HALMSTAD UNIVERSITY

Course Description

Intelligent Vehicles, 7.5 hp

Björn Åstrand

Spring 2013

Course code: MK8005. Homepage: www.hh.se/mk8005

Table of Contents

MK8005 – Course Description

1 Welcome!

The aim of this course description is to support your learning during this course. The goal is that this document will help you reach intended learning outcomes. The document contains a more detailed description of what you suppose to learn compare to the syllabus. It also describes your role as a student and what you suppose to do under and between different scheduled learning activities. Most of your time you will spend on this course is non-scheduled. The role of the teacher is to support you in your learning, but it is up to you how you learn. We also expect that you take responsibility for your learning, meaning that you plan your studies so that you reach the course objectives in time. Some of the learning activities are done together with one or more of your fellow students, e.g. seminars and exercises. This requires that you are well prepared before these learning activities so you have something to contribute with. Studies show that you actually learn a lot from your fellow students and these learning activities are designed based on this.

There are some requirements to pass this course. This document tells you what these requirements are and how they will be assessed. It is important for us that you feel that your examination has been correctly assessed and that it is according to current regulations.

The course consists of lectures/seminars and four exercises. To pass the course, you have to pass all four exercises (a written report on each of the exercises), pass the written exam and give an oral presentation in the end of the course. Moreover, you should, together with the course literature, read some additional papers, which are discussed on seminars. The questions, which are given additional to each paper, form the basis of these discussions.

Exercises are done in groups of two students and you write a report together. First exercise starts week 5 and following are scheduled to week 7, 9 and 10. The paper discussion starts week 4.

The course has a homepage where you can find most of the material and information given in this document and some additional material see http://www.hh.se/MK8005

Contact information

Teacher/ Course examiner	Björn Åstrand
Mail	bjorn.astrand@hh.se
Homepage	http://islab.hh.se/islab/islab/people/astrand/

Important! **Mark all mail with “MK8005” in the subject field. Please keep track on all history in mailing conversation. Use “reply”!**
You shall also use your university mail address in conversation. According to university regulations you should regularly check your email box and read relevant messages contained therein.

1.1 Student’s working environment

“Creating a good working environment is something which is collectively of importance for management, employees and students all of whom have a responsibility to participate in the process”. To read more about Halmstad University´s programme for systemic working environment

initiatives, use following link:
http://www.hh.se/english/education/registeredstudent/commonregulations/workingenvironment.2369_en.html

2 Course objectives and intended learning outcome

The goal of the course is to provide advanced knowledge for being able to develop intelligent vehicles and mobile robots with the emphasis on sensor systems, signal processing and control and regulation. The course focuses on sensor fusion, i.e. how information from several sensors should best be combined.

Upon completion of the course you should be able to:

Knowledge and understanding

- describe and compare different navigation systems for indoor and outdoor navigation
- explain how basic GPS-based systems work

Skills and abilities

- apply, appraise and explain fundamental models for dead-reckoning and kinematic models and methods for combining information from several sensors
- select and present a scientific article in the area of sensor fusion

Judgement and approach

- assess and together with others discuss scientific articles in the area of intelligent vehicles

2.1 Course contents

The course addresses: Dead-reckoning and kinematics models, indoor navigation systems, outdoor navigation systems (e.g. GPS-based systems), sensor fusion (with a focus on the Kalman filter and the Extended Kalman filter), path-planning and obstacle avoidance.

3 Teaching formats

Instruction is by lectures, weekly discussions on scientific papers and exercises. The exercises are documented by a written report. Parts of the course is mandatory, e.g. seminars.

Teaching is in English.

The rest of this chapter is a compilation of the different scheduled teaching and learning activities in this course, how you prepare yourselves before these activities and what you expect to learn from it. This can be seen as a guideline how to embrace the course material and how different learning activities help you to reach the course learning objectives.

3.1 Course introduction

The course starts with a course introduction given by the course examiner. We will also walk-through this course description, and you can ask questions if there are some unclarities. This year we will only have one exercise group, see schedule in Chapter 9.

The second part of the course introduction will be an introduction to the subject Intelligent Vehicles and locomotion mechanism used for mobile robots.

Intended learning outcome
After this learning activity you should have gained knowledge and understanding of different locomotion systems used for mobile robots, especially with focus on mobile robots, i.e. different type of wheel used and how different wheel arrangements influence the mobile robots performance, e.g. stability, maneuverability and control ability.

Reading material
Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 1-2.**

Lecture notes, see course homepage: www.hh.se/MK8005

3.2 Basic statistics I

This is a repetition of knowledge that you hopefully already have acquired in previous courses. The intention of this learning activity is to repeat statistical concepts needed for this course, e.g. stochastic variable, expected value and variance, probably distribution (normal distribution) and linear combination of normally distributed independent stochastic variables.

What might be new to you is that we here derive an expression for the optimal combination of normally distributed stochastic variables by minimizing the posteriori variance. This is the foundation for the Kalman filter that we will treat later in the course.

Intended learning outcome
After this learning activity you should have knowledge and understanding of linear combination of normally distributed independent stochastic variables, skill and ability derive an expression of the optimal combination of normally distributed stochastic variables by minimizing the posteriori variance and the judgment then this statistical methods are valid or not .

Reading material
Bengtsson, O., *Statistics - and what you need to know about it*, Compendium, University of Halmstad, March, 2004, **Chapter 1-4**

Lecture notes, see course homepage: www.hh.se/MK8005

3.3 Basic statistics II

Here we treat the non-linear combinations of independent stochastic variables, especially how to calculate the variance and multidimensional Gaussian distributions. We also explain the theory behind *the law of error propagation*. These tools are later in the course used for calculation of, for example, the uncertainty of the mobile robot position, i.e. the variance of the estimated position.

Intended learning outcome
After this learning activity you shall have the skill and ability to use the law of error propagation to calculate the variance of the uncertainty parameters of an equation system that, for example describe a mobile robots pose. You should have knowledge and understanding of how the law of error propagation is derived.

Reading material

Bengtsson, O., *Statistics - and what you need to know about it*, Compendium, University of Halmstad, March, 2004, **Chapter 5-6**

Lecture notes, see course homepage: www.hh.se/MK8005

3.4 GPS

Localization is an important skill of a mobile robot. Global positioning system (GPS) is a positioning system that gives the position in absolute coordinates.

At this occasion we will have our first paper discussion. The goal of this is that you shall discuss a scientific paper with your fellow students. As help to read the paper and prepare for the seminar there are a couple of questions attached to the paper. The aim is that you shall learn from each other.

This learning activity is important for the upcoming GPS exercise.

Intended learning outcome
After this learning activity you shall be able to explain how basic GPS-based system works.

Reading material
Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 4.1.5.1.**

W. Lechner and S. Baumann, Global Navigation Satellite Systems, Computers and Electronics in Agriculture, Volume 25, Issues 1-2, January 2000, Pages 67-85. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.5 Exercise #1 – GPS

This is the first exercise. All exercises are performed in Matlab. If you are not familiar with this tool, it's strongly recommended that you do the Matlab Tutorial. During the exercise you have the opportunity to ask questions to the exercise teacher. A good idea is to read the exercise material before the exercise starts so that open questions can be answered at an early stage. You will not be able to finish the exercise within the four hours if you not are well prepared.

Most work you will spend on writing the exercise report following the instructions given below and in Section 11. You will get feedback **once** before its graded pass or not pass. Try to submit the exercise as soon as possible, but not later than a week after the exercise otherwise work will pile up at the end of the course.

Intended learning outcome
After this learning activity you shall knowledge and understanding about how basic GPS system work and how different measurement noise effects your observations.

Reading material
Exercise 1 - GPS (Static and mobile receiver).

GPS compendium
Global Positioning System Data Processing
Longitude and Latitude Conversion

Guidelines for writing report is available in either PDF (pdf, 8 kB) or Word (word, 28 kB) format

Matlab tutorial.

Lecture notes, see course homepage: www.hh.se/MK8005

3.6 Kinematics and dead reckoning

Kinematics is a basic description of how mechanical systems behave. You need to understand the mechanical behavior of the robot to make a good design of a robot and to be able to control it. In this course we will treat, more deeply, two types of robots with different mechanical behavior: the differential drive robot and the steer drive robot. The kinematic models are used for estimate or predict robots location. This is also known as dead-reckoning.

At this occasion we also discuss a scientific paper. This paper is a background paper for exercise 2, *Kinematics, dead reckoning and error propagation*. In the exercise you will implement and evaluate the methods presented in the paper. Again you have some questions for preparation before the seminar.

Intended learning outcome

After this learning activity you shall have knowledge and understanding about kinematic models of mobile robots and their constraints. You shall have the ability and skill to derive kinematic models for different types of mobile robots. You shall know how to apply fundamental models for dead reckoning and estimation of robot pose uncertainty.

Reading material

Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 3, 5.1-5.2**

C. M. Wang, Location Estimation and Uncertainty Analysis for Mobile Robots, IEEE International Conference on Robotics and Automation, 24-29 April, 1988, pp. 1231-1235. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.7 Perception I

Acquiring knowledge about itself and especially the environment are some of the most important tasks for a mobile robot. This is achieved using various types of sensors and then trying to extracting meaningful information from those measurements. The process of sensing and interpretation of the sensed data is called perception. Here we talk about different types of sensors used in mobile robots and how they work.

At this occasion we also discuss a scientific paper. The topic is how to combine two low-cost sensors to get a better sensor. The system will only work under very restricted constraints not told in paper. You are encouraged to find out when the system will work and under which conditions it won't. Again you have some questions to preparer before the seminar.

Intended learning outcome

After this learning activity you shall have knowledge and understanding about basic sensor used in mobile robots. How to use them, their limitation and constraints.

Reading material

Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 4**

A-J. Baerveldt and R. Klang, A Low-cost and Low-weight Attitude Estimation System for an Autonomous Helicopter, Intelligent Engineering Systems, 1997. INES '97. Proceedings., 1997 IEEE International Conference on Intelligent Engineering Systems, 15-17 Sept., 1997, pp. 391-395. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.8 Exercise #2 – Kinematics, dead reckoning and error propagation

This is the second exercise. By now you have already handed in exercise 1 and can now focus on exercise 2. This exercise is closely connected to the following exercise, and the models for dead-reckoning and estimation of robot pose uncertainty will be used in the forthcoming exercises.

Before this exercise you shall complete the *Kinematics and dead reckoning* and *Basic statistics* learning activity. A good idea is read to the exercise material before the exercise starts so that open questions can be answered at an early stage. You will not be able to finish the exercise within the four hours if you not are well prepared.

Most work you will spend on writing the exercise report following the instructions given below. You will get feedback **once** before its graded pass or not pass. Try to submit the exercise as soon as possible, but not later than a week after the exercise otherwise work will pile up at the end of the course.

Intended learning outcome

After this learning activity you shall be able to apply, appraise and explain fundamental models for dead-reckoning and kinematic models.

Reading material

Exercise 2 - Motion models, position estimates and uncertainty of position estimates Khepera mini robot (Differential drive), Snowhite (Three-wheeled robot (steer-drive)).

Guidelines for writing report is available in either PDF (pdf, 8 kB) or Word (word, 28 kB) format

Lecture notes, see course homepage: www.hh.se/MK8005

3.9 Perception II

Here we continue taking about sensors used in mobile robotics. We especially focus on the laser range finder and on cameras.

The topic of the scientific paper we will discuss this time is scan matching. Scan matching is a method to match two laser range scans with each other to derive the translation and rotational difference between them. This technique is used in mobile robot for example; derive relative movement of a robot or match the scan with a map (localization). The latter method is described in the paper by Cox. You will later implement this method in exercise 3, *Perception*. Again you have some questions to preparer before the seminar.

Intended learning outcome

After this learning activity you shall have knowledge and understanding about laser range finders, how they work and are used in the context of mobile robots. You shall have knowledge and understanding of how scan matching works and ways to estimate the uncertainty form sensor readings.

Reading material

Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 4**

I. J. Cox, Blanche - An Experiment in Guidance and Navigation of an Autonomous Robot Vehicle, IEEE Transactions on Robotics and Automation, Volume 7, No. 2, pp. 193-204, April, 1991. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.10 Exercise #3 – Perception

In this exercise, the third, you will implement the Cox scan matching algorithm used for mobile robot localization.

Before this exercise you must have finished following learning activities: *Exercise 2 – Kinematics, dead reckoning and error propagation* and *Perception II*. A good idea is to read the exercise material before the exercise starts so that open questions can be answered at an early stage. You will not be able to finish the exercise within the four hours if you not are well prepared.

Most work you will spend on writing the exercise report following the instructions given below. You will get feedback **once** before its graded pass or not pass. Try to submit the exercise as soon as possible, but not later than a week after the exercise otherwise work will pile up at the end of the course.

Intended learning outcome

After this learning activity you shall have skills and ability about scan matching using laser range finders and a map, how this can be used for localization and how to estimate uncertainty from the matching process.

Reading material

Exercise 3 - External sensor information and extraction of features (Snowhite - Laser).
Additional material - videos illustrating exercise #3 and #4 (each file is approximate 6.5Mbytes).
Robot's laser readings during a run (the position estimates are based on dead reckoning only)
Robot's position estimates are based on dead reckoning only
Robot's position estimates are based on dead reckoning and simulated position fixes (small errors)
Robot's position estimates are based on dead reckoning and simulated position fixes (small errors) which are fused in a Kalman filter
Robot's position estimates are based on dead reckoning and simulated position fixes (large errors) which are fused in a Kalman filter

Guidelines for writing report is available in either PDF (pdf, 8 kB) or Word (word, 28 kB) format

Lecture notes, see course homepage: www.hh.se/MK8005

3.11 Localization and sensor fusion – The Kalman filter

Where am I? Localization is one of the building blocks of mobile robot navigation. Localization means that the robot must have the skill to determine its position in the environment. To do this the robot uses sensors to interpret the environment and sensors for estimate ego motion. To estimate its position in the environment a robotic system often uses a set of sensors. Here we will talk about how the Kalman-filter can be used for sensor fusion. We also talk about different navigation approaches and ways to represent robot position.

Today we will discuss a paper that is an introduction to the Kalman filter. Kalman filter is in this course used to fuse information from different sources. You will implement a Kalman filter in the fourth exercise, *The Kalman filter*. Again you have some questions to preparer before the seminar.

Intended learning outcome

After this learning activity you shall have knowledge and understanding of sensor fusion, i.e. how to combine information from sensors, ways to represent a robots position and the Kalman filter.

Reading material

Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 5.1 – 5.4**

P. S. Maybeck, The Kalman Filter: An Introduction to Concepts, Autonomous Robot Vehicles, I. J. Cox and G. T. Wilfong, Eds., New York: Springer-Verlag. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.12 Sensor fusion

Here we talk about different approaches to robot localization. Especially we talk about Kalman filter localization.

Today we will discuss a paper that uses the Kalman filter to combine observations from several sensors to do robot localization. This paper is a background paper to exercise 4, *The Kalman filter*. Again you have some questions to preparer before the seminar.

Intended learning outcome

After this learning activity you shall have knowledge and understanding about probabilistic methods that can be used for robot localization and different approaches to map representations.

Reading material

Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 5.5-5.8**

K. O. Arras, N. Tomatis, B. T. Jensen and R. Siegwart, "Multisensor On-the-fly Localization: Precision and Reliability for Applications", Robotics and Autonomous Systems, pp. 131-143, 2001. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.13 Exercise #4 – The Kalman filter

This is the forth exercise and the last. In this exercise you will implement the Kalman filter and use it to fuse data coming from odometry (exercise 2) and scan-match based localization system (exercise 3).

Before this exercise you shall complete the *Localization and sensor fusion – The Kalman filter* and *Sensor fusion* learning activities. You shall also have finished exercise 2 and 3. A good idea is to read the exercise material before the exercise starts so that open questions can be answered at an early stage. You will not be able to finish the exercise within the four hours if you not are well prepared.

Most work you will spend on writing the exercise report following the instructions given below. You will get feedback **once** before its graded pass or not pass. Try to submit the exercise as soon as possible, but not later than a week after the exercise otherwise work will pile up at the end of the course.

Intended learning outcome

After this learning activity you shall have skills and ability about Kalman filter localization, i.e. how Kalman filter can be used for combining information from several sensors

Reading material

Exercise 4 - Same as Exercise 3 Sensor fusion (Kalman Filter).

Lecture notes, see course homepage: www.hh.se/MK8005

3.14 Planning, navigation and obstacle avoidance

Now we have reached the last chapter in the textbook. Navigation is basically moving from point A to point B. To do this, robot need to know its position (localization). It also needs to plan its path from A to B – this is called the path planning. To react on unforeseen events a robot must have the skill to avoid obstacles.

Today we will discuss **two** papers. The first paper is about a popular obstacle avoidance algorithm called Vector Field Histogram. The second paper describes different application of this method. Again you have some questions to preparer before the seminar.

Intended learning outcome

After this learning activity you shall have knowledge and understanding about different methods for path-planning and obstacle avoidance. You shall also understand the difference between the concepts of local and global navigation.

Reading material

Siegwart, R. & Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots*. Massachusetts: the MIT Press. **Chapter 6**

J. Borenstein and Y. Koren, The Vector Field Histogram - Fast Obstacle Avoidance for Mobile Robots, IEEE Transactions on Robotics and Automation, Volume 7, No. 3, pp. 278-288, June, 1991. Paper - Questions

S. Shoval, I. Ulrich and J. Borenstein, NavBelt and the GuideCane, IEEE Robotics and Automation Magazine, Volume 10, Issue 1, pp. 9-20, March, 2003. Paper - Questions

Lecture notes, see course homepage: www.hh.se/MK8005

3.15 Applications – student presentation

The goal of this learning activity is that you shall, together with one fellow student, present a paper on the topic mobile robot navigation (sensor fusion). Based on the experience you have gained at this point of the course you shall select a relevant paper and present it in a seminar for your fellow student. The presentation is about 15 minutes with additional 5 minutes of questions. You shall prepare a PowerPoint presentation along with 3 relevant questions on the paper. The paper and questions are sent to the examiner no later than one week before the presentation.

This presentation is graded pass or not pass.

Intended learning outcome

After this learning activity you shall have skills and ability to select and present a scientific paper in the scope of sensor fusion.

Reading material

Exercise 6 - Presentation - Sensor fusion.

Lecture notes, see course homepage: www.hh.se/MK8005

4 Course requirements

The requirement to pass this course is:

1. Hand in four exercise reports (one on each exercise). The exercise shall be written according to the guidelines given.
2. Oral presentation of selected paper. The paper should have a focus on sensor fusion techniques.
3. Actively participate in paper discussion (seminars at least 5 of 7 occasions). Actively means that you can answer paper questions, contribute to paper discussion with own views, thoughts and comments on paper.
4. Pass the written exam.

5 Examination

To get your degree you must fulfill all course requirements stated in section 4. The written exam corresponds to 4 credits, exercises 2.5 credits and paper discussion and the oral presentation corresponds to 1 credit. The reason for having a written examination is to fulfill the requirement of that all grades shall be individual assessed. The grade you achieving on the written exam gives you the finale grade on the course.

Exercises are assessed by written reports. Reports which are well written and which contain relevant experiments and well explained results (with logical conclusions drawn) favor the final grade of the course in a positive way. You will get feedback **one time only** on each exercise. The exercise report must be handed in at latest the same day as the first written examination in March.

Oral presentation of a topic chosen by groups of two students.

Example of a written exam is available on course homepage: www.hh.se/MK8005

6 Grading

The written exam is graded: not passed, 3, 4 and 5

The exercises are graded: not passed / passed.

The oral presentation along with the paper discussions is graded: not passed / passed.

7 Time for examination

The course ends Friday week 11. The following week is the first examination occasion for the written exam and the possibility to retake it is at the end of the spring semester. Last occasion to retake is just before the start of the autumn semester.

The exercise report must be handed in the latest one week after the exercise occasion. Latest time for submitting the exercise reports are the same day as the first examination in March. Next time for hand in exercises is at the same dates as the retakes. All exercised not passed one week after the last retake date will be graded as not passed.

8 Course evaluation

At the end of the course there will be a course evaluation. Here you have the possibility to give feedback on the course, hopefully in a constructive way, so it can be used as guidance for future development and planning of the course. However, giving feedback on the course is not restricted to this occasion. You can always discuss various matters of the course with the examiner.

The course evaluation is done online and a mail containing instructions will be sent to you at the end of the course.

9 Schedule spring 2013

Preliminarily schedule – always check the schedule for the current week on University homepage.

	Activity/Book/Material	Lecture / Discussion	Exercise
w. 4	**Course description** **Overview** (Chapter 1 – 2) **Basic statistics I and II** (Compendium + Chapter 4.2) **GPS** (Chapter 4.1.5.1 + Compendium + paper: Lechner and Baumann 2000)	Monday, 08-10 Wednesday, 08-10 Friday, 08-10	
w. 5	**Kinematics and dead reckoning** (Chapter 3, 5.1-5.2 + paper: Wang 1988)	Tuesday, 09-12	**Exercise #1**, GPS, Wednesday , 13-17
w. 6	**Perception I** (Chapter 4 + paper: Klang and Baerveldt 1997) **Perception II** (Chapter 4 + paper: Cox 1991)	Tuesday, 09-12 Thursday, 09-12	
w. 7	**Localization and sensor fusion - Kalman filter** (Chapter 5 + paper: Maybeck.)	Friday, 9-12	**Exercise #2**, Kinematics, dead reckoning, error propagation, Friday, 08-12
w. 8			
w.9	**Sensor fusion** (Chapter 5 + paper: Arras *et al.*) Guest Lecture	Monday, 9-12 Wednesday, 10-12	**Exercise #3**, Perception, [Cox 1991], Wednesday , 13-17
w. 10	**Planning, navigation and obstacle avoidance** (Chapter 6 + papers: Borestein and Koren 1991, Shoval *et al.* 2003) – Note: two papers this time! Guest Lecture	Monday, 09-12	**Exercise #4**, Sensor fusion, Kalman filter, Tuesday , 13-17
w. 11	**Applications** (Student presentations)	Tuesday, 09-12 Thursday, 09-12	

10 Course grading matrix – Intelligent Vehicles, MK8005, 7.5 credits

Course Objectives	How it is examined	Grade 3/Pass	Grade 4	Grade 5
describe and compare different navigation systems for indoor and outdoor navigation	By exercise reports on exercise 1 (GPS) and 3 (Perception) written according to guidelines, see chapter 11.	The report shall be written according to guidelines given. All results shall be correct and presented in such a way that they can be judged without examine the code that generate them.		
	Written exam	Can answer questions directly related to exercises contents.	Able to choose a suitable navigation method given a particular problem.	Relate methods in exercises with other navigation methods found in literature.
explain how basic GPS-based systems work	By exercise report on exercise 1 (GPS) written according to guidelines, see chapter 11.	The report shall be written according to guidelines given. All results shall be correct and presented in such a way that they can be judged without examine the code that generate them.		
	Written exam	Can answer questions directly related to exercises contents.	Explain causes to when GPS system works and not and the source of errors.	Relate and compare GPS based navigation systems with other navigation methods.
apply, appraise and explain fundamental models for dead-reckoning and kinematic models and methods for combining information from several sensors	By exercise reports on exercise 2 (Kinematics, dead reckoning, error propagation) and exercise 4 (Sensor fusion, Kalman filter) written according to guidelines, see chapter 11.	The report shall be written according to guidelines given. All results shall be correct and presented in such a way that they can be judged without examine the code that generate them.		
	Written exam	Can answer questions directly related to exercises contents.	Able to analyze result from exercises and explain causes to system performance.	Relating to existing methods and principles, so that unseen problems can be handled.
select and present a scientific article in the area of sensor fusion	By presentation of a scientific paper on sensor fusion at a seminar. The presented paper shall be at same scientific level as papers read in this course. The attached question shall be in line with those attached to papers in this course.	Presents the paper and its topic in a clear way. Can answer fundamental questions on the paper. Answers at least some of the fellow student's questions.		
assess and together with others discuss scientific articles in the area of intelligent vehicles	By actively participate in paper discussion-seminars, i.e. can answer paper questions and discuss contents with fellow students.	Can answer the major part of the paper questions and participate in discussion with own views, comments and thoughts on paper.		

11 Exercise report guidelines

Exercise 0: Guidelines for writing technical reports

Ola Bengtsson

Abstract

You should summarize the most important results of this exercise and write it in the abstract. The abstract should also include a short description of which area that is covered by the exercise and why this is important. The abstract should be 15 sentences long approximately.

1. Introduction

You should describe the area covered in the exercise. The description should be such that any person with appropriate technical knowledge should understand where and when to use the theory and methods described in this report. You might want to present, and briefly describe, work related to the work presented in the next section, Theory / Method. This means that you e.g. should refer to literature that gives a deeper presentation of the related work [Person and Person 2000]. More information can be found in [Person et al. 2001]. You should e.g. add the limitations in the experiments and under what assumptions the experiments were done. The introduction part should be one half to one page long.

To make the report consistent with scientific reports, the introduction part should also include a short description of the rest of the report, i.e. a brief description on what follows in the report.

2. Theory / Method

The experiments should be replicable, which means you should describe it in such way that any person with appropriate technical knowledge should be able to replicate your experiments by following your description in Section 2 and 3. This means that Section 2 should include all necessary theory, e.g. mathematical equations, references to necessary papers, illustrative figures etc. (Sections 2 and 3 should be the main core of the report.)

It is important to get a good structure of Section 2, why the use of sub-sections (i.e. Section 2.1, 2.2 and Section 2.2.1, 2.2.2 etc.) might be appropriate.

3. Experiments / results

You should describe the conducted experiments in such way that any person with appropriate technical knowledge can repeat the experiments. It is important to clearly explain the purpose of each experiment, show the results in illustrative ways and explain the results to the reader. In the case of many experiments, describe each experiment in a separate sub-section, i.e. Section 3.1, 3.2, 3.3, …, 3.N.

4. Conclusions and further improvements

You should make a clear conclusion on the exercise, what you have learnt etc. It is also appreciated if you write suggestion on how to improve the exercise for another year.

References

[Person and Person 2000]	Person, O.; Person, T. (2000), Title of the paper that I am referring to, Which Journal or Proceedings the Paper was Published, In which town the paper was published, What year the paper was published, In what volume the paper was published, In which pages the paper was published.
[Person et al. 2001]	Person, O.; Person, T.; Person, T. Person, F. (2001), Title of the paper that I am referring to, Which Journal or Proceedings the Paper was Published, In which town the paper was published, What year the paper was published, In what volume the paper was published, In which pages the paper was published.

Send, by e-mail, the exercise report in pdf-format to the course examiner. Don't forget to use the course code in the subject field, i.e. MK8005.