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How Peer-Review Affect Student Learning

Christian Lundquist, Martin Skoglund, Karl Granström, and Torkel Glad

***Abstract*—Courses at the advanced level in automatic control and signal processing cover mathematical theories and algorithms for control, estimation and filtering. However, practical applications on how to use these algorithms are also important parts of the courses. A goal is that the students should not only be able to understand and derive these algorithms, but also be able to apply them on real life technical problems. The latter is achieved by assigning more time to the laboratory tutorials, and designing them in such a way that the exercises are open for interpretation. An example is giving the students more freedom to decide on how to acquire data needed to solve the given exercises. The students are asked to hand in a laboratory report in which they describe how they solved the exercises. In this contribution the peer-review process of laboratory reports introduced at the department of Electrical Engineering at Linköping University is presented. A survey has been performed among the students and the results are summarized in this work. Furthermore, the teachers' experiences of peer-review, and also their experience of how students perform later in their education when they write their master's theses, are discussed.**

***Index Terms*—Peer-review, Learning, Laboratory work**

I. Introduction

SCIENTIFIC publications are usually peer-reviewed by other researchers before being published. Despite the fact that this is a major part of scientific work, students rarely practice how to criticize and motivate their point of view in a comprehensive way [1]. If the students are required to read, question and assess their fellow students' reports, as well as to propose alternative solutions and communicate these, the students are forced to spend more time on the task. This means they are repeating the content again, and thereby acquire an increased understanding of the subject.

The engineering profession is practical, and the aim of the engineering education is to prepare the students for their working life. In the education system the lab is the only part where the student is confronted with practical exercises. Labs can be divided into tree classes, depending on their purpose [2]. A *development lab* is used by engineers who need experimental data to design and specify their products, and to validate that the products fulfill the requirements. General questions are analyzed in a *research lab*, without having a certain product in mind. An *education lab* is aimed at students' learning of matters that are already known and practicing engineers are expected to know. The intention at Linköping University has been to let the labs in the last years of the Master of Science education be a bit closer to the research, thus moving away from the traditional education labs, with predefined solutions.

The authors are with the Department of Electrical Engineering, Linköping University, 582 83 Linköping, Sweden. E-mail: {lundquist,ms,karl,torkel}@isy.liu.se.

Laboratory work is usually less formal than traditional classroom teaching, creating other social conditions, particularly as regards the interaction between students and teachers. Hofstein and Luneta [3], [4] refer to a number of studies showing that collaborating students learn more than if they were to learn the material on their own. Colosi and Zales [5] are critical to formal labs and show that cooperation and student involvement is important for optimal learning. By letting the students collect their individual datasets in our courses, they are allowed to cooperate finding solutions. Since the datasets vary among the groups, they are not able to copy each others solutions, they are only able to discuss conceptual question with each other.

The peer-review process includes giving and receiving criticism, and justifying one's position in a comprehensible way. Topping [6] gives a good overview of the literature and how the parameters to be considered in a peer-review process should be used. Such parameters include whether the reviewers grade, give written or oral assessments. Other parameters are the degree of teacher involvement in the process, the degree of anonymity, etc. The students appreciate that their work is reviewed by more people than the teacher, they believe that it can provide a fairer assessment [6], and they can often get more detailed feedback on their work. Negative effects are that there may be embarrassing situations, that it is more demanding and strenuous but less accurate than if the teacher does the job. If the students read, question and evaluate each others work and also suggest alternatives and communicate this, then students will spend more time on task and will have to repeat the stages again. This provides an additional learning element and deepens understanding.

The article is outlined as follows: Section II discusses literature related to this work. Section III describes how the labs and the peer-review process is organized. Section IV summarizes and discusses the results from interviews with students and teachers, a student questionnaire and comments from course evaluations. Finally, Section V draws conclusions and gives directions for future work.

II. Related Literature

A. Laboratory Work

Kirschner and Meester [7] have found four basic principles for carrying out laboratory work in education. A first principle states the *illustration and concretization objective*, which should make it easier for students to grasp the often complex and abstract subject. The second purpose is the *cognitive aspect* that promote problem solving, analysis, synthesis and development of course content. As a third factor they mention the *practical laboratory work*, i.e., that students should be able to handle the methods and lab equipment in their professional

careers. The fourth principle is the students' *motivation* to carry out practical work based on the theories taught.

Lab objectives, according to [7] is to teach general methods that students will use in their professional lives. To teach laboratory skills are of great benefit to laboratory technicians, but less beneficial for graduate engineering students. Hofstein and Luneta [4] refer to a number of studies showing that much of the time in the laboratory is devoted to handling the technical details, which limits the time that can be used for meaningful learning. Students rarely remember details, instead, the time is better used if students manage to obtain fundamental insights into the subject, as the latter can easily be used on other problems in their professional lives.

Hofstein and Luneta [3] conducted a literature survey in which they primarily examine the effectiveness of the labs for educational purposes. As a part of teaching, the lab is widely accepted, however teachers rarely ask themselves what the goals and purposes of the labs are, and whether labs as teaching are an efficient use of resources. Twenty years later, they published a follow-up [4] of the first article. They mention the idea of purposeful learning and argues that the lab will give students the opportunity to test equipment and theories based on their current knowledge. They use the term *inquiry* extensively in the publication, and interpret many features of this word, including ability to observe, ask questions, find information, plan, investigate what is already known in the literature, use equipment and tools, collect, analyze and interpret data. The term also includes features like being able to propose interpretations, explanations, predictions, and to communicate the results. It requires the student to make assumptions, use critical and logical thinking and takes into account various alternative explanations. They emphasize that the lab focus should not be to teach specific scientific methods and laboratory techniques, but that students must use methods to conduct inquiry.

Hofstein and Luneta [4] describe the study of how students perceive the learning objectives of the lab. Many students perceive the goals of the lab to be following the instructions and giving the right answers to the questions. Coping with the equipment is often regarded as more important than understanding concepts and relationships in the exercise. The lab is part of the education and the course, and should at least be integrated in the course with a pre- and post-lab. The post-lab can be implemented by asking students to describe how they understood the concepts and issues. In one of our courses the collection of data is conducted very early in the course. Some of the questions that the students should answer have not been examined in the lectures and lessons. Our idea is that students in their groups do these tasks as the course content is presented, and that it creates opportunities for them to process data and laboratory work on their own and at the times they decide on to solving the assignments.

That teachers do not assess student performance may lead to the lab being seen as a less important part of a course. According to [8] this depends above all on the teachers' lack of experience to fairly assess student performance in the lab. The feedback and understanding that occur in the assessment is important, but in reality this often means that the teacher grades with rejected or accepted without comment on the student's choice, methods or mistakes.

B. Peer-review in Education

When designing a peer-review process one must consider what is standard and what is reference. There is no record or examples of good reports, so the students will assess each others' reports on their own. Their assessment is very likely to vary. According to Topping, and Ehler [9], it is important that the teacher clearly communicates what is considered important in the assessment. They also point out that when students compare works of others with their own, they tend often to also assess their own and then discover weaknesses and identify opportunities for improvement. Liu et al. [1] and Trautmann [10] suggest guidelines or instructions to the students that they must follow when carrying out the assessment. Pelaez [11] have used a system where students are encouraged to read three reference statements, evaluate them and compare with a professional evaluation before being allowed to assess each other's reports.

Topping [9] describes various forms of assessment. Open criticism of the essay form is considered more valuable than the scores. Confirmation that the authors of the lab report have made correct assumptions and derivations is important. In a more formal process where students are asked to write a review report, the students tend to become more responsible and think about their questions and criticisms carefully. Peer-review should be conducted during class, not at its end [9].

Many of the theses presented above are based on assumptions and experience. There are only few studies on the effects of peer-review. Pelaez [11] reports a study in which she compared students who completed a problem-based task and peer-review with students who have learned the material in a classical way with lectures and exercises. The first group passed the test (with answers) better than group two. Trautmann [10] conducted a comprehensive study on the students, where students have the opportunity to submit their works for a second time after a certain time. She shows that students who carry out peer-review are more likely to update, revise and improve their own work for a second submission, than students who only review their own work. She also examined the impact of obtaining criticism versus criticizing others. Students who receive criticism are more likely to revise their reports. Topping [6] describes a study in which students assessed each other's work. Half the group received feedback on the assessment and the other half did not receive it. They were subsequently asked to improve their work and submit it again. It turned out to be no significant difference between groups. This shows the effect of *"learning by assessing"*.

There are different opinions on whether peer-review saves teacher resources. Topping [6] concluded that in the short term before the system has been established it will require more resources than expected. These resources will be moved from the actual assessment of work to organizing, monitoring and mentoring the students. However, students' review reports and questions let the teachers gain new insights into the students' understanding, learning and their perceptions of course goals.

For these reasons, the teacher should allocate resources to supervise students and thus early detect systematic errors in the process. This may also help to get a more consistent reference to the assessment.

Berry and Fawkes conducted a study where they investigated how peer-review affects lab-report writing in two chemistry courses given to second year students [12]. Their impressions had previously been that the quality of the students' writing often was poor, and that the students lacked motivation to improve. Further, students are more likely to improve when they know that the target audience is their peers, rather than the teaching staff. To improve the students' writing, Berry and Fawkes implemented a peer-review system, however it was done with the explicit intention of not increasing the students' workload. Previous to the peer-review system, the students had been guided in their writing by instructions in the lab material, and a simple mock-report. However, this was unsatisfactory, as it did not prepare the students sufficiently for the more advanced writing needed in advanced courses.

Berry and Fawkes received mainly positive comments in the peer-review system, most students felt that reviewing others was better than being reviewed. When the peer-review system was introduced, Berry and Fawkes intentionally tried to avoid creating an atmosphere of students grading and assessing each other. They wanted the students to use peer-reveiwing to improve their own writing, rather than correcting the writing of others. As a consequence, Berry and Fawkes no longer distribute the reviews to the reviewed students. Berry and Fawkes conclude that the students that participated in peer-reviewing improved their writing skills.

III. Performing Lab and Peer-Review

Peer-review was introduced into courses in Sensor Fusion, Modeling and Simulation, and Digital Signal Processing at Linköping University. In each of the courses a laboratory session was chosen to include the peer-review task. The lab session is primarily aimed at data collection, see Figure 1 for an example setup. The students work in pairs, and at each occasion two groups collect data together. The students receive a number of tasks to solve beforehand, this gives them time to think over and plan the experiment design before they arrive at the lab session. The complete task is in the format of a small Master's Thesis, i.e., the students must not only answer some questions, they must prepare the experiments, implement the solutions and come up with results. The lab memo does not contain very detailed instructions, with the result that the experiments and the results vary between groups.

The organization of the review process mimics that of a journal article. In this way the review process can be motivated for the students as an additional exercise of something they might be confronted with in their professional life. The steps of the review process is summarized in the following list.

1) At the data collection each group receives an anonymous ID number, to ensure a double blind review process.
2) The students perform the lab and solve the given tasks. They describe the experiment design, the lab implementation, the derivations they do and the results in a lab report. The students are not allowed to write their names in the report, they must only write the ID on the first page.
3) The lab report are sent to the course assistant, who serves as an *Editor-in-Chief (EiC)*.
4) The EiC sends the lab reports to a randomly chosen group after having briefly checked the content. The students have some days to read and assess the lab report they received. They write a review report based on their comments and findings. Again they do not write their own names on the report, they only write their ID, and the ID of the lab report they have assessed.
5) The students send the review report to the EiC, who distributes them among involved teachers, who here serves as *Assistant Editors (AE)*. An AE receives lab reports with the corresponding review reports.
6) The AEs read the lab and the review reports, summarize their impressions and decide on the grades; in this case pass, supplementary examination or fail.
7) The review reports and teachers' assessments are sent to the groups.

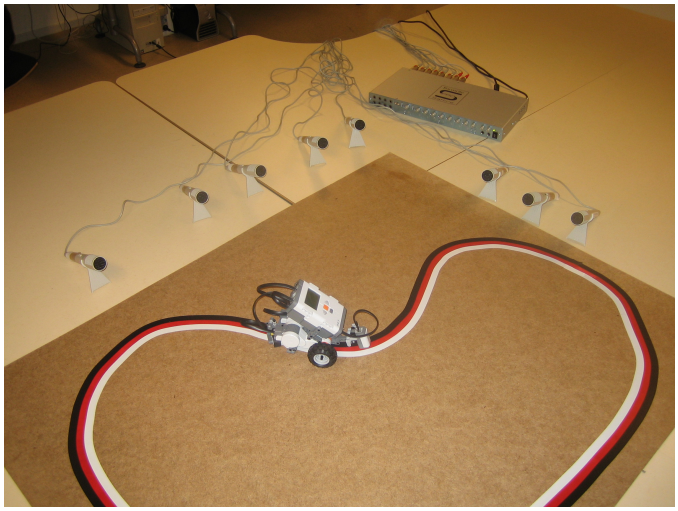

Fig. 1. Example of a data collection setup in the Sensor Fusion course.

Since the students are not used to writing reviews, and in order to get the review reports on an as similar level as possible, the lab memo contains instructions about "how to review". To mimic professional review processes from e.g., scientific journals, the written review report is in the format of an essay. In this way the students must not only think about what to write, but also how to formulate the criticism.

The following instructions are given to the students in the lab memo:

"The questions shall be answered in the form of a discussion. Present arguments for your point of view and propose alternative methods. Some more specific tips:

- *Present useful criticism and make sure your comments are constructive.*
- *Use a positive tone and consider how you would feel if someone sent your review to you.*
- *Be clear and specific about things you think could be*

improved.
- *Point out strengths as well as weaknesses.*
- *Use a courteous language.*
- *Avoid comments that might be read as insulting or inappropriately personal.*

Most people ignore feedback that they find hostile, vague, or confusing. Try to keep your comments positive and specific: this will make them much more useful to your peers."

Furthermore in the review report the following questions shall be answered:

"In the review report you should respond to and discuss the following questions

- *Are the data sets presented clearly? Are the procedures to acquire data described in enough detail for the experiment to be copied by someone else?*
- *Is there a clear explanation of the solutions of the tasks. Discuss each task separately.*
- *Are the conclusions well supported by the data, the experiment and the results? Do you agree with the conclusions? What would you like to add to the conclusions, based on the data and the results of the task?*
- *What is a particular strength in this lab report? Discuss the content, not the format.*
- *What suggestions can you make for improving the overall quality of the writing in this report? Discuss clarity, readability and technical accuracy."*

IV. Results

A. Interview with two students

Two students, Morgan and Lasse[1], were questioned about their experiences of working with peer-review, and how it affects writing skills. The interviews were held after they had written their respective master's thesis. In this context it is important to note that lab reports typically are written in Swedish, while Master's Thesis reports typically are written in English. Thus, there are language differences here which the peer-reviewing does not capture. Morgan and Lasse were asked the following two questions:

1) Do you think that reviewing another groups lab report gave you new knowledge of how a report should be written?
2) Do you think that receiving a review of your lab report from another group gave you new knowledge of how a report should be written?

On the first question, Lasse answered that he definitely gained new knowledge of how to write a report by reviewing another groups' report. Partly because it gave new perspectives on the subject which the report was about, and partly, and above all, because he was able to see structural differences and similarities with his own report. Regarding question two, Lasse did not feel that it gave as much new knowledge to be reviewed as being the reviewer. The reason is that the review he received mainly pointed out fact errors or typing errors, rather than comment on the structure and outline of the report he had written. Thus, it did not give very much new knowledge of report writing to be reviewed. Finally, Lasse points out that he thinks peer-reviewing as part of the course work is good, and that it could be introduced in the engineering education at an earlier stage in order to give the students more time to practice both writing and reviewing reports.

Morgan is of the opinion that all forms of practice are good when it comes to writing academic reports, and he explicitly states that constructive criticism is always positive. Peer-reviewing gave beneficial information regarding the outline and structure of a good report, as well as how important it is to use a correct language. For his own part, he felt that by the time of writing his Master's Thesis report, he already had quite a lot of writing experience from high school and university courses, however there were still things to learn. Morgan also felt that introducing peer-reviewing during the second semester of year four is a little late.

In conclusion, both Lasse and Morgan think that the peer-review process has a positive effect on their abilities to write and structure a report. Another conclusion that can be drawn from Lasse's and Morgan's experiences is that it would be beneficial to introduce the peer-review process to the students as early as possible.

These findings are in line with both Trautmann's [10] and Berry's and Fawkes' [12] work. Peer-review appears to have a positive influence on the students' report writing. Whether it is reviewing another report, or having your own report reviewed, that is most beneficial is individual. Some students benefit more from the one, other students benefit more from the other. An interesting and important detail are the writing instruction given to the students, which both Trautmann and Berry and Fawkes find are quite important. The laboratory instructions given to the Linköping students could probably benefit from evaluation, keeping the writing quality aspect in mind.

B. Student questionnaire

The students' experiences are an important source for evaluation and further improvement of the labs and the peer-review process. A questionnaire with twelve questions, containing multiple choice questions, graded questions and free text answers, was constructed and given to the students in the Sensor Fusion course. Unfortunately the response rate was only about 30 percent, hence no general conclusions should be made. Questions which are graded range from *strongly disagree* to *strongly agree*, with three steps in between. We translate this into an agree number ranging from 1 to 5, where 1 corresponds to strongly disagree and 5 corresponds to strongly agree. The questionnaire consisted of the following questions:

1) How many hours did you spend solving the exercises? Average was 28 hours.
2) How many hours did you spend writing the lab report? Average was 8 hours.
3) The lab is relevant for the course? 5.0 agreed.
4) The design of the lab is good. 3.9 agreed.
5) Knowing that the lab report would be peer-reviewed affected the report quality positively. 3.2 agreed.

[1]The names are simulated to ensure anonymity.

6) To give feedback by peer-reviewing another groups report gave me a deeper understanding of the course content. 4.0 agreed.
7) To receive feedback from the peers regarding my report gave me a deeper understanding of the course content. 3.4 agreed.
8) To receive feedback from the teachers regarding my report gave me a deeper understanding of the course content. 4.1 agreed.
9) To receive feedback from the teachers regarding my review report gave me a deeper understanding of the course content. 3.7 agreed.
10) I feel that the knowledge I have obtained during the lab, including the review process, is something that will be useful when writing other reports. 4.7 agrees.
11) Describe the most significant differences of this lab compared to others labs in which you participated.

The Sensor Fusion course is likely to be one of the students' last courses, therefore many (91%) of the students that answered the questionnaire had already participated in a course with peer-review. We think that this particular sensor fusion lab is rather ideal for peer-review because it can be performed independently of other groups, and solved in many different ways. This is partly confirmed by the free text answers, e.g., *"It is good that you have to do all steps because it gives you a better understanding of the whole lab."* and *"Hard to know where to begin. Some advice would have been nice."*. How to solve the lab is up to the students to decide, this can lead to some initial frustration because they might not get started as fast as in other labs.

Regarding the peer-review, the students' gave positive responses to reading other groups' reports, but not all were positive, e.g., *"It depends on the quality of the report you receive."*. This cannot be circumvented if all reports are subject to peer-review, because there will always be reports of lesser quality.

The students' experience the lab as more free, because the have a lot of room to choose themselves how to solve the problems. The students also find the lab to be more extensive than other labs are in general. Some students tend to appreciate more independence in labs while others want more advice. An encouraging answer to question 12 was: *"You understand more of the course content. You try harder compared to a lab without peer-review."*

C. Course evaluations

After every course at Linköping University, students are encouraged to fill out a course evaluation. The course evaluation serves as an important quality indicator to both teachers students, either regarding certain parts, such as labs, lectures and course alignment, or regarding the course as a whole. There are two types of questions in the evaluation, the first are specific questions which the students disagree or agree to on a scale from 1 to 5, the second contains free text answers related to specific questions, or it can be any course related comments. Below we have summarized the free text answers concerning the peer-review process which were received since its introduction. This corresponds to a total of 235 students of which 47% answered the course evaluation. We did not categorize the answers according to the specific course.

"The peer-review process is good."

"I appreciate reviewing other peoples reports"

"An excellent exercise in writing reports. It is rewarding to obtain feedback from fellow students and teachers. It is also rewarding to give feedback to another student group."

"The structure of the labs was nice since we got to practise problem solving, report writing and reviewing reports."

"The part with writing the report and receiving feedback was very rewarding."

"It is good to review other students' reports. You learn a lot and at the same time you will put a bit more effort into your own report."

"It's good to write a report, the peer-review process is also good and it will be useful for coming courses and my master's thesis project."

The students seems positive about peer-review labs in general. In fact, there was no criticism to be found in the course evaluations regarding the peer-review labs.

D. Interview with teachers

The teachers' views and experiences are also important for understanding how the labs work in practice. We interviewed most of the teachers involved in courses with peer-review, a total of seven. Below is a summary of these interviews, and some conclusions.

1) *What is your impression regarding the quality of the lab reports?*
   The reports are more concise, but sometimes it seems like the students' write too much just to make sure that they cover what they believe should be covered in the report. The best reports do not get better but the average level is better, and the writing is better which reduces the teachers' workload. Parts that should obviously be in the report, such as conclusions, are sometimes missing, however this also happens in courses where the report format is explicitly given.
2) *What is your impression regarding the quality of the review reports?*
   In general, the quality is good and the students appear to be rather honest, which perhaps can be explained by anonymity of the review process. The reviews also reflect the students' knowledge since they need to understand, explain and criticize someone else's work. Other impression are that the reviews could be more critical, less negative and clearer.
3) *How big is the workload for the teachers with this type of lab?*
   It can be easier to read a lab report using the comments in the review report, however a poor review gives extra work and you have to match the contents of the lab report and review report. Some teachers' tend to read the lab reports as careful as they would have without having the review reports.
4) *What are the unique benefits of having labs of this form?*

There is a lot of freedom in how to perform the lab and there are no unique correct answers. More independence in the labs require the students to reflect upon their work. Also, it seems that questions and discussion tend to be of a more fundamental character and the review gives more repetition which facilitates further learning.

5) *What are the shortcomings of having labs of this form?* It is not as easy for students to ask the teachers questions, however this could also be something good. The students never get an option to respond to the review and report comments they receive. There can be terrible miss-matches in the review process if, e.g., a poor group is asked to review a poor report. On the other hand, there can also be terrific matches leading to a knowledge leap for both parties. This is not a suitable format for all kinds of labs, and at its current form it requires more administration from the teachers involved.
6) *What improvements can be made?* There is a need for better instructions, both to students and teachers, and report templates for the students to use. An obvious improvement would be the administration, where some kind of submission portal, like the ones for scientific articles, could reduce the teachers' workload.

One should bear in mind that peer-reviewing in labs was introduced at Linköping University in 2009 and is therefore something rather new. Hence, there are many things that need to be improved before things work as smoothly as intended. Despite this, the majority of the teachers are positive in general about peer-reviewing in labs, and its effects on student learning.

V. Conclusion

Peer-review has been introduced as a laboratory task in three courses in the engineering program at Linköping University. Although the experience is so far rather limited, some tentative conclusions can be drawn:

- The student response is essentially positive.
- The teachers involved in the courses are also positive, but some of them fear that the teacher workload might have increased.
- There are indications that the quality of the student reports has improved.

To improve the overall quality of the labs some suggestions are:

- Cooperate between the courses and create general guidelines, both for students and teachers.
- Better administration tools for handling of the reports and the grading.

In the first round of courses with peer-review given at Linköping University, the peer-reviews were handed out to the students who had written the report, along with comments from the teachers. An early student response to this practise stated that receiving comments from a peer (i.e. another student) and only an assessment (pass, fail, completion) from the teacher was insufficient. The students did not like the feeling of being assessed by other students, they wanted to hear the teachers' comments. This is quite similar to the findings by Berry and Fawkes [12], as mentioned in the litterature section. They found that the quality of review reports was improved when the students knew that the review would not be read by the author, only by a teacher. The practise at Linköping University of handing out the reviews to the authors could be discussed, and possibly discontinued, to further improve the implemented peer-review system.

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Christian Lundquist received the M.Sc. degree in automation and mechatronics engineering from Chalmers University of Technology, Gothenburg, Sweden, in 2003. He is currently working towards the Ph.D. degree at the Division of Automatic Control in the Department of Electrical Engineering of Linköping University, Linköping, Sweden.

Between 2004 and 2007, he worked with active steering systems at ZF Lenksysteme GmbH, Germany. His research interests include sensor fusion and target tracking for automotive applications.

He is CEO and co-founder of the company SenionLab, developing navigation and positioning solutions for indoor usage.

Martin A. Skoglund received the M.Sc. degree in applied physics and electrical engineering in 2008, and the Tech.Lic. degree in automatic controlin 2011, both from Linköping University, Linköping, Sweden. At present he is working towards a Ph.D. degree at the Division of Automatic Control at the Departmend of Electrical Engineering, Linköping University, Linköping, Sweden.

His research interests include sensor fusion, visual augmented reality systems, mapping and navigation with particular focus on aerial vehicles.

Karl Granström received the M.Sc. degree in applied physics and electrical engineering in 2008, and the Tech.Lic. degree in automatic controlin 2011, both from Linköping University, Linköping, Sweden. At present he is working towards a Ph.D. degree at the Division of Automatic Control at the Departmend of Electrical Engineering, Linköping University, Linköping, Sweden.

His research interests include sensor fusion, target tracking, mapping and localisation, especially for mobile robots.

Torkel Glad was born in Lund, Sweden in 1947. He received his M.Sc. degree in Engineering Physics in 1970 and the Ph.D. degree in Automatic Control in 1976, both from the Lund Institute of Technology, Lund, Sweden. Since 1988, he is professor of Nonlinear Control systems at Linköping University, Linköping, Sweden. His research interests include optimal control, nonlinear systems and differential-algebraic equation models.