Instrumentation of biped prototype

Project description report

Jonas Hjulstad, Endre T. Ellingsen, Henrik Baldishol ,
Jakob Karlsen, Kristoffer Nordvik

Project description report for TELE3001 Bachelor Thesis

Supervisor: Torleif Anstensrud, ITK

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Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Engineering Cybernetics

NTNU

Abstract

The project is given by the Department of Engineering Cybernetics, NTNU where research has been conducted on the gaits of walking, biped robots. Our project is to complete a physical prototype for testing developed models of said research. The completion mainly consists of obtaining an accurate measurement of the attitude and angular velocity of the robot limbs as well as wiring and migration to an independent micro controller. The product should be a system that precisely feeds its state to the micro controller and successfully actuates its movements dictated by an implemented program derived from earlier work of motion planning [1].

This report is a preliminary study to the main project where we also plan division of labour, estimation of time consummation, documentation of earlier work of assembly, definition problem statement, presentation the team as well as their agreement of cooperation, and which objectives we are set to achieve.

Preface

The main project of this thesis is the finalizing endeavour of our third year and Bachelors degree. It presents 20 points of study, which in this project corresponds to about 500 hours per student. The assignment is given by Department of Engineering Cybernetics, NTNU.

Dato / sted

Jonash Hjulstad (JH) Endre T. Ellingsen (EE) Henrik (H)

Jakob Karlsen (JK) Kristoffer Nordvik (KN)

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1 Introduction

1.1 Background

In modern industry, robotic solutions is taking an increasingly larger share of production. While these are essentially mounted operations in predictable environments, it is highly desirable to extend this technology to be applied to challenges outside the factory floor. This would require development of robotics with a better capability for mobility. A suitable proposal would be machines that mimics the gait of humans.

Since McGeer's seminal paper[2] on planar passive walkers, research has been inspired to further examine the possibility of underactuated walking machines. At NTNU, advanced mathematical models [1] have been develeoped in order to plan the motions of such gaits. A physical prototype has been assembled to test the feasibility of these models. Our Bachelor thesis concerns the instrumentation and completion on said prototype.

The current mathematical model concerns a bipedal machine which is constricted to move in the sagittal plane. It is equipped with two pairs of legs, each pair powered by a motor rotating parallel to each other. A torso, mounted as the "hip", constitutes a third degree of freedom and connects the assembly together. The torso is only affected by Newtons third law; the reactionary torques from the motors. Since the orientation of the torso is not directly controlled, the machine is thus of underactuation one.

With that being said, the main structure of the prototype is already completed. There is still a considerable amount of work to do concerning measurements, mounting components, cabling, system identification and documentation. The prior work and design is described in greater detail in 3.2.

1.2 Assignment

This projects assignment is to create an easily-operated bipedal robot, reliable for robot gait research. Instrumentation and programming will be accessible and user-friendly. All previous and planned implementations will be well-documented to ensure that all information needed for further research is accessible. The original assignment text can be found in attachment D.

1.3 Definitions

PWM	Pulse Width Modulation, DC-voltage chopping used to imitate AC-voltage/current
Servo motor	Actuator with rotation proportional to given input signal
Microcontroller	Small computer on an integrated circuit
dSpace	Open-source software respository
dSpace Control Desk	Open-source instrumentation software for experimentation
Simulink	Programming/modeling environment licensed by MathWorks
Matlab	User-friendly programming environment licensed by MathWorks
Visio	Diagramming software licensed by Microsoft
Microsoft Project	Project management software licensed by Microsoft
C	Low-level programming language
Python	High-level programming language simpler to use than C
Linux	Open-source operating system distributions
Beaglebone (Black)	Linux-based microcontroller supporting multiple programming languages
AutoCAD	Computer Aided Design software by Autodesk
SMART-model	Guide to set criterias for objectives in project management

1.4 Structure of the report

The report consists of seven chapters with subsections where we describe the numerous, preliminary prospects of undertaking the upcoming Bachelors project.

1. Chapter: An introduction to the project assignment; background information, definitions related to the report, and the structure of its contents.
2. Chapter: A specific description of the problem statement and its underlying tasks.
3. Chapter: Technical details concerning the goals of the thesis, preliminary work of assembly and estimation of upcoming challenges.
4. Chapter: Presents the planned timetabling.
5. Chapter: Expected outcome; Discusses the criteria of success with regards to progression, final result, communication and education benefits
6. Chapter: Discusses the significance of the completion of the prototype.
7. Chapter: A presentation of the team.

2 Problem Statement

The main problem statement of the thesis is to apply instrumentation for a two-legged robot prototype, which we can divide into five different categories:

- Voltage supply
- Position-feedback torso
- Servo control
- Wiring, mounting, communcation
- Documentation

2.1 Voltage supply

The robot has two electric motors with their own driver requiring a specific voltage. Also, the servos and the micro controller require some specific voltage, so the robot needs a power supply delivering the right amount of power for each part.

2.2 Position-feedback torso

To know the position of the robot's parts, a sensor is needed to give us the position in referance to its surroundings. This is to be accomplished by utilizing an IMU mounted on the torso. From the IMU's gyroscope and accelerometer we get the angular velocity and the torso's orientation relative to the world frame. Since we already have encoders telling us the angles between the torso and each leg this should be sufficient information for finding the robots orientation and position. There is, however, a known issue regarding slack in the transmission for the leg's actuators, which would result in an erroneous bias in the measurement.

2.3 Servo Control

Each leg is equipped with two servos, so the robot has four servos in total. Our job is to identify the PWM input signals we need to make the servos operate equally.

2.4 Wiring, Mounting and Communication

All the parts are to be mounted and wired together in a functional and pleasant way, thus making them able to communicate through a micro controller.

2.5 Documentation

All our work is to be documented in detail, meaning the people working on the robot in the future will find what they need from our work without any inconvenience.

3 Technical Details

3.1 Project objective

3.1.1 Performance goals

- Make our work applicable for future research without any unreasonable modifications.
- Keeping the deadlines.
- Get to the last phase of the project in time to deliver an appreciable result there as well.

When our tasks are completed the robot will have improved walking mechanics and be closer to a finished product. We shall obtain knowledge on implementing theory of robotics, electronics and instrumentation to practical use and learn how to work as a team.

3.1.2 Outcome goals

- Mount a fully functioning IMU to the robot.
- Read measured values from the IMU to a BeagleBone micro-controller.
- Control the robot's retractable feet with the BeagleBone.
- Control the voltage input to each actuator through the BeagleBone.
- Make a reliable model of the robots physical properties and limitations.

3.1.3 Process goals

- Better our communication between colleagues to prepare ourselves for a work environment.
- Complete the project with the letter grade A.
- Learn more on implementing theory in practice.
- Work according to the cooperation agreement.
- Fulfill the clients expectations.

3.2 Preliminary design and work

3.2.1 Frame

The frame is designed through AutoCAD and built at the Department of Engineering Cybernetics, NTNU. It is constructed using square aluminum tubing and custom-machined aluminum parts as the housings for the bearings, the flexible actuator couplings, the motor mounts, and the retractable point feet. The aluminum tubes are connected through custom-machine angle brackets. The bipedal is fully disassemblable with the exception of the bearings which are press-fitted into the construction.

3.2.2 Actuators

Each leg is separately rotated with an electric motor which has a max torque of approximately 3 Nm. The motors operates optimally at 48v and are powered with a power supply on 600 W through two servo controllers. The controllers receive a [-10V,10V] signal from a dSpace Controller Board and send a [-3A,3A] signal to the motors. Each leg has two feet equipped with retractable pointers which are separately powered by a servo motor for extension. To function properly, the servos require a PWM signal delivered at 4.8V. Furthermore, the feet are designed such that the weight of the bipedal rests on a lockable joint.

3.2.3 Measurements

Each of the hip actuators has an encoder attached to measure rotation angle between its rotor and stator. In addition, the encoder's measurements are directly transferred to the dSpace Control Panel. The measurements can then be read through dSpace Control Desk. In each gearbox there is a slack which is noticeable when switching torque direction.

3.2.4 Power and Control

The main components that need external power are the micro controller, the two motors and the four feet servos. The current power supply can deliver 600 W across two separate channels. One is reserved for the two motors, while the other is reserved for the electronics. Currently all the I/O is handled by the dSpace Controller Board via a Connector Panel.

3.2.5 Preliminary parts list

The following table includes all the parts that are currently mounted on the robot or disposable for use.

Description	Product name	Manufacturer
Flexible actuator coupler	4779823	Ruland
Hip bearings	6004-C	Fag
Electric motors for leg actuation	14887	Maxon Motor
1-to-6 Gearbox for motors	Planetary Gearhead	Maxon Motor
Servo controllers for motors	ESCON 50/5 (409510)	Maxon Motor
Servos for retractable feet	S9254	Futaba Corporation
Encoders for relative leg angles	2RMHF	Seancon
IMUs for absolute leg angles	Breakout-LSM9DS1	Sparkfun
Arduino for processing IMU	Arduino MEGA ADK	Arduino
600W power supply	QPX600D	Aim-TTI
Connector Panel for I/O	CLP1103	dSpace
Controller Board	DS1103 PPC	dSpace
BeagleBone Black	BeagleBone Black	BeagleBone
ControlDesk	ControlDesk	dSpace

Table 1: Parts list

3.3 Specifications

When using the Beaglebone micro controller, the programs are written in Python or BoneScipt. The Arduinos utilize Arduino C.

Communication protocolls between the micro controllers and instrumentation is yet to be decided between SPI and I2C.

3.4 Problem areas

3.4.1 IMU Usage

In pure terms of technicalities, the most challenging task will possibly be obtain an accurate measurement of the attitude of the upper body. This will require utilization of a combination of a gyroscope and an accelerometer. The Breakout-LSM9DS1 IMU already has these integrated, but figuring out the means of using it and its placement on the robot, with respect to accurate velocity measurements and disturbance, might prove difficult.

3.4.2 Efficiency and Time Estimate

Currently the main project is divided into three parts where the two first are of highest priority. For now, time has been evenly rationed between each part, but there is still uncertainty in how much time each work package will require. Therefore our current time estimate might present itself to be amiss. Working hours might also forego with uneven productivity as unexpected events may occur.

3.4.3 Exams in March

On the 15th of March, three out of five team members will be taking a postponed exam. This will create a roughly two week time-window prior to the 15th where the majority of work hours shared among them will have to be migrated to the Easter holidays. For now the Gantt Diagrams in 4.2, leaves this out of consideration because of uncertain time estimation of part one and two. (B.1)

4 Timetabling

4.1 Work Packages

Every objective is broken down into work packages to make it easier to decide which tasks to solve first. This structure is used to solve tasks in the right order and to spend the right amount of time on each task.

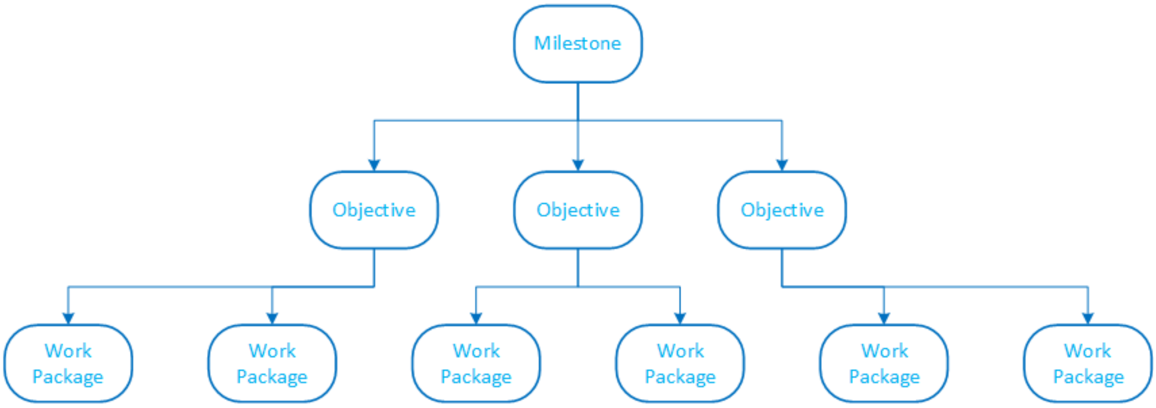


Figure 1: Workload separation

Each student's workload during a time period is divided between these work packages. Some tasks will be more time demanding than others, which is why all packages will have individual deadlines.Past and future activities are included in each work package to show where current tasks fits according to others. All packages contain a detailed description of its task(s), and goals for the time period.

4.2 Workplan

In order to get the results we are looking for, an essential prerequisite is an effective but realistic workplan. However, in order for this to have any positive effect, it is crucial that each member respects the workplan and is committed to keeping the deadlines. Breaking deadlines may occur. It is therefor critical that we have an open dialogue, identifying this prior to the actual deadline, making us able to adjust and minimize the deviation of the time schedule.

The first step is to construct a cooperation agreement which the whole group acknowledges and intend to follow. See Cooperation Agreement C.1

After we have identified the workload of the project we can set up a plan for how to finish in time, assigning tasks to every member with an estimated time-usage in Work Packages. See attachment A.

We have used a Microsoft Office program called Microsoft Project for this. There we can insert every Work Package assigning resources(group-members) and time usage. Also we are able to add milestones and different events such as group-meetings.

From this we get a Gantt-diagram (attachment B.1), a resource usage diagram (attachment B.3) and lastly a timeline, which is known to be a great tool in group projects like this. See attachment B.2. All this helps us to keep track of the project progression and keep up the momentum, in addition to discovering any deviations from the plan and adjusting as early as possible.

4.3 Gantt diagram

We have divided the project in four phases. Firstly we complete the project description process, followed by three stages within the main project in the given order. Documentation of our work goes on throughout the entire project.

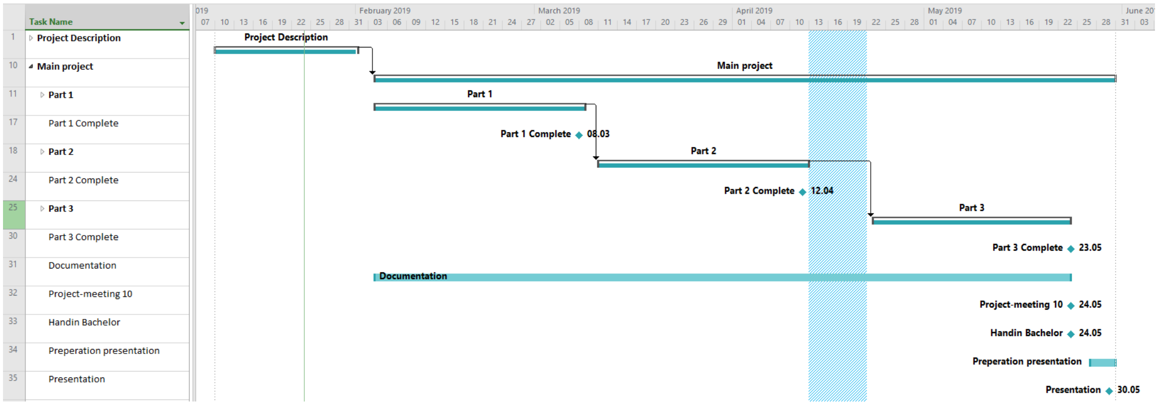


Figure 2: Main parts Gant diagram

Project description During the project description part we have for the most part kept up with the plan and the time-schedule. We tried to set the schedule for this part rather tight to get a good start but also prioritize our time for the main project.

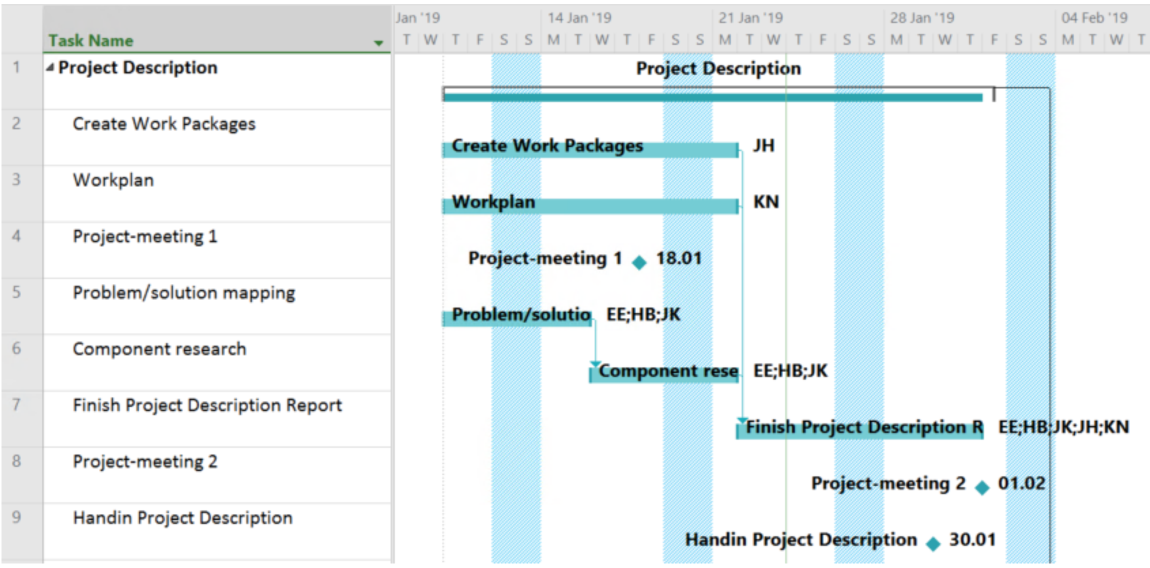


Figure 3: Project description Gant diagram

Part 1 This is the most basic part of the project which we need to complete to continue on to the next part, see attachment A. We consider this as the least challenging part, thus we plan to complete this within a relative short amount of time. This will let us spend valuable time on the more challenging parts. However, the actual work amount for each work package may vary from our estimate since our experience with a project like this is rather lacking. This is something we must take into account and adjust during the project.

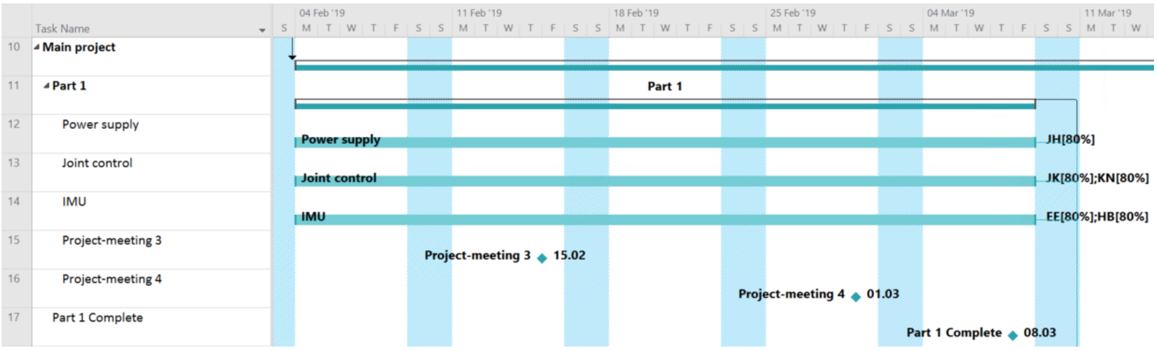


Figure 4: Part 1 Gant diagram

Part 2 The next phase of the project is to get every part communicating through a micro controller and to make the IMU deliver the information we want. We consider this to be the most challenging part, hence the distribution of work assignments.

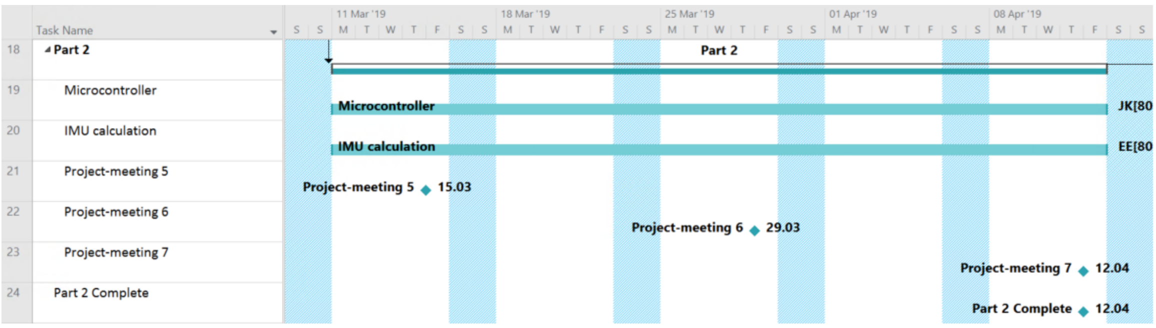


Figure 5: Part 2 Gant diagram

Part 3 When/if we complete part 2, we can start on the last part regarding System Identification and Actuator slack. Particularly the System Identification part is something we think is rather implausible to finish, however the plan is to start with this and keep at it until the projects end. If we manage to follow the time-schedule there should be enough time to get some results here as well.

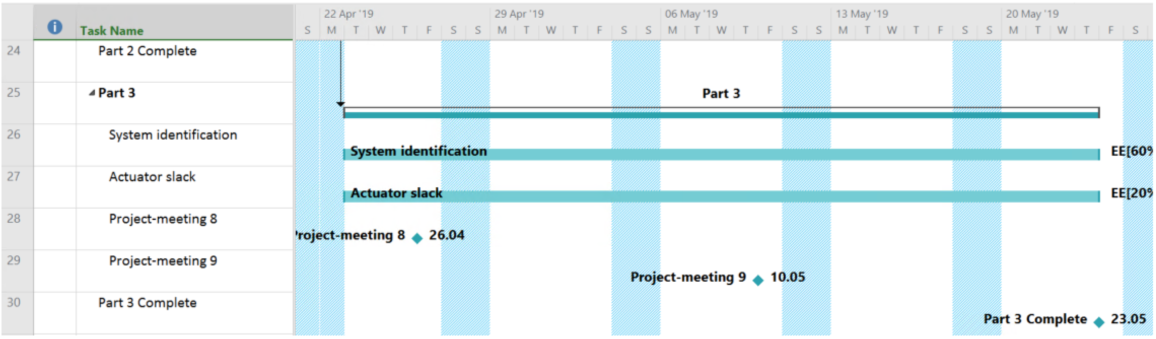


Figure 6: Part 3 Gant diagram

5 Expected outcome

5.1 Product result

At the conclusion of the project, the robot is expected to have fully operational sensors for precise measurement of angles and angular momentum for the swing leg, standing leg and body in reference to the ground. These measurements will be made by an IMU and encoders located in each actuator. Reading of the sensor values will be managed by a BeagleBone micro-controller mounted on the upper body. The BeagleBone will also control the robot's retractable feet, allowing it to walk.

5.2 Educational gain

The project will give the students valuable experience in instrumentation of a real world automated system. The students will learn to use the necessary data protocols for operating a BeagleBone micro-controller, as well as writing code in Python.
Additionally the students will gain experience in teamwork on a larger scale project. They will familiarize themselves to documenting and reporting to their supervisor the work that is being done.

5.3 Quality assurance/Criteria for success

A test plan will be made to ensure the quality of the work being done. All testing will be documented for future reference. All sources for academic materials being used will be thoroughly evaluated for their reliability.

5.4 Communication of results

While working on the project, the students will hold regular meetings with the project supervisor and give updates on where they are in the work process in reference to the given timetable. At the conclusion of the project, the students will write a comprehensive report of all work done on the robot. The students will also give an oral presentation where they show their finished work to the project supervisor.

6 Significance and innovation

The specific purpose of the bipedal robot is to test a mathematical approach to walking called "falling gait" in which the robot falls forward onto its leg in similar fashion to how a human would walk. This method of walking is highly efficient in energy usage, which makes it a valuable subject of study.

Most modern walking gaits for robots are based on keeping the body in constant balance throughout the entire walking animation. This makes the robot's walk highly robust, but it limits the potential for movement. The falling gait allows for more movement as the robot is not required to hold its balance, opening the possibilities for faster and simpler walking and running.

Similar mathematical models have previously been tried on other bipedal robots. While others have gotten their robot to walk properly, they often had to result to modifying the original approach. The purpose of this robot is to walk properly without any modifications to the original model.

Later research using this robot can influence the use of walking robots in industry and make it more practical. New ways to reduce gait energy consumption could be developed. Bipedal robots in larger research facilities are often specialized, and may be able to be equipped with more limbs and components. A simpler version could present efficient solutions to a broader audience.

7 Team members

7.1 Jakob Karlsen

- Age: 22 years old
- Phone: 46676230
- Mail: Jakob-Karlsen@outlook.com

Competence I went to high school and took courses in science, which has made me good at learning theory, but less so at implementing it in reality. I'm a hard and disciplined worker.

Expected result My goal is to get the grade A.

Schedule and motivation I will have a lot of time to work on the bachelor, because my schedule is highly flexible. I have no problems with starting early and leaving late, or work during the weekends. My ambition for this project is to broaden my practical understanding of electrical engineering, and further to develop my theoretical understanding. I'm motivated to perform the work necessary and optimistic to work with my group, as we can learn from each other and get a great result.

About me I work well in groups and love to share and discuss ideas with my fellow group members. I love to push my self and those I work with and keep a good atmosphere during the hours we are together. My weakness is that I'm not great at handling conflicts. Ideally I prefer to maintain a positive impression on my co-workers and have a frictionless environment. This may be a problem during difficult times, when conflict is inevitable.

7.2 Jonas Hjulstad

- Age: 22 years old
- Phone: 40523352
- Mail: jonasbhjulstad@gmail.com

Competence

I graduated at Melhus Videregående Skole in general studies, specialized in physics, chemistry and mathematics. I served the initial service in the Norwegian infantry, 2nd Battalion the next year. Afterwards i started studying electrical engineering at NTNU, now specialized as an automation engineer.

Expected result

I aim for grade A in this subject

Schedule and motivation

Besides a small part time job in the service department at Elkjøp, i am very flexible when it comes to working hours. I will put in all the hours necessary to get good results out of this project. I think electronics and robotics are the most interesting subjects within automation and electrical engineering. Being able to implement electronics for robots will be important for further education. To apply to cybernetics and robotics at NTNU next semester, i need to perform well in this subject. After this project i think we will get a better understanding of embedded systems and sensors, and the practical limitations of the robot. Though it might be optimistic, i hope we will see the robot walk at the end of this semester!

About me

I consider progress and efficiency to be the most important qualities of a group. When deadlines are tight and workloads high, i tend towards working independently to complete assignments, but i will try to cooperate as well as i can. I am arrogant and stick to decisions i favor, even though other choices could be better.

7.3 Kristoffer Nordvik

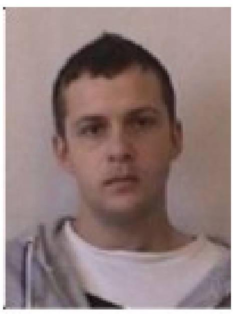
- Age: 24 years old
- Phone: 99117516
- Mail: Kristono@stud.ntnu.no

Competence Graduated at Surnadal Highschool in the field of automation and took my certificate of apprenticeship afterward. I served the initial service in the army stationed at the Garrison of Sør-Varanger, guarding the Russian border. Took a preparatory course and then started my study in Electrical Engineering, specializing in the field of automation, at NTNU.

Expected result My intention is to earn an A in this project

Schedule and motivation Regarding schedule I am available the entire project period, also in the weekends. However, my ambition is to avoid wasting any time and mainly work only weekdays, but I will work weekends as well if needed. My plan is to apply for a master's degree in Cybernetics and Robotics, which means my grades needs to hold a certain standard. More important increasing my expertise going into this study I believe is of great interest for me. And of course, I find my field of study interesting, in particular the subjects covered by the assignment. Both the instrumentation part, but maybe even more the field of robotics and control theory. This should be motivation enough.

About me I consider myself as a responsible person devoting myself to my personal goals. In group projects I appreciate efficiency and believe this is one of the main challenges during a project like this. I tend to take things too personally and is reluctant to change. Which clearly is a challenge during a group project. On the other side, I am reliable, loyal and hard-working, ensuring things are done to the highest standard.



7.4 Endre T. Ellingsen

- Age: 21 years old
- Phone: 46672181
- Mail: endrete@stud.ntnu.no

Competence

I graduated at Byåsen VGS in general studies, with electives in chemistry, mathematics and English. I started studying electrical engineering in 2016 as my intention were to specialize in cybernetics and automation later on. My impression was that it was an exciting approach to solving physical problems using a combination of computer science, control engineering and physics. I am currently doing a bachelors degree in automation.

Expected result

I am aiming for an A.

Schedule and motivation

Concerning the project I have found the subject of robotics and robots with a underactuated gait compelling and would very much like to help complete the prototype.

As I find the field of the bachelor thesis particularly interesting I also want to pursue a masters degree in Cybernetics and Robotics.

With regards to the schedule, I have nothing else on my agenda with the exception that I am retaking a few exams on previous topics. My ambition is to be time efficient enough to avoid this being an obstacle for the project.

About me

I tend to be a more reserved, especially in unfamiliar environments. I am more intuitive than observant. This might seem naive, but I believe nothing should stop the right attitude from achieving its goal. I also believe that efficiency is more important than cooperation, but considering achieving difficult goals, teamwork is key.

7.5 Henrik Baldishol

- Age: 22 years old
- Phone: 95300104
- Mail: henrik.baldishol@gmail.com

Competence

I graduated from Brumunddal VGS general studies in 2015 with electives in physics, mathematics, chemistry and English. After one year of military service i started my Bachelor's degree in electrical engineering and automation.

Expected result

My goal for this project is an A.

Schedule and motivation

My schedule is flexible, which allows me to dedicate most of my time to work on the project. I am very exited to work with instrumentation and sensors, as it is one of the subjects i feel the least familiar with from our studies. I believe the project will be a good experience for future work and studies.

About me

When it comes to teamwork, I believe i can be a little challenging to work with. I tend to work after my own schedule and I often insist on doing things my way. However, I take this project very seriously and will work hard to cooperate fully with the rest of the team. I already know the other team members well, so I believe we will be able to make a good team.

References

[1] Sætre, C. F. (2016). "Stable Gaits for an Underactuated Compass Biped Robot with a Torso - Trajectory Planning and Control Design using the Virtual Holonomic Constraints Approach". Norwegian University of Science and Technology, Trondheim, Norway.

[2] T. McGeer. Passive dynamic walking. The international journal of robotics research, 9(2):62–82, 1990.

A Attachment - Work Packages

Department of Engineering Cybernetics,
Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**			**Date:** 10.01.2019
Project:	Instrumentation of bipedal robotprototype			
Activity:	Create Work Packages			**Activity nr:** 01
Starting date:	10.01.2019	**End date:**	21.01.2019	
Dependency:	**Past Activities:**			
	Following Activities:	(Component research) Finish project description		
Goal:				
Description: Divide all objectives into work packages, assign team members to each objective. Describe each objective and its duration. Split total work hours reasonably across all objectives and team members.				
Total Workload: 20 hours		**Work distribution:** Jonas	20 hours	
Expenses:				
Resources:				
Hazards:				

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
Jonas Hjulstad	jonasbhjulstad@gmail.com	40523352
Endre T.Ellingsen	endre.t.e@hotmail.com	46672181
Henrik Baldishol	henrik.baldishol@gmail.com	95300104
Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

NTNU

Department of Engineering Cybernetics, Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**		**Date:** 10.01.2019
Project:	Instrumentation of bipedal robotprototype		
Activity:	Workplan		**Activity nr:** 02
Starting date: 10.01.2019		**End date:** 21.01.2019	
Dependency:	**Past Activities:**		
	Following Activities:	Finish project description	
Goal: Create a completion plan containing work distribution and deadlines			
Description: Create Gantt-diagram to visualize how much time is going to be spent on each work load throughout the project. Specify deadlines and special cases where standard workplan can't be followed. Set general dates for all meetings inside the group and with supervisor.			
Total Workload: 20 hours		**Work distribution:** Kristoffer	20 hours
Expenses:			
Resources:			
Hazards:			

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
Jonas Hjulstad	jonasbhjulstad@gmail.com	40523352
Endre T.Ellingsen	endre.t.e@hotmail.com	46672181
Henrik Baldishol	henrik.baldishol@gmail.com	95300104
Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

NTNU

Department of Engineering Cybernetics, Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**			**Date:** 10.01.2019
Project:	Instrumentation of bipedal robotprototype			
Activity:	Component research			**Activity nr:03**
Starting date: 16.01.2019		**End date:** 21.01.2019		
Dependency:	**Past Activities:**	Problem/solution-mapping		
	Following Activities:	Finish project description		
Goal: Gather information about every component required to start the project				
Description: Research preinstalled components. Consider which components to use for solving future objectives.				
Total Workload: 60 hours		**Work distribution:** Jakob Henrik Endre	 20 hours 20 hours 20 hours	
Expenses:				
Resources:				
Hazards:				

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
Jonas Hjulstad	jonasbhjulstad@gmail.com	40523352
Endre T.Ellingsen	endre.t.e@hotmail.com	46672181
Henrik Baldishol	henrik.baldishol@gmail.com	95300104
Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

NTNU

Department of Engineering Cybernetics,
Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**		**Date:** 10.01.2019
Project:	Instrumentation of bipedal robotprototype		
Activity:	Finish thesis preparation report		**Activity nr:04**
Starting date: 22.01.2019		**End date:** 31.01.2019	
Dependency: Component research Workplan Work packages	**Past Activities:**	Component research Workplan Work packages	
	Following Activities:	Voltage supply IMU Joint control	
Goal: Complete project description			
Description: Fill in all information found from technical research/workplan development. Describe project goals, issues and possible solutions. List resources and applications planned to be used during the project. Write short summaries of each team members qualifications. Create table of contents, abstract, figure list and introduction. Finish report with summary.			
Total Workload: 100 hours		**Work distribution:** Kristoffer Jakob Henrik Jonas Endre	 20 hours 20 hours 20 hours 20 hours 20 hours
Expenses:			
Resources:			
Hazards:			

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
Jonas Hjulstad	jonasbhjulstad@gmail.com	40523352
Endre T.Ellingsen	endre.t.e@hotmail.com	46672181
Henrik Baldishol	henrik.baldishol@gmail.com	95300104
Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

NTNU

Department of Engineering Cybernetics,
Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**		**Date:** 24.01.2019
Project:	Instrumentation of bipedal robotprototype		
Activity:	Power supply		**Activity nr:05**
Starting date: 04.02.2019		**End date:** 08.03.2019	
Dependency: Finish project description	**Past Activities:**	Finish project description	
	Following Activities:	Microcontroller	
Goal: Supply all components with required voltage			
Description: Find voltage drop in motor controller, readjust power supply to give motors their required voltage. Implement circuit and wiring to supply servos, controller and IMU.			
Total Workload: 110 hours		**Work distribution:** Jonas	110 hours
Expenses:			
Resources:			
Hazards: Motor torque, Voltage			

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
Jonas Hjulstad	jonasbhjulstad@gmail.com	40523352
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Henrik Baldishol	henrik.baldishol@gmail.com	95300104
Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

NTNU
Department of Engineering Cybernetics,
Automation Technology Programme

Course: TELE3001 Bachelor Thesis				**Date:** 24.01.2019
Project: Instrumentation of bipedal robotprototype				
Activity: Joint control				**Activity nr:06**
Starting date: 04.02.2019		**End date:** 08.03.2019		
Dependency: Finish project description	**Past Activities:**	Finish project description		
	Following Activities:	Actuator slack IMU calculation		
Goal: Find upper/lower joint limits and voltage/PWM-frequency to reach limits				
Description: Wire signal connections from joints through motor control units to the DS1005 dSpace hardware. Use dSpace to measure joint limits and test actuator linearity.				
Total Workload: 220 hours		**Work distribution:** Jakob Kristoffer	 110 hours 110 hours	
Expenses:				
Resources:				
Hazards: Motor torque, Voltage				
Project supervisor: Torleif Anstensrud **Project team members:** Jakob Karlsen Jonas Hjulstad Endre T.Ellingsen Henrik Baldishol Kristoffer Nordvik	**Mail:** torleif.anstensrud@ntnu.no jakob-karlsen@outlook.com jonasbhjulstad@gmail.com endre.t.e@hotmail.com henrik.baldishol@gmail.com kristono@stud.ntnu.no		**Tlf:** 95808760 46676230 40523352 46672181 95300104 99117516	

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Department of Engineering Cybernetics,
Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**			**Date:** 28.01.2019
Project:	Instrumentation of bipedal robotprototype			
Activity:	IMU Implementation			**Activity nr:07**
Starting date: 04.02.2019		**End date:** 08.03.2019		
Dependency: Finish project description	**Past Activities:**	Finish project description		
	Following Activities:	IMU Calculation		
Goal: Create a reliable source for position measurement from a point on the robots body frame				
Description: Decide placement for IMU on the robot frame. Measure gyro/accelerator inaccuracy using dSpace or microcontroller. Choose I2C or SPI communication protocol and implement wiring required to run measurements on microcontroller.				
Total Workload: 220 hours		**Work distribution:** Henrik Endre	 110 hours 110 hours	
Expenses:				
Resources: Sparkfun LSM9DS1, wiring				
Hazards: Motor torque, Voltage				

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
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Department of Engineering Cybernetics, Automation Technology Programme

<table>
<tr><td colspan="3">Course: TELE3001 Bachelor Thesis</td><td>Date: 24.01.2019</td></tr>
<tr><td colspan="4">Project: Instrumentation of bipedal robotprototype</td></tr>
<tr><td colspan="3">Activity: Microcontroller</td><td>Activity nr:08</td></tr>
<tr><td colspan="2">Starting date: 11.03.2019</td><td colspan="2">End date: 12.04.2019</td></tr>
<tr><td rowspan="2">Dependency:</td><td>Past Activities:</td><td colspan="2">Joint control
Power supply</td></tr>
<tr><td>Following Activities:</td><td colspan="2"></td></tr>
<tr><td colspan="4">Goal: Move all measurements and joint controls over to microcontroller</td></tr>
<tr><td colspan="4">Description: Decide placement for microcontroller on the robot frame. Wire all controls and measurement intstruments to the microcontroller pins. Program microcontroller to do the same tasks as dSpace using desired language.</td></tr>
<tr><td colspan="2">Total Workload: 220 hours</td><td>Work distribution:
Jakob
Jonas</td><td>
110 hours
110 hours</td></tr>
<tr><td colspan="4">Expenses:</td></tr>
<tr><td colspan="4">Resources: Arduino Mega ADK, ADK mounting bracket, wiring</td></tr>
<tr><td colspan="4">Hazards: Motor torque,Voltage</td></tr>
<tr><td colspan="2">Project supervisor:
Torleif Anstensrud
Project team members:
Jakob Karlsen
Jonas Hjulstad
Endre T.Ellingsen
Henrik Baldishol
Kristoffer Nordvik</td><td>Mail:
torleif.anstensrud@ntnu.no

jakob-karlsen@outlook.com
jonasbhjulstad@gmail.com
endre.t.e@hotmail.com
henrik.baldishol@gmail.com
kristono@stud.ntnu.no</td><td>Tlf:
95808760

46676230
40523352
46672181
95300104
99117516</td></tr>
</table>

NTNU

Department of Engineering Cybernetics, Automation Technology Programme

Course:	**TELE3001 Bachelor Thesis**			**Date:** 24.01.2019
Project:	Instrumentation of bipedal robotprototype			
Activity:	IMU calculation			**Activity nr:09**
Starting date: 11.03.2019		**End date:** 12.04.2019		
Dependency: IMU	**Past Activities:**	IMU		
	Following Activities:	System identification Actuator slack		
Goal: Reduce noise impact and calculate center of mass positions on the body frame				
Description: Measure and reduce noise using digital or analog filters. Use measurements aquired from the accelerometer and gyro on the IMU to calculate positions and angles.				
Total Workload: 330 hours		**Work distribution:** Kristoffer Endre Henrik	 110 hours 110 hours 110 hours	
Expenses:				
Resources:				
Hazards: Motor torque				

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
Jonas Hjulstad	jonasbhjulstad@gmail.com	40523352
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Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

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Department of Engineering Cybernetics,
Automation Technology Programme

Course: TELE3001 Bachelor Thesis		**Date:** 24.01.2019
Project: Instrumentation of bipedal robotprototype		
Activity: Actuator slack		**Activity nr:09**
Starting date: 23.04.2019	**End date:** 23.05.2019	
Dependency: Joint control	**Past Activities:**	IMU calculation Microcontroller
	Following Activities:	
Goal: Eliminate actuator slack impact		
Description: Measure actuator angles with encoder while switching torque direction on the actuators. Decide if measurement errors while switching are considerable. If the slack has a meaningful impact, find a way to compensate for it.		
Total Workload: 100 hours	**Work distribution:** Kristoffer Jakob Henrik Jonas Endre	 20 hours 20 hours 20 hours 20 hours 20 hours
Expenses:		
Resources:		
Hazards: Motor torque,Voltage		

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
Jakob Karlsen	jakob-karlsen@outlook.com	46676230
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Automation Technology Programme

Course: TELE3001 Bachelor Thesis				**Date:** 28.01.2019
Project: Instrumentation of bipedal robotprototype				
Activity: System Identification				**Activity nr:11**
Starting date: 23.04.2019		**End date:** 23.05.2019		
Dependency: Complete instrumentation of the robot	**Past Activities:**	IMU Calculation Microcontroller		
	Following Activities:			
Goal: Obtain a complete mathematical model of the prototype robot				
Description: Find the masses of the different parts of the robot and their associated center of mass. Find any other physical properties that may be o finterest.				
Total Workload: 300 hours		**Work distribution:** Kristoffer Jakob Henrik Jonas Endre	 60 hours 60 hours 60 hours 60 hours 60 hours	
Expenses:				
Resources:				
Hazards: Motor torque, Voltage				

Project supervisor:	**Mail:**	**Tlf:**
Torleif Anstensrud	torleif.anstensrud@ntnu.no	95808760
Project team members:		
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Department of Engineering Cybernetics,
Automation Technology Programme

Course: TELE3001 Bachelor Thesis			**Date:** 24.01.2019
Project: Instrumentation of bipedal robot prototype			
Activity: Documentation			**Activity nr:12**
Starting date: 04.02.2019		**End date:** 27.05.2019	
Dependency:	**Past Activities:**	Finish project description	
	Following Activities:		
Goal: To have all work done during project documented and structured in final bachelor thesis report			
Description: Write down all work performed on the robot, and all information required to use components mounted on it. Refer to and explain theory applied during the project with a good structure			
Total Workload: 400 hours		**Work distribution:** Kristoffer Jakob Henrik Jonas Endre	 80 hours 80 hours 80 hours 80 hours 80 hours
Expenses:			
Resources: Leg mounting bracket, hip stabilizer			
Hazards: Motor torque,Voltage			

Project supervisor: Torleif Anstensrud	**Mail:** torleif.anstensrud@ntnu.no	**Tlf:** 95808760
Project team members:		
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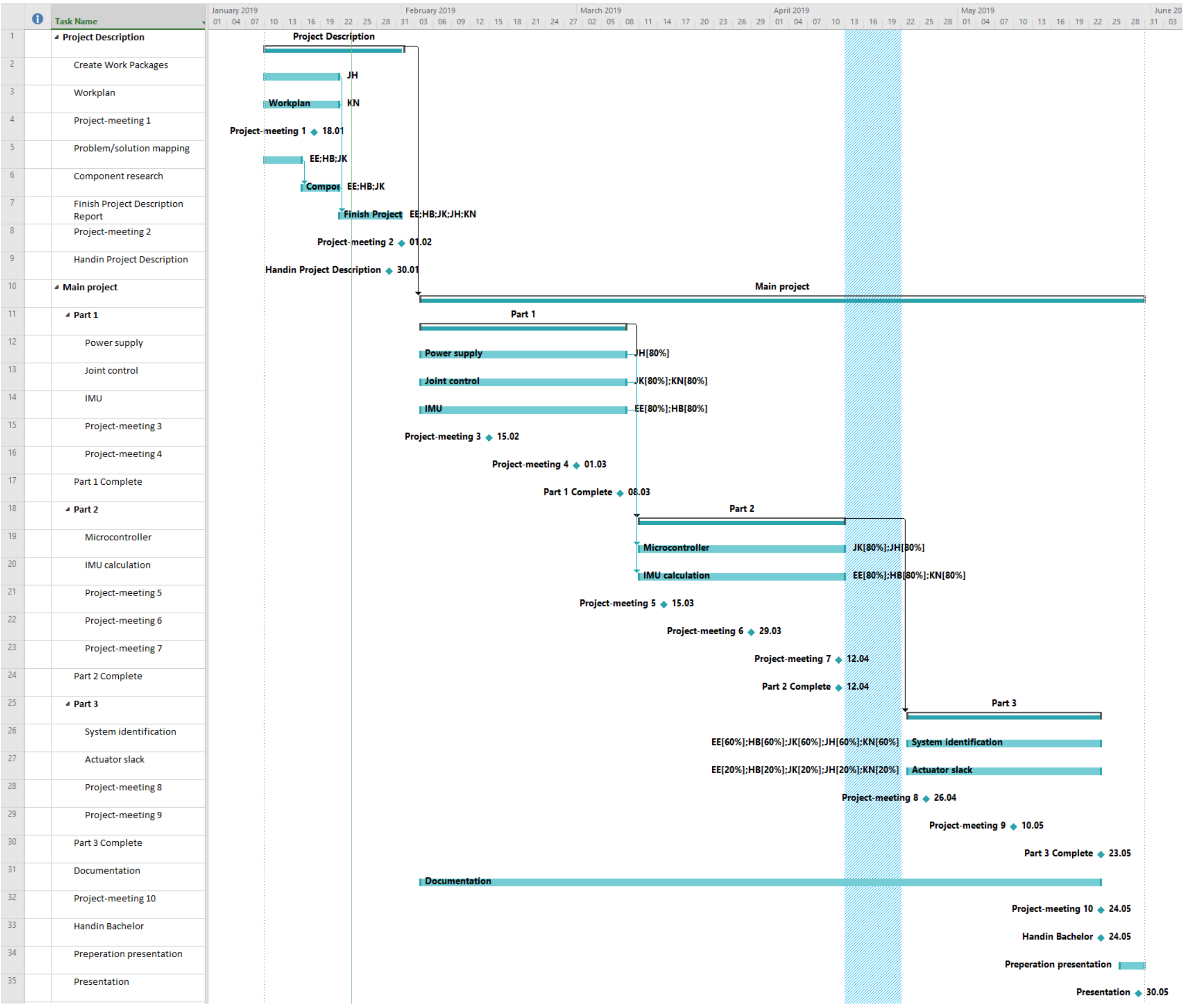
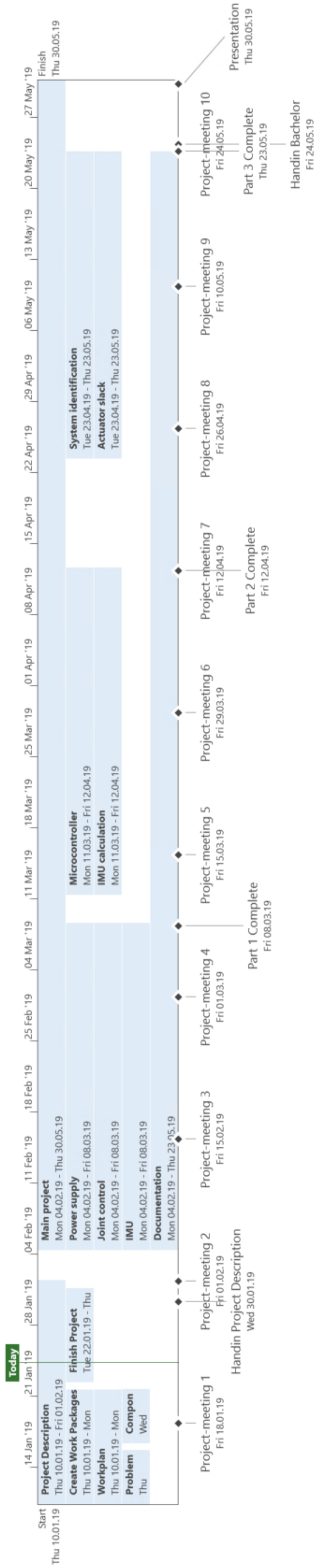
Henrik Baldishol	henrik.baldishol@gmail.com	95300104
Kristoffer Nordvik	kristono@stud.ntnu.no	99117516

B Attachment - Project plan

B.1 Gant-diagram

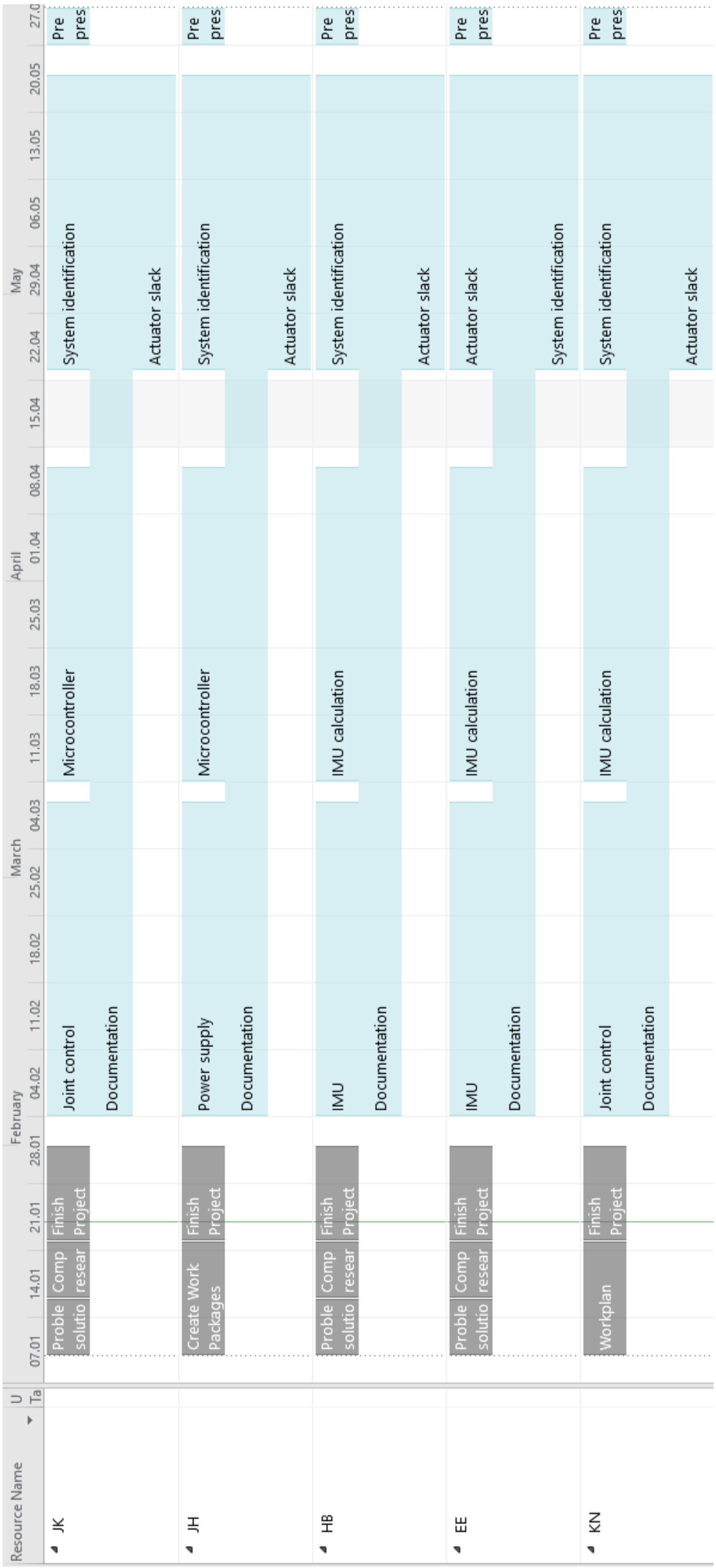


B.2 Timeline



Start
Thu 10.01.19
Finish
Thu 30.05.19
Today
14 Jan '19
21 Jan '19
28 Jan '19
04 Feb '19
11 Feb '19
18 Feb '19
25 Feb '19
04 Mar '19
11 Mar '19
18 Mar '19
25 Mar '19
01 Apr '19
08 Apr '19
15 Apr '19
22 Apr '19
29 Apr '19
06 May '19
13 May '19
20 May '19
27 May '19
Project Description
Thu 10.01.19 - Fri 01.02.19
Create Work Packages
Thu 10.01.19 - Mon
Workplan
Thu 10.01.19 - Mon
Problem
Thu
Compon
Wed
Finish Project
Tue 22.01.19 - Thu
Main project
Mon 04.02.19 - Thu 30.05.19
Power supply
Mon 04.02.19 - Fri 08.03.19
Joint control
Mon 04.02.19 - Fri 08.03.19
IMU
Mon 04.02.19 - Fri 08.03.19
Documentation
Mon 04.02.19 - Thu 23.05.19
Microcontroller
Mon 11.03.19 - Fri 12.04.19
IMU calculation
Mon 11.03.19 - Fri 12.04.19
System identification
Tue 23.04.19 - Thu 23.05.19
Actuator slack
Tue 23.04.19 - Thu 23.05.19
Project-meeting 1
Fri 18.01.19
Project-meeting 2
Fri 01.02.19
Handin Project Description
Wed 30.01.19
Project-meeting 3
Fri 15.02.19
Project-meeting 4
Fri 01.03.19
Part 1 Complete
Fri 08.03.19
Project-meeting 5
Fri 15.03.19
Project-meeting 6
Fri 29.03.19
Project-meeting 7
Fri 12.04.19
Part 2 Complete
Fri 12.04.19
Project-meeting 8
Fri 26.04.19
Project-meeting 9
Fri 10.05.19
Project-meeting 10
Fri 24.05.19
Part 3 Complete
Thu 23.05.19
Handin Bachelor
Fri 24.05.19
Presentation
Thu 30.05.19

B.3 Resource usage



C Attachment - Agreements

C.1 Cooperation Agreement

Instrumentation of biped prototype

Cooperation Agreement

Jonas Hjulstad, Endre T. Ellingsen, Henrik ,
Jakob Karlsen, Kristoffer Nordvik

Cooperation Agreement for TELE3001 Bachelor Thesis

Trondheim, January 2019

Nowegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Engineering Cybernetics

NTNU

1 Cooperation Agreement -JK

Purpose

With this cooperation agreement we want to assure

- A structured framework on how to deal with difficulties
- Efficient and open communication between co-workers
- Satisfying productivity in order to reach our goals
- Optimal completion of the the tasks carried out

1.1 Content

- The group are assigned to complete the bachelor project given in subject TELE3001. The cooperation agreement ensures that social and practical problems along with issues regarding meeting arrangements will be solved with a common understanding.

1.2 Terms

- The student is obliged to contribute to progress during this project
- The student is obliged to stay informed and inform other group members about progress and changes relevant to the project and given tasks.
- The student must to finish tasks within given deadlines. In cases where this is impossible, other group members must be informed.

1.3 Meetings

- All project meetings arranged with subject supervisor are mandatory
- Progress and labor distribution will be discussed at mandatory meetings every thursday. All members are to give each other feedback concerning last weeks performance and cooperation. Any new tasks should be distributed during this meeting. Time and duration will be set a reasonable time prior to the meeting.
- A short briefing will be held every morning for members scheduled to work. All members are responsible for sharing their own and keeping up to date with others progress
- Anyone unable to attend to a meeting should inform the rest of the group as soon as possible. Members who repeatedly fails to attend, or who constantly prevent progress will receive a warning. If this problem persists and same member refuses to cooperate, the person may be excluded from the group

1.4 Signature

Members of this group

- Agree to cooperate and contribute to the project
- Are equally responsible to maintain a good environment for collaboration
- Have read and agree to the terms of this agreement

____
Dato / sted

Endre T. Ellingsen (EE)	Jakob Karlsen (JK)	
Jonas Hjulstad (JH)	Kristoffer Nordvik (KN)	Henrik Baldishol (HB)

NTNU

FAKULTET FOR INFORMASJONTEKNOLOGI OG ELEKTROTEKNIKK

AVTALE

Avtale for gjennomføring av bacheloroppgaven mellom NTNU, oppdragsgiver (firma, etat) og student(er).

Avtalepartnere

NTNU Institutt for elektroniske systemer / elkraft / teknisk kybernetikk	Veileders navn/telefon/e-postadresse.: Torleif Anstensrud 95808760 torleif.anstensrud@ntnu.no
Oppdragsgiver (Firma/etat): NTNU Institutt for Teknisk Kybernetikk	Kontaktperson/navn: Torleif Anstensrud Telefon/e-postadresse/adresse: 95808760 Torleif.anstensrud@ntnu.no
Student: Jonas Hjulstad	
Student: Endre Torvanger Ellingsen	
Student: Henrik Baldishol	
Student: Jakob Karlsen	
Student: Kristoffer Nordvik	
Prosjekt-tittel/arbeidstittel	Instrumentering av tobeinet robotprototype
Prosjektnr.	E1911

Andre relevante dokumenter: Prosjektmanual Bacheloroppgaven.

Avtalen angir avtalepartenes plikter vedrørende gjennomføring av prosjektet og rettigheter til anvendelse av de resultater som prosjektet frembringer.

1.
Studenten(e)/prosjektgruppen skal gjennomføre prosjektet i perioden fra januar 20xx til yy. mai 20xx.

Studentene skal i denne perioden følge en oppsatt fremdriftsplan der NTNU og oppdragsgiver yter veiledning. Oppdragsgiver stiller til rådighet kunnskap og materiale som vil kunne bidra til gjennomføringen av prosjektet. Det forutsettes at de gitte problemstillinger det arbeides med er aktuelle og på et nivå tilpasset studentenes faglige kunnskaper. NTNU skal stille til rådighet egen veileder. Oppdragsgiver plikter å gi en evaluering/sensur av prosjektet vederlagsfritt.

2.
Kostnadene ved gjennomføringen av prosjektet dekkes på følgende måte:
Oppdragsgiver og NTNU dekker hver sin del av den veiledningstid som gis. Dekning av reiser og opphold langt fra studiested dekkes enten av studentene eller av oppdragsgiver ut fra den part som er aktiv for at reise og opphold er nødvendig. Studentene dekker evt. utgifter for trykking og ferdigstillelse av den skriftlige besvarelsen vedrørende prosjektet med mindre oppdragsgiver yter slik bistand.

3.
Eiendomsrett
Besvarelsens spesifikasjoner og resultat kan anvendes i oppdragsgivers egen virksomhet inklusiv publisering. Gjør studenten(e) i sin besvarelse, eller under arbeidet med den, en patentbar oppfinnelse, gjelder i forholdet mellom oppdragsgiver og studentene bestemmelsene i Lov om retten til oppfinnelser av 17. april 1970, §§ 4-10.

Eiendomsretten til eventuell prototyp tilfaller den som har betalt komponenter og materiell mv. som er brukt til prototypen. NTNU skal ha rett til vederlagsfri utnyttelse av besvarelsen og resultatene fra bachelorarbeidet til undervisnings- og forskningsvirksomhet inklusive publisering. Dette gjelder også data som underbygger resultatet i besvarelsen med mindre

AVTALE

det vil være i strid med lov/forskrift eller godkjennelser som er gitt av Regional komité for medisinsk og helsefaglig forskningsetikk (REK), Norsk samfunnsvitenskapelig datatjeneste (NSD) eller andre institusjoner.

Hvis kandidaten skal utføre forskningsprosjektet som del av et større prosjekt, gjelder det som er avtalt om IP-rettigheter i dette prosjektet. Dette beskrives her:

4.
Hvis arbeidet medfører publisering og studentenes bidrag tilfredsstiller Vancouver-konvensjonens krav til medforfatterskap, skal studentene oppføres som medforfattere. Dersom bidraget deres ikke tilstrekkelig for medforfatterskap, skal de anerkjennes for bidraget.

5.
NTNU står ikke som garantist for at det oppdragsgiver har bestilt fungerer etter hensikten. Prosjektet må anses som en eksamensrelatert oppgave som blir bedømt av faglærer/veileder og sensor.

6.
Offentliggjøring.
Papirkopi av besvarelsen registreres og plasseres i et åpent arkiv ved instituttet. Oppdragsgiver kan ved prosjektstart kreve at prosjektet skal behandles som *lukket prosjekt* det vil si ikke publiseres eller plasseres i det åpne arkivet dersom dette kan begrunnes i lov eller forskrift eller ut fra kommersielle hensyn. I tilfelle av lukket prosjekt, skal allikevel besvarelsen normalt kunne publiseres og plasseres i åpent arkiv etter en på forhånd avtalt periode, som normalt ikke skal overskride 3 år.

7.
Når NTNU også opptrer som oppdragsgiver, trer NTNU inn i kontrakten både som utdanningsinstitusjon og som oppdragsgiver.

8.
Taushetserklæring
Ved underskrivelse av denne avtalen erklærer studentene ved sin underskrift alminnelig taushetsplikt vedrørende tekniske innretninger, fremgangsmåter, drifts eller forretningsforhold hos oppdragsgiver som det er av betydning å behandle konfidensielt.

9.
Eventuell uenighet vedrørende forståelse av denne avtale løses ved forhandlinger avtalepartene imellom. Dersom det ikke oppnås enighet, er partene enige om at tvisten løses av voldgift etter LOV 2004-05-14 nr. 25: Lov om voldgift.

10.
Denne avtalen utferdiges med et eksemplar til hver av partene. Signert dokument godtas på pdf-fil. På vegne av NTNU er det intern veileder som godkjenner avtalen.

11. Annet

NTNU

FAKULTET FOR INFORMASJONTEKNOLOGI OG ELEKTROTEKNIKK

AVTALE

12.
Signaturer

Dato/ Veileder NTNU Institutt for elektroniske systemer/elkraft/teknisk kybernetikk
Dato/Oppdragsgiver/kontaktperson
Dato/Student
Dato/Student
Dato/Student
Dato/Student
Dato/Student

D Attachment - Assignment

NTNU

Institutt for elektroniske systemer
Institutt for elkraftteknikk
Institutt for teknisk kybernetikk

Oppgaveforslag bacheloroppgave elektroingeniør i Trondheim, vårsemester 2019

<table>
<tr><td colspan="2">Navn bedrift:
Institutt for Teknisk Kybernetikk</td><td colspan="3">Kontaktperson: Torleif Anstensrud
Epost: torleif.anstensrud@ntnu.no
Telefon/mobil:</td></tr>
<tr><td colspan="5">Tittel på oppgave:

Instrumentering av tobeinet robotprototype</td></tr>
<tr><td>Hvilke studieretninger passer oppgaven for (kryss av for alle aktuelle retninger):</td><td>Automatisering
X</td><td>Elektronikk
X</td><td>Elkraftteknikk</td><td>Instrumentering
X</td></tr>
<tr><td colspan="2">Er oppgaven reservert for noen bestemte studenter? I så fall skriv navnene på studentene til høyre.</td><td colspan="3"></td></tr>
<tr><td colspan="5">Kort beskrivelse av oppgaven med problemstilling.

En stadig økende del av arbeidsoppgavene i samfunnet vårt blir utført av statisk monterte industriroboter. For å løse framtidens teknologiske og humanitære utfordringer er vi avhengige av å utvikle nye robottyper som i større grad etterlikner menneskelig framdriftsegenskaper. Dette stiller krav til utviklingen av avanserte matematiske metoder for å generere et stort utvalg energieffektive gangmønstere for gående roboter.

For å validere de teoretiske resultatene fra dette arbeidet, har man startet utviklingen av en enkel fysisk prototype på en tobeinet robot med overkropp. Roboten er begrenset til å bevege seg i et 2D – plan, og har 3 frihetsgrader (2 bein og 1 overkropp), der beina er aktuert med DC – motorer i hoften.

De mekaniske delene av prototypen er allerede produsert og satt sammen, men det mangler betydelig arbeid knyttet til instrumentering og kraftforsyning. Foreløpig er DC – motorer og tilhørende enkodere koblet til UI via et eksternt dSpace Controller Board, det er ønskelig at hele roboten istedenfor skal drives via embedded hardware.

Det er tiltenkt at studentene skal arbeide med følgende problemstillinger
· Identifisere egnet embedded hardware plattform for overgang fra dSpace, foreløpig er det tiltenkt en Arduino eller BeagleBone – plattform
· Dimensjonering av strømforsyning for å drive DC – motorer, servoer og embedded hardware
· Identifisere egnet sensor for måling av overkroppens helling, og montering av denne på roboten med eventuelt 3D – printete braketter. Utvikle algoritmer for å bestemme hellingsvinkelen til roboten basert på sensormålinger
· Oppkobling av servomotorer for aktuering av føttene, og kontrollere disse via embedded hardware
· Utvikle software for kjøring på embedded hardware for styring av servoer og motorer, samt sensoravlesing
· Systemidentifikasjon av fysiske komponenter basert på sensordata

Det er ønskelig at rapporten skrives på engelsk, men dette er ikke et krav.</td></tr>
</table>