

A Trans-National Smart Manufacturing Education Hub

Intellectual Output 4

Mobility Strategies of the Involved Institutions and Corporate Partners



CREATING OPPORTUNITIES FOR THE UK ACROSS EUROPE









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Mobility Strategies at Smart-Edu4.0

1. Introduction

This document presents the actions that have been done during the three-year Erasmus+ project Smart-Edu4.0 in order to embed the mobility in all training programs that are supported by the partners. The mobility which is one of the key objectives of the project is expressed through exchanges of academic staff and students between the partners in order to assist them in researching and studying different international industry models. Moreover, mobility actions include summer schools, joint project supervision, activities for schools, research collaborations and organization of events related to smart manufacturing.

The remainder of the document is structured as follows: Section 2 demonstrates the approach of the project partners regarding students' mobility in general and in particular within the project. Section 3 presents the academic staff mobility and section 4 illustrates the diploma thesis that are planned to be jointly-supervised by the partners. Section 5 shows the already existing collaborations with the academia and industry as well as the collaborations developed during the project. Section 6 presents the training activities that took place at schools and section 7 displays the summer camps that were organized with the support of the Smart-Edu4.0 project. Finally, Section 8 demonstrates the Multiplier Events that were implemented by the partners to promote the project and create collaborations with other educational institutions and industry and section 9 concludes the report, highlighting the most important issues.

2. Exchange of students

Partners' approach

All partner institutions (Queen's University Belfast, SERC, University of Limerick, National Technical University of Athens) promote student exchange and aim to deliver high quality mobilities with sustainable impact on participants. Student mobility supports student personal and professional development and improves their employability opportunities. Students have also the opportunity to gain international experience and respond to global issues and challenges. Following, the existing mobility strategies for students are presented for each partner.

Queen's University Belfast (QUB)

Queen's University Belfast encourages student exchange via various institution-backed schemes:

<u>Turing scheme</u>¹: Any student enrolled in Higher Education Student is eligible for this scheme, independent of nationality. They can be studying full time, part time or have recently graduated. Current students can take part in a study or traineeship placement and those who have graduated within the last 12 months can carry out a traineeship abroad. Funding will be available through the Turing Scheme for placements during the period from September 2021 to August 2022, with the duration of study or traineeship placements ranging from four weeks to 12 months. The host institution can be a non-UK HE institute, or any non-UK public or private organisation active in the labour market in the fields of education and training.

¹ https://www.turing-scheme.org.uk/



<u>International Association for the Exchange of Students for Technical Experience (IAESTE)</u> is a student exchange organisation helping STEM students gain placements abroad during the summer. QUB has supported successfully IAESTE student placements the last years. Students can choose from a variety of host institutions, and likewise several students are hosted annually in the Schools of the Engineering and Physical Sciences Faculty in QUB.

<u>Erasmus placements</u>: QUB has been a member of the Erasmus network for many years, with several successful placements throughout the years. Going forward after Brexit, the UK can continue to participate in the Erasmus programme until the end of the current cycle of the programme, up to 31 May 2023. Erasmus exchange opportunities and funding are continuing for placements in mainland Europe in the 2021-22 academic year, subject to the approval of the international placement by each School. Although the UK government has announced that the UK will not be participating in the next Erasmus programme, other options for student exchanges and work placements in Europe and worldwide will be available. The details of these new programmes are currently being developed and should be published very soon.

South Eastern Regional College (SERC)

SERC has been working internationally for over 12 years with partnerships in over 49 countries across the globe. The International Unit has experienced steady growth over the period with an increasing reputation for delivering high quality projects underpinned by proven Project Management processes.

Whilst much of the work centres around the Erasmus+ programme, the international team continuously seeks additional funded and commercial opportunities to help position SERC in new markets through the British Council, Department for International Trade and other overseas development funds. SERC is also an integral part of the International Working Group playing an active role in seeking out and applying for larger projects that focus on skills development and capacity building.

SERC also holds the Erasmus+ Higher Education Charter and Further Education VET Mobility Charter in recognition of the College's commitment to maintain the Principles of the European Union and deliver high quality mobilities that deliver sustainable impact on participants. SERC has a strong international dimension via the enhanced curriculum that supports and its ability to respond to global challenges. SERC's global profile and reputation is positively affected and additional sources of income are generated.

University of Limerick (UL)

University of Limerick supports an Erasmus and International Exchange programme that allows students to study abroad at a partner university as part of their degree programme. The academic semester abroad is fully recognised as an academic component of UL degree programmes. Each year, over 600 UL students study abroad at EU and non-EU partner institutions.

In UL, there are courses with compulsory academic semester abroad, and courses with an elective academic semester abroad. There are eight UL programmes with an integrated academic semester abroad:

- LM002 Arts
- LM019 Social Sciences
- LM038 Psychology and Sociology
- LM039 Journalism and Digital Communication
- LM040 European Studies
- LM044 Applied Languages
- LM056 International Business



LM102 – Psychology

The academic semester abroad is available to most other UL degree programmes, with some exceptions due to accreditation requirements. The selection process is competitive and students must be in good academic standing for their application to be approved. The academic placement may be undertaken in Year 2 or Year 3. Most UL students go on a semester abroad in Year 3. The majority of academic exchanges abroad are for one semester (approximately 4-5 months). It can be possible to extend the academic exchange programme to the full academic year (approximately 9 months), depending on the degree programme.

UL also offers a support programme for Marie Curie fellowship -MSCA-PF applicants. UL provides a Masterclass with travel bursaries to UL for selected applicants in late May each year. Online masterclasses were scheduled during the pandemic. The Confirm centre ran the MSCA SMART4.0 which offered 16 international participants post-doctoral fellowships in Ireland across the Confirm network.

National Technical University of Athens (NTUA)

All nine schools of National Technical University of Athens (NTUA) within the scope of the <u>Erasmus</u> European funded programme, provide the opportunity to undergraduate, graduate and postgraduate students to visit partner universities within E.U. or non E.U. countries, for studies or internships.

The collaboration agreement between the universities is established through initiatives by the teaching staff of each School and their personal contacts with members from other universities. The number of participating students in the exchange programme is predetermined and the duration of the stay in each partner university ranges from 3 to 12 months. All students that are entitled to participate in the programme, should be at least at the second year of their studies and should have successfully completed at least 3/4 of the first-year courses. As it is very important for students to carefully select the courses that they are going to attend in the foreign partner university, they are strongly encouraged to consult the teaching staff of their school before making their decisions. There is also the opportunity for a Master's Thesis to be written abroad with the agreement of the supervising professor of the NTUA School. Students are offered the possibility of subsidized professional employment in a foreign country during the summer vacation. The extra costs, incurred by the difference in cost of living abroad, are covered by scholarships granted from the European Union as well as supplementary scholarships from NTUA. Students should be aware that the procedures for granting a scholarship must start at least six months before they move abroad. The selection of students that participate at the ERASMUS+ programme, is based on the following criteria, as they are defined by the ERASMUS+ committee:

- 1. Current year of studying.
- 2. Level of language proficiency for the first or the second institutional language, in the foreign university.
- 3. Student's competence (average score in taught courses).
- 4. Rate of ECTS of successfully completed courses / Total course programme ECTS based on the current semester of the applicant.

Regarding incoming students, NTUA has a specialized Erasmus Office that helps everyone interested in the ERASMUS+ programme and provides full administrative support to all foreign students. It assists students in finding accommodation, applying for the Greek language courses, the meal card at the campus restaurant and the student card that gives 50% reduction at all public means of transportation and reduced ticket prices for cultural places and events.



Moreover, the regulations regarding Erasmus and the application procedure are the same for all nine schools of NTUA. The very good knowledge of Greek or English language and the participation in the final exams of the selected courses are prerequisites. In each school, there is a teaching staff member who is responsible for supporting international students and solving any arising issues regarding their studies or residency in Athens.

Apart from the Erasmus, NTUA is involved in the IAESTE. Every year NTUA sends numerous students for practical training in technical companies or University Laboratories of member countries of IAESTE, and accepts a similar number of foreign students in Greece. The student work placements are funded by the companies themselves. Every year, they inform the authorities about places they have available and what conditions the candidates must fulfil. Applications are submitted in October and November of the previous year and the selection of successful candidates is made in February and March on the basis of objective criteria such as school, year of graduation, knowledge of the required foreign language and degree of success in the studies of the previous academic year. The student exchanges usually take place during vacations July-September.

Smart-Edu4.0 approach

All Smart-Edu4.0 partners recognize the essential benefits of student mobility and are willing to support a mobile and flexible education environment by investigating any possible options for student exchange on mechatronics or engineering courses between partner institutes.

The consortium supports student visits to partner institutes to keep up with the different culture and state-of-the-art facilities of each university. Students could spend short periods of time (five days to one month) working on a specific project in the facilities of the Northern Ireland Technology Centre (NITC) or QUB laboratories related to manufacturing and autonomous system/control.

Moreover, students from QUB will be encouraged to take <u>final year projects</u> that will either have part of the work completed in NTUA and/or joint supervisory team consisting of an academic from NTUA. For further details, see <u>section 3</u>.

3. Exchange of academic staff

All four partners utilize the Erasmus+ programme for teaching staff exchange. Academics are subsidized to spend time teaching at a partner institution abroad and participate in training weeks in order to increase their experience and skills. Staff mobility is essential for both educators and institutes because teachers

- acquire knowledge, practical skills and expertise from training or teaching abroad,
- discover best practices and generate new ideas,
- be inspired by new colleagues and different perspectives,
- exchange expertise and experience,
- explore new ways of teaching, new tools and technologies in their field,
- learn about another education system,
- enhance their professional development,
- develop their international network and open up possibilities for future collaboration and partnerships,
- explore a new culture or language.



Regarding QUB, academic staff apart from Erasmus programme, is also receiving financial support from university backed internal funding² for academic visits to various research institutions to foster collaboration and research. Furthermore, it is customary practice in QUB and especially on pure research, or research and development industry-driven projects to plan short- or long-term visits between academic staff.

UL has been an active participant in the European Union's Erasmus programme since 1988. UL has over 300 EU University partners from 26 countries in Europe where staff mobility can take place.

As far as NTUA is concerned, in case a member of the teaching staff is interested in participating in an Erasmus programme, he/she should search for the training programme that interests him/her and submit a request to the foreign school for the specific programme. If the candidate receives the letter of acceptance, then creates a report for NTUA school, describing the training programme, the goals and the expected results of this teaching practice. The training can last from two to five days without considering the travel days.

In addition, NTUA schools very often organize lectures with guest speakers as they provide an important educational experience for students. Guests' contributions can take the format of a single lecture, a lecture series over a specific period or workshops. Lecturers can be from universities within E.U. or non E.U. countries as well as experts in their field working on the public or private sector. These lectures are supported by NTUA funds or individual laboratories' expenses.

All consortium members, encourage mobility of academic staff and during this three-year project either hosted academics or travel to partners' institutions for the purpose of collaborative research and teaching activities. The blended learning model that has been adapted by universities and institutions around the world due to COVID19 further facilitates academics mobility as they can give lectures to foreign universities or receive training without traveling abroad. This change exploited by the partners and organized several training sessions in the field of mechatronics and industry 4.0 that are presented in the following sections.

4. Joint project/diploma thesis supervision

The already existing approach in QUB, UL and NTUA regarding project or diploma thesis is that they can be supervised in cooperation with a foreign university.

More specifically, in QUB, the final year project runs for a nine-month period and one or two supervisors and a moderator who evaluates the work towards the end of the period are assigned to each student. Joint supervision between different schools, and industry, is encouraged in QUB. The supervisor from the school where the programme runs has the final responsibility of grading the final report and overall report, however after considering comments from the whole supervisory team.

UL permits the joint supervision of theses but there is little documentation on the number of joint supervision activities currently ongoing at the university.

NTUA students are able to attain their diploma thesis in a foreign university. Initially, they find the subject they want to further research and the professor of their NTUA school they want to work with. Next with tutor's guidance, students choose a foreign university to attain their diploma thesis. The thesis is constantly supervised by the NTUA professor as the final grade and diploma will be given by NTUA school. Similarly, international students can join any NTUA school to write their diploma thesis.

² <u>https://www.qub.ac.uk/Research/Support-for-researchers/</u>



The thesis should be written in English and there will be a strong cooperation between the student's university and NTUA school. In the above cases, NTUA students are funded by the Erasmus programme.

Regarding the Smart-Edu4.0 project, all consortium partners are happy to involve external experts as supervisors for thesis, which will improve candidates' visibility and network and they are also delighted to discuss supervision of students outside of their universities.

Actually, QUB and UL proposed a number of topics for co-supervision (Section 3.1, 3.2) and one of these topics has been chosen by a student from the School of Electrical and Computer Engineering in NTUA.

a. Theses proposed by QUB

The project members within QUB are members of the Centre for Intelligent Autonomous Manufacturing Systems (i-AMS), consisting of academics from the School of Electronics, Electrical Engineering and Computer Science, Psychology, Applied Mathematics and Mechanical Engineering. They proposed four topics for theses to be co-supervised with the NTUA which are about: (i) safety of robotic manipulators, (ii) edge computing and resource allocation/scheduling challenges, (iii) planning of mobile robots and (iv) safety of CPS and cybersecurity. The theses are presented below and are also included in <u>Appendix</u>:

i. Safe planning of robotic manipulators by modelling collision impact

N-link robotic manipulators can perform complex tasks, and are expected to do so very fast, reliably and safely. In the new paradigm of collaborative robotics, safety plays a huge role as the new generation of robots will be designed to operate alongside with humans and other autonomous robots with limited communication between each other. In general, planning is a complicated task, especially for N-link manipulators. One of the approaches is to pre-determine a feasible path for the endeffector, and consequently create a velocity profile for the manipulator on that path. An optimal control technique has been successfully developed under this framework for more than 30 years, leading to efficient implementations in real robotic manipulators. Nevertheless, the incorporation of constraints enforced by potential collision from static or dynamic obstacles has not particularly been explored so far.

The scope of the project is to provide a systematic way of incorporating collision constraints efficiently and fast in trajectory generation of robotic manipulators, potentially changing in real time the control profile of the torques applied in each joint. To do so, modelling of the impact of collisions needs to be taken, together with an estimation of the safe region of the space of the parameters of the robotic manipulator. The project is a mixture of robotics and control engineering, and aims at incorporating constraints induced by collaborative robotics to standard algorithmic planning procedures in robotic manipulators.

This project will be well suited for students interested in robotics. Programming (Matlab or other platform) and mathematical skills are expected.

ii. Event-triggered Scheduling and Resource allocation in Edge Computing

Eighty billion devices are going to be connected to the Internet by 2025. Using the Cloud alone to process all data generated by these devices will not be pragmatic. Edge computing is a novel paradigm that will tackle the above concern by bringing computing closer to the devices; in this setting, existing Internet nodes, such as routers, base stations or gateways may be enhanced with computing resources, or dedicated micro data centres may be placed at the Edge of the network. Services from



the Cloud may then be offloaded onto these Edge nodes. One of the key challenges in this space is the scheduling and allocation of resources on Edge nodes.

This project will be focused on developing smart scheduling and resource allocation strategies that specifically target various performance metrics such as average response time. A dynamical model based on existing approaches from systems and control theory will be employed.

This project will be well suited for students interested in cloud/edge computing, dynamic networks, control. Programming (Matlab or other platform) and mathematical skills will be useful.

iii. Planning in mobile robotics in nonconvex environments

Modern mobile robots are supposed to find their way, i.e., plan paths, avoid obstacles, move in dynamic environments. This is possible by the advancement of sensing devices, cheap hardware and new smart decision mechanisms. However, there are many tasks to be carried out that are computation-intensive and memory-intensive. On top of that these tasks are often safety- and time-critical, meaning they should be carried out in real time. The goal of this project is to develop light planning algorithms for mobile robots for navigation in nonconvex environments.

We are going to use tools developed from the hybrid systems and cyber-physical systems community, adapted and tailored for problems in robotics. The project is both practical and theoretical, and will be benchmarked on an actual robotic setup that will be purchased. s

iv. Analysing the impact of cyber-attacks in cyber-physical systems

Cyber-security is becoming a major challenge in every aspect of everyday life. Systems engineered and controlled by software, hardware, and communication networks, becoming increasingly vulnerable to attacks, that become themselves more and more sophisticated; covert attacks, replay attacks, stealthy attacks, data injection, bias injection, denial of service, are some of the so far identified and documented attack strategies that have been attempted in safety-critical infrastructure involving electricity networks, power generation, manufacturing, military, transportation etc.

This project aims to analyse the impact of attacks, specifically on dynamical systems controlled by a 'cyber' component (hardware, software, communication network), also known as cyber-physical systems. Our aim will be to properly categorise and unify the different types of attacks in a rich model borrowed from hybrid systems theory, namely, linear hybrid automata. The goal is to use mature tools from modern control theory to analyse the impact of different types of attacks on a dynamical system.

The project is best suited for students with an interest in control, computer science, and cybersecurity. Programming skills and mathematical reasoning are useful.

The project is well suited for students that are interested in working on control and planning of robots. Strong programming and mathematical skills will be useful.

b. Theses proposed by NTUA

Respectively, the NTUA proposed the following diploma thesis which was assigned to a student who was interested in the subject and is co-supervised with QUB.

Trend analysis and future state forecasting of devices located at the network edge by employing Digital Twins

Digital Twins are digital replicas of physical systems and are currently the focus of interest for many researchers. A Digital Twin (DT) models a physical system and is designed aiming to be its exact (virtual) representation. It emulates both the current state of the system as well as its reaction. At the



same time, it offers communication capabilities with the actual system, affecting in near-real time its state, according to the results of various algorithms executed in the DT. DTs are important tools that assist in optimizing the operation of a system and can also aid in reducing costs and resources because they enable the execution of a multitude of scenarios without the involvement of the physical counterpart.

The goal of this diploma thesis is to create a DT of a system equipped with sensor devices operating at the network edge. The DT is always up-to-date regarding the current state of the system, collects the generated data, offers a visual representation of them to the user via the development of a suitable User Interface (UI). The DT should detect any anomalies and recommend to the user appropriate plans of action.

The interested students from the above four Schools will then have the opportunity to choose from these projects, effectively materialising collaboration between partner institutions.

More details about the above thesis are in the <u>Appendix</u>.

5. Mobility in Research collaborations with academia and industry

a. Existing collaborations

Input from industrial stakeholders is a well-structured procedure within <u>QUB</u>. Specifically, via the Northern Ireland Technology Centre³, QUB has the opportunity to monitor the technological readiness of local industry, the challenges faced in high-tech applications of the local industry (military, aerospace, semiconductor design, edge computing etc). The members of the QUB group also sit in various technical committees within IEEE (Institute of Electrical and Electronics Engineers) and IFAC (International Federation of Automatic Control). It is also worth mentioning that QUB has several active collaboration networks in the research funded consortia.

<u>UL</u> researchers are known for their cutting-edge research, which they carry out in collaboration with leading national and international engineering researchers. These projects are published in top international journals. While many of the Department's research studies are based in the purposebuilt labs on the UL campus, UL is involved in a number of transnational projects conducted across numerous international sites. The Confirm Smart Manufacturing research centre is based in UL and hosts a number of national and international industry research partners. Mobility of researchers between the University and industry is encouraged.

<u>NTUA</u> has recently announced the establishment of the first Energy Competence Center in Greece, a cluster that aims to support and promote innovation, entrepreneurship and technical competencies among enterprises that are operating in the energy sector - a fundamental pillar of the Greek economy. Within the activities of the Energy Competence Center, collaboration between enterprises and other organizations/bodies is envisaged to take place. Where possible, the involvement of students will be promoted.

b. Collaborations established and mobility within the Smart-Edu4.0 project

Collaboration between project partners has already proved fruitful.

<u>NTUA and QUB</u> are core partners of the CHIST-ERA DRUID-NET project. They collaborate on designing smart resource allocation mechanisms for Cyber-Physical Systems and collaborative robotics use-case. Furthermore, QUB was funded for the IIoT-REPLAN experiment by the Fed4FIREplus project. This

³ https://www.qub.ac.uk/sites/nitc/



experiment focused on robotics applications and NTUA, as Fed4FIREplus partner, acted as the Patron of the experiment. Also, NTUA and QUB share expertise, improve visibility of their research and produce high-impact and far-reaching research outputs by leveraging their network. Since 2018, QUB and NTUA have many joint publications. Finally, joint work of academic and industrial partners is envisaged, considering the involvement of post-graduate students in various levels.

<u>QUB and SERC</u> have jointly designed the **"University Access Diplomas"** to provide a route to higher education for those who have been away from education for an extended period with a two years minimum period. The course has been validated and approved by QUB with the first cohort expected to commence from September 2023. The diploma will be offered for both full-time (1 year) and part-time (2 years) students. SERC is the proposed collaborative/delivery partner enabling progression to the following undergraduate pathways:

- 1. Mechanical and Aerospace Engineering
- 2. Electrical and Electronic Engineering
- 3. Computer and Software Engineering
- 4. Civil Engineering

The proposed core modules include, Study and Employability Skills, Mathematics 1, Mathematics 2, and Computer Engineering (Arduino, basic electronics, sensors, actuators, introduction to programming, data collection & analysis). Additional credits will be needed according to the intended program for progression purpose.

<u>QUB and UL</u> have established many preliminary research initiatives for research collaboration via EUfunded and RoI-UK funded projects. They collaborate on designing smart resource allocation mechanisms for Cyber-Physical Systems and collaborative robotics use-case.

Finally, the QUB is actively arranging for industry backed research funding via national (UKRI, EPSRC) and international (EU, US-Ireland) means.

SERC has worked with Lahore Garrison University (LGU) over the past four years which has resulted in LGU becoming a Pearson Centre to offer Engineering at HND level and Dual study program established to allow LGU students to complete their 2nd year at SERC. This project was initial started through an Erasmus ICM.

During the Smart-Edu4.0 project, partners moved several times to give lectures to partners' institutions and not only.

A workshop about Smart-Edu4.0 project occurred during the **Irish Signals and Systems Conference (ISSC)** in Cork on June 2022. All partners had the chance to present their work in the project as well as their work and research experience in relevant fields. The program of the conference and all partners presentations are available <u>here</u> (<u>https://smartedu40.eu/?p=448</u>).



Irish Signa	als & Systems Conference 2022 09 - 10 Jun 2022 All times	s in IST	
Thurs	sday, 9 June	10:45	FAIR Skin Lesion Classification Workflows using Transfer Learning » Mr. David Walshe, <u>Dr. Ruairí O'Reilly</u>
08:00	Registration and Morning Coffee Main Hall Chaired by: Ted Scully	11:05	Segmentation of Glioblastoma Via-Attention Neural Network » <u>Mr. WILLIAMS AYIVJ</u> , Prof. Liaoyuan Zeng, Mr. Sophyani Banaamwini Yussif, Ms. Judith Ayekai Browne, Mr. Victor Kwaku Agbesi, Mr. Francis Sam, Prof. Sean McGrath
09:00	Welcome to ISSC 2022 Lecture Hall IT1	10:45	1B -Cyber Security Lecture Hall IT2
	Welcome » Sean McSweeney	10:45	Host-Based Intrusion Detection System for IoT using Convolutional Neural Networks
09:15	Keynote #1 - Dr.Karen Weekes Lecture Hall IT1		» <u>Mr. Dominic Lightbody</u> , Mr. Duc-Minh Ngo, Dr. Andriy Temko, Dr. COLIN MURPHY, Dr. Emanuel Popovici
		11:05	Fianán, Cuacha: Irish Cookie Banners » <u>Ms. Ashley Sheil</u> , Prof. DAVID MALONE
10:00	Keynote - Aoife Ni Mhuire - Machine Learning & Al Lecture Hall IT1	11:25	Tea and Coffee Break and Poster Session Main Hall
10:00	Keynote- Professor Thomas Newe - Cyber Security	11:45	Track 1C - Machine Learning & Al Lecture Hall IT1
10:00	Lecture Hall IT2 Education and Training Programmes and opportunities in Manufacturing and Mechatronics in Europe. Lecture Hall IT3	11:45	Hybrid Quantum Convolutional Neural Networks in TensorFlow Quantum » <u>Mr. Bishreit Khurelsukh</u>
		12:05	Edge-enabled Federated Learning for Vision based Product Quality Inspection
10:45	Track 1A - Machine Learning and Al Lecture Hall IT1	12:25	* <u>Dr. sourable black</u> , Dr. Ann weathing, Mr. Histan O Gorman An Iterated Local Search Approach to the Container Pre- Marshalling Problem * <u>Mr. John Farrelly</u> , Dr. Diarmuid Grimes

Figure 1 - ISSC Workshop program

On April 26, 2023, Dr Athanasopoulos who is a Senior Lecturer in the School of Electronics, Electrical Engineering and Computer Science at Queen's University Belfast gave a lecture in the School of Electrical and Computer Engineering at the National Technical University of Athens with the title "Complexity-aware set-based methods in analysis and decision making" (Fig.1).





Figure 2 - Dr Athanasopoulos Speech in NTUA

After introducing the main, celebrated methods in set-based analysis and control, Nikos presented a new approach of computing invariant sets from a computational geometry point of view. Specifically, Dr Athanasopoulos presented two new elementary operations for changing the shape of polytopic invariant sets and preserve invariance at the same time, exploiting order theoretic properties of the face lattice of polytopes. The second part of the talk was focused on application-oriented results that take into account the system structure to face the barrier of complexity, related to (i) large scale systems (scheduling and resource allocation of computing networks), (ii) nonlinearity and nonconvexity (robotics), and (iii) temporal specifications (cybersecurity). More information and pictures from this speech are available here (https://smartedu40.eu/?p=992#more-992).

Dr Mellett from the University of Limerick and Dr Zafeiropoulos from the National Technical University of Athens gave two talks around research training in engineering and mapping of UN's Sustainable Development Goals to Research and Education using AI. The talks were hosted by the EPIC group in EEECS, Queen's University Belfast, and the IEEE UK and Ireland Joint Chapter on Control and Communication.

Dr Mellett presented her research journey from industry to PhD, Post doc and managing multidisciplinary research projects. The presentation looked at her current and past research projects across disciplines including SMART manufacturing, Sustainable Seafood and Life Cycle Assessment, Water-Energy-Food NEXUS and eLearning.

Dr Zafeiropoulos presented the SustainGraph which is a Knowledge Graph that is developed to track information related to the progress towards the achievement of targets defined in the United Nations Sustainable Development Goals (SDGs) at national and regional levels. The SustainGraph aims to act as a unified source of knowledge around information related to the SDGs, by taking advantage of the power provided by the development of graph databases and the exploitation of Machine Learning (ML) techniques for data population, knowledge production and analysis. The main concepts



represented in the SustainGraph are going to be detailed, while indicative usage scenarios will be provided. The way that participatory socio-environmental systems modelling approaches are supported through SustainGraph were described. More information about these speeches is available <u>here (https://allevents.in/mobile/amp-event.php?event_id=10000656235316497</u>).

QUB organised and hosted the 23rd International Conference on Composites Materials (ICCM 23) from July 30th to August 4th, 2023. ICCM is the premier international conference in the field of composite materials and was first held in 1975 in the cities of Geneva and Boston. Since that time the conference has been held biennially in North American, European, Asian, Oceanic, and African cities. Prof Conor McCarthy from UL was the Conference Technical Chair. More information about the conference is available <u>here</u> (https://iccm23.org/about-the-conference/).

Moreover, during the Smart-Edu4.0 project, three workshops took place in Limerick (Ireland), Athens (Greece) and Belfast (UK) to advertise the project and disseminate its results. The project partners visited other partners' institutions to support these events but they also had the chance to visit partners' laboratories, exchange practices, discuss research challenges related to the theme of the project and further collaborate in a more research-oriented framework. The workshops are described in more detail in <u>section 6</u>.

Finally, UL managed to receive grants from Marie Skłodowska-Curie actions. The Marie Skłodowska-Curie actions (MSCA) aim to support the career development and training of researchers in all scientific disciplines through international and intersectoral mobility. MSCA enables excellent research and attractive working conditions by offering high quality professional opportunities to researchers of any age, nationality or discipline. Specifically, the MSCA and UL's CONFIRM Centre cofund Smart4.0 Fellowship aims to deliver the next generation smart manufacturing leaders with strong "systems-level thinking" and interdisciplinary skills, driving Industry 4.0 forward for Europe and delivering the greatest impact potential for advancement. To achieve this, CONFIRM Centre will establish and deliver, via the SMART 4.0 programme, world-class training and research opportunities to postdoctoral Fellows in order to increase Europe's critical mass in this field.

SMART 4.0 programme will offer 16 Fellowships, each 24 months in duration in the Republic of Ireland. SMART will adhere to the MSCA cofund principle of 'individually-driven mobility' meaning that Fellows will have full freedom to choose their host institution, supervisor and research topic. Prospective Fellows will be embedded in an international, interdisciplinary and intersectoral environment, and will be well-poised to capitalize on CONFIRM Centre's excellent industry and research architecture. SMART 4.0 will publish 2 open calls for proposals, which will be disseminated internationally. The evaluation and selection process will be based on international peer review, and will be open, transparent, meritbased and equitable. You can read more about MSCA and Smart4.0 program <u>here</u> (https://smart.confirm.ie/msca-smart-4-

<u>0/#:~:text=The%20goal%20of%20the%20CONFIRM%20Centre%20SMART%204.0,of%20the%20EU%</u> 20and%20Horizon%202020%20Associated%20Countries.).

6. Training programs and activities for schools supported by the Smart-Edu4.0 project

UL and specifically the CONFIRM Centre organized on March 2023 a course for Transition Year students about "A carrier in smart manufacturing and STEM science". The students who joined this work experience program got an idea about different careers that are part of smart manufacturing. They also had a brief understanding of topics such as artificial intelligence, the internet of things and robots.



W5 in Belfast have been running **FIRST LEGO League (FLL)** with support from the Institute of Engineering and Technology (IET) for over ten years and it is one of the most fun and rewarding programmes. The culmination is a competition day at W5 in which all the participating teams come in with their robots to compete, give their presentations and talk with the judges about their experiences programming their robot. Last year 20 schools from Northern Ireland were involved with each team consisting of a maximum of 10 students. The age group of FLL Challenge is 9 – 16yrs. A teacher at each school operates as the team coach and meets with the students once or twice a week to program their robot and practice completing the LEGO-based tasks. They also research and plan their project which they have to present to the judges in 10 minutes at W5. Mentors are an important part of the whole process. They can provide support in programming as well as developing a strategy for the game. They motivate, focus the team and act as role model providing guidance whilst ensuring that children find solutions themselves. Apart from providing support and encouragement to the teams, mentors also provide a link to industry or academia, helping to link FLL with the real world.

SERC Engineering Department worked with 25 Primary School children to encourage Engineering as a career, investigate barriers to career in Engineering for Women, funded through All Island Research fund. The programme designed and implemented family Saturday engineering workshops targeting families with primary school-age girls.

7. Summer Schools supported by the Smart-Edu4.0 project

UL runs a Master of Engineering (Meng) in Mechatronics, which runs across 12 months in three semesters. Semester 1 (September – December) and Semester 2 (January-May) are dedicated to lectures, while in the summer, Semester 3 (May-August), mechatronics students work on their MEng project. UL can contribute to a summer school in the form of

1) online lectures and tutorials in mechatronics related disciplines (PLC coding, 3D printing, automation and control),

2) delivery of live content on site in their state-of-the-art Mechatronics laboratory,

3) applied skills such as robot programming, 3D designs, 3D printing, and PLC programming.

SERC plans to run a Siemens Mechatronic Systems Certification Program (SMSCP) for the international market in 2-week blocks in April 2023 and June 2023. As a current Siemens Centre, SERC has approval from Siemens to run this accredited summer program. The SMSCP combines the German dual education system with Siemens' in-house know-how. It prepares students to work their way into a new system, and by means of the troubleshooting strategies which they learn, they are able to transfer their knowledge and expertise easily to another system. Students with a SMSCP certification are employees who are flexible, autonomous, and professional in their dealings with such complex systems.

SERC successfully delivered an International Summer Program to 6 students from Pakistan for training in The Internet of Things, Coding and Presentation skills.

QUB organized an Engineering and Physical Sciences International Summer School in the Faculty of Engineering and Physical Sciences (Fig. 3) between July 17 and August 11, 2023.







FACULTY OF ENGINEERING AND PHYSICAL SCIENCES

Queen's University Belfast Faculty of Engineering and Physical Sciences

17 July - 11 August 2023

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https://go.qub.ac.uk/epssummerschool



Figure 3 - QUB Summer School 2023



There were many interesting programs available among which are the "Electronics, electrical engineering and computer science" and "Mechanical and aerospace engineering". The summer school was designed for students studying an undergraduate degree in a subject area relevant to the offered programme. More information about this summer camp can be read <u>here</u>.

8. Multiplier Events

The Multiplier Events are dissemination seminars that took place at the end of the project to highlight the achievements of the project. There were three dissemination seminars, one in Ireland, organized by the University of Limerick, one in Greece organized by the National Technical University of Athens and one in Belfast organized by the Queen's University of Belfast and the South Eastern College.

These events took place with the cooperation, support and physical presence of all project partners.

The first Smart-Edu4.0 Multiplier Event was held at the CONFIRM Smart Manufacturing Centre at Limerick on February 2023 (Fig. 4).



Figure 4 - Multiplier Event at UL, Dr Mellett speech

The University of Limerick (UL) presented the Digital Mechatronics BE/ME programs that were developed by the Science Engineering UL in conjunction with @UL@Work and within the context of the Smart-Edu4.0 project. Project partners had also the chance to demonstrate project results and share their thoughts with industry representatives regarding the necessary skills and talents the workforce of the future factories should have. The presentations and pictures of the event are available <u>here (https://smartedu40.eu/?p=532#more-532</u>).

The 2nd Multiplier Event of the Smart-Edu4.0 Project was organized by the National Technical University of Athens (NTUA) on April 25th 2023 (Fig. 5). The project partners presented the results of the project to academics and industry partners and received valuable feedback from them regarding the state-of-the art programs in Manufacturing Mechatronics.





Figure 5 - NTUA Multiplier Event

Professor Symeon Papavassiliou opened the event and presented the research areas of the NTUA team (NETMODE) involved in the project. Dr Athina Thanou from the NTUA gave a brief introduction to the project and right after the coordinator of the project, professor Wasif Naeem from the Queen's University of Belfast presented the Smart-Edu4.0 project. Dr Eoin Hinchy from the University of Limerick (UL) talked about the courses in Mechatronics that are offered in UL and were developed within the project. Darren Anderson from the South Eastern Regional College (SERC) demonstrated Upskilling courses and Industrial training pathways and finally Dr Nikos Voudoukis from the NTUA illustrated the course on Sustainability that was developed for the needs of the project. More information about the event can be read <u>here</u> (https://smartedu40.eu/?page_id=756).

The 3rd Smart-Edu4.0 Multiplier Event was held within the Manufacturing and Supply Chain Conference and Exhibition at the TITANIC EXHIBITION CENTRE LIMITED in Belfast in June 2023 (Fig.8-9). The project was presented by Darren Anderson, Wasif Naeem, and Sean McLoone on behalf of the consortium, while discussion about Bridging the Talent Gap: Empowering Manufacturing in Northern Ireland through Skills and Expertise was made.



Smart-Edu4.0



Figure 6 - QUB Multiplier Event, panel discussion

The panel highlighted the importance of collaboration between academia and industry to develop relevant educational programs and bridge the skills gap in the manufacturing sector. Skills development and talent investment can ensure a prosperous future for the manufacturing sector. More information and pictures from the event are available <u>here</u>.

9. Conclusions

This document presents the Mobility Actions that were implemented by the partners of the Smart-Edu4.0 project. At the beginning, the existing Mobility Strategy of the partners for both students and academic staff is illustrated and then the actions taken during the project are demonstrated. Briefly, the partners started to co-supervise some diploma thesis, have continued their strong collaboration in research, organized several workshops where they supported one another with their participation, created new joint diplomas, gave lectures at each other's universities. Also, this report presents the training programs and activities in manufacturing that were implemented by the partners at schools and the summer camps that were organized for students.



Appendix

QUB Master Theses for co-supervision within Smart-Edu4.0

Electrical & Electronic Engineering, Software & Electronic Systems Engineering

Final Year Projects 2022-2023

Safe planning of robotic manipulators by modelling collision impact **Supervisor: Dr Nikolaos Athanasopoulos**

х	Control		Embedded Systems		High Frequency Electronics		Microelectronics
	Electric Power	х	Software		Connected Health		MEMS
	Cyber-Security		Wireless Communications		Signal/Image Processing	х	Intelligent Systems
	Digital Design		Sensor Networks	х	Data Analytics		Electronics

N-link robotic manipulators can perform complex tasks, and are expected to do so very fast, reliable and safely. In the new paradigm of collaborative robotics, safety plays a huge role as the new generation of robots will be designed to operate alongside with humans and other autonomous robots with limited communication between each other. In general, planning is a complicated task, especially for N-link manipulators. One of the approaches is to pre-determine a feasible path for the endeffector, and consequently create a velocity profile for the manipulator on that path. An optimal control technique has been successfully developed under this framework for more than 30 years, leading to efficient implementations in real robotic manipulators. Nevertheless, the incorporation of constraints enforced by potential collision from static or dynamic obstacles has not particularly been explored so far.

The scope of the project is to provide a systematic way of incorporating collision constraints efficiently and fast in trajectory generation of robotic manipulators, potentially changing in real time the control profile of the torques applied in each joint. To do so, modelling of the impact of collisions needs to be taken, together with an estimation of the safe region of the space of the parameters of the robotic manipulator. The project is a mixture of robotics and control engineering, and aims at incorporating constraints induced by collaborative robotics to standard algorithmic planning procedures in robotic manipulators.

This project will be well suited for students interested in robotics. Programming (MATLAB or other platform) and mathematical skills are expected. For any questions or help with references below you can send a message to <u>n.athanasopoulos@qub.ac.uk</u>

[1] McGovern, R. and Athanasopoulos, N., 2022, July. Kinodynamic planning for robotic manipulators using set-based methods. In *2022 European Control Conference (ECC)* (pp. 1309-1314). IEEE.



[2] Lynch, K.M. and Park, F.C., 2017. *Modern robotics*. Cambridge University Press., especially Chapter 9.

Objectives

- 1. Learn about N-link robotic manipulators (path planning, trajectory generation and tracking control).
- 2. Program in a scientific computing language (e.g., MATLAB or Python) state of the art algorithms for path planning/trajectory generation.
- 3. Model and include collision constraints in the trajectory generation problem. Propose a new method of designing stable and safe controllers for robotic manipulators.

MEng Extension

1. Explore compositional methods for combining safe trajectories (motion primitives), allowing a wider range of motion for the robotic manipulator.

Learning Outcomes

Upon completion of the project, you will expect to:

- 1. Have a very good understanding of N-link robotic manipulators, and in general robotics.
- 2. Learn about advanced control methods in analysis of dynamical systems (reachability, stability, control)
- 3. Learn several tools in addressing challenges in planning in robotics.
- 4. Learn to program / simulate using scientific computing software.

Event-triggered Scheduling and Resource allocation in Edge Computing

Supervisor: Dr Nikolaos Athanasopoulos

х	Control		Embedded Systems	High Frequency Electronics		Microelectronics
	Electric Power	х	Software	Connected Health		MEMS
	Cyber-Security		Wireless Communications	Signal/Image Processing	х	Intelligent Systems
	Digital Design	x	Sensor Networks	Data Analytics		Electronics

Eighty billion devices are going to be connected to the Internet by 2025. Using the Cloud alone to process all data generated by these devices will not be pragmatic. Edge computing is a novel paradigm that will tackle the above concern by bringing computing closer to the devices; in this setting, existing Internet nodes, such as routers, base stations or gateways may be enhanced with computing resources, or dedicated micro data centres may be placed at the Edge of the network. Services from the Cloud may then be offloaded onto these Edge nodes. One of the key challenges in this space is the scheduling and allocation of resources on Edge nodes.

This project will be focused on developing smart scheduling and resource allocation strategies that specifically target various performance metrics such as average response time. A dynamical model based on existing approaches from systems and control theory will be employed.



This project will be well suited for students interested in cloud/edge computing, dynamic networks, control. Programming (Matlab or other platform) and mathematical skills will be useful. For any questions, or help with retrieving references below you can send a message to <u>n.athanasopoulos@qub.ac.uk</u>

[1] Vlahakis, E., Athanasopoulos, N. and McLoone, S., 2021, December. AIMD scheduling and resource allocation in distributed computing systems. In *2021 60th IEEE Conference on Decision and Control (CDC)* (pp. 4642-4647). IEEE.

[2] Ren, W., Vlahakis, E., Athanasopoulos, N. and Jungers, R., 2022, June. Optimal Resource Scheduling and Allocation in Distributed Computing Systems. In *2022 American Control Conference (ACC)* (pp. 2327-2332). IEEE.

Objectives

- 1. Literature review on state-of-the-art approaches dealing with the resource allocation problem in Edge computing.
- 2. Investigate dynamical models describing the process of allocating resources and processing requests to the cloud/edge cluster.
- 3. Evaluate (with simulation) existing queueing models for job scheduling and resource allocation, and Implement decision algorithms in a programming environment and evaluate via simulation one new approach.

MEng Extension

1. Extend the proposed algorithms to account for one additional practical phenomenon present in real edge servers such as communication constraints, coupled resource constraints, quantization of resources.

Learning Outcomes

Upon completion of the project, you will expect to:

- 1. Have a good understanding of distributed computing environments: cloud and edge computing
- 2. Gain experience in modelling of dynamical systems.
- 3. Gain experience in programming and in specific implementing control algorithms in software.
- 4. Acquire a set of tools from control engineering useful for optimization of resources in cloud computing and computer networks.

Planning in mobile robotics in nonconvex environments

Supervisor: Dr Nikolaos Athanasopoulos

х	Control		Embedded Systems		High Frequency Electronics		Microelectronics
	Electric Power	х	Software		Connected Health		MEMS
	Cyber-Security		Wireless Communications	x	Signal/Image Processing	x	Intelligent Systems



	Digital Design		Sensor Networks	х	Data Analytics		Electronics
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Modern mobile robots are supposed to find their way, i.e., plan paths, avoid obstacles, move in dynamic environments. This is possible by the advancement of sensing devices, cheap hardware and new smart decision mechanisms. However, there are many tasks to be carried out that are computation-intensive and memory-intensive. On top of that these tasks are often safety- and time-critical, meaning they should be carried out in real time. The goal of this project is to develop light planning algorithms for mobile robots for navigation in nonconvex environments.

We are going to use tools developed from the hybrid systems and cyber-physical systems community, adapted and tailored for problems in robotics. The project is both practical and theoretical, and will be benhmarked on an actual robotic setup that will be purchased. s

The project is well suited for students that are interested in working on control and planning of robots. Strong programming and mathematical skills will be useful. For any questions regarding the project you can contact me via email to <u>n.athanasopoulos@qub.ac.uk</u>

[1] LaValle, S.M., 2006. Planning algorithms. Cambridge university press.

[2] Athanasopoulos, N. and Jungers, R.M., 2016, April. Computing the domain of attraction of switching systems subject to non-convex constraints. In *Proceedings of the 19th International Conference on Hybrid Systems: Computation and Control* (pp. 41-50).

[3] <u>https://www.youtube.com/watch?v=8SbICF_M1uw&ab_channel=CPS-IoTWeek2021</u> (plenary lecture CPS-IoT week 2021)

Objectives

- 1. Familiarize with basic planning algorithms for mobile robots (simple differential/unicycle dynamics).
- 2. Program in a simulation environment the robot dynamics, the environment, and the planning algorithms together with the trajectory tracking controller (using e.g., Matlab, ROS).
- 3. Develop a new planning algorithm, specifically tailored to nonconvex environments and real-time solutions with experimental validation.

MEng Extension

1. Systematic benchmarking and comparison with state of the art approaches on a mobile robot.

Learning Outcomes

Upon completion of the project, you will expect to:

- 1. Learn about planning methods in mobile robots.
- 2. Learn about dynamical models of computation/memory/communication resources in a control engineering application/
- 3. Gain experience in programming and simulation
- 4. Learn about a significant control problem in robotics and in general in cyber-physical control systems.
- 5. Develop good mathematical and algorithmic reasoning.



Analysing the impact of cyber-attacks in cyber-physical systems

Supervisor: Dr Nikolaos Athanasopoulos

х	Control		Embedded Systems	High Frequency Electronics	Microelectronics
	Electric Power	х	Software	Connected Health	MEMS
x	Cyber-Security		Wireless Communications	Signal/Image Processing	Intelligent Systems
	Digital Design		Sensor Networks	Data Analytics	Electronics

Cyber-security is becoming a major challenge in every aspect of everyday life. Systems engineered and controlled by software, hardware, and communication networks, becoming increasingly vulnerable to attacks, that become themselves more and more sophisticated; covert attacks, replay attacks, stealthy attacks, data injection, bias injection, denial of service, are some of the so far identified and documented attack strategies that have been attempted in safety-critical infrastructure involving electricity networks, power generation, manufacturing, military, transportation etc.

This project aims to analyse the impact of attacks, specifically on dynamical systems controlled by a 'cyber' component (hardware, software, communication network), also known as cyber-physical systems. Our aim will be to properly categorise and unify the different types of attacks in a rich model borrowed from hybrid systems theory, namely, linear hybrid automata. The goal is to use mature tools from modern control theory to analyse the impact of different types of attacks on a dynamical system.

The project is best suited for students with an interest in control, computer science, and cybersecurity. Programming skills and mathematical reasoning are useful. For any questions regarding the project or help with retrieving reference below send a message to <u>n.athanasopoulos@qub.ac.uk</u>

[1] Sandberg, H., Gupta, V. and Johansson, K.H., 2022. Secure networked control systems. *Annual Review of Control, Robotics, and Autonomous Systems*, *5*, pp.445-464.

[2] Milošević, J., Sandberg, H. and Johansson, K.H., 2019. Estimating the impact of cyber-attack strategies for stochastic networked control systems. *IEEE Transactions on Control of Network Systems*, 7(2), pp.747-757.

Objectives

- 1. Familiarize with attack strategies for dynamical systems, and modelling of cyberphysical systems.
- 2. Adapt safety analysis algorithms for dynamical systems so they can incorporate attack models.
 - Analyse impact of attacks on a specific benchmark problem, to be agreed.

MEng Extension

3.

1. Define proper attack impact metrics for the developed algorithms.

Learning Outcomes



Upon completion of the project, you will expect to:

- 1. Learn about attack modelling and simulation for dynamical systems
- 2. Learn about formal modelling methods in control
- 3. Gain experience in programming and simulation
- 4. Develop good mathematical and algorithmic reasoning.
- 5. Be exposed and become comfortable with multidisciplinary problems that require analytical and innovative thinking.

NTUA Master Theses for co-supervision within Smart-Edu4.0

Trend analysis and future state forecasting of devices located at the network edge by employing Digital Twins

Thematic Areas

- Computer Networks
- Data Analyis

Description

Digital Twins are digital replicas of physical systems and are currently the focus of interest for many researchers. A Digital Twin (DT) models a physical system and is designed aiming to be its exact (virtual) representation. It emulates both the current state of the system as well as its reaction. At the same time, it offers communication capabilities with the actual system, affecting in near-real time its state, according to the results of various algorithms executed in the DT. DTs are important tools that assist in optimizing the operation of a system and can also aid in reducing costs and resources because they enable the execution of a multitude of scenarios without the involvement of the physical counterpart.

The goal of this diploma thesis is to create a DT of a system equipped with sensor devices operating at the network edge. The DT is always up-to-date regarding the current state of the system, collects the generated data, offers a visual representation of them to the user via the development of a suitable User Interface (UI). The DT should detect any anomalies and recommend to the user appropriate plans of action.

Tools employed:

- Python
- Java/Javascript
- Eclipse Ditto

Indicative references

- Juarez, M. G., Botti, V. J., & Giret, A. S. (2021). Digital twins: Review and challenges. *Journal of Computing and Information Science in Engineering*, *21*(3).
- Liu, M., Fang, S., Dong, H., & Xu, C. (2021). Review of digital twin about concepts, technologies, and industrial applications. *Journal of Manufacturing Systems*, *58*, 346-361.