# DEIS COURSE DESCRIPTION (2019/7/5)

## Introduction

Welcome to Design of Embedded and Intelligent Systems!
(DEIS, 15 credits; course examiner Wojciech Mostowski (wojciech.mostowski@hh.se), course responsible Martin Cooney (martin.cooney@hh.se))
Please read this course description carefully at the start of the course!

**Syllabus**
Please see the Syllabus in Swedish (or translation in English) on Blackboard.

**Intended Learning Outcomes (ILOs)**
The basic course objective is that the student will develop their practical skills and conceptual knowledge related to the design of embedded and intelligent systems while considering various perspectives; upon completion of the course the student will be able to:

- apply basic skills and knowledge related to designing embedded and intelligent systems in problem-solving while collaborating with peers in a small group
- hypothesize independently about some new useful work which could be done in their speciality (e.g., embedded, intelligent, or communication) and specific steps required to accomplish it
- reflect on their experiences above in terms of the advantages and disadvantages of various approaches and explain how simplified embedded and intelligent systems work as a whole.

Thus, the three intended learning outcomes relate to *applying and collaborating* (the basic requirements), *hypothesizing independently* (creativity), *and reflecting* (excellence of methodology).

**Teaching/Learning Activities**
Based on and aligned with the learning outcomes, there are two teaching/learning activities:

- *main: a problem-solving project in groups from embedded, intelligent, and communication (conducted on your own),* to let you apply basic practical knowledge in DEIS while collaborating, exercise creativity, and reflect upon your experience in a specific context
- *supplement: lectures and labs from various teachers*, to help you to refine your basic conceptual knowledge, see from new perspectives, and reflect upon standard approaches

**Summary of TLA1: Course project**
Embedded and intelligent systems such as robots and autonomous vehicles offer various interdisciplinary challenges.
One challenge currently receiving much attention, e.g., in the Grand Cooperative Driving Challenge (GCDC), is how to design systems which can navigate (semi-)autonomously in platoons.
For your project you will tackle this challenge by programming little robots with Raspberry Pi/Arduino to run around a track on E1 in platoons.
Please see Project Description for details.

**Summary of TLA2: Lectures and Labs**
The content of the lectures and labs was chosen to represent some key areas in DEIS as described above in regard to "basic skills and knowledge", as well as for relevance to the project.
1 Basic introduction to course and design of embedded and intelligent systems (system modelling, project platform/environment (Martin, several lectures/labs)
2 Sensor Fusion (Naveed 1 lecture, 1 lab)
3 Embedded/real-time programming (Wojciech 1 lecture, 1 lab)

4 Odometry/path planning (Eren 1 lecture, 1 lab)
5 Simulation (Wojciech 1 lecture, 1 lab)
6 GCDC/Autonomous Vehicles (Cristofer 1 lecture, 1 lab)
7 Wireless communication (Alexey 1 lecture)
8 Image processing (Josef 1 lecture, 1 lab)
Slides will be uploaded to Blackboard as the course progresses.

**Examination**

Examination is aligned with the intended learning outcomes and teaching/learning activities and focuses half on the project (tollgates/report) and half on the course overall (oral exam). Please see the Examination Section for details.

# Project Description

The theme this year is terraforming!

**Basic idea:** We will imagine that humans are planning to colonize another terrestrial body like Mars, the moon, Venus, Titan, Callisto, Ganymede, Europa, Mercury, Enceladus, Ceres, or such.

Since these planets are not ready for humans, we have sent some robots to do some tasks to make the atmosphere, temperature, and ecology okay for us.

The robots will need to autonomously travel in platoons and navigate through intersection crossings in a safe way.

If the class agrees the robots will also be "cyborgs"; they will have a manual mode in which the robots can be partly controlled by some tiny "drivers" like shrimps or small fish. (No living creatures will be harmed.)

**Basic motivation:** This topic relates broadly to the School of Information Technology's focuses on (1) autonomous vehicles in smart cities/platooning and (2) health technology involving living creatures. By focusing on this project topic, we hope to help prepare HH students to do research and development in designing embedded and intelligent systems related to autonomous vehicles and/or health technology.

**Groups:** Students should try to form groups with a mixture of useful knowledge in embedded systems, intelligent systems, communication, etc, with a similar level of knowledge/expectations for grades. Students will get the chance to form their own groups but the course responsible can reassign group members based on the goal as needed.

**Setup:** Each robot will have infrared light sensor arrays pointed downwards to follow tracks, a forward-facing camera to do more complex sensing, and encoders attached to its wheel shafts. Two motors power the robot's wheels. Processing will be conducted with a microcontroller (Arduino) for low level tasks, a small computer (Raspberry Pi) running Linux with Wifi for some higher level tasks. Communication will be conducted using a predetermined protocol, running on robot operating system (ROS), which is designed to handle cases with multiple robots sending much information, on our own network, which is not connected to the internet. Groups can choose to add other sensors, actuators, computers, etc. ("eduroam" can be used to download software.) The robots will run on top of a 1.8 x 2.4 meter table on E1, equipped with "tracks" made from black tape.

**TOLLGATES:**

The student's engagement and progress in their project will be monitored by a set of "examination events" (tollgates). At these the student as part of their project group will report about their achieved results orally as a presentation (EX-1, 4), by practical demonstration of results (the robots will be videotaped in EX-2,3,5), and in a written report (EX-6). The tollgates are intended to be a continuous evaluation for the project portion of the course, giving timely feedback and exposing problems before it is too late; this is in place of only having a single large exam at the end, which could be stressful. The tollgates together will be used to determine the student's grade for the project (half of the grade for the course). To get a grade of 3, a student is expected to complete all basic tasks for all tollgates; for 4 and 5, a student should also complete additional tasks demonstrating creativity and technical excellence such as those described below. **Please note: grades are assigned based on the criteria on the grading sheet; please think of the tollgate tasks below as guidelines/suggestions!** Also, please note that for grades 4 and 5 often _you_ have to think of what you are going to show and how you will show it in a convincing way. Also the robot should be mostly autonomous: the group should be able to run and stop a task by running a command, clicking, or pressing a button, and move away from computers while the robot runs. If needed, objects and other "robots", etc, can be simulated with a marker/image stuck to a stick or cardboard box, etc.

**EX-1 (mid-September)**: System modeling.
Grade 3:
Oral presentation with powerpoint slides, specifying:
(a) requirements: functional and non-functional (system and contents)
(b) system architecture/design: connecting requirements to approach.
Grade 4:
+independent work: slides submitted before the tollgate day, with a tentative idea for each student's research step
+critical thinking: a question about each of the other groups' presentations submitted at end of class (done at the individual, not the group level; write your own questions on paper or send email in class)
Grade 5:
+excellence: clean/clear dissemination, with no spelling mistakes, summarized in a short written report from the group (due preferably within a week)
+comprehensive: uses various diagrams (e.g., at least five kinds) and considers various aspects: stakeholders, priorities, etc; trade-offs for design choices

**EX-2 (mid-October)**: Basic robot behavior.
Grade 3:
(a) Basic setup: Each robot kit should be assembled, with a raspberry pi connected to an arduino
(b) Basic motion/control: The group should be able to press a key on some computer to get robot to go forward following the tracks, and another button to tell the robot to stop.
This will be shown by having all robots from all groups driving together on the table at the same time. It does not matter if they collide, etc.
(c) Basic communication: Each robot should be able to get data from the "GPS server" (overhead camera system). This includes positions of the robots, as well as a message from the GPS server to turn left, turn right, move forward, and stop, based on the shared communication protocol.

This will be shown by having all robots from all groups on the table at the same time in some nice formation; we will send commands to turn left and right from the GPS server to get the robots to "dance" as a group.
(a) Changing lanes (right to left and left to right) when commanded (e.g., when a button is pressed).
(b) Turn on intersection. This could be left, right, or both.
Grade 4-5: +
-Robot has been personalized (e.g., something 3d printed? related to terra-forming?)
-E.g., show something with encoders. Like different speeds , or tracking for set distance (either on a track or off the tracks or both), or driving in a box or hourglass shape. or ability to adapt to/deal with difficult situations (e.g., twisted paths, slopes, or tunneled areas; the groups can build their own props for slopes or tunnels e.g., out of cardboard), or statistical analysis e.g., comparing driving for a set distance using encoders vs. GPS. (is there a significant difference?)
-E.g., PID controller...

**EX-3 (mid-November)**: More complex robot behavior. Cyborgs and Platooning.
Grade 3:
Robots should demonstrate complex behavior:
(a) Basic "Cyborg" control. Each group should use some detected biological motion to control their robot. For grade 3 this can be some pretaped footage. For higher grades, this can be live streamed, or preferably from our own setup (a computer with a camera in front of an aquarium with something like shrimp or fish). "Drivers" can be humans, animals, insects, birds, etc. How to tie biological behaviors to robot behaviors is up to the group.
Robot behaviors can include: change lane, forward, backward, stop, turn left/right at intersection. This will be shown by putting all robots on the table at the same time.
It is fine if robots collide, run off lanes, etc.
(b) Platooning 1. Follow the leader: driving directly behind another "robot" at some fixed distance (e.g., 30cm). This could be to get through a narrow passage, if the robots need to mine for resources.
(c) Platooning 2. side formation: two robots should be able to drive side by side, this could be to detect dangerous areas of the surface of the planet.
(d) Platooning 3. new leader: change the leader of a platoon of two robots, so the follower becomes the leader. This could be like with bicycles or birds in formations, where the leader expends more effort against air resistance, etc, or sustains more damage due to harsh terrain/weather like sandstorms, etc.
Grade 4-5: +
-E.g., Detecting something; the group should have imagined some terra-forming problem(s), and generated a recognition system to recognize these, possibly using the robot's camera or attaching sensors to their robot, or other). One example for general driving could be "Active safety": use detection for the robot to do something, like change lanes automatically when there is an obstacle, stop when there is a moving obstacle like a robot, slow down in front of a health problem, etc. This can also involve letting other robots by in an intersection without colliding.
-E.g., Locomotive capabilities such as parking (e.g., perpendicular, angle, or parallel?)

**EX-4 (End of November)**: The "research" step.
Each team member should themselves conceive of, implement and demonstrate something.
This task is intended to prepare students for research, in which it can be the case that neither the interesting problems nor possible solutions are known to anyone. Synergies with other students can be explored and we will offer some typical electronics parts (e.g., sensors, LEDs, resistors).
Demonstrations will be done through a five minute powerpoint presentation in class.
The research steps must also be described in the final report.

Grade 3: Can show some simple preparation for research: e.g., present on a paper, or add a sensor like ultrasonic or actuator like LED for brakelights to their robot.
Grade 4: +the work is creative (novel and relevant) (we can make an exception here if the student does a lot of learning of material which is new to them and highly technical)
Grade 5: +the work uses excellent methodology (robustness, generality, challenge, etc), shown in the presentation and description in the final report.

**EX-5 (mid-December)**: Final demonstration including all groups. Spare day to show anything you want to show.
Grade 3:
(a) “cyborg” last step: if we are using drivers like shrimps or small fish, each group should place the driver on the robot and show driving.
This will be shown by having all robots from all groups driving together on the table at the same time. It does not matter if they collide, etc.
Grade 4-5: +
-Intergroup platooning: some formation or maneuver with 3+ robots, like a robot enter the middle of a platoon of other robots etc.
-“Fix” some detected problem using some actuator
-More complex “cyborg” behavior: Like, one driver controls two or more robots. This could be the distance between robots, etc.
-Learn about animals by using the robot: with an animal like a shrimp, what happens when you put a light in front of it, does the robot try to go toward the light, away from it? What happens when you have a sound source, a human, etc? Can the biological agent learn that its actions are controlling the robot? Can you use the robot to do something for the biological agent?

**EX-6 (w02: 1/11)**:
Grade 3:
(1) The student’s group will also submit a written report summarizing all work on the project, including original discussion and reflections about experiences and achieved results, including limitations and what might be done differently in the future. *
Grade 4:
(2) + Creativity
Grade 5:
(3) + Excellent methodology.
Additionally: code uploaded to Github, demo video(s) on YouTube.

*EXTRA NOTES:
In addition to the report each student must submit a proposal for their grade using the grading criteria form, with an accompanying portfolio of evidence. This is due at the same time as the report but will be sent directly by the student to the course responsible and examiner (Martin and Wojciech). This is confidential and only between the student and the course responsible and examiner: do not show others or ask others to show you theirs. Also let us know if someone asks you to show your grade proposal. We take issues of academic honesty seriously, as noted in the grading section.
***Also please remember there is also an oral exam which will check conceptual knowledge.**
Questions about the project can also be asked during the oral exam.
*”Question: But, I did some tollgate tasks for grade _, why did I get a lower grade?”

Answer: First, please remember that **the grades are assigned based on the criteria on the grading sheet**; please think of **the tollgate tasks as guidelines/suggestions**, and carefully check the grading sheet! Second, in general it is not enough to just do some tasks; **all** tasks for a grade should be completed in order to receive it (although again the most important thing is if the grading criteria on the grading sheet are met or not).

OTHER (some pictures and examples from last year)

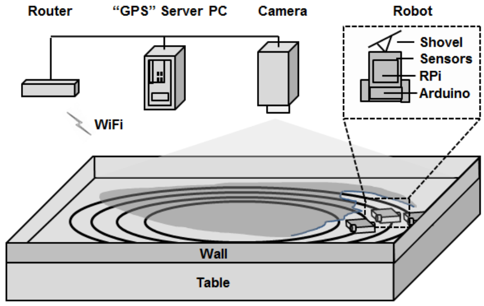



**Fig.**2017 project set-up.

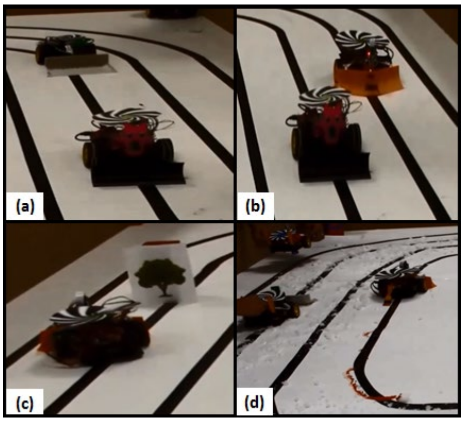



**Fig.** Some scenes from 2017 project work: (a) Platooning in a straight line formation to reach a destination, (b) Diagonal formation to clean, (c) Swerving out of the way of a detected obstacle (here a "tree"), and (d) a final task in which robots had to deal with some artificial "snow" (movements were visualized by attaching a paint brush to the backs of the robots).

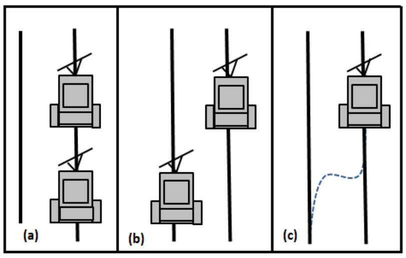
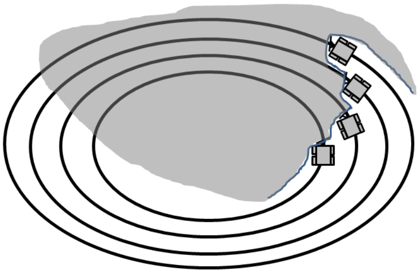
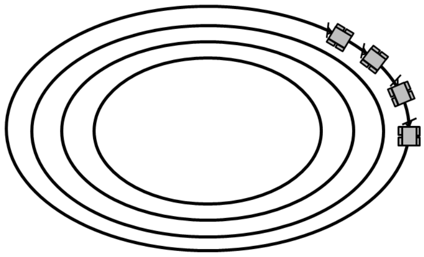


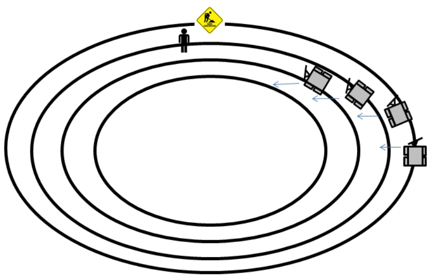

**Fig.** 2017 platooning examples: (a) straight line formation for traveling, (b) diagonal formation for cleaning, (c) changing lanes



Example of four robots in a diagonal formation on the tracks on the table on E1 to clean “snow” (gray).



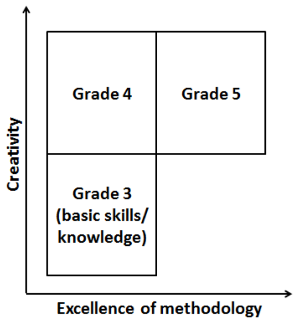
Example of robots in a line formation, travelling to a place where snow removal will be needed.



Example of robots changing lanes to avoid a construction sign and a human.

This document seeks to explain what a student needs to do to or does not need to do to earn a certain grade.
Grading criteria have been chosen to be aligned with the intended *learning outcomes* and learning activities of the course, as have been described in the Introduction.
In short the student is expected to engage in *applying basic knowledge in DEIS while collaborating* (the basic requirement), *hypothesizing independently* (creativity), *and reflecting* (excellence of methodology), in collaborating on a problem-solving project and during lectures and labs (half the grade will come from the tollgates including a written report about the project; half the grade will come from the oral exam).
Based on these intended learning outcomes, grading criteria are as follows.
Simply and informally, a failing mark will be given if a student has not fulfilled the basic requirement for applying knowledge or sought to hypothesize and reflect to a basic degree.
**Also note that we expect all labs/reports/code to be completely original (it is not okay to turn in a lab report with unreferenced material from others/work done by students from previous years).**
A grade of 3 will be given if a student has achieved the first learning outcome, and fulfilled the other two to a basic degree. A grade of 4 will be given if a student has completed the first two learning outcomes to a high degree and the third to a basic degree (thus fulfilling basic requirements and demonstrating *creativity)*. A grade of 5 will be given if a student has achieved all three learning outcomes to a high level, fulfilling basic requirements, demonstrating creativity, and furthermore showing a deep understanding of *excellent methodology* reflecting the literature and their own experiences.

**PLEASE SEE BLACKBOARD/COURSE INFORMATION FOR THE CURRENT detailed grading sheet for the course!**




The figure above illustrates the basic concept of the grading criteria.

In summary, the final grade given is weighted in relation to the quality of basic skills/knowledge, creativity and methodology demonstrated, by which we hope to motivate students to learn in a way which will lead to deeper knowledge and enable further learning and also research in the area of intelligent and embedded systems.

**Please also see the following additional important notes.**

## Other notes

- All examinations should be passed to complete the basic requirements of the course and receive a passing grade. This does not mean that each point listed for an examination event must be completed in order for the examiner to provide a passing grade, because grading in this course is done *qualitatively* and not quantitatively. There may be reasons for not being able to complete some part of an exam which can be unforeseen, clear, extenuating, and outside of a student's control. If there is some problem, we ask students to inform the course responsible in a timely manner either in person, by email, or by phone. Opportunities to retake an exam will be offered more than once in a year.
- There is a subjective component to any such evaluation which is not ideal but cannot be avoided. (Quantitative evaluations also incorporate a subjective component, and researchers also receive subjective evaluations on the papers they submit.) Therefore, at the end of the course each student will also be asked to describe to the examiner which grade they feel they deserve and why, before grades are given.
- If there is a problem working in the group we ask that the student contacts the course responsible immediately and not in a week or a month or just before an exam. Furthermore we suggest as a first recourse that the group meets with the course responsible and tries to resolve the problem by communicating. If a problem cannot be resolved, as a last recourse changes in group memberships may be considered.
- The student is responsible for scheduling times and places for their group to meet to work together. In doing so each student's needs must be considered. For example, some students might not be comfortable in meeting in a private setting such as someone's room, at night, or on weekends. Rooms are available at the university for groupwork, such as the project room on E1, which students are encouraged to use.  Also, meetings must begin soon into the course in order to be on time to meet the tollgates, so students are encouraged to form groups and meet as soon as possible after the course starts. And, for platooning cooperation is required between more than one group; the student is responsible for finding times to meet and collaborate with other groups.
- In some cases in a group there may not be one student from each background (embedded, intelligent, and communications) or fewer or more members than other groups; robots and materials made available will probably also have slightly different capabilities; and the schedule for lectures and labs is tentative due to the nature of the course (there are many teachers, who might become sick or might have to deal with other responsibilities) so students should check blackboard regularly for any changes to be announced.
- Special treatment cannot be given for a student who lives far away or not in Halmstad (e.g., in Gothenburg or Malmö). By choosing to enroll in the course a student agrees to spend a certain amount of time each week working on the course (e.g., to work with others on their projects and attending lectures and labs), irrespective of commuting time. Without engaging in learning activities course objectives such as collaborating with others cannot be met.

- all rules, addressed or not addressed above, e.g., regarding decisions by examiner (they are final) and exams (a passing grade cannot be given for a missing or interrupted result), are in accordance with the usual legal procedure at Halmstad University (there is equal treatment and legal certainty; more information can be obtained from, e.g., the Student Affairs section).

Please note also some additional definitions and considerations:

- “Basic skills and knowledge” here refers to key concepts indicated in the teaching/learning activities in this course in regard to research and development (requirements specification/problem formulation, design/modeling, evaluation), embedded systems (e.g., real-time programming, communication, and odometry), and intelligent systems (e.g., path planning, sensor fusion, simulation, and image processing (slides and materials will additionally be made available on Blackboard for students who wish to check). Just as an example, the student should know at least at a basic level a difference between “waterfall” or “agile” development models, a Kalman or particle filter, MSB or LSB (or big-endian and little-endian), a process and a thread, kinematics and dynamics, medium-fidelity and low-fidelity simulations, CAM and DENM, TCP and UDP, RGB and HSV.
- The first ILO also includes “collaborating”. It is important for the student to be able to collaborate because systems engineering is rarely conducted by only one person.
- “Hypothesizing” here is used in a general sense; we all engage in some form of hypothesizing in everyday life (e.g., when we guess what we will do on the weekend), and the aim here is just to bring this creative thought to play also in the topic of designing embedded and intelligent systems. Regarding the order of the learning outcomes, creativity is a highly important quality to develop for preparing students to engage in novel work (research) at the master’s level. Also, creativity is possible even without a deep knowledge of a field; thus it can come before a deep capability to reflect and judge based on excellent methodologies.
- “Reflecting” can also be defined in various ways; here we take it to mean a documentable activity of self-assessment and adaptation conducted by the student during learning. For example, the student can describe design options or initial approaches tried and rejected; for describing trouble-shooting, symptoms can be listed, followed by possible causes, and potential solutions; and one short line each week describing progress/plans for the next week could be recorded.