



2017-03-13

Universitetskanslersämbetet
Box 7703
103 95 Stockholm

Luleå tekniska universitet

Härmed översändes underlag för utvärdering av forskarutbildningsämnet Kommunikation- och beräkningssystem. Förfrågningar rörande text hänvisas till utsedd kontaktperson, Camilla Lindmark, camilla.lindmark@ltu.se.

A handwritten signature in blue ink, appearing to read 'Johan Sterte', is written in a cursive style.

Johan Sterte
Rektor

.....

Swedish Higher Education Authority, Education Evaluations

Self-evaluation

University: Luleå University of Technology

Research subject: Dependable Communication and Computation systems (DCC) (<i>Kommunikations- och beräkningssystem</i>)
Licentiate degree: yes
PhD degree: yes

1. Introduction

1.1 History

The research subject of Dependable Communication and Computation systems (DCC) (*Kommunikations- och beräkningssystem*) was established in February 2011 (LTU dnr 2607-10). It was an outcome of a strategic decision by the department to create a larger research environment based on two existing research subjects, and at the same time fill a gap that had been identified in the systematic monitoring of the research areas at the department. The new subject was to be central in the prioritized research area of Process IT, and support topics such as cloud computing, wireless sensor networks and pervasive computing. At the time, there were six researchers in place, including two associate professors and four assistant professors (or equivalent), which formed the core of the new DCC research subject from day one. The plan was to reach a critical mass in the DCC research subject within five years. Part of the plan was to recruit a chaired professor within two years, and strengthen the group with new (and promoted) associate professors, research assistants and third-cycle students. A chaired professor was recruited and started service in December 2012. At that time, the general syllabus for the research education subject of Dependable Communication and Computation systems (DCC) was formally established (LTU TFN-DB 139-12), and started early 2013.

1.2 Current state

It will be clear from this self-evaluation that, now after five years, the strength of the current research group and the third-cycle education program exceeds the originally defined target for critical mass. There is a chaired professor in the research subject and the number of supervisors as well as the expertise have developed well, while a small number of research students have been recruited. The research subject of DCC at LTU coincides with the evaluated research education subject, which is part of the SCB code Computer Science. LTU has a generic certification (i.e., not field-specific) for third-cycle education and the general approach has been to make research education subjects and research subjects coincide.

As will be seen in the evaluation, the quality assurance procedures starting at LTU, through the Department of Computer Science, Electrical and Space Engineering (*System- och rymdteknik, SRT*), through the division of Computer Science (*Avdelningen Datavetenskap*) and into the DCC research subject are coherent and well defined. The quality and outcomes requirements as formulated in the Swedish Higher Education Ordinance (*Högskoleförordningen 1993:100*), are literally described, monitored, and followed up through these organizational levels, and are part of the individual study plans of the doctoral students.

1.3 Document Outline

The document is outlined as follows. Section 2 Presents our *systematic quality monitoring process*: The rationale for Section 2 is that the B questions in the template used in Section 3 cover how each particular Aspect is systematically monitored and followed-up. In our organisation, we have *one* established model for systematic quality monitoring, actions, and feedback. In that model several quality aspects are covered. Therefore, in Section 2, we describe generally our systematic approach.

Section 3 follows the structure of the evaluation template provided by the Swedish higher education authority. The assessment criteria provided in the English version of the guidelines are included in *blue text, italics*. Under the B questions, we then refer to our systematic approach (Section 2) and present the particular criteria for each aspect in question, plus our own reflections. Those reflections are conclusions drawn by the authors of this document, based on the factual description of current state under the A part, on the factual description of our systematic follow-up presented under the B part, and on input from other seniors and the doctoral students. In our responses, the terms *third-cycle student or education* is used interchangeably with *doctoral student or education*.

2. Our systematic process for quality definition, follow-up and feedback

At LTU and the Department of Computer Science, Electrical and Space Engineering (CSESE) we use a systematic process aimed at defining, monitoring, and improving quality and expertise. Described top-down it is as follows:

- At LTU, there is a generic model for evaluation of research subjects and research educations (LTU dnr 253-15). All subjects are monitored and evaluated by the Faculty Boards in two year cycles, producing updated strategic plans. The evaluation per subject includes quantitative measures (e.g., on funding, competence profile, staff/supervisors, doctoral students, publications, graduations), a template-based self-assessment by the chaired professor (*Ämnesföreträdare*), and an identification (performed by the faculty boards) of needed actions. The outcome of the evaluation is communicated to the Head of Department (HoD) by the Faculty boards. Then the HoD considers the department strategic plan and has dialogue with each chaired professor in order to decide, fund, and lead actions to improve the competitiveness of the research group. Actions stemming from this evaluation include consolidation of research subjects, replacement of chaired professors, and recruitments funded by the department. The current strategic plan is for the period 2017-2018 (LTU dnr 2017-5), where the specific plan for CSESE is included (LTU dnr 2017-5, appendix 1:5). The initiation and build-up of the DCC research group in 2011 are outcomes of this research subject evaluation process.
- At the CSESE department level, operation is carried out according to the current strategic plan (*Verksamhetsplan*). Annual monitoring and evaluation is performed regarding the strategic position and the expertise development across the research subjects. This evaluation includes a deep investigation of the competence profiles of each research group, and based on these evaluations there are strategic initiatives of recruitments, promotions, pedagogical development etc. The evaluation is led by the HoD. The input to the department strategic plan is both bottom-up and top-down. Top-down input is for example given by the research subject evaluation, university risk assessment, and specific strategic areas/actions. Bottom-up input is collected from the (i) joint LTU strategy days held every two years with all chairs, deans, vice-chancellors, and line managers at LTU, (ii) Professors meeting held four times per year at the department, (iii) meeting with the faculty and the doctoral students (separately) at the department prior to the creation of the strategic plan. The department strategic plan, including individual actions, are followed up, in writing, twice per year and finalized in the end of the year.

- At the department level, Supervisors' forums are conducted 4 times a year, led by the department coordinator of third cycle studies (UL-F). The primary objective is to improve the quality in the doctoral education at the department. The UL-F feeds back to the HoD and to the Doctoral student representative at the department.
- At the division level (inside CSESE), there are annual individual career development dialogues, carried out by the division managers, where performance for the last year is assessed, and an individual development plan for the next year is set-up and agreed. These meetings are held with all personnel, including doctoral students and supervisors.
- Students and supervisors meet frequently in supervisory meetings, typically with one or two week intervals. At those meetings, students report What did you do this period? What is your plan for next period? Are there any impediments in your way? Are the conditions as desired, including quality of the doctoral education and supervision? A check against the individual study plan is performed so that planned activities are met.
- The Individual Study Plan (ISP) is central in the education process of doctoral students at LTU. The ISP is structured according to the required outcomes of the Higher Education Ordinance, and is periodically updated with evidence and new learning activities to meet these outcomes. The ISP is discussed between student and supervisors regularly, and updated at minimum two times per year.

Along with the top-down process for defining and monitoring the quality and experience criteria, there is a bottom-up process for identifying issues, taking actions, and transferring feedback regarding resolutions. The objective is to resolve issues in the immediate contact between students and supervisors, as a part of the supervisory meetings. There is a problem escalation order where the next upper level is convened to resolve problems that could not be resolved by supervisory meetings. Issues identified by students (e.g., on supervision, doctoral environment, personal development) are first raised directly in the supervisory meetings, for discussion and resolution. If the problem cannot be resolved, the student can escalate the issue to the division manager. This can be done at any time, but at the minimum the student has the annual career development meeting with the division manager where he/she is explicitly asked to provide information on any issues regarding their doctoral education.

3. Aspects evaluated

3.1 Aspect: Third-cycle subject area

Assessment criteria: The demarcation of the third-cycle subject area and its connection to scholarship or artistic practice and proven experience are adequate and appropriate.

3.1.1 Demarcation of the research subject of DCC

The research subject of Dependable Communication and Computation Systems (DCC) is an emerging area of computer science that covers design and development of mission-critical computer-based information, control, and communication systems in various industries. The area has emerged from the recognition of specific scientific challenges that are observed in emerging technologies, such as cyber-physical systems, Internet of Everything, virtualisation and digitalisation in industry. There are two research cores demarcating our fields of depth:

- 1) *Dependable design of industrial computing systems*: Design and assurance of dependability of industrial information and control systems, such as (but not limited to): industrial automation systems; material handling and transport infrastructures; new energy generation and consumption infrastructure (SmartGrid or Energy Internet).
- 2) *Dependable Communications*: Design of novel communication paradigms (5G and beyond) for future intelligent computing elements and their industrial applications. The research concerns (but not limited to): Optimization of communication protocols with methods of artificial intelligence, communications for distributed cognitive architectures, and communications for low-power approximate computing electronics.

Each core has a distinct history and some specific methods. However, since industrial systems are becoming more and more distributed and communicating, the two cores demonstrate a high degree of synergy and interrelation, and consequently the research challenges are to a large degree addressed from common theoretical positions. Scientific foundations are demarcated by theory of communication networks, software and system engineering, machine learning and artificial intelligence, formal models of computation in reactive systems, formal methods of system verification, theory of computation and algorithms, cyber physical systems, hyper-dimensional computing, recurrent neural networks and reservoir computing.

Recent examples of synergies include the application of cognitive reasoning to the problem of distributed fault diagnostics:

D. Kleyko, E. Osipov, N. Papakonstantinou, V. Vyatkin, A. Mousavi, "Fault Detection in the Hyperspace: Towards Intelligent Automation Systems Fault Detection in the Hyperspace: Towards Intelligent Automation Systems", *IEEE International Conference on Industrial Informatics INDIN'2015*, Cambridge, July, 2015,

The DCC subject is strongly connected with other subjects at CSESE, such as Pervasive and Mobile Computing, Industrial Electronics, Embedded Systems, and Automatic Control, which is confirmed by joint publications, co-supervision of doctoral and master students, joint participation in research projects, and joint organisation of workshops and special sessions at international conferences. It is complementary to other subjects represented at the department, such as Signal Processing and Information Systems.

3.1.2 Demarcation of the third-cycle subject area of DCC

The evaluated research education subject of DCC coincides in terms of scope with the research subject of DCC. The research education subject, here denoted as the *doctoral program*, in DCC was established at LTU in 2013, when the current three candidates Kleyko, Patil, and Yang were enrolled. All of them are making good progress and are expected to graduate in 2017. One of them has received licentiate degree. Note that, up to 2013, doctoral students were enrolled in the research education subjects of Communication systems and Computer science. Laurynas Riliskis, who graduated in 2014, became a part of the DCC research education subject at its inception, but was initially enrolled to the previously available topic of Communication systems.

Doctoral education in DCC is organized according to the senior research conducted within the research environment. This way, students are closely linked to the senior research. **The philosophy of doctoral education at DCC is to expose the third cycle students to aspects of senior research as early as possible.** Figure 1 illustrates the demarcation of the DCC third-cycle education. The demarcation of the research education subject is a large subset of the demarcation of the research subject (Section 3.1.1), because foundations studied by senior researchers may not yet be part of the research education subject. The two research cores in the third-cycle education have theoretical background in mainly six fundamental areas of computer science. For example, research work of students: Denis Kleyko is related to topics 1,2,3,4. Sandeep Patil to 3,4,5,6, and Chen-Wei Yang to areas 2,3,6.

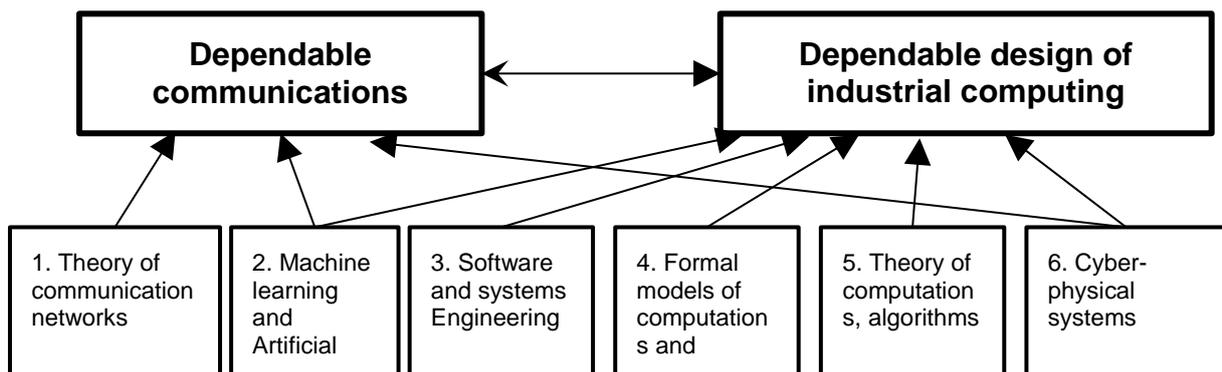


Figure 1. Demarcation of the third-cycle education at DCC w. r. t. scientific foundations.

3.1.3 Experimental support

To ensure high level of experimental support of the research, the laboratory of Automation, Industrial Communication, Computation and Control has been established with funding at the level of 4.5Mkr in 2015–2016 funded jointly by the LTU Lab Fund and The Kempe Foundations. The lab offers a unique combination of equipment representing models of the variety of industrial processes, from manufacturing and assembly lines, building management systems, energy management and SmartGrid, all equipped with sensor and actuator networks with advanced wireless communication. All doctoral students of DCC use the lab facilities in their on-going research.

3.2 Aspect: Staff

A. The number of supervisors and teachers and their combined expertise are sufficient and proportional to the content of the programme and its teaching/learning activities.

3.2.1 Combined expertise of supervisors and teachers

The DCC supervision group includes 2 professors, registered as main supervisors, one adjunct professor, 1 docent, 2 senior lecturers and 2 lecturers, one international visiting professor who visits LTU on a regular basis for the last three years. Confirming the broad interaction of DCC with other subjects of the department, as well as internationally, two co-supervisors are Prof. Wolfgang Birk from the Automatic Control subject at the same department and Prof. Urban Wiklund from Umeå University. Visiting professor Victor Dubinin from Penza State University (Russia) has been involved in research supervision at LTU since 2013. In this period, he did 10 joint publications with DCC doctoral students Patil and Yang, at conferences and journals of highest international standing, for example:

- D. Drozdov, S. Patil, V. Dubinin, V. Vyatkin, “Formal Verification of Cyber-Physical Automation Systems Modelled with Timed Block Diagrams”, IEEE International Symposium on Industrial Electronics, Santa-Clara, CA, June, 2016
- Yang C.-W., Dubinin V., Vyatkin V., “Ontology Driven Approach to Generate Distributed Automation Control from Substation Automation Design”, *IEEE Transactions on Industrial Informatics*, 2017, accepted

The DCC doctoral students benefit from the broad expertise of the DCC senior researchers, of the division and of the entire department. There are 3 research subjects at the Computer Science division, each lead by a chaired professor (Vyatkin, Åhlund, Päivärinta). In addition, the division consist of 7 professors, 8 associate professors, 1 docent, 1 adjunct professor, and 3 guest professors. Interaction is carried out in joint research projects. For example, the following recent publication shows collaboration of the DCC doctoral student Sandeep Patil with docents Jan van Deventer and Jens Eliasson from the Industrial Electronics group:

Hasan Derhamy, Dmitrii Drozdov, Sandeep Patil, Jan van Deventer, Jens Eliasson and Valeriy Vyatkin, “Orchestration of Arrowhead services using IEC 61499: Distributed Automation Case Study”, IEEE International conference on Emerging Technologies and Factory Automation, Berlin, September, 2016

The tight synergetic research collaboration at the CSESE department is also reflected in the fact of co-supervising doctoral students from other subjects by the DCC supervisors. For example, Professor Vyatkin is co-supervising Marcus Lindner, a doctoral student at the Embedded Systems group together with Professor Per Lindgren.

High expertise and academic standing of the main supervisors at DCC, Vyatkin and Osipov, is seen from their Hirsch indexes (Vyatkin $h=33$, Osipov $h=8$) and their roles of principal investigators in the ongoing VR projects DIACPA and ICASP (2016-2019).

Research at DCC is strongly related to such societal developments as changing the shape and role of manufacturing and production industries, such as Industrie 4.0. Prof. Vyatkin participates in high-level activities in this arena, e.g. he was invited to OECD International Conference on Smart Industry in Stockholm in November 2017. The societal and political demands developed there are then translated to research agendas, such as Factories of the Future of Horizon 2020 program in European Union, in which doctoral students of DCC participate directly.

B. The combined expertise of supervisors and teachers and skill development are followed up systematically to promote high quality in the programme. The outcomes of the follow-up are translated, when necessary, into actions for quality improvement, and feedback is given to relevant stakeholders.

3.2.2 Supervisors' expertise monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies to supervisor expertise. The process is aimed at defining, monitoring, and improving the supervisor expertise. The personal career development meetings are especially important for the expertise criteria. Ensuring supervisor expertise development includes assuring that the current state and the latest development (delta) is satisfactory regarding the following supervisor **expertise criteria**:

- Supervisors are actively publishing.
- Their citation indexes are high.
- Supervisors are visiting leading international universities.
- Talks at international conferences (keynotes, invited).
- They are involved in projects with industry and society.
- Understanding of societal development is discussed as a part of career development.
- They have taken the available supervisors courses & pedagogical education as required by LTU (for example the docent course and 7.5hp of university pedagogy).
- They have suitable number of doctoral students (as main supervisor and as co-supervisor).
- They have sufficient funding, and efforts for raising new funding.
- They perform relevant, and sufficient amount of, teaching at undergraduate levels.
- They have had their annual career development meeting and established their personal expertise development plan.

Professional development for supervisors

The personal development plan for each supervisor is updated at the annual career development meeting with their division manager. Besides acting on subject specific issues, there are also actions on generic knowledge and skills. Courses in supervision and leadership development, from assistant professor to professor are compulsory, provided annually at university level. Supervisors and doctoral students follow societal developments by participating in external networks as described in Section 3.3.2 and 3.3.4 respectively.

Ensuring sufficient supervisor resources in the long term

In annual monitoring at department level, the need for new recruitments is assessed. The status and findings are documented in the recruitment and skills development plan (*Kompetensförsörjningsplan*) which is part of the strategic plan (*Verksamhetsplan*), published internally on-line every second year. New recruitments are performed according to the procedures defined in the employment ordinance. In the department Strategic plan for 2017-18, no competence development actions are detailed for the DCC group since the group composition is considered satisfactory. Instead the department is growing competence in other complementary, nearby groups.

Changing supervisor

The division manager monitors the overall work situation for the doctoral students and carries out individual career development meetings with them. Doctoral students who are not satisfied

with their supervision may request a change of supervisor. This is initially handled by the division manager, and then discussed with the head of department who takes the formal decision. Students are informed about the requirements and responsibilities for supervisors, which are published in the handbook for third-cycle education, in Swedish and English (Chapter 9 of <http://www.ltu.se/research/Utbildning-pa-forskarniva/Handbok>).

3.2.3 Supervisor expertise, reflections

Based on the factual description above, we find that the current number of supervisors and the level of supervision expertise is satisfactory for the current scale of doctoral students. We also find that the processes (Sections 2 and 3.2.2) for monitoring, acting on issues, and providing feedback, regarding supervision is satisfactory. We would like to increase the number of doctoral students. The current group of supervisors can probably handle a group of 5-8 doctoral students, for which the main issue preventing growth is the lack of stable funding. We would also like to grow the supervisor group in order to further increase the number of doctoral students, where the main challenges are to attract the right competences and to secure the required funding.

3.3 Aspect: Third-cycle programme environment

A. Research and artistic research at the HEI has sufficient quality and scale for third-cycle education to be carried out at a high scientific/artistic level and within a good educational framework. Relevant collaboration occurs with the surrounding society, both nationally and internationally.

3.3.1 Composition of supervisor group and doctoral student group

The group of supervisors is described in Section 3.2.1. All students have a main supervisor and one or more assistant supervisors. The supervisors are full time employees at LTU, except one co-supervisor who is external and based in Umeå. Language skills include Swedish (native, fluent, basic), Russian (native, none), English (fluent). To mitigate travels of the main supervisor the supervisor meetings are normally carried out bi-weekly when the main supervisor is in place, but may occasionally be carried out entirely online. The group of doctoral students is small (currently three students, all male) but international, representing Russia, New Zealand, and India. They are aged between 26 and 32. They are based in adjacent offices at LTU. The framework for doctoral educations at LTU, including definitions, quality assurance, organisation, admission, financing, education processes (e.g., individual study plans and the program for teaching and learning), supervision, and examination are applicable to our students, and explained in the handbook for third-cycle education, in Swedish and English (<http://www.ltu.se/research/Utbildning-pa-forskarniva/Handbok>)

3.3.2 Broadening the program environment through external networks

The Doctoral student's research at DCC is a part of the senior research, and its level can be demonstrated from the quality of corresponding publications, standing of the research projects, level of citation, and international collaboration of the researchers. The projects funding the students are provided by the European Commission (Projects: Arrowhead and DAEDALUS), the Swedish Energy Agency, Energimyndigheten (Project: Cost Effective Automation), and the Swedish Research Council, VR (Projects: ICASP and DIACPA). Further, Professor Vyatkin is associate editor of IEEE Transactions on Industrial Informatics, the journal with the highest impact

factor in this research area. He has organised dozens of international workshops, special sessions, special issues in journals and invited tracks at international conferences of IEEE. Several academic collaborators have visited LTU and conducted joint research with the DCC doctoral students, for example: Prof. R. Sinha (New Zealand), Prof. P. Roop (New Zealand), Prof. H.-M. Hanisch (Germany), Prof. B. McMillin (USA), Dr. A. Zoitl (Germany), Prof. A. Huang (USA), Prof. A. Legalov (Russia), Prof. Siemens (Germany), and Dr. N. Papakonstantinou (Finland). Among other research outcomes, these visits have resulted in several joint publications with the named researchers who are prominent international research leaders. DCC also organises (compulsory for our doctoral students) research retreats, workshops and summer schools, such as the Summer School on Distributed Automation in 2013, which has been attended by several top experts Dr. Toujilov (UK), Dr. Christensen (USA), Dr. Sierla (Finland).

The broad research networks of the DCC researchers (Figure 2) help the doctoral students of the subject to benefit from the direct interaction with top international experts. Many of the research connections lead to joint publications. The research network is supported by formal collaboration agreements with several Universities, for example there is on-going long term collaboration agreement with Monash University (Australia), MOU with the University of Auckland (New Zealand), Dual award doctoral program with Penza State University (Russia) and another dual award doctoral program with ITMO University (Russia) in process of being finalised. There are Erasmus+ agreements with ITMO University, Penza State University, Siberian Federal University, Southern Federal University, Tomsk State University, Siberian State University of Telecommunications and Information Sciences (all Russia), Belarus State University (Belarus), Petronas University of Technology (Malaysia), etc.

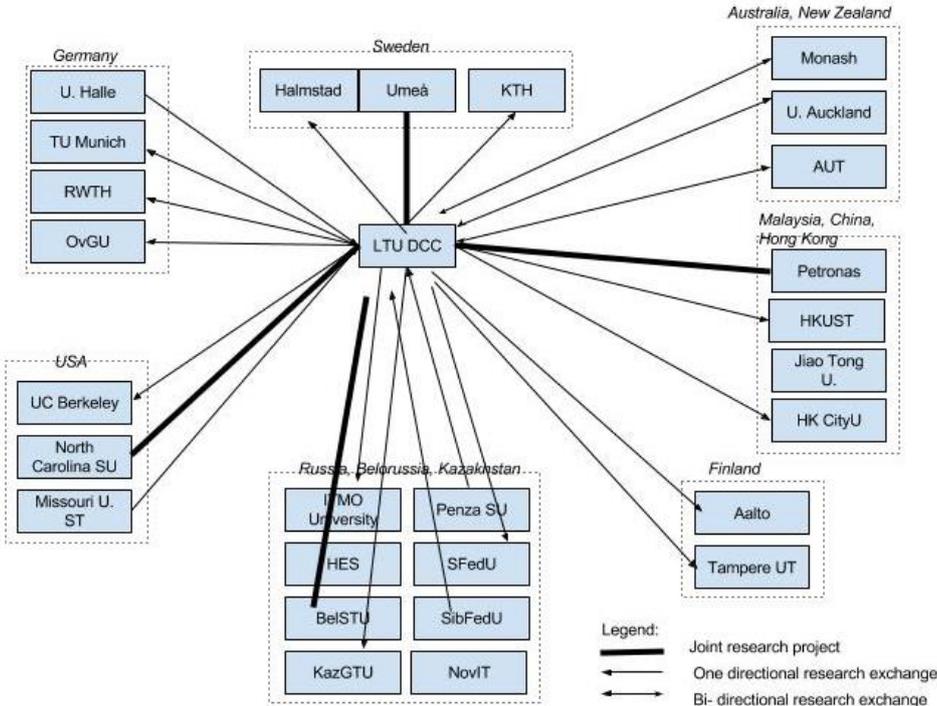


Figure 2. International networks of LTU DCC.

3.3.3 Structured process for publication and dissemination of results

It is compulsory for doctoral students of DCC to publish in journals and conferences of high academic standing. Scientific tradition in computer science puts high emphasis to peer-reviewed conferences even compared to journals, due to their very quick turnover and opportunity for doctoral students to present the work to an expert audience, and thereby build their own international network. However, there is big difference between high-level conferences which are very competitive from the multitude of newly emerged events, which accept virtually any submission. Therefore, the DCC doctoral students submit to, and compulsory attend when accepted, scientific conferences of high profile, mainly organised by IEEE, or other academic societies, with proceedings published in Lecture Notes in Computer Science and indexed by the Web of Science. The aim is that each Doctoral student should have 8-10 of peer-reviewed international publications at the last year of their studies. The expectation is that they also prepare several journal papers, aiming at IEEE transactions or journals with similar high standing. For the moment, each Doctoral student has at least one journal paper accepted and several in the pipeline. Our structured progression for publications is shown in figure 3.

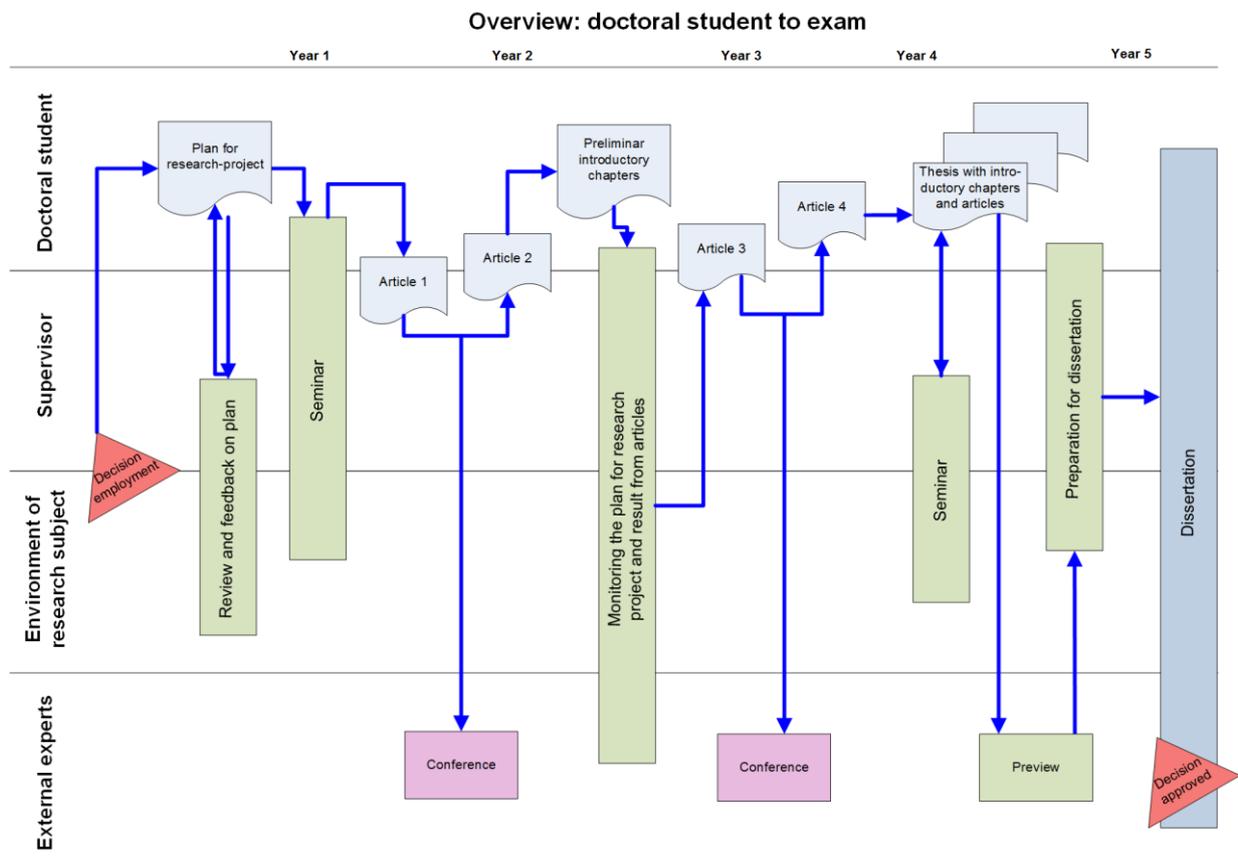


Figure 3. Structured progress for publications and dissemination.

3.3.4 Interaction with the research community and surrounding society

To ensure high international level of research, the DCC doctoral students make research visits to leading universities, where they can conduct joint research works with collaborators, and also presenting seminars and taking doctoral education courses. It is compulsory to perform this at least once in their third cycle education. We seek additional funding for this from international mobility programs, such as MSCA, STINT and Erasmus+. Presentations at conferences and seminars are presented in Table 2.

	2013		2014		2015		2016	
	Conf	Seminar	Conf	Seminar	Conf	Seminar	Conf	Seminar
Kleyko	1	0	1	4	1	3	2	2
Patil	0	3	0	6	1	8	1	3
Yang	2	4	4	7	1	3	1	1

Table 2. Doctoral student presentations. Each cell includes number of presentations.

The doctoral students have been involved in research projects of the universities abroad. For example, C.-W. Yang has been contributing to two projects hosted by Aalto University (EFEU and S-STEP, funded by the Finnish innovation agency TEKES), and S. Patil to another project (SAUNA funded by the Finnish nuclear safety program SAFIR). The projects have strong industrial involvement, thus helping to ensure high relevance of the conducted research with the challenges of industry. The CSESE department organises a biennial doctoral conference in order to train such skills as presentation technique and popular science presentation abilities. Feedback to the doctoral students is given, orally at the conference and written after the conference, by the supervisors at the department according to well-defined criteria. All DCC doctoral students took part in the conference. Doctoral students Patil and Yang have attended DOCEIS doctoral conference in Portugal in 2015, 2016, which brings together doctoral students from many European countries. It is also very competitive and publishes accepted papers in Springer Lecture Notes in Computer Science. Furthermore, our doctoral students interact with the surrounding society. One means is the DCC web site, which is maintained by Chen-Wei Yang, with contributions provided by all group members. Denis Kleyko has been active in organising “Scientific Afterwork”, which are open popular science events.

B. The third-cycle education environment is systematically followed up to ensure high quality. The result of the follow-up is translated, when necessary, into quality improvement actions and feedback is given to relevant stakeholders.

3.3.7 Education environment monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies to education environment. The process is aimed at defining, monitoring and improving the education environment. The third-cycle education quality monitored according to the following criteria:

- The Individual Study Plan is instrumental for quality monitoring and feedback (described below this bullet list). Doctoral students must update their ISPs at minimum two times per year, in dialogue with supervisors.
- Students must pass the third-cycle student introduction school (Section 3.4.1).
- As employees of LTU, doctoral students must have their annual career development meeting with the head of the division, where education environment and quality of supervision is discussed (note that the supervisor is not part in this meeting).
- There are scheduled supervisory meetings (at least twice a month with main supervisor and regularly with co-supervisor)
 - Recent steps and progress towards publications
 - Next steps, research strategy, goals for the short and midterm
 - Any impediments, e.g., in the education environment

- Students provide communication via personal research blogs at Google Docs
 - Patil:https://docs.google.com/document/d/1ehq8rpEjXadxNwzY5_N1xnxr9E9UYa1Tp4VFPXd3cak/edit?usp=sharing
 - Yang:https://docs.google.com/document/d/1IAxyhxPgi38VyiOsS2tBP0R_xfsa12Oz1hQu349USMsY/edit?usp=sharing
- Students present work and review papers of each other in a seminar series.
- Students present their work at the scientific biennial conference for doctoral students, arranged by the department.
- Students have peer-reviewed papers accepted and presented at high profile international conferences.
- Students have cooperation with other research teams (as described in 3.3.2 and 3.3.4)

Individual Study Plan

In the ISP, doctoral students and supervisors can comment on the question "Follow-up – third-cycle student. Does the third-cycle student feel that the education is proceeding as planned? Select Yes/No, if no, please write a short comment about the deviation from the planned education". The ISPs are read by the HoD and the UL-F. If the doctoral student progress is slow or if the student or supervisor indicate that the work is deviating, they will be contacted by the HoD or UL-F. A potential slow down in following the study plan by a doctoral will handled first by the supervisors, who increase the intensity of supervision, frequency of meetings, try to identify the roadblocks and mitigate them in a timely manner.

Ensuring quality of the dissertations that are publicly defended

For the final dissertation, there is a specific procedure for quality monitoring. The students have a number of peer-reviewed papers and the compilation thesis includes a selection of those. This ensures that individual pieces of work have good quality. In addition, we monitor the extent and impact of the total contribution, the quality of the introduction, and the individual contribution by the doctoral student. Finally, supervisors provide proposals for the grading committee, based on that the candidates have adequate knowledge and will be challenging and fair. The proposals are reviewed (and reverted if needed) by the HoD and the Board of faculties. The process is documented in the LTU handbook for third cycle studies.

3.3.8 Education environment, reflections

Based on the factual description above, we find that the third cycle education environment is satisfactory. We also find that the processes for monitoring, acting on issues, and providing feedback, regarding the education environment is satisfactory. We have identified, from the experience with the beginning group of doctoral students, that there is a misbalance of theoretical and practical skills. For students with engineering background we need to improve mathematical skills. Actions and vision for the future are that this will be achieved by:

- Taking courses, reading, visiting other Universities and working on joint projects with colleagues having more theoretical background.
- Extending the selection base and adjusting the requirements and the selection process to attract students with higher initial level of mathematical education.
- Increasing the ratio of journal publications, start earlier to publish in journals.

3.4 Aspect: Achievement of qualitative targets for knowledge and understanding

A. The programme ensures, through its design, teaching/learning activities and examination, that doctoral students who have been awarded their degrees show broad knowledge and understanding both within their third-cycle subject area and for scientific methodology/fine arts research methods in the third-cycle subject area.

The required learning outcomes, defined in the HEO, serve as basis for the Intended Learning Outcomes (ILOs) at all levels of our process. ILOs on knowledge and understanding are literally included in the ISPs, followed by concrete Teaching and Learning Activities (TLAs).

3.4.1 Broad knowledge and systematic understanding of the research field and scientific methodologies

Broad knowledge is achieved via **interdisciplinary** research, e.g., by interaction with collaborators from various academic and industrial organisations in course of research projects, such as VTT, Aalto, AUT and industry, e.g. ABB, Volvo, KYAB. The Arrowhead project (2013–2016) included 68 partners, most of which were companies. Doctoral students of DCC are also working in industrially driven organisations, such as IEC, CIGRE and IEEE. Thus, Chen-Wei Yang has been involved in a working group of CIGRE and Sandeep Patil is regularly communicating with the international standardisation committee of IEC on the IEC 61499 standard.

Among different kinds of publications, survey papers demonstrate strongly the breadth of the authors' knowledge. Currently S. Patil have been involved in writing a survey paper for IEEE Transactions on Industrial Informatics, which is to be submitted in early 2017. Doctoral students further broaden their expertise by joint publications with external collaborators and senior colleagues. This practice gives the students valuable collaboration skills and helps them from examples of experienced colleagues. Supervisors, who are involved annually to numerous activities on editing journals and organising special sessions at conferences, involve the doctoral students to reviewing of papers. Such reviews are used as a practical exercise on judgement and also help the students understand the adjacent field of research.

An important contribution to the knowledge and understanding are gained through TCS courses, 30–60hp (licentiate degree) and 60–120hp (doctoral degree), which are organized at university, department and research subject levels (see examples in the table below).

University level (LTU)	Department level (SRT)	Research subject level (DCC)
University pedagogy Designing and publishing scientific research FOR021F Academic Publishing FOR021F Philosophy of Science FOR022F Research ethics FOR023F Case study methods FOR024F	TCS introduction course Introduction to Programming for Modelling and Simulation (MatLab) Industrial automation Linear algebra Estimation theory	Function blocks and distributed systems IEC61499 (DCC Summer Camp) Abstract state machines* Machine learning *

Project management for doctoral students FOR025F Experimental methods and design of experiments FOR027F Sustainable development FOR030F Numerics (FOR012F) Information retrieval, publishing and reference management	Introduction to LabView Software design for industry automation D7033E * Modelling and control R0002E * * MSc level courses	* Reading courses Note: The course extent is in each case fixed to between 4.5 and 7.5 credits.
---	--	--

The TCS include mandatory courses, such as the TCS introduction course at the department level (see below). All doctoral students must pass the LTU level course on design and publishing to broaden their horizons and set the framework for independent research work in the field. It is also possible that doctoral students follow MSc level courses (with additional tasks) as part of their training, if they lack a specific basic knowledge. Research subject courses are typically tailored to the specific research for particular students, for example *Machine learning* or *Abstract state machines*, in the form of specialized reading courses. The doctoral students may in addition follow TCS courses at other institutions, such as at Aalto University. Additional training events are also organised which are not part of a formal course, such as *Education during lunch break* (by LTU HPC) or *Scientific afterwork* (by SRT).

The TCS Introduction school at CSESE runs for one year. The intended learning outcomes (ILOs) are aligned with the knowledge and understanding objectives of the Higher Educational Ordinance (HEO), where the Doctoral student after one year shall be able to:

- define and pose research questions,
- create a credible research plan to address a research question,
- identify risks and minimize them through careful planning,
- understand publication strategies and how to build a publication portfolio,
- understand how research results can be made available to the general public and how industries make use of research results,
- distinguish between research methods, and
- understand their limitations and when they are applicable.

The TCS introduction school implements a set of independent but synchronized teaching and learning activities that support the Doctoral students to achieve the goals. It is important to note that the learning objectives are formulated such that awareness of the different aspects is created. Students will be enrolled on a regular basis and after completion of the first year the student will hold a seminar. The seminar not only concludes the participation in the school, but also assesses the abilities of the student to create a credible research plan including research question(s), plan(s) for research/studies, and reflections on literature/risks/ methods/exploitation. A department level review of the progress during the first year is then conducted, where a panel of senior researchers act as panel to assess the student. The assessment criteria are based on the required general outcomes defined in the HEO, specifically targeting the topics of the research plan.

3.4.2 How progression is achieved, and keeping scheduled time

The progression towards graduation, including activities, deliveries, surveys, plans, and relevant stakeholders is shown in figure 4. The process ensures our qualitative targets as it is designed to meet the intended learning outcomes (ILOs), to provide relevant teaching and learning activities (TLAs), and to structure the continuous assessment and examination on a timeline with checkpoints. The process provides a high probability that students graduate on time, that delays are promptly determined, and that actions are taken.

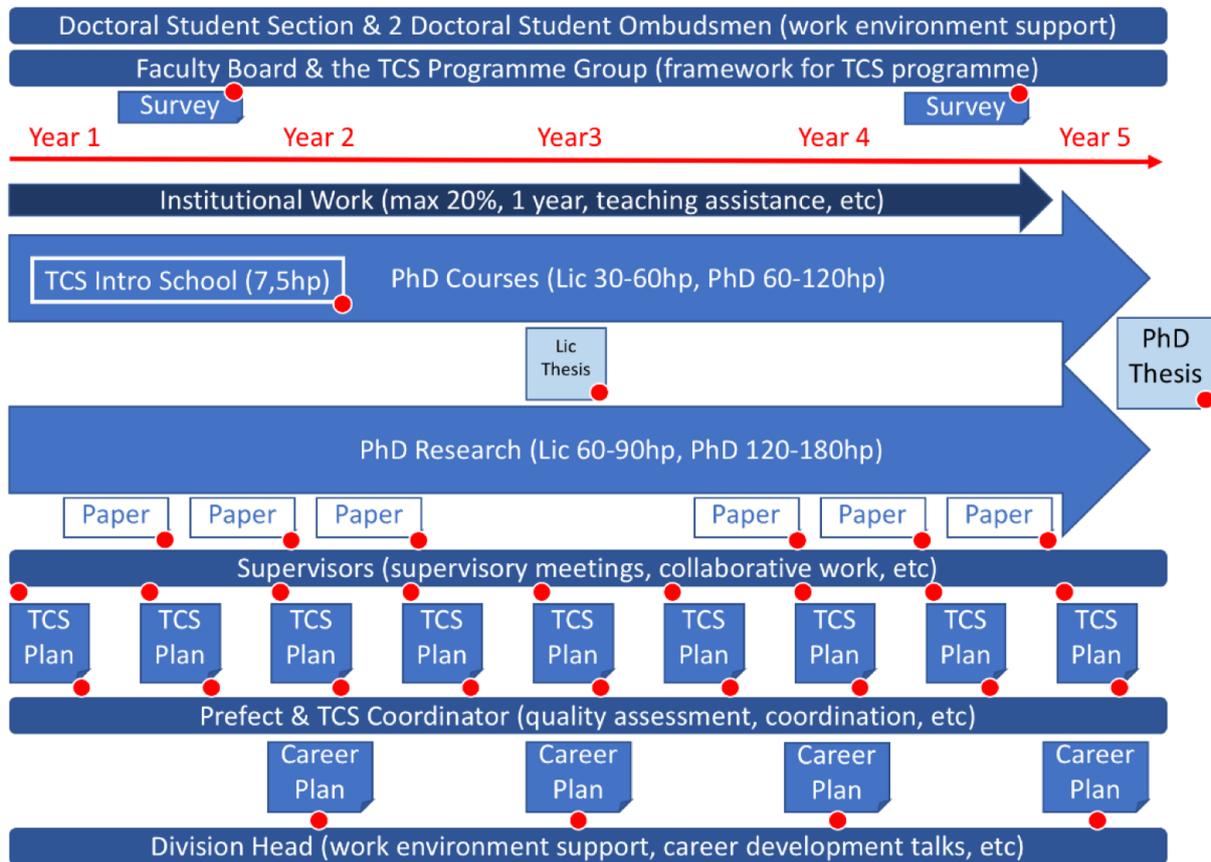


Figure 4. Progression and stakeholders through the third cycle education.

The education for a doctoral degree (240 credits) in DCC includes 60–120 credits in courses and 120–180 credits of dissertation work. The education for a Licentiate degree (120 credits) in DCC includes 30–60 credits in courses and 60–90 credits of licentiate thesis work.

The process depicted in figure 4 works very well, mainly because the control points (in red) are enforced and followed-up. DCC updates the TCS Plans regularly, usually two times per year. Career development talks are conducted every year for all doctoral students. The final seminar at the end of the TCS Intro School, together with a potential intermediate licentiate seminar, works as valuable control point where feedback from more than the supervisors are given. In addition, papers are natural control points and progress is followed-up through the TCS Plan (for example by analysing the appropriate progress related to research credits). This process is a cornerstone for achieving quality in the doctoral education, with the TCS Plan at its centre – a living document that documents progress and plans work ahead.

Should a doctoral student lag behind (without having any medical conditions or other reasonable causes), this will be first detected in supervisory meeting and handled by the supervisors, who will discuss with the student to identify roadblocks, increase the intensity of supervision, frequency of meetings, and making action items until next meeting more specific and measurable. Should this

not provide desired effect, the issue is escalated to the division manager (manager of staff) career development process, etc. (Section 2)

B. The programme's design and teaching/learning activities are systematically followed up to ensure achievement of qualitative targets. The results of the follow-up are translated, when necessary, in actions for quality improvement, and feedback is given to relevant stakeholders.

3.4.3 Knowledge and understanding monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies to knowledge and understanding monitoring. We use the following Knowledge and understanding monitoring criteria:

- The student's progression develops according to checkpoints (Figure 4, Section 3.4.2)
- The ISP is updated regularly and includes the outcomes criteria of the higher education ordinance as ILOs, and has concrete evidence and planned TLAs regarding these criteria.
- Activities defined in the ISP are relevant for the education and for the thesis work.
- Students receive credits for the educational activities mentioned in the ISP.
- The regular supervisor meetings are carried out as expected
- Individual research blogs, and shared online documents, provide a channel for continuous monitoring.
- Participation in local seminar series, both as presenter and as "opponent".
- Publications in high-end conferences are performed, with corresponding presentations.
- Publications in Journals are performed.
- Reviews of articles in real conferences are performed.
- Certain number of invited speakers to listen to, and meeting with.

3.4.4 Knowledge and understanding, reflections

Based on the factual description above, we find that the knowledge and understanding obtained by doctoral students are satisfactory. We also find that the processes for monitoring, acting on issues, and providing feedback, regarding knowledge and understanding, are satisfactory. Most importantly the works are published in peer-reviewed international conferences and journals, which would reveal gaps in knowledge and understanding. On continuous base, there are structured and frequent meetings between students and supervisors, where gaps in knowledge and understanding are early detected. We have identified that, while there are sufficient number of generic courses given at LTU level, we have too few courses on common theory at department level, suitable across the third-cycle subjects at the department. Currently, the different subjects give some similar courses. A better model would be to have a few generic courses, with subject specific tasks regarding for example use cases and experimental activities. Imminent activities:

- DCC will increase organization of academic seminars and workshops to provide students with feedback from experts of different background;
- The department Director of third cycle studies (UL-F), has taken an action item to initiate development of additional third-cycle courses at the department level.
- More Industrial internships shall be organised for doctoral students.
- Online courses provided by the world leading universities shall be wider used in our doctoral education, their selection shall be done in collaboration of supervisors and students and the course progress shall be monitored closely by the supervisors to achieve stronger synergetic effect.

3.5 Aspect: achievement of qualitative targets for ‘competence and skills’

A. Through its design, teaching/learning activities and examination, the programme ensures that doctoral students whose degrees have been awarded can plan and use appropriate methods to conduct research and other qualified (artistic) tasks within predetermined time frames, and in both the national and the international context, in speech and in writing authoritatively, can present and discuss research and research findings in dialogue with the academic community and society in general. Doctoral students are to also show they can contribute to development of society and supporting the learning of others within both research and education and in other qualified professional contexts.

The required learning outcomes, defined in the HEO, serve as basis for the Intended Learning Outcomes (ILOs) at all levels of our process. ILOs on knowledge and understanding are literally included in the ISPs, followed by concrete Teaching and Learning Activities (TLAs).

3.5.1 To perform scholarly analysis and synthesis, and to review and assess new and complex phenomena, issues and situations

It is compulsory for doctoral students to read and review a large number of papers in the field, provide analysis, and write at least one state of the art survey, which is examined by the supervisors and typically published in a peer reviewed journal and finally becomes part of their dissertation. Students present work and progress, and review papers of each other in a seminar series. Students present their work at the scientific biannual conference for doctoral students, arranged by the department. Doctoral students practice peer-reviewing papers for international conferences and journals (e.g., IEEE INDIN, ETFA, IECON, Transactions on Industrial Informatics, etc.) by taking part in supervisors’ reviewing tasks. Along with theoretical studies, students also develop prototype implementations of their research ideas in form of software and complete cyber-physical systems in AIC3 lab.

3.5.2 To identify and formulate issues and need for further knowledge critically, autonomously and creatively, and to plan and use appropriate methods to undertake research and other qualified tasks within predetermined time frames

The main means for achieving successful completion of doctoral studies are careful planning and resourcing. This is performed jointly by the student and the supervisor, according to the progression plan (Section 3.4.2), documented as TLAs in the ISP. Planning involves risk assessment and mitigation actions, which aim at minimising the impact of potential failures on the research path. The resourcing aims at providing the student with adequate experimental base and abilities to be involved in the international research community.

Publications are seen as important milestones on the way to doctoral qualification (Section 3.3.3). The typical purpose of student publications is to identify issues, provide analysis and quantitative or qualitative evaluations. This also includes considerable amount of planning in order to meet deadlines. Most of conference publications authored by the DCC doctoral students are peer reviewed by at least three peer reviewers. The acceptance rate of those international conferences, which we submit to, ranges from 50 to 25%. The journal publications, for example in IEEE Transactions, have even stricter reviewing, typically double-blinded and requiring several revision rounds. Guiding students through the revision process is an important learning experience.

It is ongoing practice at DCC research that doctoral students also coach master students who perform their research projects at DCC. Often this collaboration results in publications at international conferences, for example:

- S.Patil worked with 4 master students with 3 publications done and one in progress.
- C.-W. Yang worked with 2 master students, with one publication done and the other in progress.
- D. Kleyko worked with 14 master students, resulting in one joint publication with three of them.

The progression, the connections between ILO, TLA and examination, and the defined track to finish on time are described in Section 3.4. Furthermore, doctoral students practice their planning by playing important roles in running the ongoing externally funded research projects. Thus D. Kleyko has been responsible for a task related to dissemination of tools across the consortium in the European project Arrowhead. In a similar manner, Patil is responsible for LTU tasks in the ongoing H2020 project DAEDALUS, and C.-W. Yang has been responsible for tasks in the Energimyndigheten project “Low cost automation”. Doctoral students also help in applying for research grants. For example, S.Patil in 2016 applied for a PiiA pre-study project, while D. Kleyko has been active in preparation of a H2020 FET proposal together with Prof. Osipov. This experience will guide the Doctoral students in their research directions, and help in ability of research results evaluation. All doctoral students have been participating in planning and building of the AIC3 research lab, being solely responsible for particular subsystems.

The final dissertation ultimately demonstrates the ability of a doctoral student to make a significant contribution to the formation of knowledge through own research. A dissertation at DCC is typically planned as a compilation dissertation (*sammanläggningsavhandling*), where select peer-reviewed papers are included, together with an introduction that summarizes the field, positions the papers with respect to scientific contribution and explains the specific contribution that has been provided by the doctoral student. The supervisors’ role is to give the student guidance on the thesis composition, provide feedback and guide the student through the revisions of the thesis. Our approach is to invite top experts in the area to the grading committee and as opponent. Invitation to these roles is preceded by discussing the thesis draft with the supervisor.

3.5.3 Ability to present and discuss research, and to contribute to social development and the learning of others

In Sections 3.3.2 and 3.3.3, we describe how students practice and demonstrate the ability, in national and international contexts, to present and discuss research and findings authoritatively in speech and writing and in dialogue with the academic community and society in general.

Doctoral students are also actively involved in teaching and other departmental duties, up to 20% of their time. They primarily provide teaching assistance, including lab and seminar assistance, and development of teaching materials for research related master courses. Current doctoral candidates Kleyko, Patil and Yang have participated as teaching assistants in 14, 10 and 8 courses respectively. Furthermore, students are involved in the activity *Scientific afterwork* that helps to expand knowledge horizons of LTU researchers by presenting highlights of great research careers and ideas in a free mix and mingle atmosphere.

B. Programmes are followed up systematically to ensure that their design and teaching/learning activities are high quality and that the doctoral students achieve the qualitative targets. The results of the follow-up are translated, when necessary, into actions for quality improvement, and feedback is given to relevant stakeholders.

3.5.4 Competence and skills monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies to defining, monitoring and improving the competence and skills of students. We use the following monitoring criteria:

- The student's progression develops according to checkpoints (Figure 4, Section 3.4.2)
- The ISP meets the outcomes criteria of the higher education ordinance.
- Specific TLAs are defined in the ISP that ensures knowledge and understanding, as well as competence and skills.
- Students receive credits for the educational activities mentioned in the ISP.
- Individual research blogs, and shared online documents, provide a channel for continuous monitoring.
- Participation in local seminar series, both as presenter and as opponent.
- Publications in high-end conferences are performed, with corresponding presentations.
- Publications in Journals are performed.
- Reviews of articles in real conferences are performed (typically informally delegated from supervisors' program committee work)
- Certain number of invited speakers to listen to, and meeting with.
- They take part in undergraduate or masters level teaching
- The subject undergoes periodic evaluations of the subjects by the faculty board, which pinpoints weaknesses and gives concrete improvement directions.

3.5.5 Competence and Skills, reflections

Based on the factual description above, we find that the competence and skills obtained by doctoral students are satisfactory. We also find that the established processes for monitoring, acting on issues, and providing feedback, regarding competence and skills are satisfactory. LTU research environment provides several opportunities for further improvements of skills and competence of doctoral students, for example:

- The strategic research areas of LTU have recently introduced the popular science presentations of ongoing research works to the public. Doctoral students shall be also involved in this activity.
- We shall involve doctoral students to the preparation of research funding proposals of increasing complexity from earlier stages of their education. We already have a regular practice of discussing funding calls and brainstorming ideas of future projects, but it shall be taken a step further so the students themselves prepare applications. The strategic research area "Intelligent Industrial Processes" has a mechanism of activity initiation grants, which can be used as a starting point.

3.6 Aspect: Achievement of qualitative targets for 'judgement and approach'

A. Through its design, teaching/learning activities and examination, the programme ensures that doctoral students who have been awarded degrees show intellectual independence, (artistic integrity) and scientific probity/disciplinary rectitude and the ability to make research ethics assessments. The doctoral student is to also have a broader understanding of the science's/Fine Art's capabilities and limitations, its role in society and human responsibility for how it is used.

The required learning outcomes, defined in the HEO, serve as basis for the Intended Learning Outcomes (ILOs) at all levels of our process. ILOs on knowledge and understanding are literally included in the ISPs, followed by concrete Teaching and Learning Activities (TLAs).

3.6.1 Intellectual independence, scientific rectitude, and ability to make assessments of research ethics

Doctoral students at DCC are encouraged to develop intellectual independence and this is supported by a number of measures. For example, prior to writing a publication in collaboration with other authors they are asked to define their personal intended contribution and its novelty explicitly. This is discussed with, and approved by the supervisors. The most important means to teach students these skills is personal example of their supervisors. Students often accompany supervisors to academic and industrial meetings where the supervisors have a chance to demonstrate these qualities and pass them to their students.

The essence of research in the DCC subject does not have direct concerns with ethical issues, however numerous activities give students practical insights to the research ethics and scientific rectitude/honesty. For example, the TCS course, taken by all DCC doctoral students covers such issues as plagiarism. Further involvement of doctoral students as reviewers of journals and conferences helps them to develop proper approach to evaluation of own research results and to avoid self-plagiarism, even unintended, since it is strictly monitored by the IEEE journals and all reviewers receive the corresponding advices.

The students who help in preparation of grant applications also see subsequent evaluation results and participate in refinements and addressing comments of reviewers. Another exposure to research independent practice is preparation of competitive travelling scholarship applications, such as the Wallenberg foundation scholarship applied to by Kleyko in 2016.

B. Programmes are followed up systematically to ensure that their design and teaching/learning activities are high quality and that the doctoral students achieve the qualitative targets. The results of the follow-up are translated, when necessary, into actions for quality improvement, and feedback is given to relevant stakeholders.

3.6.2 Evaluation ability, judgement and approach monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 is aimed at defining, monitoring and improving the evaluation ability and judgement of students, and the approach taken by students.

The monitoring criteria for evaluation ability, judgement and approach are as follows:

- The student's progression develops according to checkpoints (Figure 4, Section 3.4.2)

- Specific Activities defined in the ISP, ensures that abilities, judgement and approach are developed.
- Students receive credits for the educational activities mentioned in the ISP.
- Individual research blogs, and shared online documents, provide a channel for continuous monitoring of judgement and approach.
- Participation in local seminar series, both as presenter and as “opponent”.
- Publications in high-end conferences are performed, with corresponding presentations.
- Publications in peer-reviewed journals with very thorough review process are performed.
- Reviews of articles in real conferences are performed.
- Periodic evaluations of the subjects by the faculty board

3.6.3 Evaluation ability, judgement and approach, reflections

Based on the factual description above, we find that the evaluation ability and judgement obtained by doctoral students regarding intellectual independence and scientific honesty are satisfactory. We also find that their training in approaching problems and challenges is satisfactory. However, we find that we are weak on assessing ethical issues. A university level course on Research ethics is available and will be considered as a part of the ISP, or that a module on Research ethics is to be included in the TCS introductory course. Finally, we find that the processes for monitoring, acting on issues, and providing feedback, regarding ability, judgement and approach is satisfactory.

3.7 Aspect: Working life perspective

A. The programme is useful and prepares students for an ever-changing working life.

3.7.1 Getting working life perspective through doctoral studies

Doctoral research at DCC gives students' skills and outlook for many career paths, which includes work in academia, in industry, and by creating start-ups on their own. Insights into the academic working life is provided by carrying out research and through teaching assistantships (TAs) within the **departmental duties** (up to 20% of their time). In general, doctoral students have approx. 8% of departmental duties, typically TA, during the course of their studies. Following the declared philosophy of early involvement of doctoral students to senior academic research, the students are actively involved in the execution of **externally funded, industrial projects**: from initial interaction with companies, to definition of research challenges, writing collaborative research proposals, conducting the research, adhering to deadlines, dissemination, reporting, and follow-up. This exposes students to the realities of academia and to R&D at companies, both in Sweden and internationally. All of the doctoral students at DCC, are involved in externally funded projects. The external funding rate for research projects is 65% for 2017 and typically never below 60%. For example, Denis Kleyko has been involved in the Arrowhead project, responsible for implementation of several training and dissemination tasks with representatives of the consortium of 68 partners. In course of working on AIC3 lab development project in 2013 Patil and Yang have visited NxtControl in Austria. Industrial focus of the DCC research and of the doctoral program implies involvement in research projects that often include interaction with startup companies that were spun off from the LTU innovation ecosystem, by LTU alumni. For example, in the BALD project, Sandeep Patil worked jointly with KYAB AB, a company founded and managed by an alumni. Opinions from doctoral students, supervisors and alumni are monitored at university level through periodic surveys every three years. Questionnaire results are communicated to the department and the faculty research training group (FOG), and disseminated to supervisors and students.

There are several researchers at our department that have long experience and current engagements with industry. Associated with DCC, Adjunct professor Xiaojing Zhang at ABB Research provides a direct channel to internships and employment options at the company. A similar role is played by Ericsson Research, whose representatives have a regular dialogue and have been involved in several research projects with DCC.

The TCS introduction course includes activities related to working life perspectives, such as patents, research exploitation, standards and early career planning, which is then further followed up by yearly development talks with the division head. LTU is offering courses on grants writing and patenting, which are recommended by supervisors to the DCC students. The future career planning is a part of the regular dialog with supervisors, which is reflected in ISPs. The LTU Career Centre can finally be of further assistance to form concrete future prospective career paths. LTU has an established system of giving the students entrepreneurial perspective. There is a startup school operating. Several startup companies have been established by former students and current researchers of the department. Examples are Effnet (<http://www.effnet.com>), Marratech (acquired by Google in 2007), Operax (now Xarepo <http://www.xarepo.com>), NordNav (acquired by Cambridge Silicon Radio in 2007). A more complete list of spinoffs from SRT (<http://www.ltu.se/centres/cdt/Resultat/Avknoppningar>). **Business and innovation support** is provided by LTU Business (<http://www.ltu.se/org/LTU-Holding/LTU-Business>).

B. The programme's design and teaching/learning activities are systematically followed up to ensure that it is useful and prepares for working life. The results of the follow-up are translated, when necessary, into actions for quality improvement, and feedback is given to relevant stakeholders.

3.7.2 Working life perspective monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies to applies and is aimed at defining, monitoring and improving the insights into working life perspectives obtained by students.

The working life perspective monitoring criteria:

- The ISP meets the outcomes criteria of the higher education ordinance.
- Specific Activities defined and credited in the ISP, ensures cooperation with industry.
- Specific Activities defined and credited in the ISP, ensures teaching assistance.
- Suitable amount of on-site work in industry is performed.
- Individual research blogs, and shared online documents, provide a channel for continuous monitoring.
- The department in general, and subjects in particular receive feedback on the performance of doctoral graduates from industry.
- Supervisors visit industry and discuss perspectives of their doctoral students' employment on a regular basis.
- As part of the doctoral education, students should meet with LTU Business to discuss potential business projections (e.g., startup, IPR)
- The TCS introduction course has been taken, and working life perspective discussed with supervisor.
- Students take part in results from surveys, regarding feedback from alumni.

3.7.3 Working life perspective, reflections

Based on the factual description above, we find that the working life perspective obtained by doctoral students is satisfactory. The active work in defining, fundraising, and carrying our joint academia-industry projects, together with the industrial experiences obtained give the student a perspective on required skills both for successful industrial career and successful academic career. The interaction with companies provides feedback to supervisors regarding strengths and weaknesses of the students and their skills, so that TLAs can be adjusted.

3.8 Aspect: Doctoral student perspective

A. The programme allows the doctoral students to play an active part in the work of improving the programme and learning processes.

3.8.1 Students take active part in development of education and learning processes

Doctoral students are normally employed by LTU and admitted to doctoral education for at least 4 years. The division manager monitors the overall work situation for the staff, including doctoral students. Our process (Section 2) ensures that students are part of continuous and ongoing efforts to determine their goals and develop their educations. In this process, students and supervisors meet in supervisory meetings, typically with an interval of two weeks. There, students report: What did you do this period? What is your plan for next period? Are there any impediments? The ISP is monitored and updated regularly in discussion with supervisors, so that students can influence their TLAs. This fosters a dialogue between students and supervisors. Should problems not be resolved, students can escalate issues to their division manager.

At the CSESE division level there are annual individual career development dialogues with each of the students, carried out by the division managers, where performance for the last year is assessed, and a development plan for the next year is set-up and agreed. These meetings specifically address the student's perspective, including opinions on supervision. At the department level, the doctoral students are represented in the department board (*ledningsgrupp*) along with the department heads, division heads, head of doctoral education, and head of administration. This is where specific decisions regarding procedures and guidelines for our doctoral education is taken. The department board is also in charge of the quality work at the department and the work to develop the department business plans (*verksamhetsplan*). Each department has a Coordinator of doctoral education (*utbildningsledare för utbildning på forskarnivå*, UL-F) with main responsibilities to (i) lead the quality work and (ii) secure the implementation of the common models and steering documents for the doctoral education at the department. For example, the Third cycle introduction school (previously mentioned) at the department was a strategic initiative developed and executed by the Head of doctoral education as a part of the department business plan 2013–2014. The doctoral students at the department, led by the doctoral student representative, which is also part of the department board, has a yearly budget to spend on joint meetings. This is to secure that all doctoral students have the possibility to meet the doctoral student representative and other doctoral students in the joint meetings and give feedback regarding the education. After each meeting, the doctoral student representative gives a presentation of the outcome to the department board and, when needed, suggest immediate actions, suggest development work, or input to the department business plan.

At LTU level, the doctoral student perspective is accounted for regarding quality work and environment (physical and psychosocial) in several ways. There is a Doctoral Student Section (DSS) (*Doktorandsektion*) that is “working to safeguard the doctoral students' interests and participate in the development of doctoral education”. Each department is represented by a doctoral student in the DSS board. The representative calls the doctoral students at their department to several yearly meetings to discuss and then feedback, to the department board issues of importance. There are also two doctoral student ombudsmen, who are professors to deal with problems associated to individual Doctoral student problems.

Surveys conducted by the faculty board and the continuous development of the ISP process together provide a mechanism for receiving feedback from doctoral students and adjusting their TCS plans. In the survey, doctoral students of DCC answered the question “How do you help to steer your education process?”

3.8.2 Psychosocial aspects

Addressing psychosocial aspects is imperative for ensuring effective education and learning. There is systematic work environment management to investigate, implement and follow-up operations so that ill-health and accidents are prevented, and a satisfactory work environment is achieved. Monthly workplace meetings provide a forum for employers and employees to jointly develop, plan and monitor the workplace operations and psychosocial aspects, including capturing and following up doctoral student opinions and experiences. In addition, a safety inspection is conducted at least once a year as a robust way to examine the work environment. The deficiencies detected during safety inspections are written into an action plan.

Doctoral students may contact the graduate student representative in the doctoral student section or the safety representative on matters related to physical or psychosocial environment. The infrastructure for student support includes student administration, company health, career centre, library, language workshops, counselling, international offices and special educational support for disabilities.

B. The programme is systematically followed up to ensure that doctoral student input is used in quality assurance and improvement of the programme. The results of the follow-up are translated, when necessary, into actions for quality improvement, and feedback is given to relevant stakeholders.

3.8.3 Doctoral students’ perspective monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies and is aimed at defining, monitoring and improving the doctoral students’ perspectives. The students’ perspective monitoring criteria:

- The student has been part of updating the ISP, especially regarding TLAs.
- The individual career development meeting was carried out and it was checked that the student’s input has been taken into account in developing the education.
- Students have met their doctoral student representatives in the department board, and in the doctoral student section, and have taken part of relevant information and issues.
- Students are aware of the doctoral student ombudsman, if they need to escalate issues.
- They take part in the surveys and the results from those (incl feedback from alumni).

3.8.4 Doctoral students’ perspective, reflections

Based on the factual description above, we assess as satisfactory the opportunities provided for our doctoral students to play an active part in the work of improving the programme and learning processes. The strong sides of our supporting infrastructure include the psychosocial support, the ISP based mechanism of steering the study and modifying the study direction when need. We are also satisfied with the representation of doctoral students in the departmental board that gives them sufficient leverage in the decision-making. Imminent activities include increase in the students’ involvement to new projects preparation, which could give them more skills of independent research and provide means for steering the research direction.

3.9 Aspect: Gender equality perspective

A. A gender equality perspective is integrated in the programme's design and teaching/learning activities.

3.9.1 Gender balance

The gender balance at the DCC definitely could be improved - all three doctoral students currently enrolled are male. Looking across the department, there are 28 % women doctoral students enrolled from recruitments both nationally and internationally, which is satisfactory considering the overall gender balance in CSEE educations. This partly stems from the low rate of female students in the undergraduate and master's programs in this area, which typically never exceeds 10%. In general, the problem of gender inequality is of high priority both within the university and department.

The department have several activities directed to girls in the age of 10-18 with the goal of attracting them to science and technology at high school and to the computer science and engineering programs at university. One initiative called *#include* (established 2014), supports women that have enrolled in these programs and addresses short and long term recruitment activities based on the Maker Culture, showing how modern technology can be used *from idea to prototype*. The event *MakerTjej Luleå* runs annually at LTU with 75-90 girls in the age of 10-18, where they experiment with technology such as 3D modelling and 3D printing, graphical programming for quad-copters and robots, soldering, and programming electronics. LTU and the department support several generic gender equality activities such as the Pepp- network where girls in local schools get a female student mentor at the university. During 2017 a 2-3 day camp is planned where more than 100 girls are welcome to LTU to create and learn with modern technology. LTU collaborates with the city of Luleå and the Regional Council on a plan to improve gender balance in tech fields and to create a positive gender image. Finally, the department works with the Swedish National Agency for Education on introducing digital competence into the school curriculum and promoting gender balance by making young girls get in contact with technology and computational thinking at an early age.

Changing the gender balance of the local recruitment base takes time, and therefore DCC attempts to improve the situation by attracting more international female students in the academic exchange programs, such as Erasmus+. We have one female senior staff member Dr. Gulnara Zhabelova, one visiting researcher Yulia Berezovskaya. In 2017 we expect also 4 exchange female master students. We have identified that there are countries where the gender balance is much better than in the nordic countries, so building competence from those regions will help in performing accurate recruitments from those regions. Use cases are often driven by industry, but we strive to find use-cases in fields that are attractive to women. At university level there are several initiatives to improve gender balance, including a network for female doctoral students, and a number of steering documents, policies, and metrics to control and monitor the gender balance (see next subsection).

B. Systematic follow-up is performed to ensure that the programme's design and teaching/learning activities promote gender equality. The results of the follow-up are translated, when necessary, into actions for quality improvement, and feedback is given to relevant stakeholders.

3.9.2 Gender equality monitoring

The systematic process for quality definition, follow-up and feedback as defined in Section 2 applies and is aimed at defining, monitoring and improving gender equality perspectives. The personal meetings that are part of the process are important in detecting gender equality issues in the design and execution of the third-cycle education. Furthermore, the gender perspective is integrated into the university's balanced control. This means that there are a number of employer policy documents to support the gender perspective at all levels, and especially to ensure that the doctoral training design and implementation meets the gender equality policies of equal rights and obligations. There are also appointment procedures and Guidelines for recruitment.

The employer policy documents provide a framework for monitoring and control measures, by providing supplemented checklists on quality assurance activities and internal training. There is statistics generated three times per year, grouped by gender where possible for monitoring and control measures. The follow-up includes that the head of the department provides comments and suggestions on actions / activities. The following questions are included:

- What is the age distribution and gender distribution within individual subjects?
- Do our actions support equal opportunity and gender equality for students and employees?
- Do our actions meet the objectives of the university's recruitment targets for female professors?
- Do we promote diversity and pluralism in the measures concerning recruitment?
- Do we ensure that any measures do not constitute a direct or indirect discrimination from a gender and equality perspective?

3.9.3 Gender Equality perspective, reflections

The gender balance at the DCC must be improved – all three doctoral students currently enrolled are male. Our actions, as described above, address the problem already from undergraduate level and indeed in promoting our computer science and engineering programmes for women already at high school level. This is an ambitious program, but it takes time until we will see the effects at doctoral level. Our immediate effort is to recruit internationally, where gender balance in general is better than in Sweden. We have been successful recruiting at postdoc level, and to transform such enrolments into permanent employments. We have experience of advertising a doctoral position for which a female candidate was selected (Yulia Berezovskaya). However, unfortunately we could not proceed with the appointment due to a deteriorated funding situation (project was not extended as expected). We must now show in the coming recruitments that we can enrol female doctoral students. However, it should be noted that funding is a prerequisite to enrol more doctoral students. We must also review whether we treat the gender equality issues in the design and execution of the third-cycle education sufficiently well, probably by interviewing the female doctoral students at the department.