Aalto University
ELEC-E8004 Project work course
Year 2022

Project plan

Project #1-10
Building a Quadruped Robot for Reinforcement Learning research

Date: 07/02/2022

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3) Background

In this project, all work is based on the Real-Ant quadruped robot. The Real-Ant is an open-source robot designed to represent the eight degrees-of-freedom robot in the Ant benchmark for reinforcement learning (RL). In RL, the goal is for the robot to learn desired behaviour, for example, manoeuvres such as standing, turning and moving in the case of the Real-Ant. Another goal in RL can be to learn to operate in untypical situations, e.g., moving with broken legs or joints. The Real-Ant platform is open-source, instructions and code are freely available online (https://github.com/OteRobotics/realant). A paper previously researched with the Real-Ant gives a detailed description of the robot (Boney *et al.*, *2020*, https://arxiv.org/abs/2011.03085, https://github.com/AaltoVision/realant-rl).

Using a physical robot for RL results in a more realistic scenario than simulations. The physical robot has increased complex dynamics, noise/inaccuracies, transmission delays, and the robot's durability must be considered. The robot consists of a 3D printed body with 3D printed legs, connected with servos at the eight joints. For pose estimation, a web camera is used to detect a marker on the robot and a reference marker in its operating environment. The training system in which the robot is used is distributed across multiple devices. The microcontroller for joint actuation and the previously mentioned web-camera communicate with higher performance computers that coordinate the communication and run the RL algorithms. Real-Ant aims to be a low-cost platform for RL research, resulting in 3D printed parts and a simple web-camera.

Due to the exploratory nature of RL, applying RL algorithms to a physical robot will cause wear on parts due to violent maneuvers. As this has proven to be an issue in previous research using the Real-Ant at Aalto, areas of improvement will be identified in this project, and new parts will be designed to make the robot more durable and easier to repair. Thus, the main goal of this project work is to make the Real-Ant more robust and possibly easier to maintain. This makes the robot more useful in future research projects, as less time and resources are used to maintain the robot. However, before improving on the robot, the project group will have to manufacture a standard version and test it to verify that it works.

Boney *et al.* justified using more high-end servos (Dynamixel AX-12A) for the Real-Ant due to their durability, so improvements in the choice of servos will not be pursued. Instead, the aim is to improve the design of 3D printed parts and find additional ways to increase durability, for example, by adding cushioning. The project group will not only work with the design, manufacturing, and assembly of parts but will also learn about the system in which Real-Ant is used during the testing of the robot. However, this project will not include any development of new software for the Real-Ant nor the system it operates in.

4) Expected output

This project aims to produce a RealAnt robot for RL research. The user for the finished robot is the intelligent robot research group at Aalto, but the robot can also be used by other groups focused on RL research. An example of the finished robot is shown in Figure 1 below.

Figure 1 Real-Ant Quadruped Robot

The project can be divided into two objectives. The main objective is the production of a working RealAnt robot. This will include procurement of parts, 3D printing of parts, assembly of the robot, and verification that the robot is working as intended.

The secondary objective is to improve the robot with the aim of making it better suited for its intended use in RL research. The improvements are focused on improving the robustness of the robot so that it can perform RL training without needing maintenance. The improvements will happen in two stages. The first stage involves making soft/rubberized feet for the robot and can happen concurrently with the building of the robot. Soft/rubberized feet will make the robot more robust by reducing the shocks on the components. A second possible benefit is that rubberized feet might reduce slipping. The second stage of improving robustness involves testing and then improving possible points of failure. This second stage is optional and will be finished with enough time.

The project also includes some course-specific goals, including the project plan document, business plan document, business plan presentation with slides, and gala presentation.

A working RealAnt robot will have been produced at the end of the project. The robot can be verified to be working correctly if it can run the codes available on the RealAnt Git page and perform like other examples of the robot found on the internet (RealAnt Introduction). Verification of the improvements happens through testing where points of failure are identified, and the changes are confirmed to improve the robustness.

5) Phases of project

5.1) Phases

This section outlines the phases of work which are further expanded upon in the work packages chapter. The project will follow a waterfall type cycle followed by agile development, which will lead up to the final product.

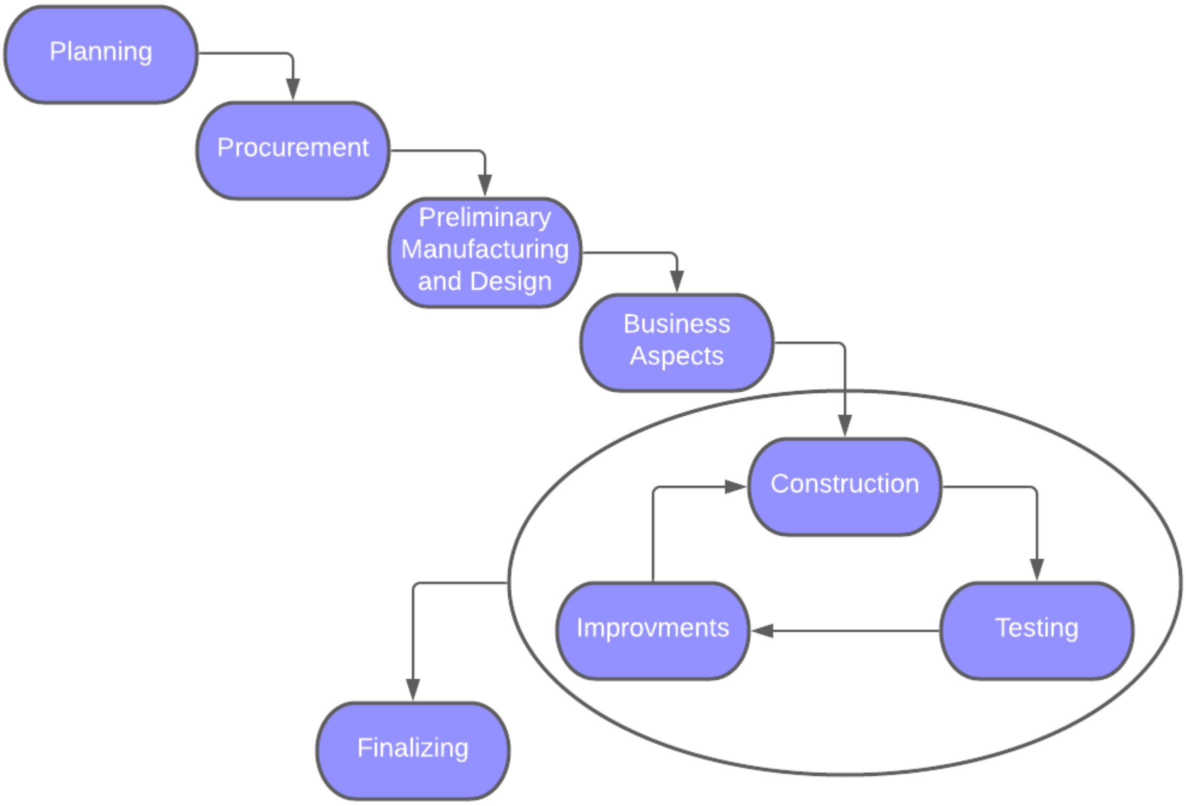

Figure 2 Project Life Cycle Diagram

Each phase is explained below:

- **Planning -** During this section, we finalize the project plan and agree on how the project should proceed.
- **Procurement -** Entails ordering and 3D printing the parts of the robot.
- **Preliminary Manufacturing and Design** – Made for tasks to be done whilst parts are being delivered, and the Business aspects have not started yet. This task involves 3D printing and some design testing.
- **Business aspects** – Involves producing a presentation and report about the business aspects of the project.
- **Construction -** Once the parts are ready, the robot can be assembled.
- **Testing -** is done to confirm that assembled robot performs as intended. This phase will also include the testing of improvements
- **Improvements -** includes the soft feet mentioned previously and then other parts to be improved can only be identified once the robot is tested.
    - **Research** is done to identify what and how parts are to be improved.
    - **Implementation** entails designing and procuring the proposed implementations.

- **Finalizing –** Involves finalizing the project by documenting what has happened and producing reports and presentations to present what has been achieved.
    - **Final Gala**
    - **Final report**

Figure 2 and the phases described above shows an abstract representation of how the project will be conducted. Tasks from each phase may overlap with other phases based on what can be done concurrently to maximize the time spent on the project.

5.2) Milestones

The milestone section outlines the deadlines for the events and deliverables related to this project. Some milestones are connected to course deadlines, so they cannot be delayed. Those deadlines have been bolded. M6 is connected to the aim of the project and thus cannot be postponed further than M7, so it has two deadlines, the latter being a hard deadline.

M1 Project plan document finished and approved by instructor (**10/2/2022**)

M2 Procurement and printing normal parts (25/05/22)

M3 Design and printing of alternative parts (04/03/22)

M4 Business plan presentation slides (**11/03/22**)

M5 Business plan document and approved by instructor (**18/03/2022**)

M6 Assemble and confirm working robot (20/05/22) (**24/05/22**)

M7 Gala (**24/05/22**)

M8 Final Report and approved by instructor (**03/06/2022**)

The following deadlines are optional and will be finished if there is time.

M9 Test how the robot should be improved (15/04/2022)

M10 Development and printing of improvements (29/04/2022)

M11 Test improvements (23/05/2022)

6) Work packages and Tasks of the project and schedule

6.1) Work packages

A work package leader is selected for each work package, and they are responsible for organizing and planning the work in the corresponding work package. The tasks in each work package can be distributed between multiple persons. See chapter "8.1) Roles Within the Project" for more details. The expected workload is calculated for each WP by taking the sum of the estimated workloads for each task in the WP. The estimated workloads of the tasks are calculated using a three-point-estimation in the following subchapter, "Tasks":

$$\text{Expected} = \frac{optimistic + most\ likely + pessimistic}{3}$$

WP1 Planning (All): The project planning WP begins immediately at the start of the course, and all other WPs depend on the completion of this WP. The milestone of this WP is M1, and the deliverables are the Project plan document. Estimated workload: 45h.

WP2 manufacturing of standard parts (WP leader: Antti Sippola**):** In this work package, the 3D printed parts are manufactured for the standard version of the Real-Ant. The milestone of this project is M2, and the deliverables are the 3D printed parts (4x legs, 2x body plates, plus spare parts). Estimated workload: 29h.

WP3 Design and Manufacturing of alternative parts (WP leader: Julius Mikala**):** In this work package, the possibilities of manufacturing soft parts for the robot are studied, and more robust parts are designed and manufactured. The milestone of this project is M3, and the deliverables are parts with alternative designs (more robust legs and/or body plates). Estimated workload: 80h.

WP4 Business aspects (All): In this WP, the business opportunities of the project are studied, resulting in two milestones: The milestones of this WP are a presentation (M4) and a business aspects document (M5). The deliverables are the presentation slides and the business aspect document. Estimated workload: 63h.

WP5 Assemble and test the standard Real-Ant (WP leader: Antti Sippola**):** After the business aspects assignments, the ordered parts will hopefully have arrived. In this WP, the Real-Ant is assembled first using standard parts. The provided codes for the Real-Ant are tested. The project group gets familiar with its operation environment (web camera and reference markers, etc.). The milestone of this project is M6. The deliverable of this WP is the assembled standard Real-Ant, whose correct operation has been verified. Estimated workload: 38h.

WP6 Test robustness with different designs and identify further development needs (WP leader: Jere Vepsä**):** Both standard and alternative configurations of the Real-Ant are tested to determine if the new parts increase robustness. Additional development needs are identified. The milestone of this project is M9. The deliverable of this WP is the documentation of test results and identified development needs. Estimated workload: 47h.

WP7 Create improved designs (WP leader: Eric Hannus): New designs are created to solve the problems found in WP5. Multiple new designs can be designed and manufactured in parallel. The milestone of this project is M10. The deliverables of this WP are the manufactured new parts and documentation justifying the new designs (Which problems do the designs try to resolve? How?). Estimated workload: 120h.

WP8 Test improved designs (WP leader: Jed Muff**):** New designs are tested: Do they successfully increase the robustness of the Real-Ant? Based on the results, the designs can be further improved (Only smaller changes will probably be possible). The milestone of this project is M11. The deliverables of this WP are documents describing the tests and the final assembled and tested Real-Ant with increased robustness. Estimated workload: 109h.

WP9 Delivery (All): This WP is related to the presentation and documentation of the project and includes two milestones: The milestones of this WP are the final Gala (M7) and the final report (M8). The deliverables of this WP are the presentation material (slides) and video for the final Gala and the final report document. Estimated workload: 65h.

WP10 Continuous tasks (All): This WP includes tasks that are executed continuously throughout the project, such as attending lectures and weekly meetings, and thus no milestones or deliverables are listed. Estimated workload: 330h.

6.2) Tasks

The estimated workloads of the tasks are calculated using a three-point-estimation:

$$Expected = \frac{optimistic + most\ likely + pressimistic}{3}$$

Table 1 List of Tasks and Estimated Woking Hours

Task	Estimated working hours
1.1 Meet group and instructor and plan regular meetings	(2+2+2)/3 = 2
1.2 Study available materials (GitHub, Research paper)	(2+2+2)/3 = 2
1.3 Create parts list for ordering	(1+1+1)/3 = 1
1.4 Write project plan	(30+40+50)/3 = 40
	WP1 Sum: 45
2.1 Get familiar with facilities and tools	(2+5+8)/3 = 5
2.2 Learn to use 3D printers	(5+7+12)/3 = 8
2.3 Print legs (4x or more)	(8+10+12)/3=10
2.4 Print body plates (2x or more)	(3+6+9)/3 = 6
	WP2 Sum: 29
3.1 Study 3D printing soft parts (or other improvements)	(10+15+20)/3 = 15
3.2 Learn necessary skills in 3D/CAD design	(20+25+30)/3 = 25
3.3 Design alternative parts	(15+20+25)/3 = 20
3.4 Manufacture alternative parts	(16+20+24)/3 = 20
	WP3 Sum: 80
4.1 Discuss and research business opportunities	(10+14+18)/3 = 14
4.2 Prepare presentation slides	(6+8+10)/3 = 8
4.3 Prepare for business pitch and attend workshop	(5+6+7)/3 = 6
4.4 Write business aspects document	(30+35+40)/3 = 35
	WP4 Sum: 63

5.1 Assemble the standard Real-Ant	(2+4+6)/3 = 4
5.2 Study available code and how the manufactured Real-Ant robot operates in the larger research setup	(10+15+20)/3 = 15
5.3 Set up Real-Ant in test environment (Web-camera, markers, PC etc.)	(7+11+15)/3 = 11
5.4 Test available codes	(4+8+12)/3 = 8
	WP5 Sum: 38
6.1 Run tests until parts fail	(9+16+20)/3 = 15
6.2 Manufacture replacement parts for tests	(16+20+24)/3 = 20
6.3 Analyse causes of part failure, improvements in the alternative parts, and further improvement needs	(8+13+15)/3 = 12
	WP6 Sum: 47
7.1 Design new 3D parts (or other improvements) – option 1	(10+20+30)/3 = 20
7.2 Design new 3D parts (or other improvements) – option 2	(10+20+30)/3 = 20
7.3 Design new 3D parts (or other improvements) – option 3	(10+20+30)/3 = 20
7.4 Manufacture (3D printing or otherwise) new parts – option 1	(15+20+25)/3 = 20
7.5 Manufacture (3D printing or otherwise) new parts – option 2	(15+20+25)/3 = 20
7.6 Manufacture (3D printing or otherwise) new parts – option 3	(15+20+25)/3 = 20
	WP7 Sum: 120
8.1 Test improvements (run Real-Ant until new robustness can be asserted) – option 1	(9+16+20)/3 = 15
8.2 Test improvements (run Real-Ant until new robustness can be asserted) – option 2	(9+16+20)/3 = 15
8.3 Test improvements (run Real-Ant until new robustness can be asserted) – option 3	(9+16+20)/3 = 15
8.4 Do small design adjustments based on test results	(20+25+30)/3 = 25
8.5 Manufacture final improved design	(18+24+30)/3 = 24
8.6 Do final tests with final design	(10+15+20)/3 = 15
	WP8 Sum: 109
9.1 Prepare for final gala and present on final gala	(12+15+18)/3 = 15
9.2 Write final report	(40+50+60)/3 = 50
	WP9 Sum: 65
10.1 Attend lectures	(26*5+28*5+30*5)/3 = 140
10.2 Attend meetings	(1*19*5+2*19*5+3*19*5)/3 = 190

	WP10 Sum: 330
	Total Sum: 926

6.3) Detailed Schedule

See the Gantt chart below for the detailed schedule:

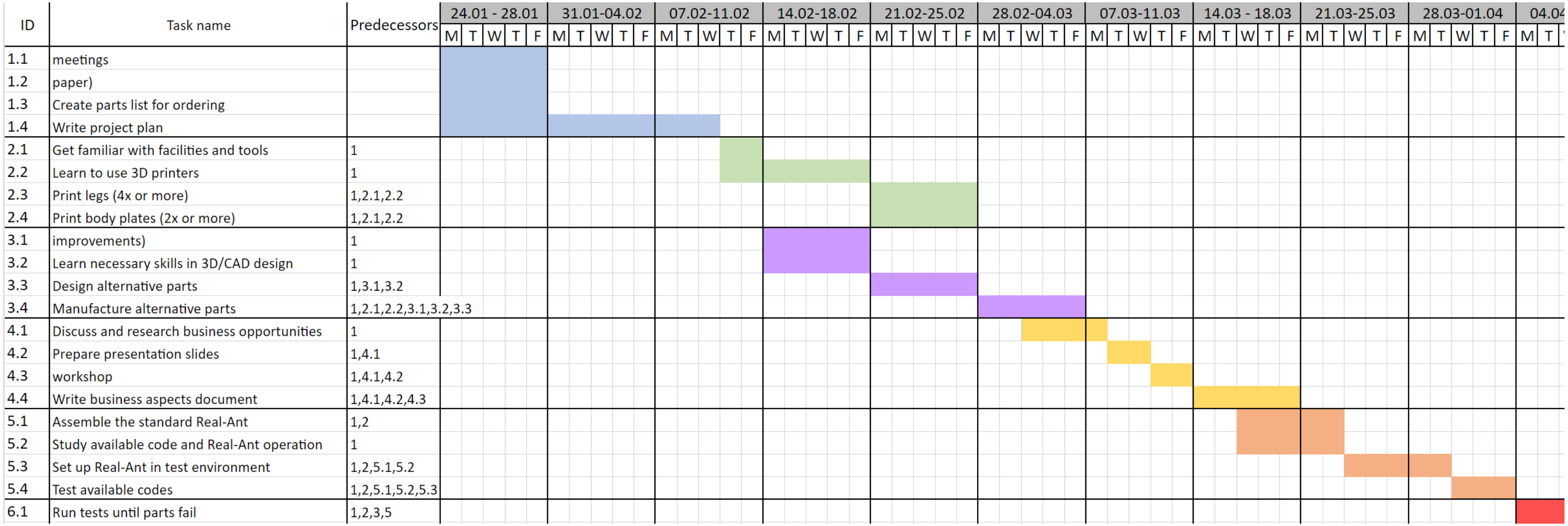

Figure 3 Project Gannt chart part 1

ID	Task name	Predecessors
6.1	Run tests until parts fail	1,2,3,5
6.2	tests	1,2,3,5
6.3	needs	1,2,4,5,6.1
7.1	option 1	1,2,3,5,6
7.2	option 2	1,2,3,5,6
7.3	option 3	1,2,3,5,6
7.4	Manufacture (3D printing or otherwise) new parts – option 1	1,2,3,5,6,7.1
7.5	Manufacture (3D printing or otherwise) new parts – option 2	1,2,3,5,6,7.2
7.6	Manufacture (3D printing or otherwise) new parts – option 3	1,2,3,5,6,7.3
8.1	Test improvements – option 1	1,2,3,5,6,7.1,7.4
8.2	Test improvements – option 2	1,2,3,5,6,7.2,7.5
8.3	Test improvements – option 3	1,2,3,5,6,7.3,7.6
8.4	results	1,2,3,5,6,7,8.1,8.2,8.3
8.5	Manufacture final improved design	1,2,3,5,6,7,8.1,8.2,8.3,8.4
8.6	Do final tests with final design	1,2,3,5,6,7,8.1,8.2,8.3,8.4,8.5
9.1	Prepare for final gala and present on final gala	1,2,3,4,5,6,7,8
9.2	Write final report	1,2,3,4,5,6,7,8
10.1	Attend lectures	
10.2	Attend meetings	

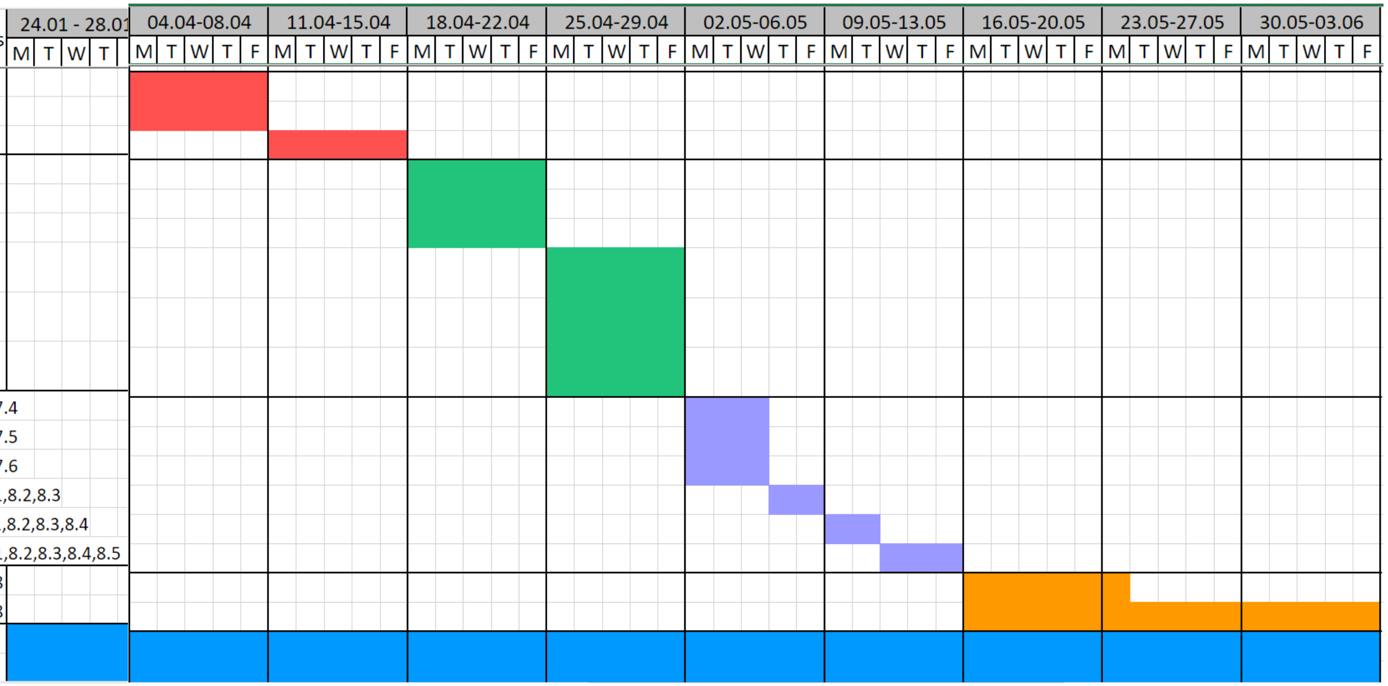

Figure 4 Figure 3 Project Gannt chart part 2

7) Resources

7.1) Work resources

Personal availability during the project

It is expected that over approximately five months (from start to end of the course), each person puts in 270 hours' worth of work. This course is worth ten credits, each credit worth 27 hours. This includes:

- The planning
- The product concepting and business aspects
- Meetings
- Report preparation and writing
- General project activities

The actual group project started on week 3 (24/01/22) and ends on week 21 (23/05/22) with the final report on the (24/05/22). Other milestones to consider are found in section 5.2).

Considering 19 weeks on the project gives 13 hours per week.

Table 2 The number of hours available for the project (excluding lectures and seminars) per week

	Antti Sippola	Eric Hannus	Jed Muff	Jere Vepsä	Julius Mikala
Week 1 (10/01/22)	0	0	0	0	0
Week 2 (17/01/22)	0	0	0	0	0
Week 3 (24/01/22)	4	4	4	4	4
Week 4 (31/01/22)	6	10	6	10	6
Week 5 (07/02/22)	10	10	10	10	10
Week 6 (14/02/22)	10	10	10	20	10
Week 7 (21/02/22)	20	15	5	5	20
Week 8 (28/02/22)	10	10	15	5	12
Week 9 (07/03/22)	10	10	15	16	12
Week 10 (14/03/22)	10	10	12	12	12
Week 11 (21/03/22)	10	10	12	12	12
Week 12 (28/03/22)	10	10	15	12	12
Week 13 (04/04/22)	10	5	15	12	10
Week 14 (11/04/22)	20	5	16	12	5
Week 15 (18/04/22)	20	20	16	16	20
Week 16 (25/04/22)	18	20	16	16	20
Week 17 (02/05/22)	16	20	5	16	20
Week 18 (09/05/22)	16	20	17	16	20
Week 19 (16/05/22)	16	20	17	20	20

Week 20 (23/05/22)	16	20	17	16	8
Week 21 (30/05/22)	8	11	17	12	7
Total	**240**	**240**	**240**	**240**	**240**

Notes in terms of in-person availability:

Jed Muff is out of the country 18/02/22 - 25/02/25 and 30/04/22 - 08/05/22, but can still do work and keep in contact online.

Personal goals

Antti Sippola: I view this project as an opportunity to focus on the hardware side of robotics. This project will require skills in parts design, 3D printing, electronics, and microcontrollers. My goal is to develop my abilities in those areas as well as learn about project management and teamwork.

Eric Hannus: My goals are to get practical experience of 3D printing, learn problem solving by identifying and fixing weaknesses in the Real-Ant design, get a glimpse of what kind of research is being done in fields that interest me like robotics (even though we will not be creating new RL code), and to learn more about working as part of a team and develop related skills.

Jed Muff: My current skills relate primarily to programming and theoretical understanding, so I hope to expand my practical skills. These practical skills relate to some mechanical sides: 3D printing, CAD and Manufacturing, some practical robotics and artificial intelligence: seeing how robots are programmed and how reinforcement learning is introduced, and finally growing some project management skills and even some business sense. I am also looking forward to learning more about the intelligent robotics research group as they may heavily influence my future career.

Jere Vepsä: I have some experience in 3D printing, CAD design and robotics. I will try to take advantage of this project to develop these skills. My main learning goal is to develop competencies related to carrying out this type of hardware assemble project and possibly learn something new ROS also.

Julius Mikala: My goals include further learning how to use CAD if that is a possibility, as well as learning how to assemble and configure hardware such as this. I also believe that learning how to work in a group project of this size will prove instructive. Lastly, I'm excited to see RL techniques at work.

7.2) Cost plan and materials

The project budget is spent on acquiring the necessary component and materials for the robot. Since the students have no access to university funds and are not allowed to procure them, the project budget management and purchasing are handled through the instructor. The students are responsible for creating a purchasing proposal for the needed components and materials. The proposal should include the needed items, their quantities, and links to websites where the items can be purchased. The proposal is sent to the instructor, who then forwards the plan to the university's procurement services. A similar procedure is followed for all purchases.

The project budget is estimated using the costs of all main components for the robot ordered at the beginning of the project. In addition, the budget includes materials that are known to be needed later during the project. Therefore, the current estimate only represents a lower limit for the project's total costs. However, it is expected that the potential purchases made later are relatively inexpensive (e.g., screws and glue). Therefore, the current budget estimation can be assumed to be reasonably reflective of the project's final costs.

budget estimation:

item	quantity	unit price	total
Dynamixel AX-12A actuator	8 + 1 spare	43,21 €	388,89 €
OpenCM9.04 control board	1 + 1 spare	9,54 €	19,08 €
OpenCM9.04 accessory set	1 + 2 spares	5,66 €	11,32 €
US sales tax			32,93 €
shipping for the robotis.us order			85 €
customs fees for the robotis.us order			119,71 €
two-wire power cable	3m	0,88 €/m	2,64 €
shipping for the thomann.de order			12 €
USB-A – Micro-USB cable (3m)	1	1,95 €	1,95 €
shipping for the hobbyhall.fi order			5,99 €
		total:	679,51 €

7.3) *Other resources*

The robot and its components need to be stored in a place accessible for all team members. The robot and its components will be stored in the Intelligent Robotics research group's facilities at the TUAS building (Maarintie 8). Students should have open access to the lobby and the corridors of the TUAS building. However, only the instructor has keys to the research group's facilities. Therefore, the instructor needs to be present and available to open doors for the students to access the materials. This means that the students and the instructor need to agree on the times when the materials can be accessed.

To ensure that none of the materials are lost during the project, the components should be stored in a locked room and separated from other research materials. In practice, this could mean a labelled box or a shelf used exclusively for this project's purpose.

In addition to the access to the components, the project requires access to tools and facilities where the tools can be used. The electronics workshop (TUAS, room 1558) is open to students and should have the most needed tools. The workshop has soldering stations, 3D printers (at least 3), and available tools, such as screwdrivers and side cutters. The lab also has bench power supplies that can power the robot. Although, it needs to be noted that the power supplies probably cannot be borrowed for use outside the workshop. Another facility that can be used for 3D printing is the Aalto ADDLAB (Sähkömiehentie 4 J).

Once the robot has been assembled, its use for reinforcement learning research requires a camera that can be connected to a computer. The existing documentation mentions a Logitech Brio 4K webcam as one suitable option. It is also mentioned that the training should be done in a well-lit room to minimize motion blur in the video feed.

8) Project Management

8.1) Roles Within the Project

Within the project are three types of roles. Two of them are made for two individual people in the group, while the third is a more general one relating to the work package leaders. Although each role has its responsibilities, everyone has some general responsibilities. These responsibilities include:

1. Ensure their work is of good enough quality (details found in the Ensuring Quality section 9.2).
2. They can do the set work within the time frame given.
3. They do the work within the time frame given.
4. It is human nature to make mistakes, and therefore if it is not possible to do the work in the time frame given, they need to let everyone know so the group can re-plan accordingly.

Project Manager

The project manager in this project has the following responsibilities:

- The project meetings are efficient, on topic and well documented. This involves:
  - Writing an agenda and sending the agenda to everyone at least an hour before the meeting. The purpose is to keep the meetings productive and with direction.
  - To keep meeting memos to document the decisions made and essential notes.
- Ensure the project remains on topic and relevant to the expected output. This involves referring back to the expected output after each project phase.
- The project manager needs to keep everyone informed and maintain a good level of communication to make it clear what people need to do before specific deadlines.
- The project manager also communicates with the course leads/department about project logistics. This mainly refers to the Gala at the end of the project.
- The project manager is also responsible for submitting the reports to the appropriate place.

Instructor

The instructor acts as the technical expert within the project. Where all other members could lack experience, the instructor's responsibility is to provide advice on areas that the members lack knowledge of. This does not mean doing the work but advising how they would do it. They also serve as the primary point of contact between the group and the Robotics Learning group, the primary customer of this project. Because of their prior experience with the department workspaces and the COVID restrictions, they also act as an assistant in using the campus workspaces. The responsibilities include:

- They provide the group with advice about the project and answer their questions to the best of their ability.
- Acting as a communicator between the Intelligent Robotics Research group and the Team
- The handling of order forms.
- The organization of accessing and using laboratory equipment
- Storing project components

Work Package Leaders

The work package leaders serve to divide the micro-managing parts of the project. Each work package leader is given a specific part of the project. Their primary goal is to ensure that this part is done with good quality. Their responsibilities include:

- Organizing the work package. Whereas the project plan already outlines what needs to be done, this role requires the work package leader to understand each part of the plan, know precisely what needs to be done, and tell other people what they should do next.
- They should plan efficiently and effectively the way to do that work package to get the best result, given resource constraints.
- Organize meetings should they be necessary.

8.2) Project Meetings

Meetings are crucial for communication within the group for adaptability and efficiency. However, having meetings too long and full of irrelevant detail can get in the way of productivity. A mandatory meeting for everyone to attend (unless a person is deemed purposeless to attend by everyone in the project) will be held every Thursday from 1130 to 1200. There is a possibility for other meetings earlier in the week. These will be held for only people relevant to their agenda. Meetings will be online for the first few weeks, but as COVID restrictions ease, we may move to campus.

An agenda will be made before the meeting, stressing what needs to be discussed to ensure productive meetings. Once the agenda is completed and no one has anything else to discuss, the meeting can end. The project manager is responsible for releasing the agenda before the meeting. This will happen within 24 hours of the meeting and no later than an hour before the meeting. The agenda will be an editable word document to allow group members to add topics they would like to discuss before the meeting. This allows everyone to add want they want without relying on the project manager.

The agenda will contain the following general topics:

- Progress report on last week's action log.
- General progress report of the project and relating it to the project plan.
- Summary of what needs to be done next.
- Filling in next week's action log.

Philippe Kruchten once said, "If it is not written down, it does not exist", and this emphasizes the importance of documenting these meetings, just in case someone missed it or people need a reminder of what has been discussed or defined previously. Responsibility for the memos is also the project manager's responsibility. This could mean the project manager delegates who records the memos. The memos will contain the following information:

- When: Date and time
- Place
- Attendance
- Agenda
- Outcomes of the meeting (What was discussed, what is left to discuss, what was decided, other notes)
- Action log

A template can be found in the append section 11.1) page 22. The memos will be published within 24 hours after the meeting to ensure the information is the most accurate and detailed. Once complete, it is announced in the Teams chat to allow group members to challenge, change or add information. All memos are uploaded to the shared Teams file manager (Meetings and Minutes).

8.3) Communication plan

The main communication channel is the Team's chat. This is where we can communicate with both the instructor and other team members. Within Teams, primarily two chats will be used: 'General' and 'Meetings and Minutes'. 'General' serves as a place to communicate to everyone about general topics. 'Meetings and Minutes' serves primarily to keep memos of the meetings and document the times they are released; this will save clutter in the more general chat. Throughout the project, the Teams chats will be split into different channels for specific parts. The purpose of these channels should be for the following reasons: to save spam or clutter in the general chat or to mute conversations that are not relevant to people (stop annoying notifications). It should be noted that all chats should remain public for people to reference and keep people informed if they wish to do so.

A telegram group chat was set up as a less formal way of communication. This provides us with a quick and easy backup way for communicating within the group, and just in case people do not have Teams notifications, it serves as a way of communicating urgent messages. The last way of communicating is via email. Email will primarily be used for communication externally to the group. If not everyone in the email chain was cc'd for any reason, it is the group member's responsibility to forward the essential information to the Teams chat.

9) Controls and Contingencies

9.1) Risk management

Several aspects that can set back or endanger the project are identified below, with possible ways to mitigate the chance of a risk happening. Few of the risks presented are expected to cause a total project failure. Instead, they are likely just time consuming and will mean that fewer of the optional milestones will be realized. Each risk also includes an assessment of the risk possibility and its effect on the project should the risk happen.

Part procurement

- Lateness in part delivery. (Risk possibility: med, Effect: High). The risk is mitigated by ordering the parts needed as soon as possible.
- 3D printing difficulties.
    - 3D printing failure. (Possibility: High, Effect: Low). Risk can be mitigated by ensuring that the printer has enough filament. The printing of the parts should start early to mitigate the effect of printing failure on the schedule.
    - Availability of 3D printers. (Possibility: Medium, Effect: High). Risk can be mitigated by confirming several places where printing can be done to increase the odds of finding an available machine.

Part failure. (Possibility: Med, Effect: High) The effect of part failure is effectively mitigated by ordering and printing enough spare parts.

The key person's illness or quarantine (Risk: Med, Effect: Low) Reduces the effect by not having anyone too specialized in the project so that no one is irreplaceable. The risk mainly affects presentations and things that require physical presence.

Losing a file. There is the possibility that an important file, such as a new STL file, is lost. (Possibility: Low, Effect: Med). Files should have a copy, be in cloud storage, or be stored with Git to reduce the possibility of this risk.

9.2) Ensuring Quality

Quality management is needed to deliver a project output that meets its requirements. The only way to ensure quality is through the customer, as the customer defines the specifications and what is acceptable. In the case of this project, the customer is the Intelligent Robotics Research group, and our point of contact for the research group is our instructor. Therefore, the instructor's role is to help ensure the project is heading to a product with good quality defined by the Intelligent Robotics Research group. From another point of view, our customers could be the potential clients willing to invest money into the project. This would mean creating a product with a good business plan to sell to these clients. These specifications are currently defined by group members, although later could be added to customer specifications. These specifications are secondary to the customer specifications.

Internally (without customer consultation), there are a few techniques to ensure quality. These are primarily the responsibility of the project manager. However, it should be noted that everyone is responsible for the quality of the work they produce.

- Each week to ensure the project is kept in line with the customer's needs, the expected output of the project should be consulted. A more detailed review of the specifications can be reviewed at the end/start of each project phase.

- If any group member observes problems in quality, they should bring it up as soon as possible to the group to address the problem and act/change the plan accordingly. See Changes to the project plan section 9.3) for more detail.
- Because this is a small project, everyone in the group needs to read through each critical document to ensure it is clear and everyone understands it. This allows for clear understanding in the group and keeps the excellent quality of work. People should be free to critically review work and tell people what can be done to improve it.

One of the issues with working in a group is ensuring all work is up to the same standard. To ensure the maximum amount of work is done, all members should be utilized to their fullest abilities. This, means everyone is given an equal amount of work. However, because peoples skills are different, this leads to a difference in writing and quality. This means not all work is of the best quality that the group can produce. To counter this, the group needs to critically review each other's work and provide feedback that works towards a solution. This does not mean providing only criticisms but ways to improve the outcome. One problem with this technique is that it can inevitably cause friction between group members if they differ in opinion on what 'quality' is. However, maybe the conflict is evidence enough that the group ensures quality adequately. For this reason, feedback on other people's work should be written politely and provide examples as not to cause any personal grudges.

9.3) Changes to the project plan

A project plan is a jointly agreed entity for implementing this project. The progress and schedule of the project will be reviewed at regular group meetings. Changes are agreed upon between the members of the group. The process for making changes to the plan includes considering the need for change, an open discussion of the change, a decision to make the change, and its implementation.

The decisions made at the meetings are recorded in a memo, from which everyone can check the agreed matters. Where possible, we confirm decisions on changes from absent members using instant messaging applications, such as Telegram. When making changes, the effect of the change on other parts of the project must be considered. The group instructor will approve changes related to the project objectives.

Certain schedule features are unchangeable due to the deadlines on the course. These deadlines are:

- The deadline to submit the project plan (10/02/2022 23:59)
- The deadline to submit presentation slides for business aspects webinar (11/03/2022 23:59)
- The deadline to submit the business aspects document (18/03/2022 23:59)
- The deadline to submit final reports to MyCourses (03/06/2022 12:00)

10) Measures for successful project

The success of a project is determined by the number of goals achieved. The essential criteria for the success of the project are:

- Completing the project within the scheduled time
- Planned training is being conducted successfully with the appropriate teams.
- Achieving the customer/client satisfaction target
- Project handover is well documented and completed in the required manner.
- The project delivers all deliverables within the agreed scope.
- The Learning Goals of the project are achieved

The most important output for the project is a working robot. The robot is considered to be working as intended if the robot can run the codes and operate in the desired way. The robot will be tested using a suitable RealAnt test environment with PC and external camera.

Project progress such as reaching milestones and goals will be documented in memos and monitored. The realization of learning goals is measured through self-assessment.

11) Appendix

11.1) Meetings and minute template

Date:	Time:	Place:

Attendance

Attended: Jed Muff (JeM), Eric Hannus (EH), Julius Mikala (JuM), Antti Sippola (AS), Jere Vepsä (JV), Rituraj Kaushik (RK)

Apologies:

Missing:

Agenda

1. Approval of previous minutes.
2. Session aims
3. Review of previous meeting action log
4. Any other business

Outcomes:

Action Log

Action to be taken	Who is responsible	Deadline