SUBMISSION FORM OF PROPOSALS FOR DOCTORAL RESEARCH PROJECTS

Objective of the Doctoral Programme in Health Sciences and Technologies

The objective of the new interdepartmental Doctoral Programme in Health Sciences and Technologies is to train the next generation of leaders in industrial, clinical, and academic research. Our goal is to develop an organic research programme at the interface between engineering and medicine, which is inspired by the quantitative and integrative approach of physical sciences, and by the latest development in biomedical research, drive the development and clinical translation of disruptive health technologies.
The doctoral training programme will prepare students in conducting research which:
- Extend the comprehension of how human physiology and pathology work in term of physical and chemical mechanisms, and how these mechanisms respond when perturbed by external factors such as therapies, changes in life style, and environmental factors;
- Develop new technologies that by leveraging on this mechanistic understanding pursue a wide spectrum of applications relevant to human health, including prevention, diagnosis, prognosis, treatment, and rehabilitation.

Procedural aspects on the submission of proposals for doctoral research projects

Every year the PhD process will start with the submission of proposals for doctoral research projects. Each proposal must be submitted jointly by two supervisors, one providing the clinical expertise, the other the technological expertise. The Project Selection Committee will select a number of projects that is three times the number of available scholarships and should be distributed in similar proportion between medical-led or technology-led proposals. The resulting list of projects will be included in the call for student applications that the Executive Committee will compile soon after. Each student, depending on their degree, will be able to apply only for a sub-set of projects; among them each student will be allowed to select three projects, and name them in order of preference; however, in some cases it might not be possible to satisfy all requests, and some students might be offered a research project different from those they selected.

Doctoral training program

In order to be admitted to the selection, a student needs a five-year higher education degree, which includes at least one module for each of the following disciplines: mathematics, physics, computer science, biology, physiology, and anatomy.

Max number of proposals for each member of the Academic Board: 3 (three)
Max number of selected projects for each member of the Academic Board: 2 (two)
Max number of selected projects for 2019: 12 (twelve)

Title of the project

Digital Twins for Smart Hospitals - Models, Architectures, Implementations

Student's degree (you can choose more than one, if needed)

Yes/Not	Cultural area
Not (necessarily)	Medicine, biology, or related disciplines
Yes	Engineering, physics, mathematics, computer science, chemistry, materials science or related disciplines

Student's skills (you can fill more than one field, if needed)

Cultural area	Skills

Medicine, biology, or related disciplines	
Engineering, physics, mathematics, computer science, chemistry, materials science or related disciplines	Computer Science and Engineering

Tutors (2, from different cultural areas and with at least 1 from the Academic Board)

Cultural area	Name & Surname	Department
Medicine, biology, or related disciplines	Dott. Vanni Agnoletti	Surgical and Trauma Department: Anesthesia and Intensive Care Unit (director), Cesena Hospital, AUSL Romagna Trauma Center (director)
Engineering, physics, mathematics, computer science, chemistry, materials science or related disciplines	Prof. Alessandro Ricci	Department of Computer Science and Engineering, DISI, University of Bologna

Research project

	Synthetic description
Summary (max 1000 chars)	**The research project is about investigating the application and extension of the Digital Twin concept - as recently used in Industry 4.0 - to clinical environments, as a blueprint for future smart hospitals and Hospitals 4.0. This calls for understanding and conceiving the information technology adopted in a Hospital as a socio-technical system providing both horizontal functionalities across the whole clinical environment (examples are tracking, planning) and vertical functionalities to support the specific daily work practice of the clinical staff, providing a seamless integration of digital technologies and the physical assets. A concrete case study (Bufalini Hospital) will be used to support both the analysis and the validation of the results. The expected results include open-source technologies, as prototype implementation of the Hospital Digital Twin.**

Objectives (max 1000 chars + max 5 relevant references)	**The objective of the project is the study and definition of a model and architecture of a "Digital Twin" for hospitals and clinical environments, as well as a prototype implementation. The concept of Digital Twin [1,2] is explored as blueprint to enhance the idea of "smart hospital" [3] and the Medical Internet of Things [4] towards a systemic/holistic approach. The objective is to envision a model and architecture for a Hospital 4.0, as complex socio-technical systems [5] where heterogeneous ICT technologies and software are pervasively used and integrated to augment the functionalities of the environment according to the need of different stakeholders and their activities in the care process, to support daily work as well as capacity/resource planning and management.** **[1] Michael E. Grieves. DIGITAL TWIN: Manufacturing Excellence through Virtual Factory Replication (LLC 2014)** **[2] Industry 4.0 and the digital twin - Manufacturing meets its match. Deloitte University Press. Deloitte series on Industry 4.0, digital manufacturing enterprises, and digital supply networks. 2017** **[3] Holzinger A., Röcker C., Ziefle M. (2015) From Smart Health to Smart Hospitals. In: Holzinger A., Röcker C., Ziefle M. (eds) Smart Health. Lecture Notes in Computer Science, vol 8700. Springer** **[4] S. M. Riazul Islam et al. The Internet of Things for Health Care: A Comprehensive Survey. IEEE Access, vol 3, p. 678 - 708. IEEE 2015** **[5] Gordon Baxter, Ian Sommerville. Socio-technical systems: From design methods to systems engineering. Interacting with Computers, Vol: 23 , Issue: 1, Jan. 2011.**

Rationale and scientific background y (max 2000 chars+ max 5 relevant references)	**Recent advances in ICT and digital technologies labelled under the "4.0" umbrella are triggering radical innovations inside enterprises and industries in different domains, in terms of smart environments, processes and management [1]. Healthcare and Hospital environments in particular are one the most challenging domains to innovate because of intrinsic complexities, as witnessed by research in Computer Supported Cooperative Systems and projects failed worldwide [2,3].** **Besides the adoption of ICT and software technologies to tackle and support specific assets, there is a clear need to adopt a more systemic viewpoint about digital technologies that considers the hospital as an organism-as-whole, yet composed by several heterogeneous autonomous interacting subsystems, with their own specificities. This need goes beyond interoperability problem: it calls for conceiving and designing hospitals as hybrid physical-digital environments, as socio-technical systems where the digital/computer-based services and functionalities are exploited in synergy with hospital physical assets to support the whole care process, assisting the clinical and management staff in both their daily activities and strategic planning.** **This research project aims at exploring the Digital Twin - or its extensions - as architectural blueprint to support that view, integrating different kinds of horizontal and vertical functionalities. Digital Twins have been first introduced as virtual replica of physical assets, updated by data in real-time, as a tool to simulate and analyse possible scenarios [4]. This view can be extended to consider the Digital Twin as the software augmentation of the physical asset, providing functionalities empowering the clinical staff in their daily work practice, as socio-technical mirror worlds [5].** **[1] Porter, Michael E., and James E. Heppelmann. "How Smart, Connected Products Are Transforming Companies." Harvard Business Review 93, no. 10 (October 2015): 97–114.** **[2] Robert Wachter. The Digital Doctor: Hope, Hype, and Harm at the Dawn of Medicine's Computer Age. McGraw-Hill Education. 2017** **[3] Geraldine Fitzpatrick and Gunnar Ellingsen. 2013. A Review of 25 Years of CSCW Research in Healthcare: Contributions, Challenges and Future Agendas. Comput. Supported Coop. Work 22, 4-6 (August 2013), 609-665.** **[4] Applying Simulation Modeling to the Hospital Environment. GE Healthcare Partners. White Paper. 2018** **https://uscan.gehealthcarepartners.com/insight-detail/applying-simulation-modeling-to-the-hospital-envir** **[5] David Gelernter. Mirror Worlds or the Day Software Puts the Universe in a Shoebox: How will it Happen and what it will Mean. Oxford University Press, Inc., New York, NY, USA.**
Preliminary results if existing (max 1000 chars+ max 5 relevant references)	**Preliminary results include the design and prototype development of systems for Trauma Tracking, to improve the accuracy and quality of documentation in Trauma resuscitation [1] and then exploiting the data for alerting [2].** **[1] S. Montagna, A. Croatti, A. Ricci, V. Agnoletti, V. Albarello and E. Gamberini. Real-time tracking and documentation in trauma management. Health Informatics Journal (to appear)** **[2] A. Croatti, S. Montagna, A. Ricci, E. Gamberini, V. Albarello and V. Agnoletti. A BDI-based personal assistant agent for trauma tracking and assistance. Artificial Intelligence in Medicine (In press).**

Research project including methodology (max 5000 chars)	**The objective of the project is the definition of a model of a Hospital Digital Twin, as well as a prototype implementation using a concrete Hospital as a case study (Bufalini Hospital, Cesena) and selected scenarios - e.g., Trauma Management, Operating Room Management.** **A main aim of the Hospital Digital Twin is to identify, factorise and provide "horizontal" digital functionalities across the whole hospital environment. An example is "tracking" [1]. Another example, which is layered upon tracking and data aggregation, is proper support for decision making and strategic planning, by means of e.g. simulations.** **Nevertheless, Hospital Digital Twin is meant to provide extreme flexibility to seamlessly integrate the digital layer on top of the physical one and the "vertical" needs of specific clinical contexts, according to an pervasive system perspective [2], enhancing the functionalities available to the clinical staff for tackling the complexity of their job, providing different levels of assistance.** **Methodology (sketch)** *** Analysis stage** **- Analysis of the literature** **-- state-of-the-art in CSCW in healthcare environments** **-- standards and infrastructures** **-- smart hospitals, pervasive healthcare systems** **-- Digital twin literature and pervasive computing systems** **- Analysis of the case study** **-- Bufalini Hospital in Cesena** **- Selection of the key representative scenarios, assets and functionalities to focus on** **-- examples: Trauma Tracking, Operating Room Management** **- Definition of the objectives and of the validation/evaluation criteria/ assets** *** Modeling, Design and Prototyping stage** **- Incremental/iterative definition of a model and design for an Hospital Digital Twin** **- Incremental/iterative prototyping of Hospital Digital Twin implementation, as open-source technologies** **- Incremental/iterative evaluation/validation upon the case study** **[1] S. Montagna, A. Croatti, A. Ricci, V. Agnoletti, V. Albarello and E. Gamberini. Real-time tracking and documentation in trauma management. Health Informatics Journal (to appear)** **[2] A. Mihailidis, J. E. Bardram. Pervasive Computing in Healthcare. CRC Press. 2006**
Innovation potential (scientific and/or technological) (max 1000 chars)	**Health Information Technologies** **1. Definition of a reusable model for an Hospital Digital Twin** **2. Open-source prototype implementation of the technology** **Medical side:** **1. Pervasive tracking (horizontal)** **a. to provide an integrated tracking functionality across all the clinical environment, enabling (big) accurate data aggregation for data analytics** **b. to exploit this data by means of simulation / analytics / machine learning based decision support tools** **2. ORM scenario (vertical)** **a. to build an Operating Room Governance structure, centered on data.** **b. to measure and better understand surgical activity (waiting list)**

Expected results and applications to human pathology and therapy (max 1000 chars)	**Medical side:** **1. to improve quality and safety in perioperative path** **2. to optimise surgical activity (improvement)** **3. to satisfy sustainability criteria of the healthcare system**

Available resources for the project

	Synthetic description
Research environment (labs involved, background, and location)	Nuovo Campus Cesena, PSLAB and Area 4.0 Lab Ospedale Bufalini Cesena - Trauma Center
Main equipment (facilities and location)	PSLAB and Area 4.0 technologies
Additional funding (title, amount, start date, duration)	T4C - Tracking for Care - 3-years project supported by AUSL Romagna and DISI Department - start date: before mid 2019.

International collaborations for the project (also in view of the Student's secondment)

	Project	**Location and team**
#1	Operating Room Management	Bassam Kadry, Stanford Healthcare
#2		
#3		