpolation

Linear interpolation is used to calculate a DTC-position from two base positions. This is done separately for the latitude and longitude coordinates. The coordinates can be seen as x and y in a two-dimensional coordinate system.

The first thing is to check which of the two base positions that is first in time , i.e. base position1. A multiplier is then calculated using the formula below to weight the two base positions according to how close in time they are compared to the DTC-time stamp:

$$\text{multiplier} = \text{Abs}(\text{diff2}) / (\text{Abs}(\text{diff1}) + \text{Abs}(\text{diff2}))$$

diff1= time difference between FMS-time stamp1 and the DTC-time stamp.

diff2= time difference between FMS-time stamp2 and the DTC-time stamp.

The multiplier is then used together with the coordinates from the base positions to calculate the DTC-position using a factor f .

$$f = \text{abs}(\text{coordinate base position1} - \text{coordinate base position2}) * \text{multiplier}$$

The calculation starts with base positions1. Determine if the latitude coordinate is bigger for base position1 then the latitude coordinate for base position2. If that is the case f is added to latitude of base position1 otherwise f is subtracted. The pseudo code is given below:

If the latitude for base position1 < latitude for base position2

$$\text{DTC-coordinate} = \text{coordinate base position1} + f$$

If the latitude for base position1 > latitude for base position2

$$\text{DTC-coordinate} = \text{coordinate base position1} - f$$

The process is then repeated for the longitude coordinate.

An example illustrates the DTC-position determination:

A selected DTC has a *DTC-time stamp*: 2010-06-01 13:31:00.

The two closest FMS-time stamps and belonging positions are selected:

FMS- time stamp1: 2010-06-01 13:30:00

FMS- time stamp2: 2010-06-01 13:35:00

Base position1: (55.6244, 13.0377)

Base position2: (55.6437, 13.0651)

diff1 and diff2 are calculated:

$$\text{diff1} = 60$$

$$\text{diff2} = -240$$

The multiplier is calculated:

$$\text{Multiplier} = 240 / (60 + 240) = 0.8$$

The factor f is calculated for the latitude:

$$f = \text{abs}(55.6244 - 55.6437) * 0.8 = 0.01544$$

And for the longitude:

$$f = \text{abs}(13.0377 - 13.0651) * 0.8 = 0.02192$$

Finally the DTC-coordinates are calculated:

$$DTC\text{-latitude}=55.6437-0.01544=55.62826$$

$$DTC\text{-longitude}=13.0651-0.02192=13.04318$$

The DTC-position gets the coordinates: (55.62826, 13.04318)

5. Environmental data

This chapter describes the chosen environmental data and how it were used.

Once a DTC is given a position the next step is to find relevant data to present together with the DTC. The data sources that are used for this purpose and why those are relevant is described in this chapter. All data is connected to a position, i.e. latitude and longitude coordinates. However some data is also connected to time. A form was sent to possible related system owners at Scania to get some ideas about what data to look for (see *Appendix*).

5.1 FMS

Operational data apart from time stamp and coordinates (see *4.2.1 OP Test*) are stored in the OP Test database. Some of this data was used to add operational data to the DTC, see table Table 5-1 for a summarize. The data comes from the FMS positions table (see *4.2.1 OP Test*) and belongs to the *FmsTimeStamp*.

Table 5-1: Operational data from OP Test that were used.

Attribute	Description
Speed	The speed of the vehicle.
Heading	The vehicles direction given in degrees.
NearestTown	Nearest town.
NearestTownCountryCode	Nearest town country code.
NearestTownDirection	Direction to nearest town.
NearestTownDistance	Distance to nearest town.

Speed can be used to determine whether the vehicle was standing still at the time of the DTC creation or not. *Heading* can be used to together with wind direction to calculate crosswind. Information about the vehicle (*Heading*, *NearestTown*, *NearestTownCountryCode*, *NearestTownDirection* and *NearestTownDistance*) gives additional information about the position of the vehicles and where the vehicle was heading.

5.1.1 Adding FMS data

This kind of operational data does not really fit for the purpose of this thesis since the data belongs to a specific position and time stamp. The data is therefore hard to use for a DTC-position determined by interpolation. For the purpose of this thesis the FMS data is added to a DTC-position from the closest base position even though the DTC-position was calculated by interpolation.

5.2 Workshop data

Whether a DTC was created at a workshop or not is interesting to find out. This is because those DTCs often can be ignored since they are created because of the repair work. This happens for example if the ignition is turned on during the reparation when an ECU is disconnected which results in a CAN timeout DTC. One way to do this is to compare DTC-positions to workshop positions.

The workshop data was received from Scania Assistance. The data includes coordinates for the workshops as well as address details. The coordinates has been converted from degrees, minutes, seconds-format (WSG84) to long, lat-format (WSG84). The total number of workshops is 1329 of which 93 are located in Sweden.

Table Workshop locations

This table contains the coordinates for each workshop. *WorkshopId* uniquely identifies each row.

Table 5-2: Table with attributes for table Workshop locations.

Attribute	Description
WorkshopId	Id number.
Latitude	Latitude coordinate.
Longitude	Longitude coordinate.

Table Workshop data

This table contains data about the workshops including name of the workshop and address details. *WorkshopId* uniquely identifies each row.

Table 5-3: Table with attributes for table Workshop data.

Attribute	Description
WorkshopId	Id number.
Country	Country code
CountryName	Country name.
CompanyName	Workshop name
City	City.
VistingAddress	Road.
PostalCode	Postal code.
PostalCity	Postal city.

5.3 Weather data

The weather conditions in which the DTCs were created are interesting since it affect how the vehicle is driven in many ways. The speed and how the brakes are used are factors that often are adjusted according to the weather. Swedish Transport Administration (Trafikverket) use so called road weather stations which are located along the roads to represent the road weather. Weather data from these stations were used for the thesis. The weather data is usually measured every 30 minutes. The data does only contain stations located in Sweden. Historical international weather data is problematic to find since each country own their own data. Data from 771 stations where used in total, however only 150 of the stations are in use during the summer due to maintenance. Two tables were created to store the weather data gathered from Swedish Transport Administration.

Table Weather locations

Table Weather locations contains information about the road weather stations including id, name and coordinates. The coordinates were converted from x,y (SWEREF99) to latitude, longitude (WSG84). *StationId* uniquely identifies each row.

Table 5-4: Table with attributes for table Weather locations.

Attribute	Description
StationId	Station id.
StationName	Station name.
Latitude	Latitude coordinate.
Longitude	Longitude coordinate.

Table Weather data

Table Weather data contains information about the weather data including time stamp when the weather was measured and weather parameters (air temperature, road temperature, rainfall type, rainfall amount, max wind and wind direction). One hour was withdrawn from the *ObservationTime* to make it UTC instead of UTC+1 time. *StationId* together with *ObservationTime* uniquely identifies each row. *RainfallCode* contains a code which belongs to a Type which is stored in table Rainfall Type table.

Table 5-5: Table with attributes for table Weather data.

Attribute	Description
StationId	Id number.
ObservationTime	Time stamp for the observation.
AirTemp	Air temperature.
RoadTemp	Road temperature.
RainfallCode	Code corresponding to a rainfall type.
RainfallAmount	Rainfall amount since last observation.
MaxWind	Maximum wind since last observation.
WindDirection	Wind direction.

Table Rainfall type

Table Rainfall type contains codes and belonging rainfall types. The different codes and corresponding types are presented in Table 5-7.

Table 5-6: Table with attributes for table Rainfall types.

Attribute	Description
Code	Code for identifying precipitation.
Type	Rainfall type.

Table 5-7: Table with rainfall type codes and types.

Code	Rainfall type
2	Rain, air ≥ -2
3	Rain, air ≥ -10 (eventually supercooled rain)
4	Snow
5	(Snow) old definition
6	Snow mixed rain
7	(Drifting snow)
8	(Hail)
9	Unknown type
80	Unknown category (Old type of rainfall sensor)
-9	Sensor is missing/Sensor fail
-999	Sensor is missing/Sensor fail
-10	Station out of service

5.3.1 Adding weather data

In order to add weather data to a DTC the DTC's position and time stamp are used. The DTC-position is compared with all the road weather station positions and the closest stations are chosen. The DTC-time stamp is then compared with the observation-time stamps for the station and the closest observation in time is used to represent the weather for the given DTC.

5.4 Traffic data

The traffic situation, as the weather conditions, affect how a vehicle is driven. For instance number of starts and stops, speed, how the brakes are used and so on. Swedish Transport Administration logs and stores (mostly Swedish) traffic incidents which is often used in present time to help the drivers plan their trips. However, historical traffic data is used for the purpose of this thesis. Two tables are created to represent the data.

Table Traffic locations

Table Traffic locations contains the coordinates for each report (a reported is a reported incident). The coordinates represents the midpoint of spread of the incident which is defined by the traffic controller. The coordinates were converted from x,y (SWEREF99) to latitude, longitude (WGS84)

Table 5-8: Table with attributes for table Traffic locations.

Attribute	Description
ReportId	Id number.
Latitude	Latitude coordinate for the incident.
Longitude	Longitude coordinate for the incident.

Table Traffic data

Table Traffic data contains data for traffic incidents including place, impact, road number, starting- and stopping time. Start- and stop time is the time for the incident which is defined by the traffic controller. One hour was subtracted from the time stamps to make them UTC instead of UTC+1 time.

Table 5-9: Table with attributes for table Traffic data.

Attribute	Description
ReportId	Id number.
Place	Place of the incident.
Impact	The impact of the incident.
RoadNumber	Road number.
StartTime	Start time of the incident.
StopTime	Stop time of the incident.

5.4.1 Adding traffic data

In order to add traffic data to a DTC the DTC-position and DTC-time stamp are used. All traffic data (incidents) that has a start time before the DTC-time stamp and a stop time after the DTC-time stamp are listed. All traffic incidents that lies in a range of 15 km from the DTC-position are then presented.

5.5 UV

High radiation from UV might affect the wear of color, plastic and gum components. (Svensson, 2009) STRÅNG is a model that SMHI uses to measure different types of radiation. CIE-weighted irradiance is used as UV data in the thesis. STRÅNG covers Scandinavia and some parts of the Baltic Sea and has data since 1999. (SMHI, 2010) The UV data were gathered from the STRÅNG homepage using the DTC-coordinates and DTC-time stamp as parameters. (SMHI, 1010) STRÅNG use UTC-time and WGS84 as GPS reference system.

5.6 Altitude

GeoNames is a geographical database which covers altitude data for all countries. Altitude (meters above sea) is gathered from the GeoNames homepage using the DTC-coordinates as parameters. GeoNames WGS84 as GPS reference system.

5.7 Cross wind

Cross wind might affect the vehicles direction stability, especially for vehicles with high wind catching and center of gravity. (Svensson, 2009)

Unfortunately the data needed to calculate cross wind were not accessible. (Elofsson, 2010) However a simplified definition of cross wind is used to give an example of how interesting data might be calculates from available operational data. Crosswind was therefore calculated using the formula below. (Ehow, 2010)

$$\text{Crosswind} = \sin(\text{vehicle heading} - \text{wind direction}) * \text{wind power}$$

Where vehicle heading (*Heading*) is taken from the FMS-operational data and wind direction and wind power (*WindDirection* and *MaxWind*) are taken from the weather data.

5.8. Interesting but unused data

As mentioned before, some data were identified as interesting but not possible to find or acquire for this thesis.

Topography has big impact on the power train since it affect the torque. This affects the fuel economy, the power train performance and the durability. (Svensson, 2009) The Scania Look Ahead Project (LAD) has a database including topography data, however that database is in a format which could only be read from a specific map tool.

The queue situation affects how a car is driven, i.e. the number of starts and stops increases. This affect both the wear of the power train and fuel consumption. (Svensson, 2009)

6. Demonstrator

This chapter describes the demonstrator that was created for presenting fault code positioning.

The last part of the result is presented in form of a demonstrator. The purpose of the demonstrator is to give an example of how fault code positioning can be used to present DTC-position and relevant data in a useful way. The demonstrator consists of two interfaces (gui1 and gui2). Gui1 is used to plot one or multiple DTCs geographically on a map and gui2 is used to present statistics for all occurrences of a specific DTC. The idea is then that the user should jump between the two interfaces; from specific to general and vice versa. Both of the interfaces plots data according to decisions made by the user, i.e. defining search criterions.

6.1 Gui1

Gui1 is an interface used to plot DTCs geographically on a map. The interface is built up of drop down lists, checkboxes and bottoms to select data and a map with markers for plotting data. Google map API, which is a free service, is used for map and to handle markers. (Google, 2010)

6.1.1 Choosing DTC

The DTCs are ordered by vehicles and readouts. The vehicles are from the selected group and readouts are the readouts these vehicles had for the selected time period, see 4.3 *Selection group and time period*. A specific DTC is chosen by first choosing a vehicle, then by choosing a belonging readout and finally by choosing a DTC for that readout.

6.1.2 Plotting

Three different plots are possible to make. Plot all DTCs for all readouts and vehicles(1), plot all DTCs for a chosen readout(2) and plot one chosen DTC(3). Common for all plots is that the DTC or DTCs first are given a position and are then plotted in form of a marker on the map. The marker contains information about the DTC that comes from STEP and FMS but also UV and altitude, see Table 6-1 and Figure 2.

Table 6-1: Table with the information in the DTC-plot.

Data	Description
DTC	Id number.
Position	DTC-position.
Time	DTC-time stamp.
Altitude	Altitude for the DTC.
UV	UV for the DTC.
ECU	ECU name
Speed	Speed for the vehicle.
Pos info	Position information tag.

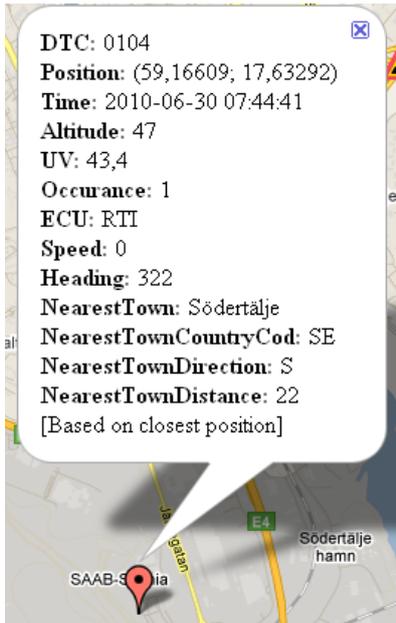


Figure 2: Marker illustrating the DTC-plot.

6.1.3 Error margin circle

If the third plot is made and the DTC's position is determined by interpolation (case1 and case2, see 4.4 *Determining position*) an error margin circle is created for the position marker. That is because the interpolation is linear, i.e. the interpolated position lies on the straight line that is created between the two base positions from OP Test whereas the vehicle probably has taken another route. The circle is created with origin in base position1 (the position belonging to the first FMS-time stamp in time) with a radius calculated using to the formula below.

$$radius = v * t$$

where:

-v is the average velocity between the FMS-time stamps which is calculated using the distance and time difference between the two base positions, $v = \text{distance} / \text{time diff}$.

-t is the time between the FMS-time stamp1 and the DTC-time stamp.

The error margin circle defines an area in where the DTC-position theoretical could be. This gives an indication of the error margin for the determination of the DTC-position. See Figure 3 for an example.

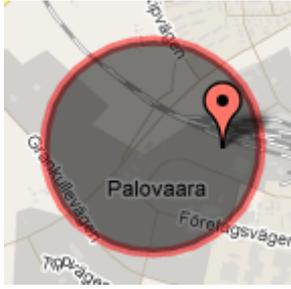


Figure 3: Error margin circle.

6.1.4 Adding markers

There are three checkboxes which can be used to plot data along with the DTC; workshops, weather and traffic. Markers are created if the respective checkbox is checked.

6.1.4.1 Workshop marker

Markers for all workshops are plotted. The markers contain the name, address, postal address and postal code for the respective workshop.

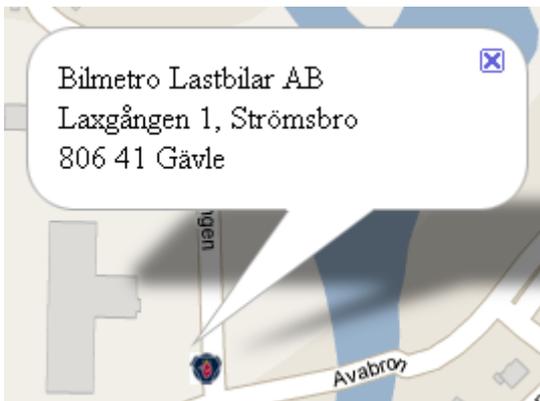


Figure 4: Workshop marker.

6.1.4.2 Weather marker

A marker for the closest weather station is added described in 5.3.1 *Adding weather data*. The marker contains station id, coordinates, time stamp for the observation, air temp, road temp, rainfall, max wind, wind direction and rainfall type.



Figure 5: Weather marker.

6.1.4.3 Traffic marker

Markers for the current traffic incidents in surrounding area, see 5.4.1 *Adding traffic data*. The markers contain report id, place, impact, type, road number, starting time and stopping time.



Figure 6: Traffic marker.

6.2 Gui2

Gui2 is an interface used to plot data and statistics for all occurrences of a specific DTC. The plot contains three parts; a table with raw data for each occurrence of the DTC, a table with statistics and histograms for some of the data.

6.2.1 Choosing DTC

There are two alternatives for this gui; choosing one or two DTCs. This results in two different plots which are described below. The DTCs are ordered by ECU. This is because the DTCs are unique for each ECU.

6.2.2 Plotting

There are two plots depending on whether one or two DTCs is chosen. The plot for a selected DTC contains statistics about the DTC whereas the plot for two selected DTCs is a more simple comparison between the two DTCs.

6.2.2.1 Plot1

The first plot consists of three parts. Firstly, a data table which contains raw data for each occurrence of the DTC, see Figure 7 for an example and Table 6-2 for description of the columns. Two of the columns need some further explanations. The position column contain the coordinates of the DTC in form of a link to a map plotting the location of the DTC. The workshop column is given a “X” if the DTC-position is close (within a range of 500 meters) to a Workshop-position.

Vehicle	Position	Pos info	Time	Air temp	Road temp	Max wind	Crosswind	UV	Altitude	Speed	Workshop
Ledin	59.17991, 17.58994	[Interpolated position]	2010-09-15 10:21:00	6,8	-99,6	5,3	4,98	43,8	54	0	X

Figure 7: Data for one occurrence of a DTC.

Table 6-2: Description of columns for the raw data table.

Column	Description
Vehicle	Vehicle name.
Position	DTC-position.
Pos info	Position information tag.
Time	The time stamp of the DTC.
Air temp	Air temperature for the DTC.
Road temp	Road temperature for the DTC.
Max wind	Maximum wind for the DTC.
Crosswind	Calculated crosswind.
UV	UV for the DTC.
Altitude	Altitude for the DTC.
Speed	Speed for the vehicle.
Workshop	Whether the DTC is Close to workshop.

Secondly, a table containing statistics (average, standard deviation, median, max and min) for some of the variables (air temperature, road temperature, maximum wind, UV and altitude) in the data table. That is the variables which are appropriate to calculate statistics for, see Figure 8 for an example. This table is created if there are three or more rows in the data table. Fault codes are omitted in the statistic calculations; thisfore the number of occurrences can differ for the different variables.

Statistics

Variable	Average	Std	Median	Min	Max
Air temp	13,75	6,89	16	0	19
Road temp	18,3	10,69	20,3	0,4	29,2
Max wind	5,74	1,54	5,2	4,4	8
UV	29,06	21,23	34,5	5,1	53,8
Altitude	153	113,59	223	22	245

Rows: 6

Figure 8: An example of the statistic table.

Finally, a histogram is presented for each of variables in the statistic table. Each histogram is created if there are more than four occurrences for the variable and if at least one value differ from the others. The width of the intervals are vary depending on the variable (2 for air temperature, 2 for road temperature, 2 for maximum wind, 25 for UV and 25 for altitude). See Figure 9 for an example.

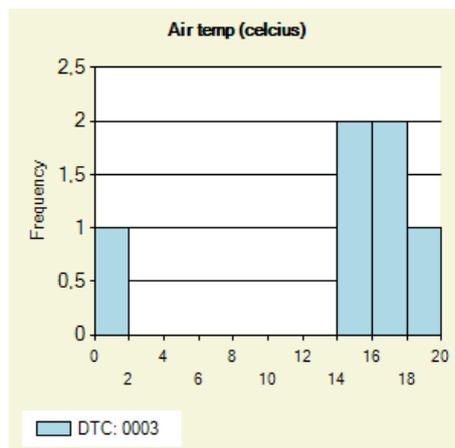


Figure 9: Example of histogram for plot1.

6.2.2.2 Plot2

The plot used to compare two different DTCs consists of a histogram. The histogram is similar to the one in plot1, but the difference is that this histogram contains two data series (for the two chosen DTCs). See Figure 10 for an example.

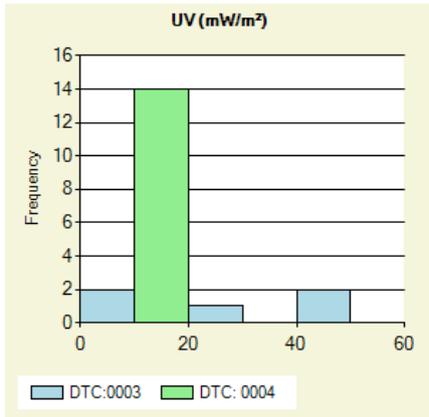


Figure 10: An example of a histogram for plot2.

6.3 Fault codes and error messages

Air temp, road temp and max wind have fault code defined in the database. UV and altitude are collected from web pages and are given fault codes if they return abnormal values. Cross wind is given a fault code if any of the parameters used to calculate it contain a fault code value.

Error messages are displayed in form av alert windows once an error has occurred. Examples of actions that will result in error messages are, trying to plot a DTC from an empty drop down list, trying to plot a DTC without a valid time stamp.

7. Discussion

This chapter presents a discussion about the results and states some suggested approaches for future work.

The objective of this thesis was firstly to create a method for determining the position of a DTC. Secondly, to find relevant data to present along with a DTC-position. And finally, show how fault code positioning might be used to give additional information about the environment in which the fault code was created.

Linear interpolation has been used to determine the position of DTCs. Interpolation is the normal case and would be the only case if the coverage of the position data would have been perfect. However, it is not and some exception cases are used if the data lack in coverage. The lack could be due to lack of GPS reception resulting in missing positions from the OP test database. However each determined position is given a position information tag which explains how the position was determined. This gives an indication of the quality of the position. However, if a DTC-position is calculated by interpolation, how accurate is that position?

The linear interpolation gives a DTC-position which is located on the straight line between the two base positions. However the route the vehicle took is most probable not a straight line. A marginal error circle is therefore created around the first position representing the area where the vehicle might have been when the DTC was created.

Whether the DTC-position is accurate enough depend on how and what the position is used for. One of the features in the demonstrator is to connect weather data from the closest weather station to the DTC-position. Whether the DTC-position is accurate enough for that case depends on if the closest weather station changes when we move around in error margin area since another weather station might result in other weather data.

An obvious improvement of the interpolation method would be to make it less linear and more realistic. For example if it is possible to capture possible roads between two given positions and thereafter make the interpolation along that road. This requires a better map but also a more sophisticated interpolation method. Besides that, a closer interval for the positions from FMS would of course make the DTC-position more accurate. However, that is a matter of cost for Scania.

Internal (Scania) as well as external (environmental) data has been used to present information about the environment in which the fault codes were created. It has however been hard to figure out what kind of data that could be interesting to present along with a fault code, employees do not seem to think it through. This thesis could hopefully serve as an inspiration for future research. However to find relevant data is not the only problem, the data needs to be accessible as well. It is for example hard to find historical weather data which is free of charge.

The position of fault codes are presented along with the collected data in a demonstrator. The demonstrator was divided into two interfaces; gui1 and gui2. The approach of gui1 is to look

at a specific occurrence of a DTC and get as much information as possible about it. The DTC is plotted on a map along with workshops, weather stations and traffic accidents. The approach of gui2 is to get a general picture of a DTC. Data for all occurrences of a DTC are presented and statistics and diagrams are calculated for appropriate variables.

There are of course many ways in how the demonstrator could be designed. Yet again, it is a question about usage. Since no specific objective was set up for the design of the demonstrator other than creating an example it is hard to rate the demonstrator or say something about shortages. There are however good possibilities to continue the work. The environmental data used and the demonstrator created could be further developed depending on the purpose. Some possible approaches for future work are suggested below.

7.1 Future work

Two approaches for future work with fault code positioning are suggested.

7.1.1 Further environmental data research

Environmental data seems to be interesting in a DTC context, however further research is needed by Scania to find out what and how to use the data. The Scania's användarfaktorer document can be used further to get some ideas. (Svensson, 2009)

More qualitative weather data (that is more weather stations) do not exist according to Swedish Transport Administration however other parameters are measured by other companies that have access to other weather stations. A weather sources that are worth looking into is meteogroup (www.meteogroup.se/) which stores European weather data.

7.1.2 Looking deeper into statistics

Statistics for a specific DTC were plotted in Gui2. However this could be developed much further by investigate the relationship between different environmental data and DTCs. Can some parameters determine the DTC? An idea is to compare the statistics from gui2 with the entire population. Another one is to do regression analyses.

The population has to be chosen more carefully for this approach. And furthermore, each occurrence of a DTC needs to be stored with its belonging parameters in some way. The latter also requires a gui where the user can choose to see (geographic or statistics) of all DTCs that satisfy search criterions like *road temperature below 0 degrees*.

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Appendix

Fyll i den information du önskar få från en felkodsutläsning om man har positionen av fordonet vid utläsningstillfället.

Önskemål	SSS-ID
Land, Närmaste stad avstånd och riktning dit. T.ex. Sverige, 10 km Nordväst om Stockholm	X
Om något PC-verktyg var anslutet, typ SDP3, gadget, dMec etc	X
Riktning man färdades i vid feltillfället	X
Statistik om vissa felkoder/fel i delsystem (typ EGR, SCR) är över/underrepresenterade vad gäller temperatur intervall, tryck, nederbörd, region, säsong, körstil (lättlast, tung, stadstrafik...), kombinerat med interna variabler som stadsfaktorer, adaptationer.	X
statistik för IUPM data för diagnostester, i delsystem (typ EGR, SCR), vad gäller temperatur intervall, tryck, nederbörd, region, säsong, körstil (lättlast, tung, stadstrafik...), kombinerat med interna variabler som stadsfaktorer, adaptationer.	X
I klartext om det rör sig om positionen motsvarar en Scaniaverkstad	X

Figure 11: Excel document used for the survey.