Guide for Applicants

1. General information

1.1 Introduction

I4Future – *Imaging for Future: Novel Imaging and Characterisation Methods in Bio, Medical and Environmental Research and Technology Innovations* is a new international doctoral programme coordinated by the University of Oulu (UOULU), Finland and co-sponsored by the *European Union's Horizon 2020 research and innovation programme's Marie Skłodowska-Curie Action Co-funding of regional, national, and international programmes (COFUND)*. The research actions under I4Future are aimed at employing the possibilities of modern imaging and characterization methods in interdisciplinary and inter-sectoral research. The research challenges in the programme can be aimed for example towards innovation of new high technology materials, development of cleaner and more efficient industrial processes, improved diagnostics, novel therapies and a better understanding of the world we live in.

We offer our students inspiring multidisciplinary research atmosphere in well-established research groups, world-class guidance, great secondment opportunities at industrial and international academic partners, and unique skills to realize their full potential as scientists be it be in academia or enterprises.

This is a guide to help applicants with the application procedure and to clarify recruitment and appointment procedures. The recruitment process will emphasise the excellence of the applicants and their research plans and is designed to be open, merit based, unobstructed, impartial, and give equal opportunities to all applicants.

1.2 Number of offered doctoral student positions

Total of **twenty (20) four-year doctoral student positions for 2017-2020** at the University of Oulu, funded by the programme will be offered.

1.3 Eligibility Criteria for Applicants

All applicants must fulfil at least the minimum requirements of the University of Oulu Graduate School (UniOGS) governing doctoral training at UOULU. Candidates must hold a Master's degree, or an equivalent degree (e.g. licentiate), in any of the research areas covered by the I4Future programme at the date when the call is closed, and be able to demonstrate language skills in English that are sufficient to follow doctoral studies. They will have achieved a good grade in their degree (i.e. at least 60% of the maximum grade in both taught courses and the Master's thesis). In cases of applications aimed at conducting research for a **Double Degree (DD)** or **Joint Degree (JD)** with one of the Partner Universities of the programme, the individual projects may have additional or more stringent requirements.

The candidates must, at the time of the recruitment, show transnational mobility (i.e. move from one country to another) by carrying out the research training activities in a country where they have not resided or carried out their main activity for more than 12 months in the 3 years immediately prior to the recruitment to the doctoral programme, in accordance with the mobility rule of the Marie Skłodowska-Curie COFUND action. Short stays, such as holidays, are not taken into account. The applicants that have stayed in Finland for more than 12 months during the prior 3 years must move to another country for majority of their research training

in order to be eligible for recruitment. Also researchers that are already permanently employed by the host organisation where the research training activities are planned to take place and that is recruiting them are not eligible. Furthermore, at the time of the recruitment, applicants must be in the firsts four years (full-time equivalent research experience) of their research careers and must not already hold a doctoral degree. This experience is measured from the date they obtained a degree formally entitling them to embark on a doctorate, either in the country in which the degree was obtained or in Finland. Career breaks due to parental leave or other justified reasons such as national military service or sick leave will extend this time and will not be a disadvantage in the application process.

All applicants must demonstrate that they possess English language skills that are sufficient to follow doctoral studies. For this, the applicant must provide official documents demonstrating one of the following (no other options are considered):

- The applicant has completed a Bachelor or Master degree taught in English;
- Certificate of English language proficiency from the Finnish National Board of Education (skill levels 5 in reading, writing, listening & speaking);
- TOEFL score (minimum 580 PBT / 92 IBT);
- IELTS score (minimum 6.5, with a minimum of 5.5 in each section; Academic module only);
- Pearson Test of English (minimum 62, with minimum of 52 in writing section; PTE Academic only);
- Cambridge ESOL's Certificate of Proficiency in English (CPE), or of Advanced English (CAE) (grades A, B, or C).

2. Application Process

The candidate must to **establish a contact with a prospective supervisor** associated with the I4Future research groups (see Section 7) prior to submitting an application. The supervisor, who is a professor adjunct-professor, or docent, or equivalent, must be clearly identified in the application form (full name, title, position, research unit and/or faculty at the University of Oulu). Applications must be submitted using the electronic submission system of the University of Oulu (See link in the General Call text).

2.1. Application

All applications must include:

1. A completed online "Application Form":
   The following documents must be attached to the online "Application Form" as single Portable Document Format (PDF) attachments (i.e. compiled into a total of 5 separate documents). Each attachment will have the following respective filenames: *I4Future-YourName-**CV***, *I4Future-YourName-**Diplomas***, *I4Future-YourName-**ResearchPlan***, *I4Future-YourName-**LetterOfReference***, *I4Future-YourName-**EthicsTable***. Replace "*YourName*" with your own last name (as in your passport).

   Warning: Incorrectly named attachments may not be processed correctly.

2. **CV** (Maximum size of the attachment: 5 Mbytes): Curriculum Vitae of the applicant, including a list of any peer-reviewed scientific publications (with full reference details). A recommended CV template can be found on the webpage of Finnish Advisory Board on Research Integrity.

3. **Certificates/Diplomas** (Maximum size limit of the attachment: 2 Mbytes): Scanned electronic copies of diplomas and transcripts of the records of relevant previous degrees and, if applicable, a valid certificate of language proficiency (see Section 1.3). If the original documents are not in English, Finnish or Swedish, each document must be accompanied by an official certified translation into English or Finnish. All of these documents must be compiled into a single Portable Document Format (PDF) file.

   For some degree-awarding countries there are country-specific document requirements in place. Please follow the country-specific requirements given in universityadmissions.fi in preparing your application, but send the documents directly to *I4Future* (see postal address in Section 8).

4. **Research plan** (Max. size 4 pages, 2 Mbytes): Including the title, background and significance, objectives and methods, time schedule, how the project relates to other activities in the host research group, motivation of the candidate to carry out the research, description how the project ties with interdisciplinary, inter-sectoral and international aspects of the programme, description how the issues raised in the ethical issues self-assessment of the project will be handled, and if relevant, any results that have already been achieved. A plan describing mobility during the project is seen positively, but is not obligatory in the application phase. Note that you need to discuss about the plan with your **proposed supervisor**.

5. **Letters of reference and recommendation** (Max. size of the attachment 2 Mbytes): A **letter of reference** from a senior scientist working in one of the UOULU research groups affiliated with the I4Future Doctoral Programme, and who is proposed as, and is interested in being, the applicant's Principal Supervisor, must be attached to the application. This letter will include justified recommendation for the recruitment of the applicant including a plan for supervision arrangements from one of the partner organisations. In addition **recommendation letters** from former supervisors and professors (maximum two) can be attached. All letters must be compiled into a single PDF document.

   Important: Unless explicitly stated in the letter of reference, the recommendation of the proposed supervisor does not bind the latter to any form of commitment in the event that the selection committee does not award the position for which the letter of reference was provided to the applicant. If the supervisor provides a letter of reference to more than one applicant, the supervisor may be asked later, during the selection process, to provide the selection committee with a justified ranking of the applicants.

6. **Ethics Self-Assessment Table**: A completed, signed and scanned *Ethics Self-Assessment Table* (Please find the table template in the I4Future webpage).

2.2. Application deadline

All application documents are to be submitted electronically, before the deadline on **Sunday, 31.7.2016, at 24.00 (midnight, Finnish local time, UTC + 3 hr)**. If an applicant submits more than one application for the positions, only the most recent submission before the deadline will be considered.

Applications received after the deadline, or incomplete applications, will not be considered.

2.3. After submission of application

The completeness of the applications and the **formal eligibility** of the applicants will be first verified by the Programme Administration working under the supervision of the Steering Committee. Those candidates that

are deemed ineligible will not be considered in the main evaluation process and will be promptly informed of the fact within one week of the deadline using email provided by the applicant in their application. After receiving a notification of ineligibility, the candidate has one week to send a written request for re-evaluation of their eligibility or to supplement their application with any of the missing obligatory documents as defined in the call. The Selection Committee will address these requests and re-evaluate the candidate's eligibility.

3. Selection Process

The selection process of I4Future doctoral programme will emphasise excellence of the candidates and quality of the research proposals. Equal opportunity practices concerning gender, race, nationality, and disability will be respected throughout the selection process and the doctoral programme.

3.1 Evaluation process

The main evaluation process of the candidates is a two-step procedure. The timetable and steps of the selection process are given in **Figure 1**. Each of the applications will first be assessed by three members of the Selection Committee whose experience is close to the research field proposed in the research plan but who are not named in the research plan as prospective supervisors. The members will evaluate and **score the applications** according to the evaluation criteria (given in Section 3.2) and write **short evaluation reports** that will be used by the Steering Committee to make the final decisions on the candidate selections.

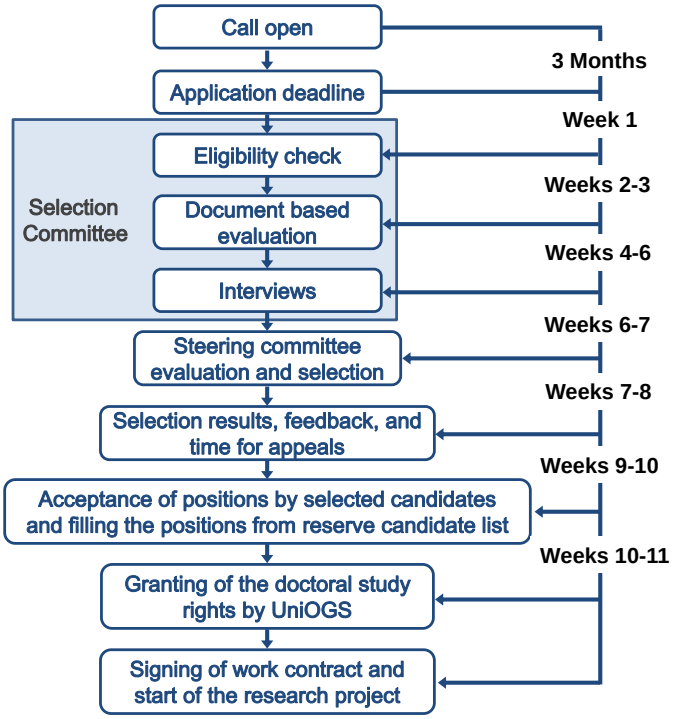

Figure 1. Selection process timetable

The applications will be given a score calculated as average of the score given by the Selection Committee members. The Selection Committee members will utilise external experts as advisors. If there is a significant discrepancy between the scores given by the members, they will be asked to discuss the application in question and agree on a new score. The applications, which achieve average score above the minimum threshold score 6 set for applications that can be chosen for the programme, will be ranked.

The **35 highest ranked** applicants will be **short-listed for interviews**. The short-listed applicants will be contacted to arrange a suitable time for an on-site, Skype or phone interview by the Selection Committee, which will be complemented by additional experts in the research fields if applicable. Based on the interviews and after discussing with the experts, the Selection Committee will score the interviews and give a short recommendation of the candidates to the Steering Committee.

The **Steering Committee will make the final ranking** of the candidates and **name the top 20 candidates** out of the short-listed candidates to whom the doctoral positions will be offered. The rest of the candidates on the short list will form a **reserve list** of candidates to whom the positions can be offered in the event of any of the higher ranked candidates being unable to accept the position offered to them.

The final acceptance of the doctoral candidates is subject to formal approval and granting of the doctoral study rights by the relevant Doctoral Training Committee (DTC) at UniOGS (i.e. DTC for Technology and Natural Sciences, for Health and Biosciences or for Human Sciences, depending on the scope of the planned

research project). This will verify the validity of the candidates' prior degrees for the doctoral training and ensure that their background education provides them with the major skills required to successfully carry out their doctoral studies.

3.2 Evaluation criteria

The applications for the doctoral programme will be evaluated on three main criteria, **quality of the applicant**, **quality of the research proposal** and **compatibility of the applicant with the host** as described in **Table 1**. Each of the main criteria will first be given a score between 1-10 by the Selection Committee members and the final score of the application will be calculated as a weighted average of the three main criteria, as shown in Table 1. The final score will be an unrounded number between 1 and 10. A minimum threshold score of 6 has been set for the applications that can be chosen for the programme, in order to maintain the quality of the programme.

The interviews can add maximum of two points to the final score of the candidates. In the final ranking of candidates with similar scores, the Steering Committee will take maintenance of gender balance and advancement of equal opportunities in the programme into consideration.

Table 1. Evaluation criteria to be used by the selection committee

Selection criteria	Weight	Points
Quality of the applicant - Prior education and qualifications judged by curriculum vitae - Grades obtained for the previous relevant degree(s) as demonstrated in the official transcript of records - Applicant's motive for research and further training - Applicant's possible publication record and research experience - Up to two letters of recommendation - Career plans of the candidate	50 %	1-10
Quality of the research proposal - Potential impact on the research field and associated fields - Originality of the approach - Embedding of interdisciplinary aspects in the project - Inter-sectoral exposure - International mobility plan aiming at DD or JD with an academic partner - Feasibility of the project in the proposed time	30 %	1-10
Compatibility of an applicant with the host - Letter of reference from the supervisor - Matching between candidate's profile and the research project, research project and partner organisation(s) of the programme	20 %	1-10

Evaluation score definitions are as follows: 1: Proposal fails to address criterion, 2: Poor, 3: Satisfactory, 4: Below average, 5: Average, 6: Above average, 7: Good, 8: Very good, 9: Excellent, and 10: Outstanding.

3.3 Selection results and feedback

The applicants will be informed of the outcome of the evaluation by email and by letter 7-8 weeks after the submission deadline. The selected candidates will be contacted and requested to confirm within 1-2 weeks whether they will accept the position. The reserve list candidates will be informed that they are on the list

and will be contacted about the final decision within 2-3 weeks. All applicants will receive a short feedback report summarising the evaluations.

The final list of successful candidates will be published on the I4Future and the University of Oulu Graduate School webpages.

Selected doctoral students are **expected to start their project no later than January, 31st 2017.**

3.4 Appeal procedure

After the applicants have received their evaluation reports they have one week to file a major complaint disagreeing with the evaluation. The Steering Committee will consider any complaints and decide if the candidate in question merits re-evaluation. Re-evaluation will be carried out by two experts who did not participate in the initial evaluation. Minor complaints, i.e. those that will not have any effect on the ranking of the top candidates, will not be considered.

3.5 Confidentiality and conflict of interest

The selection committee members are expected to be independent, unbiased, and objective and will sign an appointment letter, stating absence of conflict of interest and declaring confidentiality before beginning their work. The selection committee members are asked to inform the steering committee chair within two days of receiving candidates' applications of any known or potential conflict of interest. In case of such conflict, the application will be assigned to another member.

4. Ethical guidelines for the application process

University of Oulu and I4Future programme is committed to strictly following the fundamental ethics principles, including those reflected in the Charter of Fundamental Rights of the European Union, the relevant ethics guidelines of Horizon 2020, and national and European laws. The ethics principles include the need to ensure the freedom of research and the need to protect the physical and moral integrity of individuals and the welfare of animals.

The general principles and requirements on researchers and ethical guidelines, as defined in the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers, dictate that researchers should adhere to the recognised ethical practices and fundamental ethical principles appropriate to their discipline(s) as well as to ethical standards as documented in the different national, sectoral or institutional Codes of Ethics. As a prerequisite for being granted doctoral study rights at University of Oulu Graduate School (UniOGS), every applicant is required to respond to the following ethical considerations when they submit their application for doctoral study rights at UniOGS:

1. Will your research project involve experimentation on human subjects and/or their tissues or other samples, or the use of experimental animals?

2. Will your research involve the gathering, storage and/or use of personal information from human subjects which require an Ethics Committee statement?

3. If you answered "Yes" to one, or both, of the questions above: Has a statement been acquired, or applied for, from the relevant Ethics Committees? (List the acquired statements below, giving the name(s) of Ethics Committee(s), statement or decision number, and date of issuance.)

To ensure that the ethics principles are followed, but do not unnecessarily restrict the prospective candidates in drawing up their research plans and choosing their research fields the candidates are required to fill the

self-assessment table (see section 4.1) and attach it to their application. For the application to be successful any ethical issues raised by the self-assessment and measures taken to address them have to be described in the research plan. In case self-assessment uncovers any ethical issues the applicant should be in contact with the proposed supervisor. Supervisors will be responsible for giving guidance to the candidates on how to describe the ethics issues and on handling the ethics issues, as well as making sure all the required authorisations, licences, informed consents and notifications are in place and the proposed research activities comply with local law and EU directives.

4.1 Self-Assessment Table on Ethical Issues

RESEARCH ON HUMAN EMBRYO/FOETUS	YES	Page
Does the proposed research involve human embryonic stem cells (hESCs)?	☐	
Does the proposed research involve the use of human embryos?	☐	
Does the proposed research involve the use of human foetal tissues/cells?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	
RESERCH ON HUMANS	YES	Page
Does the proposed research involve human participants?	☐	
Are they volunteers for social or human sciences research?	☐	
Are they persons unable to give informed consent?	☐	
Are they vulnerable individuals or groups?	☐	
Are they children/minors?	☐	
Are they patients?	☐	
Are they healthy volunteers for medical studies?	☐	
Does the proposed research involve physical interventions on the study participants?	☐	
Does it involve invasive techniques?	☐	
Does it involve collection of biological samples?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	
RESEARCH ON HUMAN CELLS/TISSUES	YES	Page
Does the proposed research involve human cells or tissues (other than from human embryo/foetus)?	☐	
Are they available commercially?	☐	
Are they obtained within this project?	☐	
Are they obtained within another project?	☐	
Are they deposited in a biobank?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	
RESEARCH INVOLVING PERSONAL DATA	YES	Page
Does the proposed research involve personal data collection and/or processing?	☐	
Does it involve the collection and/or processing of sensitive personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	☐	
Does it involve processing of genetic information?	☐	
Does it involve tracking or observation of participants?	☐	
Does the proposed research involve further processing of previously collected personal data (secondary use)?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	

RESEARCH ON ANIMALS	YES	Page
Does the proposed research involve animals?	☐	
Are they vertebrates?	☐	
Are they non-human primates?	☐	
Are they genetically modified animals?	☐	
Are they cloned farm animals?	☐	
Are they endangered species?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	
RESEARCH INVOLVING NON-EU COUNTRIES	**YES**	**Page**
Does the proposed research involve non-EU countries?	☐	
Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	☐	
Do you plan to import any material from non-EU countries into the EU?	☐	
Do you plan to export any material from the EU to non-EU countries?	☐	
In case the research involves low and/or lower middle income countries are fair and equitable benefit-sharing measures foreseen?	☐	
Could the situation in the country put the individuals taking part in the research at risk?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	
ENVIRONMENT & HEALTH and SAFETY	**YES**	**Page**
Does the proposed research involve the use of elements that may cause harm to the environment, to animals or plants?	☐	
Does the proposed research deal with endangered fauna and/or flora and/or protected areas?	☐	
Does the proposed research involve the use of elements that may cause harm to humans including research staff?	☐	
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	☐	
DUAL USE OF RESEARCH RESULTS	**YES**	**Page**
Does the proposed research have the potential for military applications?	☐	
MISUSE OF RESEARCH RESULTS	**YES**	**Page**
Does the proposed research have the potential for malevolent/criminal/terrorist abuse?	☐	
OTHER ETHICS ISSUES	**YES**	**Page**
Are there any other ethics issues that should be taken into consideration? Please specify.	☐	
I confirm that I have taken into account all ethics issues described above and, that if any ethics issues apply, I will complete the ethics self-assessment and attach the required documents.	☒	

Note that following the rules of Horizon 2020 the programme cannot finance research activities aiming at human cloning for reproductive purposes, intended to modify the genetics of human beings that could make such changes heritable, or intended to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer.

With regard to the Human Embryonic Stem cells (hESC) related policy, reference is made to the current EC policy. Research on hESC may not start without the approvals of the EC ethics review and of the Horizon 2020 Programme Committee completed by the communication of the explicit approval in writing from the Research Executive Agency.

5. Appointment Conditions for Recruited Doctoral Students

University of Oulu has strong commitment to development of the research environment and the research career as testified by the **HR-Excellence in Research award** given by the EU Commission in 2014.

Doctoral students in I4Future doctoral programme will receive monthly salary that will cover their living expenses. The research costs including participation in workshops and conferences in the programme will be covered by the research groups the students will be joining.

5.1 Work contract

Selected doctoral students will be by default offered four-year fixed-term full-time employment contracts. The work contract may last until the student has completed a total of no more than four years of doctoral training (adjusted for possible part-time status prior to the start of the contract) from the date on which study rights are granted, and will include a trial period of four months. The salary of the selected doctoral students will be paid monthly. The gross salary (before taxes) for doctoral students enrolled in the programme will be 2 875 Euros / month for full-time employment. The employment contracts are based on total working time of 1600 hours per year, which gives the students freedom to plan their working hours. For doctoral students aiming for DD or JD projects with Partner Universities, an additional agreement will be signed between doctoral student, supervisors from each partner and legal representatives of each Partner University.

5.2 Social and health insurance and taxes

The work contract will entitle the doctoral students to the same preventive occupational health services, general medical care, maternity or parental leave options, children day-care services, and same standards of safety as those applicable to researchers holding a similar position, and will receive annual and sickness leave according to local law and internal rules of host organisations. For doctoral students staying with the partner universities of the programme the partner universities will ensure that the doctoral students will be covered under the social security legislation which is applied locally.

Doctoral students will pay tax from their remuneration to the country where they are mainly conducting their research. In Finland taxes are withheld from the remuneration according to the Finnish income taxation. In addition to taxes earnings-related pension and unemployment insurance premiums are also withheld from the remuneration.

5.3 Services provided by the host

Throughout the project the doctoral students will be provided with means, including the infrastructure, equipment and products for implementing the project in the scientific and technical fields concerned, and these are made available as necessary. This will include royalty-free access rights to background, foreground and any pre-background information required by the training activities.

Programme administration will support selected students with legal and administrative aspects (work permits etc.) to ensure smooth transition to Finland and start of their doctoral studies. Doctoral students hosted by partner universities will be helped by the partner university administration.

Student Housing Foundation of Northern Finland (PSOAS) organizes accommodation for students and employees of the University of Oulu. Some houses and apartments have income limits, but there are bigger apartments without any limits too. PSOAS has apartments all over Oulu. More information can be found at http://www.psoas.fi/en/. There are other options for housing available on the private market.

Additional support services are provided by International Services at UOULU, student activities in UOULU are organised by Student Union's Doctoral Students' Section, City of Oulu Guide, and City of Oulu services for foreigners are also available.

5.4 Related funding

Travel grants for conferences and international workshops will be available via University of Oulu Graduate School and the I4Future programme upon application.

5.5 Residence permits

Citizen of countries outside EU/EEA will need to apply for a right to residence as a researcher (and may need a VISA) before coming to Finland (for more info see www.migri.fi). Citizens of EU/EEA countries do not need a residence permit or visa but need to register for a right to reside in Finland at the local police station within three months of arrival. Regardless of their nationality everybody have to register at the local register office and apply for the Finnish personal ID code.

5.6 Responsibilities of the doctoral students in the programme

The employment contract to be signed between the doctoral student and UOULU will define the rights and obligations of each party. Doctoral students enrolled in the programme are expected to establish a **Personal Career Development Plan** with their supervisors, to devote their full working time to training and research activities, to commit to the completion of the degree within the four years of full study, to inform UOULU, as soon as possible, of circumstances likely to have effect on the performance of their doctoral student project (e.g. major change in the Personal Career Development Plan, a pregnancy or sickness that would have a direct effect on the implementation of doctoral study project), to keep confidential and not to disclose any information about an invention or work subject to copyright to a third party without permission from UOULU, and assist with the submission of any of the progress reports.

6. Support for Recruited Early-Stage Researchers

6.1. Training

Training for doctoral students enrolled in the I4Future programme will include the individual scientific training given under supervision and during the secondments by the companies and academic partners of the programme. This individually tailored doctoral training will include complementary training in transferable skills such as science communication and presentation skills, and project management and business skills through seminars, workshops, and conferences. The training and research of each doctoral student will be carried out in-line with the **Personal Career Development Plan** of the doctoral student, which will be formulated in agreement with the supervisor at the start of the doctoral student's training. The Personal Career Development Plan will be presented to student's Doctoral Training Follow-up Group, who recommends the approval to UniOGS, which formally approves the plan.

In addition to individually tailored training there will be common formal scientific training and transferable skills training included in the programme. Transferable skills training will give doctoral students a good concept of the innovation process and the roles of different players in the process. It will also help assessing the applicability of the scientific results for commercialisation; provide knowledge of the requirements and steps in commercialisation of the results, and the skills to establish a collaboration that can implement commercial utilisation of the research results.

6.2 Career development support

The mentoring and supervision activities and the activities described in the Personal Career Development Plan of each student are aimed at providing the doctoral students with the best tools for a successful research career. UniOGS offers a mentoring programme for doctoral students to increase their working life awareness, support their personal and professional growth, and help clarify how to exploit their doctoral degree in future working life.

6.3 Follow-up group and progress reports

Each doctoral student will have an individual Doctoral Training Follow-up group of specialists. The Follow-up group acts as an independent thesis advisory committee to support and monitor the progress of the individual student's doctoral training and career plans. The group gives constructive feedback on the research and studies. It also follows that the training is progressing according to the planned schedule and makes sure that the training environment and supervision of the doctoral student are appropriate in the context of the announced training plans.

The Follow-up group will convene at least annually where doctoral student presents his/her progress in the studies and discusses about the progress with the group. The members of the follow-up group are there also in other times to give support for the doctoral student with regards to their studies or career plans. To ensure impartiality and fairness of the follow-up group the members of the group will not be directly connected to the research of the doctoral student or the research group the doctoral student works in.

7. Research options & Partners in the Programme

7.1 Research Options and Expertise Offered by the Research Groups of the Programme

UOULU hosts expertise on state-of-the-art imaging and characterisation methodologies, which form the heart and **base of the I4Future programme**. The physics research group partners of the programme are experts in developing **synchrotron radiation-based spectroscopy and imaging** and possess a unique facility of potential access for the programme. The local **NMR infrastructures** and the world-leading experimental team have distinct expertise in developing magnetic resonance-based imaging methodologies, which are expected to provide standard tools for as yet unforeseen applications of the future. The **expertise** gained **in the dust and nanoparticles research** related to optical and spectroscopic characterisation experiments in the NASA space missions strengthen the data and image analysis excellence of the programme. Combined with the capabilities offered by the **leading machine vision group**, focusing on emerging innovative applications, a uniquely wide fundamental imaging and characterisation **methodology portfolio is available for the programme**. In the constant interplay with **theoretical** molecular materials research, a solid background for phenomenological understanding of materials in an interdisciplinary research programme benefiting from novel imaging and characterisation methods is also ensured.

The technically orientated **Engineering and Materials** focus area of the programme is provided through the UOULU key partner groups from **microelectronics** and **material physics,** as well as **optoelectronics** and **measurement technologies**. These provide great excellence in knowledge of synthesis of materials, their functionalisation and development for applications to create future technologies and make them available to the general public. Combined with the **process metallurgy group** and **environmental and chemical engineering group**, the best expertise of UOULU on the threshold of materials and molecular level knowledge will be disseminated to industrial applications. The existing collaborations and constant interactions with the many Partner Organisations in **metal processing, materials and electronics**

development, as well as **data handling and storage**, will ensure the quality of the research options in the focus area.

The **Environment and Bioeconomy** focus builds from the wide expertise of the plant and animal genetics and physiology group. They offer an extended dimension of research on **living organisms** from **cellular level** to the **epigenetic variations of trait breeding**. Grouped interdisciplinarily with the Biophysics group's expertise in **neural activity** from subcellular level to neural networks, they will generate a wide base for understanding the physiology of living matter. The group focusing on Fibre and particle engineering will directly extend the understanding of plant physiology on the biology side to the **bio-nanomaterials, fibres and composites** related to the novel pulp processes and sustainable cycle of products. The interplay with environmental science and chemical engineering fully connects basic biology knowledge to understanding of materials chemistry and its relation to structure and morphology. The research aims, from **wood and forest research** to **bioenergy** and **biocatalysis**, cover the European-scale key industrial partners, as well as widespread public organisations committing to **sustainability**. World-leading research is also being carried out on **atmospheric processes** with the novelty of molecular-level process understanding and this, in combination with the international network of the programme, elevates the programme status to the foremost level.

The **Medicine and Biosciences** focus area is one of the spearheads of the programme. The large and strong Academy of Finland **Centre of Excellence in Cell-Extracellular Matrix Research** hosts the best expertise on biology from model organisms to tissue and organ level. The research group on **structural enzymology** provides a direct link from molecular-level interactions to structural biology and biocatalysis of enzymes and complexes in lipid metabolism in humans. The highly accredited **osteoarthritis** research team has the aim of developing methodologies in understanding the interplay of **bone and cartilage** and combined with the **medical technology** development team with its novel technologies in medicine, ensures the inclusion of the full potential of medical understanding in the programme. The importance of exploiting the **full benefit** of unleashing the power of novel imaging and characterisation methodologies in **medical science and related industries is obvious.**

Synchrotron radiation (SR) is the ultimate tool for imaging and characterisation. Unique access to the world's brightest photon source, MAX IV, is provided for the I4Future programme by the Infrastructure Partner Organisation MAX IV laboratory and the current role of UOULU as national coordinator for the MAX IV partnership. SR-based characterisation techniques are immensely powerful tools with applications ranging from ***fundamental science to applied and industrial research***. Molecular and cluster physics, atmospheric chemistry, surface structures and nanomaterials research already takes place in SR facilities in ***close collaboration with life sciences and medical imaging***. The SR provides a radiation source 10^7-10^{10} times more intense than any conventional laboratory-based source. The radiation is continuously tuneable from infrared and visible light to 'hard' X-rays. The time scale (sub-picosecond) of the pulses provides an unparalleled means of investigating electronic transitions, chemical reactions and atomic structure changes in matter, while the ability to choose suitable light polarisation enables experiments that are impossible with any other sources. The extremely high stability of SR enhances the statistical significance, reliability, repeatability and measurement time tremendously.

The expected potential of the SR in novel areas can be seen for example in the rapidly growing community for ***forest and wood science***. In the I4Future programme the Fibre and Particle Engineering (FPE) research group is strongly expanding its research by exploiting the imaging and characterisation possibilities of novel SR sources. Tools such as small-angle X-ray scattering (SAXS), extended X-ray absorption fine structure (EXAFS) and scanning transmission X-ray microscopy (STXM) can provide novel approaches in morphological investigations and in structural analysis of biocomposites. The application of SR-based spectroscopic techniques established through the I4Future programme opens up a ***completely new***

door to gain ***insights into lignocellulosic*** materials, especially ***cellulose nanocrystals and -fibres***. The constant interplay through an ESR to Partner Organisations will build a ***direct link to benefits in enterprises at industrial scale***.

The power of the novel imaging ability of SR can also serve as a base for research linking genomic and epigenetic variations to the actual ***functional properties of wood*** products, i.e. hardness, tensile strength, durability. SR-based micro-computed tomography (μCT) imaging could provide novel prospects for such research, leading e.g. to future ***optimisation of tree breeding*** work and increased ***profitability and efficiency of forestry***. Such structural studies are of high interest for the biology researchers [Genetics and Physiology (GP) group] in shedding light on actual changes in wood structures caused by ***epigenetic effects***, i.e. environmental variations.

Radiation-induced photofragmentation of DNA and RNA sugars utilizing the latest coincidence spectroscopic tools demonstrate existing research directions.[1] The preliminary information gained in previous studies by the ***Nano and Molecular Systems*** (NANOMO**)** group opens up a new ***interdisciplinary*** research field inside the I4Future programme where participation of the ***Northern Ostrobothnia Hospital District*** (NOHD) provides a unique possibility to study and develop more ***localised and targeted cancer therapies***. These new therapies are expected to be based on Auger resonant decay and the recently identified intermolecular Coulombic decay (ICD) phenomenon. The ICD work, being a hot topic in fundamental physics research, would be ***applied directly and in an otherwise unachievably short time*** span to ***cancer patient treatment***. The X-rays produced at the MAX IV SR facility and the access to the intended medical MEDMAX beamline provide the ultimate tools for the research aims communicated through NOHD and NANOMO.

Operando measurements are another example of the emerging trends in characterisation of materials. In operando spectroscopy, for example, catalytic materials are characterised with multiple in-situ measurements in conditions (temperature, pressure, and matrix) corresponding to actual use. The methodology combines time-resolved measurements with IR, Raman, UV-Vis spectroscopies, mass spectrometry, and gas chromatography. The operando measurements open up a ***new complete insight into the catalytic processes***. The properties of catalytic materials are the main interest of the Environmental and Chemical Engineering (ECE) research group, offering operando methodology to the various interdisciplinary projects in the programme. The benefits can be used for example in determining the changes in material properties of nanoparticles, semiconductors [Microelectronics and materials (MIC) group] or composites [FPE group] in different conditions. The exploitation of **hyperspectral imaging** in the research projects of I4Future provides ***major opportunities for characterisation*** of biological and materials research samples and for developing ***process monitoring infrastructures***. The hyperspectral imaging allows high-throughput classification of samples for defect detection and chemical imaging of materials [e.g. Process metallurgy (ProMe), FPE, ECE and MIC]. In biomedical imaging [Centre of Excellence in Cell-Extracellular Matrix Research (CoE ECM)], hyperspectral imaging can be utilised for fast tissue analysis, e.g. for determination of cell collagen content.

The in-house development of novel spectroscopic and imaging techniques e.g. ultra-fast multi-dimensional Laplace NMR by the **Nuclear Magnetic Resonance** (NMR) research group, advanced **Optical Coherence Tomography** (OCT) by the Optoelectronics and Measurement Technologies (OPEM) group, and **Time-gated Raman spectroscopy** by the Circuits and Systems (CAS) group provides unique early adoption opportunities for these powerful ***non-invasive research methods*** in various interdisciplinary research projects of the I4Future programme. The improved acquisition times of the new NMR methods make it possible to investigate ***time-dependent processes***, e.g. polymerisation reactions or physical changes in phase transitions. This will open up new possibilities for groups studying material properties (MIC and FPE

[1] Ha, D. T.; Huels, M. A.; Huttula, M.; Urpelainen, S.; Kukk, E., *Phys. Rev. A* **2011**, *84*, 033419.

groups) and chemical processes (ECE group). Furthermore, the added chemical resolution in the new NMR methods allows experiments where ***transport of substances in and out of living cells*** is monitored (CoE ECM). OCT makes it possible to obtain e.g. cross-sectional images of sub-surface tissues with better resolution than in magnetic resonance imaging (MRI) (~10 μm) and provides the means to monitor dynamic changes in the sample. Methods utilising OCT are of ***high interest to the medical imaging*** community [CoE ECM, the Diagnostics of Osteoarthritis (DIOS), and the Medical Technology (MT) research groups]. NMR measurements for analysing ***water absorption in thermally modified pine wood*** [2] demonstrate the power of NMR as a non-invasive method for studying porous materials. The information obtained on the spatial distribution of absorption of free water and amount and distribution of bound water during thermal modification highlights the potential of the ***novel methods*** in various fields of research with ***bioeconomic and sustainability*** aims.

To make is feasible to perform analyses with modern imaging methods the Center for Machine Vision (CMV) Research has developed efficient **computer-aided image analysis methods** that are of the utmost value in combination with novel imaging methodologies. The methods utilised in segmenting images, recognising textures and following moving objects with unparalleled accuracy provide tools to ***fully explore the power*** of the ***novel imaging tools***. The methods can be utilised in an ***interdisciplinary and inter-sectoral*** way in research fields ranging from analysis of ***biomedical*** events and ***pre-clinical imaging*** to control of ***industrial processes*** and ***product quality management***. Furthermore, combination of hyperspectral imaging with efficient image analysis algorithms is believed to be an avenue for producing ***effective fingerprinting methods*** for materials and products. In addition to computer vision image analysis, image-based computational *in silico* modelling of phenomena and properties is one of the major future venues for using high-resolution image data. In an ***interdisciplinary collaboration*** between CMV and CoE ECM researchers at UOULU, methods have been developed for ***automatic tracking of individual proliferating cells*** in cell cultures. This task is very challenging due to the complex and changing shapes of cells, multifaceted cell-cell interactions and collisions between cells. In order to be useful, the cell segmentation and tracking methods have to be robust and computationally efficient. The methods developed have so far been applied to 2D tracking of cells in time-lapsed phase contrast microscopy images [3] and segmentation of cells with complex shapes from cell clusters in 3D confocal fluorescence microscopy images.[4] The methods can be applied, e.g. to quantitatively ***analyse the behaviour differences of tissue types at cellular level*** in classical "wound closure" assays. Extending the ***CFD modelling*** of the ECE group to study fine ***particle deposition in human lungs*** using accurate lung topology determined from high-resolution CT images is an example of a possible research project for an ESR. The concept would have a high probability of developing a ***powerful tool for analysing nanoparticle toxicity in the human respiratory system*** taking into account characteristic features of the particles. Further beyond-state-of-the-art possibilities have been identified in image-based modelling of parameters describing ***structural changes in bone*** occurring in an ***early state of osteoarthritis and osteoporosis*** and linking the observed changes to stress-strain distributions in the bone and eventually to increased risk of either cervical or trochanteric hip fractures.

To further demonstrate the proven capabilities of the programme partners in interdisciplinary and inter-sectoral research, a project on **process monitoring with optical emission** has been conducted. Collaboration between the ProMe and NANOMO research groups and Outokumpu Stainless Oy (steel manufacturing company) has resulted in an innovative way of ***monitoring on-line the process conditions in***

[2] Kekkonen, P. M.; Ylisassi, A.; Telkki, V.-V., *J. Phys. Chem. C* **2014**, *118*, 2146-2153.
[3] Kaakinen, M.; Huttunen, S.; Paavolainen, L.; Marjomäki, V.; Heikkilä, J.; Eklund, L., *J. Microsc.* **2014**, *253*, 65-78.
[4] Akram, S. U.; Kannala, J.; Kaakinen, M.; Eklund, L.; Heikkilä. J., Segmentation of Cells from Spinning Disk Confocal Images Using a Multi-stage Approach. In Cremers, D.; Reid, I.; Saito, H.; Yang, M.-H. (Eds.) *ACCV 2014 part III*, LNCS, vol. 9005, pp. 300-314. Springer: Heidelberg, **2015**.

industrial stainless steelmaking in an electric arc furnace (EAF) using optical emission spectroscopy.[5,6] A novel method for monitoring the EAF process was developed, due to the lack of any proper on-line data on an industrial-scale process. Real-time analysis will allow tight control of the EAF process, leading to ***increased sustainability in materials and energy usage***. The project demonstrated the feasibility of OES measurements for EAF process monitoring. The method is being ***commercialised*** by an UOULU spin-off company (Luxmet oy). Within the I4Future programme, further ***excellent opportunities*** in research are available in finding the limits of the OES method and extending the measurements to monitoring of other types of metallurgical processes and obtaining better fundamental understanding of reactions in metallurgical vessels.

Multimodal measurements are an example of inter-sectoral research inside the programme related to ***human physiology***. Multimodal brain imaging studies in particular can derive advantages from simultaneous measurements using different modalities to analyse correlations, mechanisms and relationships of physiological signals and their dynamics in relation ***to brain functions***. Moreover, multimodal measurements can help identify components of physiological dynamics generated specifically by the brain. For this purpose, a multimodal measurement setup for the MRI environment was developed during several years of close ***inter-sectoral cooperation*** between the ***OPEM group*** and the ***Oulu Functional Neuroimaging (OFNI)*** group based at ***Northern Ostrobothnia Hospital District (NOHD)***.[7] At Present, the setup consists of seven independent measurement and imaging modalities that can be used simultaneously and in synchrony.[8] Importantly, responses gathered with the different methods are not influenced by each other. Currently, the multimodal setup is being used on a weekly basis at NOHD. The design and construction of the setup were enabled by a combination of skills acquired by individuals with a background in physics, medicine and engineering. The beyond-state-of-the-art aims of a project of ***optical biopsy in cancer screening*** opens up a new concept in OPEM group and NOHD collaboration to establish a proof of concept on using the fundamental properties of light, namely circular polarisation, as a novel methodology for the diagnosis of cancer at the earliest stage and for determining the special characteristics and conditions of tissues and cells. The field is of the utmost importance, as cancer is one of ***the leading causes of mortality in EU*** member states and around the globe, accounting for 24% of all deaths in Europe.[9] Recent theoretical studies show that the helicity of backscattered circular polarised light depends on the anisotropy and/or on the size of scattering particles.[10] It has been also confirmed experimentally that the changes in anisotropy of scattering particles can be clearly observed by tracking the Stokes vector of circular polarised light on the Poincare sphere.[11] The feasibility studies have shown that circular and/or elliptical polarised light scattered within tissues is highly sensitive to the presence of cancer cells and their aggressiveness. In particular, it has been found that the position of the Stokes vector of scattered light on the Poincare sphere correlates with successive grades of colorectal cancer. An ESR researcher in the I4Future programme thus has ***unique possibilities*** to immediately begin developing the ***cancer screening methodologies of the future***.

[5] Aula, M.; Leppänen, A.; Roininen, J.; Heikkinen, E.-P.; Vallo, K.; Fabritius, T.; Huttula, M., *Metall. Mater. Trans.*, **2014**, *45B*, 839-849.
[6] Aula, M.; Mäkinen, A.; Leppänen, A.; Huttula, M.; Fabritius, T., *ISIJ International* **2015**, *55*, 1702-1710.
[7] Myllylä, T., *Multimodal biomedical measurement methods to study brain functions simultaneously with fMRI*, Doctoral thesis, Acta Univ. Oul. **2014**, C 497.
[8] Korhonen, V.; Hiltunen, T.; Myllylä, T.; Wang, X.; Kantola, J.; Nikkinen, J.; Zang, Y.; LeVan, P.; Kiviniemi, V., *Brain connect.* **2014**, *4*, 677-689.
[9] Organisation for Economic Co-operation and Development (OECD), Health at a Glance: Europe 2014, OECD Publishing.
[10] Kuzmin, V. L.; Meglinskii, I. V., *Opt. Spectrosc.* **2009**, *106*, 257-267.
[11] Macdonald, C.; Meglinskii, I., *Las. Phys. Lett.* **2011**, *8*, 324-328.

7.2 Host Research Groups in the Programme

Each student will require a letter of reference from a senior scientist/professor working in one of the research groups affiliated with I4Future doctoral programme. Further information of the research groups and list of supervisors can be found on the I4Future website: www.oulu.fi/I4Future. Contact emails: firstname.lastname@oulu.fi.

Nano and Molecular Systems (NANOMO) research group (Head: Prof. Marko Huttula)
Centre of Excellence in Cell-Extracellular Matrix Research(CoE ECM) (Head: Prof. Taina Pihlajaniemi)
Diagnostics of Osteoarthritis (DIOS) Research Group (Head: Assoc. Prof. Simo Saarakkala)
Medical Technology (MT) Research Group (Head: Prof. Timo Jämsä)
Structural Enzymology (SE) Research Group (Head: Prof. Rik Wierenga)
Center for Machine Vision (CMV) Research (Head: Prof. Matti Pietikäinen)
Nuclear Magnetic Resonance (NMR) Research Group (Head: Prof. Juha Vaara)
Theoretical Physics (TP) Research Group (Head: Prof. Matti Alatalo)
Biophysics (BP) Research Group (Head: Prof. Marko Huttula)
Environmental and Chemical Engineering (ECE) Research Group (Head: Prof. Riitta Keiski)
Fibre and Particle Engineering (FPE) Research Group (Head: Prof Mirja Illikainen)
Genetics and Physiology (GP) Research Group (Head Prof. Jouni Aspi)
Process Metallurgy (ProMe) Research Group (Head: Prof. Timo Fabritius)
Microelectronics and Materials Physics (MIC) Research Group (Head: Prof. Heli Jantunen)
Circuits and Systems (CAS) Research Group (Head: Prof. Juha Kostamovaara)
Optoelectronics and Measurement Technologies (OPEM) Research Group (Head: Prof. Igor Meglinski)
Solar System and Astronomy (SOLA) Research Group (Head: Juergen Schmidt)

7.3 Partner universities

Institute of Chemical Technology – Mumbai
Luleå University of Technology
Lund University
Soochow University
Ulm University
Université Pierre et Marie Curie
University of Gothenburg
University of Liverpool
Uppsala University
Charité – Universitätsmedizin Berlin

7.4 Private partner organisations

Detection Technology Oyj
Outotec Oyj
Philips Medical Systems MR
Planmeca Oy
UPM-Kymmene Corporation
Admescope Ltd.
Luxmet Ltd.
Rikola Ltd.
Sensapex Oy
SPECIM, spectral imaging Ltd.
Timegate Instruments Oy

7.5 Public partner organisations

Natural Resources Institute Finland
MAX IV Laboratory
Northern Ostrobothnia Hospital District
VTT Technical Research Centre of Finland Ltd.

8. Contact

In case of questions please contact us at: I4Future@oulu.fi

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