

Joint International Master in Smart Systems Integrated Solutions

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Abstract—The Joint International Master in Smart Systems Integrated Solutions (SSIs) will graduate candidates for the ever-growing industry of Smart Systems, ubiquitous in all sectors of society including healthcare, transport, environment protection, energy and security. SSIs is given jointly by three universities in three European countries: Aalto University (Helsinki, Finland), University of South-Eastern Norway (USN), and Budapest University of Technology and Economics (BME) (Hungary), utilizing the complementary expertise and laboratory facilities of the three partners to create a unique programme with a more holistic approach than a single university could give. The programme collaborates closely with industry, and has EPoSS as Associated Partner, assuring its relevance. SSIs builds on the Joint International Master in Smart Systems Integration (SSI), which has been running since 2013 with Heriot-Watt University (Edinburgh, Scotland) coordinating a consortium with USN and BME.

SSIs students benefit from the combined expertise of the consortium, as well as from the extended socio-cultural knowledge obtained by living in three different European countries that represent distinctively different aspects of the diverse Europe. The students in the programme show excellent performance, and the employability of graduates has proven to be very high.

Keywords—*Joint master degree; Industry-education collaboration; Smart Systems; Microtechnology; Erasmus Mundus*

I. INTRODUCTION

The Joint International Master in Smart Systems Integrated Solutions (SSIs) is an MSc degree covering tomorrow's technologies in Smart Systems such as intelligent biomedical devices, cyber physical systems (CPS), Internet of Things (IoT), ubiquitous sensors and actuators. The focus is microsystem integration design, manufacturability, reliability and interaction with the environment (mechanical, electrical, optical, biological, chemical, acoustical). The subject is truly

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cross-disciplinary within engineering, and a single university would typically only be able to cover parts of the relevant topics for such a degree. SSIs is given jointly by three institutions: Aalto University (Helsinki, Finland), University of South-Eastern Norway (USN), and Budapest University of Technology and Economics (BME) (Hungary), each providing one full taught semester. The SSIs programme uses the complementary expertise and laboratory facilities of the three institutions to provide a unique programme that truly offers a system-level approach to Smart Systems Integration. Each institution contributes with its special expertise, giving the graduates from SSIs a much better basis for their professional career than any of the institutions could provide individually. SSIs has obtained Erasmus Mundus [1] status in the European system, which is a strong quality label known to attract many good applicants. The consortium aims at providing the graduates with a Joint Degree Certificate [2] issued jointly by the three institutions. The programme admits its first students in 2021, and is a revision of the Joint MSc in Smart Systems Integration (SSI and SSI+) given by Heriot-Watt University (HWU) (Edinburgh, Scotland) together with USN and BME since 2013. HWU is an Associated Partner in SSIs, providing guest lectures and master projects.

The programme addresses the pressing industrial needs for qualified graduates in the field. Smart systems, integrated from microsystems and microelectronics, combine data processing with multi-modal sensing, actuation and communication. Current research in SSI is global and dynamic, responding to these urgent needs. There are however far not enough young graduates to sustain this exponential industrial growth [3-5]. The Joint International Master in SSIs aims at filling this gap. The study programme covers all aspects of the SSI process, in particular both design and fabrication issues are central parts of the study programme.

The aim and objectives of SSIs are:

- To assert Europe as a focus point for higher education and research in the field of Smart Systems Integrated Solutions by delivering a cutting edge, comprehensive, master level formation of excellence, that is aligned to the complex educational, economic and societal needs of research and industry in the field. The

implementation of “learning by doing” promotes the students to adopt a holistic approach to the challenges presented.

- To attract the best students to the European Higher Education Area (EHEA) and to produce excellent, mature and industry-ready Master level graduates. The graduate will have detailed knowledge and skills to deal with complex integrated smart systems, and with employable skills such as team working, innovation, entrepreneurship, and international and cultural awareness.

- To create a community of graduates who will become the future leading research engineers of Smart Systems companies worldwide, disseminating the educational legacy obtained from the SSIs programme to their companies and institutions.

- To strengthen the position of the Consortium partners as leading academic institutions in the field of Smart Systems Integrated Solutions and in internationalisation through research, teaching and cultural exchanges with a network of international and industrial partners.

II. INDUSTRIAL RELEVANCE

SSIs has strong industry involvement and EPoSS is Associate Partner of the programme, ensuring liaison with the Smart Systems industry at European level. Relevant industry clusters and research centres in the partner countries are also associated partners: Norwegian Centre of Expertise – Micro and Nano Technologies; Innomine Digital Innovation Hub (Hungary); and VTT Technical Research Centre of Finland. Furthermore, 14 European companies and 3 universities (from Scotland, Taiwan and Russia) are Associate Partners. Roles for Associate Partners include: Participation in SSIs’ Industrial Advisory Board, hosting students for 1-2 months Industrial Internship and for 4-months master project, giving company visits, guest lectures and industry-relevant case studies. USN, the co-ordinator of SSIs, is a member of EPoSS as well as being a central actor in the NCE-MNT.

Prior to launching the first programme of SSI in 2012 a thorough industry survey was performed by EPoSS. One of the co-authors, Prof. Marc Desmulliez, was also involved in the preparation of the EPoSS SRA (Strategic Research Agenda) [6] and the later enhanced version of the SRA [7]. This document demonstrated clearly the need for a programme such as SSI, and details were used as inputs for the design of the programme structure and for the courses selected for the programme. A similar survey was performed in collaboration with EPoSS in 2016, with replies from 26 industrial companies in Germany, UK, Hungary, Norway, Sweden, France, Netherlands and Spain. Again, the survey demonstrates a clear need for the SSI programme, and details were then used as input to the revision of the course programme. When asked to grade the importance of topics and sub-disciplines of Smart Systems Integration, the highest scores are for “Sensors and Actuators”, “System integration” and “Measuring microsystems”. Each of these topics corresponds to specific courses given as part of the programme, as well as being integrated topics in other courses. “System Integration” is indeed at the core of the programme, and most of the courses contribute to System Integration understanding. High score is also given for “Assembly and Packaging” and “Modelling microsystems”, also being central parts of the curriculum. The topic “Micro/ Nano biological systems” obtained top priority for a certain number of companies, but the lowest average priority in the complete

industry survey. “Micro/ Nano Biological Systems” is an elective course in the SSIs programme, assuring that a part of the graduates learn this important topic, while realizing that it need not be taught for the full class.

III. ACADEMIC CONTENT

A. Structure of SSIs

The structure of the master degree follows a defined mobility scheme, where the whole class moves together in the first three semesters. The first semester takes place at Aalto. The second semester is at USN, which is also the Co-ordinating Institution. The third semester is at BME. The master project (thesis) is carried out in the fourth semester, where the students select their project at one of the three institutions, and the students are split in three groups each with a similar number of students. The master thesis may well be carried out at an external partner (either industrial or academic organization), but always associated with one of the three partner institutions. This ensures involvement from the consortium in external projects, as well as being an excellent way to enhance or initiate collaboration between the University and the external partner (industrial or academic). The internal master projects are always part of ongoing research projects, hence exposing the students to cutting-edge research.

In 2020 and 2021, COVID-19 has imposed particular challenges to the mobility structure of the Joint Master. This has been solved satisfactorily by quarantine at transfer between the countries and a combination of digital and on-campus teaching according to the changing restrictions in the respective host countries.

B. Course Programme

The MSc programme is developed jointly, with courses given at each institution set together in order to optimize the learning outcomes, and to best utilize the complementary expertise and laboratory facilities of the three institutions.

The mobility scheme is chosen to allow each institution to contribute its special expertise in the most appropriate timeframe for the study progress: In the first semester at Aalto, the fundamentals of smart systems are taught: the rationale for Smart Systems, the working principles, functionality, reliability, sustainability, Materials and Microsystem Integration, and applications of sensors and actuators. The course in “Design and Analysis of MEMS” is taught in close interaction with industry, with guest lecturers from several industrial partners, like Murata Finland on Inertial MEMS, VTT and Vaisala on optical MEMS and Okmetic on advanced SOI and cavity-SOI substrates. The students specialize in the second semester at USN, choosing Smart Biomedical Systems or CPS. This implies choosing courses either in Micro- and Nano-Biological Systems or in Multiphysics Modelling. For both tracks, the mass-production platform of silicon processing for microsystems is taught, as well as measurement and characterization techniques. This is supplemented with laboratory work where the students manufacture and characterize a microsystem. BME teaches design for system integration in the third semester, covering microelectronics and its integration with microsystems, sensors and actuators. The main focus is on their world renowned speciality in design and integration to create complete smart systems with integrated sensing, actuating and signal processing functionalities.

Throughout the three taught semesters, the students will carry out the “SSI Design Lab”, being a group project where the student groups shall develop a smart system for a given application, as if it were a business case. This will be supported by the coursework they have in the different semesters: In the first semester, the students will look at the sensor principle, the initial design, early prototyping and the business model. In the second semester, they will propose manufacturing platforms for volume manufacturing, perform Multiphysics modelling and modify their design accordingly. In the third semester, they will implement the functional integration with microelectronics and signal processing, and finalize their business plan. At various instances during the study track, the student groups will receive coaching from experts in industry and academia, both on business, innovation and technical aspects of their project. Particularly the Winter School (2nd semester) and Summer School (start of 3rd semester) will be important check-points.

Figure 1 presents the SSIs Education Model, demonstrating the integrated learning approach across the study programme and across the three partner institutions.

This described course programme of SSIs (starting 2021) largely builds upon the experiences of the successful SSI / SSI+ programmes (since 2013). Important revisions for the new programme include the “SSI Design Lab” as an integrated project across the three institutions and across the three taught semesters; an increased focus on societal challenges through new courses as “Sustainable Electronics” and “Design for Reliability”; the course “Design and Analysis of MEMS” with heavy involvement of industry; and the course “Multiphysics modelling” now targeting a larger range of device fabrication platforms than MEMS only.

C. Transferrable skills

Apart from the sheer academic syllabus, the development of transferrable skills are encouraged during the study programme: Such as the ability to work in a team, the ability to work independent in a research-oriented setting, communication and presentation skills and innovative thinking. Also courses in local language and the culture of the

three host countries are included in the curricula, to better prepare the graduates for working in an international environment. The three partners represent three different European countries (Finland, Norway and Hungary), representing the cultural, historical, socio-economic and linguistic diversity of Europe. The students in the programme spend at least one semester in each of the partner countries, and are thus intimately exposed to this diversity.

The ability to work in a team is a core transferrable skill, crucial for a graduate to enter an industrial position. The students are trained in teamwork throughout the study programme, particularly in the “SSI Design Lab”, where group work will be carried out throughout the three taught semesters, as detailed above.

In semester 1, the “Translational Engineering Forum” course will detail the innovation process for a new product, both in technical and mercantile terms. Topics in Entrepreneurship will cover the fundamental aspects in business startup: Intellectual Property, Writing up of a Business Plan, the eco-system of investments from Angel Investors and VC, understanding Technology Readiness levels, How to create a start-up company. These topics are initiated by Prof. Marc Desmulliez, who is winner of the £45K Converge Challenge award, the most prestigious prize in Entrepreneurship in Scotland [8]. At the Summer School (before semester 3), the students get a one-day challenge to create a startup company, elaborate details and sell it to “investors”, as a realistic approach to train their entrepreneurship abilities and encourage them to initiate startups.

The skill of scientific writing will be taught for project deliveries already in semester 1. In semester 2, students write laboratory reports in the format of scientific publications, and they are further trained in scientific writing in their project reports in the third semester, getting a firm basis for writing skills to be applied when writing their master thesis in the fourth semester. In addition to their written master thesis, the students shall also present the master project orally, thus expanding their presentation skills.

SSIs EMJMD Education Model 120 ECTS

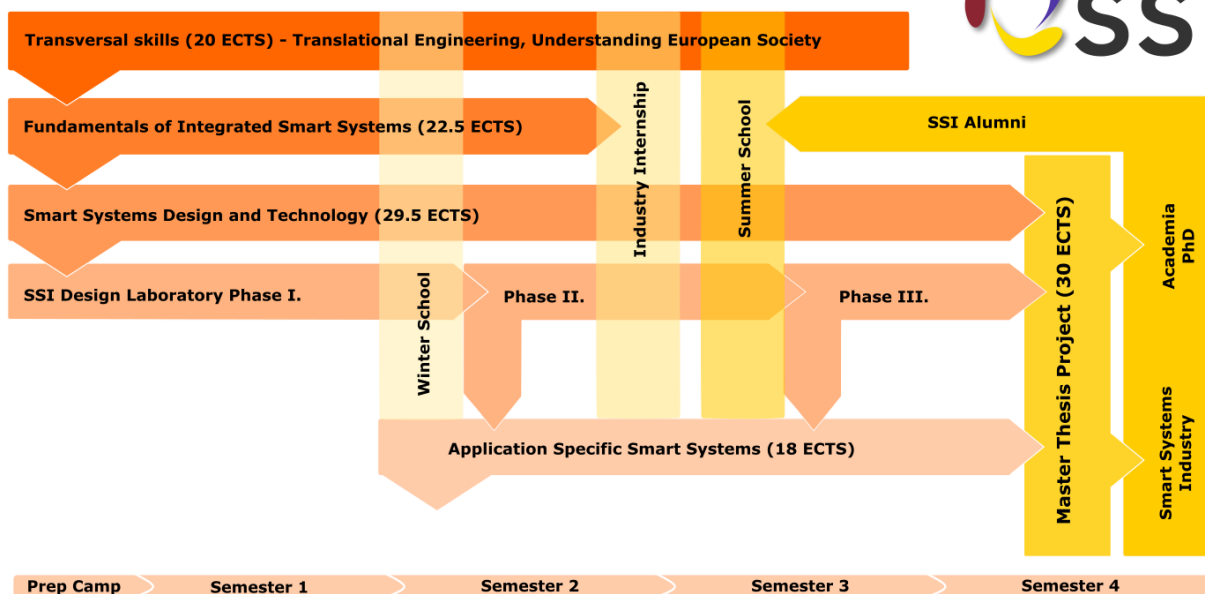


Fig. 1. SSIs Education model

Whereas the teaching language for the programme is English, it also contains courses in national language and culture, introducing the students to Finnish, Norwegian and Hungarian language while studying in the respective countries. These courses also have a culture and society component. This helps the students to better understand the country they are staying in, and how each country contributes to shaping the diverse Europe, since the three countries indeed represent different parts of the complex history of Europe. In Finland, the students get knowledge of Finnish working life and the history between eastern and western Europe. In Norway, the students are introduced to the socio-economic "Nordic Model", crucial in explaining the high living standard and societal participation in the Nordic countries. In Hungary the students learn about the specialities of the Central European countries, and how the large variations in political systems over the centuries impact societies. These courses allow the students to better understand the socio-economic differences between these three different countries of Europe. Furthermore, the students are exposed to the local culture of the three host countries as part of the study programme: In Finland they will be exposed to the sauna tradition. In Norway an on-campus skiing session is arranged, as well as a sailing trip on the Oslo Fjord. In Hungary, the students are introduced to traditional dance and music, as well as Hungarian cuisine and visits to the Buda Castle and the exceptionally multicultural capital, Budapest.

IV. STUDENTS/GRADUATES

The students of the preceding SSI/ SSI+ programmes have been truly international. Typically, 15 nationalities have been represented in each class, covering a wide range of world cultures. This, and the joint mobility the first three semesters, nurtures a strong class feeling and allows an excellent learning environment. The students call themselves "the SSI family".

The number of applications for admittance has been very high every year, allowing the Consortium to select students of excellent quality. SSI/ SSI+ students perform significantly better than the regular master students at the respective institutions, which we interpret as a consequence of the fierce competition to be admitted, together with the excellent learning environment provided by the strong personal relations between students. EU provides generous scholarships, so the applicants compete on qualifications, not on their ability to self-fund studies in Europe.

The employability of the graduates has been very high, demonstrating the societal need for those graduates. Regular surveys have been performed, showing an employment rate > 90%, with positions in >12 European countries, several in Asia and occasional in the Americas. Both small, innovative start-up companies and large multi-national companies have employed SSI graduates, and some graduates has taken the step to start their own company. Around 50% of the graduates pursue PhD studies, demonstrating the high academic quality of the graduates. We expect that these Ph.D. graduates will achieve leading positions in the Smart Systems industry worldwide.

V. CO-ORDINATION OF JOINT DEGREE

To establish a Joint Degree, a high level of interaction between the three institutions has been necessary. A joint Academic Board oversees all aspects of the Joint Master, and the

selection of students to be admitted is done in face-to-face meetings with academic members from all three institutions.

A yearly Summer School is organized in Hungary before the start of Semester 3, with academic and administrative staff from all three partner universities present. Besides academic presentations for the students, this is also an occasion for Consortium and Academic Board Meetings, important for the co-ordination of the Joint Master. No less important is the Summer School as an informal meeting-place between the academic and administrative staff of the three partner universities, which has allowed the development of a mutual understanding and trust within the consortium. The importance of such relations cannot be underestimated when explaining the success of the Joint Master. Newly graduated students present their master projects, and also some graduates from previous cohorts are present.

From 2022 we will also have a Winter School, in Norway.

VI. CONCLUSION: SYNERGY OBTAINED

The Joint International Master in Smart Systems Integrated Solutions combines complementary expertise and laboratory facilities from the three partner universities to create a unique master degree with a holistic, system-level approach to Smart Systems. As a result, the graduates obtain a wider knowledge than any of the individual universities would be able to provide. The success of the programme is evident from the large number of applicants, the excellent academic results the students obtain, and the high employability of graduates.

Since the Joint Master requires the students to spend at least one semester in Finland, Norway and Hungary, the graduates obtain a cross-cultural experience giving a far better insight in the variety of European societies than a single-university degree would give. This is extremely important for the graduates to work in an international working environment. Furthermore, the students' exposure to three different university systems and learning environments will benefit them in their careers, to easier access new knowledge and easier adapt to changes in their working environment.

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