Proposer

Institution / Initiative	EPSRC-UKRI
Contact(s)	Michael Fisher [EPSRC / Univ. Manchester] via Rachel Lamb

Topic definition

Topic title	Self-Aware Autonomous Systems in Realistic Environments
Short description *(max ½ page)*	Modern complex systems, especially those expected to act independently in realistic and real-world environments, should be required to assess their own actions and capabilities and then manage and evolve this behaviour as needed. This is vital where there is no direct human control, either because of distance from the system (leading to communication delays and lack of situational awareness) or complexity of the target scenarios (too many independent elements, moving too fast, or acting unpredictably). In these autonomous systems, software must make key decisions, often of a critical nature. To do this effectively, the system must have a clear view of its state and its capabilities. The core aspect here is self-awareness. Self-awareness about a system's capabilities, about its condition, about its targets for action, about potential threats, etc. This allows us to step on from being able to make basic decisions or adapting internal behaviours, as developed in previous Self-* work, to providing transparency of both the activities of, and the reasons for taking any decisions within, a system. By endowing autonomous systems with new, and sophisticated elements of self-awareness, they will be able to make better, and more effective, decisions over a longer period, thus providing practical systems with stronger, and more reliable, routes to key requirements such as predictability, fault tolerance, efficiency, verifiability, explainability and sustainability. Each of these is measurable, though often in very different ways, and together they provide a route to analysing the effectiveness of these self-aware autonomous systems. In particular, the step to convincing technology regulators will require strong verifiability and clear explanations of decisions, both of which are fundamentally related to the transparency provided by sophisticated system self-awareness. REFS: ICSE Technical Briefing "Self-Adaptive Systems: Why, What and How to Engineer them?" https://2020.icse-conferences.org ; IEEE Special Issue on Self-Awareness in Autonomous Systems, 2020; https://ieeexplore.ieee.org/document/9120415
Application sectors	Complex systems with software having (autonomous) responsibility for practical, real-world, issues such as monitoring, health management, resource utilisation, resilience and recovery, and vehicles/robots that must make their own decisions and assess both capabilities and outcomes, e.g., domestic/healthcare robots, distant deep sea/space vehicles, robots within hazardous environments, etc. Since they are required to work effectively in realistic scenarios, any system that must be resilient, be required to cope with unanticipated failures or situations yet must still guarantee to achieve a range of critical functions in a timely and reliable manner. Compelling examples include robots or vehicles acting in disaster recovery, fire, or chemical hazards, or deep in the sea/space/earth, where self-awareness is essential to assess problems and recover from them.

Keywords	Self-awareness; Autonomy; Self-models; Predictability; Sustainability; Verifiability; Transparency; Trustworthiness; Resilience; Fault tolerance

Scientific interest and innovation potential of topic

The concepts of introspection, self-awareness and behaviour modification are increasingly being recognized as important for computer-based systems where software must make key decisions and maintain the system's capabilities without regular human intervention (i.e. autonomously). These complex systems must be able to assess, reason about, and modify their own behaviours based on new situations, especially as we cannot predict all scenarios a system may encounter or predict all failures that might occur, as is the case in real-world, or realistic, scenarios.

Relevant work has been carried out across diverse fields: in Adaptive/Pervasive Systems, where work on Self-* capabilities has a long history; and in Agents/Robotics, where key components of reliable autonomous behaviour have been defined. However, the tight decision boundaries for Self-* systems and the lack of dynamic self-awareness in deployed autonomous systems ensures that more research is needed not only within these areas but also in bringing the elements together in a novel way and in measuring the effectiveness of self-awareness. This will provide a significant step-change enabling autonomous self-awareness and ensuring reliable behaviour in practice over a long period of time and can have a significant and measurable impact on:

- System reliability and the ability to withstand failures and unexpected events;
- Transparency of systems and the increased trustworthiness and human understanding;
- Long-lived systems resilience and the reduced need for human interventions; and
- Regulatory approval and the increase in deployable systems.

These, in turn, provide a range of societal and economic benefits, for example in the trustworthiness and transparency of social and domestic robots, the self-sufficiency of systems so providing efficiency and convenience, the reliability of systems, so ensuring greater applicability, and the resilience of systems allowing deployment into more hazardous scenarios. The key step-change involved here requires us to develop systems with strong transparency, able to expose exactly what they are doing and why. Only with these capabilities will we allow systems to act in the truly autonomous manner required in complex, and unknown, scenarios. Compelling examples include robots or vehicles acting in disaster recovery, fire or chemical hazards, or deep in the sea/space/earth, where self-awareness is essential to assess problems and recover from them. A robot exploring a city after an earthquake will not only be looking for survivors but will need to assess its own functioning, potential failures, and risks of various acts.

Suitability of topic for a CHIST-ERA call

Research occurs in relevant areas across countries, for example: work on Self-* technologies [AT, BE, FR, IE, …]; work on advanced Robotics [CH, FR, TW, …]; work on Autonomous Agents [ES, IL, LU, UK…]; work on Software Engineering [CZ, FI, PL, …], etc. However, although elements of the research are spread across academic communities and countries, the need here is not only for further development but for novel approaches to bringing together these fields, to tackle real-world problems and to evaluate the effectiveness of this self-awareness.

While there are previous and ongoing calls, within CHIST-ERA (2010 call on autonomic systems and consciousness), across HorizonEurope (Trustworthy AI, Robotics, etc) and at national levels (for example, UK programmes: "Robots for a Safer World", "Trustworthy Autonomous Systems", etc) there is no specific focus on the transparent, reliable, verifiable, and practically effective self-awareness in sophisticated autonomous systems. Since some of the relevant research is available at national/community level, it is feasible to fund extensions in this research and, more importantly, research into new ways to coalesce the diverse, and currently distinct, research streams. For a relatively modest level of funding, we have an opportunity to make this step-change in the way a wide range of future practical systems might be constructed and deployed.

CHIST-ERA Call Topic Suggestion

Proposer

Institution / Initiative	Université libre de Bruxelles / Scheduling, Optimisation and Security
Contact(s)	Bernard Fortz (bernard.fortz@ulb.be) Joël Goossens (joel.goossens@ulb.be)

Robust and sustainable Industry 4.0 operations in critical applications

Introduction and motivation

With the emergence of Industry 4.0, companies are facing a digital transformation enabled by the deployment of sensors, digital twins and the availability of massive data streams collected in real-time. The predictive power of machine learning techniques have pushed further the potential usage of these data. However, the use of data is often limited to *descriptive and predictive analytics* techniques. Uncertainties in the global and dynamic environment, as highlighted by the recent pandemic, must be taken into account in the decision support process of Industry 4.0 companies.

This requires the use of new *prescriptive analytics* techniques: In a first stage, robust optimisation is concerned with long-term decisions in order to mitigate the impact of worst-cases scenarios. This usually also involves some recourse decisions to recover the solution when the actual scenario happening is known. Secondly, real-time re-optimisation of the production process to face critical events, with sustainability and scalability as a main target. These two combined aspects are rarely tackled together. Indeed, descriptive analytics has the function of *describing*, diagnosing, and discovering trends and patterns. Predictive analytics has the function of *predicting* events than can occur in the future. While prescriptive analytics has the function of *prescribing optimal actions* in particular to reduce the chance of an unwanted event based on the prediction.

Novelty

The novelty and originality of this call is threefold: (i) to consider a **dynamic** environment based on a (ii) **prescriptive** approach that will dictate actions and decision changes in **real-time** (avoid a problematic situation rather than solve it) in a (ii) **robust** manner for **critical** applications, where the unability to satisfy given constraints, due to the uncertain environment, can be catastrophic.

Challenges

Efficient and scalable algorithms combining artificial intelligence methods for prediction and high-end optimisation techniques will be a key ingredient to make the transition to Industry 4.0 efficient and sustainable. There is a real challenge for dynamic environments and critical sectors like chemical or pharmaceutical manufacturing.

Application sectors

All sectors of industry where data is prevalent (manufacturing, supply chain management, maintenance, telecommunications, IoT, transportation, ...)

Keywords

Prescriptive analytics, robust optimisation, sustainability, scalability, reliability, critical systems, machine learning, real-time data streaming, logistics, industry 4.0

Scientific interest and innovation potential of topic

- *Describe how the topic can support the exploration of bold ideas: for radically new technologies based on high-risk / high gain cutting-edge science*

  The topic requires bold ideas and techniques in order to have robust and effective solutions in dynamic and critical environments. It aims at the development of methodologies to implement the prescriptive analytics paradigm for dynamic and critical industry environments, by making adequate usage of the huge amount of data available today. For example, in the pharmaceutical or chemical sectors, there is clearly a high risk of having to adapt decisions and take new actions in real-time. Integrating robust optimisation and machine learning beyond a simple additions of techniques, by the development of new modeling tools and efficient algorithms, could lead to significant gains in terms of robustness, efficiency and sustainability in critical environments. This call can also be seen as a first step to integrate prescriptive analytics in even more risky/critical domains such as automotive, space and aviation.

  Current advances in robust optimisation usually consider a long-term planning horizon with two levels of decisions: long-term planning decisions that must be made in an uncertain context, and short-term recourse decisions that allow to improve or recover the long-term decisions when the scenario realisation is known. Such an approach needs a very heavy machinery, where machine learning can be used to define the uncertainty sets based on observed historical data, and optimisation techniques suffer from the very large size of the resulting model and therefore, from very high computation times needed to find a solution to the problem at hand.

  However, most critical system need a real-time response to unforseen events. This is usually handled through heuristic (online) re-optimisation. An avenue not explored so far is to combine fast, responsive methods in real-time to generate robust solutions by re-optimisation of a long-term planning model, and the adaptation in real-time of the uncertainty scenarios. If such methods can be developed, they would lead to breakthrough for the management of critical systems found e.g. in pharamaceutical or chemical industries.

- *Describe how knowledge and communities from different disciplines can be brought together*

  Prescriptive analytics for Industry 4.0 operations is in essence transdisciplinary. Its design requires complementary expertise in hardware, IoT, networking, real-time computing, optimisation, machine learning, and manufacturing to name a few.

- *Describe how scientific and technological performance can be objectively measured in the area (measurement methods, metrics, tools, infrastructures, ...)*

  Robust optimisation and real-time re-optimisation of the production process are quantifiable. The aim is to measure the improvements in operational KPIs such as lead-times, on-time-delivery, inventory, equipment efficiency, throughput and use of resources such as consumables, energy, waste... The ultimate goal is to enable efficient computation techniques to contribute to higher sustainability and lower footprint. In addition, for critical systems, it is necessary to measure the proportion of faults such as delays and violations of critical constraints (precedences, jitter, etc.).

- *Describe how research results can be transformed into innovations with societal or economic impact*

Estimates are that the EU has roughly 500000 manufacturing companies, representing about 15% of its GDP. Close to 90% of those companies are SMEs. The impact is impossible to quantify but is potentially very significant. Regarding the societal impact, optimisation tools (smart factory) should cover the use of raw materials, transportation of goods, and the carbon footprint in a sustainable way.

Suitability of topic for a CHIST-ERA call

Describe the need for transnational cooperation, complementarity with existing calls, and suitability of topic size (max 1/2 page)

- *Describe how transnational cooperation in the framework of a joint call can bring added value (complementary national scientific strengths, need for critical mass, need for joint infrastructures, . . .)*

  Transdisciplinary is inherently at at the heart of the project. Research in machine learning and optimisation across Europe is varied with regional focuses on different aspects of the methodologies. Similarly, industries are often focused on regional niches, and transnational collaboration is key to identify critical process across these industries and a global methodology. Moreover, methods must be scalable but also require huge computing power that would benefit from large clusters of computing infrastructure.

- *Describe closest calls (EIC Pathfinder, Horizon Europe, H2020, ERA-NETs, . . .) and how the topic complements and/or leverages them (the topic should not be redundant with other calls)*

  The topic will require extensive use of groundbreaking operational research techniques. It comes timely with the recent addition of "operational research" in descriptor PE1_20 of ERC, and fits with the newly added PE1_21 descriptor "Application of mathematics in industry and society". The closest calls are in H2020 programme 2.1 "INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies" but projects in this program focused on the development of the environment to gather data (IoT, sensors, . . .) and big data and machine learning technologies to process the data in a predicitive way. Prescriptive analytics and operational research techniques, when present, where just minor tools. This call makes a step forward to put prescriptive analytics at the center stage of the Industry 4.0 process.

- *Describe how a significant contribution in the area can be obtained with a call of a few M€, possibly giving indications about the size of the main events, initiatives or structures in the area (conferences, programmes, teams, centres, professional associations, . . .)*

  The call targets scientists in the fields of predictive and prescriptive analytics at large, i.e., machine learning and operational research specialists. The current trend in large yearly conferences in operational research organized by professional associations such as EURO and INFORMS is the presence of large streams of sessions dedicated to the cross-fertilization of data science techniques and optimisation. We can also mention CPS-IoT Week the premier event on Cyber-Physical Systems and Internet-of-Things. It brings together five top conferences. During the last editions we can see a clear interest in the application of machine learning techniques to Cyber-Physical Systems. These conferences (EURO, INFORMS, RTAS, ICCSP, CPS-IoT Week) are clear targets for the dissemination of results from the call selected projects. These conferences gather several thousands of participants. Inside these associations, some working groups are also focusing on the integration of machine learning with optimisation. This call goes one step further by focusing on the applicability of the methodological tools to Industry 4.0 critical processes, and to the development of high-end modeling and algorithmic tools. Given the growing community of researchers working at the intersection of machine learning and optimisation, the call could be the seed of a considerable leap forward in the development and adoption of efficient prescriptive analytics tools in the context of Industry 4.0.

References and links

- Advanced analytics for Industry 4.0
- Requirements towards optimizing analytics in industrial processes
- Tackling faults in the industry 4.0 era—a survey of machine-learning solutions and key aspects
- Data fusion and machine learning for industrial prognosis: Trends and perspectives towards Industry 4.0
- Machine learning and data mining in manufacturing
- Prescriptive analytics: Literature review and research challenges
- Industry 4.0, a revolution that requires technology and national strategies
- Industry 4.0-Driven Development of Optimization Algorithms: A Systematic Overview
- Data Analytics in Industry 4.0: A Survey
- Why prescriptive analytics and decision optimization are crucial
- Building an Industry 4.0 Analytics Platform Practical Challenges, Approaches and Future Research Directions
- Hentenryck, Pascal Van, and Russell Bent. "Online Stochastic Combinatorial Optimization." (2009).

Proposer

Institution / Initiative	Database Laboratory – University of A Coruña
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Topic definition

Topic title *(2-10 words)*	Multidimensional Geographic Information Systems (4DGIS)
Short description *(max ½ page)*	Research and development efforts in recent years have made geographic information systems (GIS) technology robust and widely consolidated. Furthermore, standardization and normalization efforts promoted by organizations such as ISO TC/211 and the Open Geospatial Consortium, and legislation such as EU's INSPIRE directive, have simplified the effort required to build GIS applications for certain application domains (e.g., land management and infrastructure). However, there are application domains for which the current state of the art GIS research does not provide effective solutions. The proliferation of GPS is allowing the massive collection of position data from moving targets that generates a Big Data of trajectories that is currently not properly stored, processed, exploited, and visualized due to the lack of adequate technology. Furthermore, current GIS technology does not fully support the problems posed in application domains where it is necessary to manage information in dimensions additional to the traditional two spatial dimensions. Some paradigmatic cases are the following: • Intelligent Transport Systems: ISO TC/204 defines requirements for 13 service domains that go beyond what the current state of the art provides (e.g., traveler information, traffic management, vehicle services, freight transport, public transport, emergency services, disaster response, etc.). This application domain requires support for storing, querying, analyzing and visualizing moving objects whose position changes frequently (e.g., public transport vehicles). • Maritime Spatial Planning: coordinating the use of marine and coastal spaces in order to balance competing uses and achieve sustainable development requires advanced support for the third spatial dimension because depth is highly relevant in marine spaces. • Climate Change: monitoring, assessing the current impact, predicting the future impacts, and evaluating the appropriateness of measures require to push forward the current frontier of knowledge in GIS to support climate modeling and prediction. This application domain requires advances both in the third

	spatial dimension (to model climate) and the temporal dimension (to support assessment and prediction of impacts). Therefore, funding is needed for research projects that advance technology in the areas of data collection, data model definition and implementation, efficient data structures for information representation, or software engineering for information systems development. Hence, a pan-European effort is needed to design and implement techniques and tools to support 4D geographic information (4DGI) in GIS. Moreover, international cooperation is required to define models for cross-border use cases such as mobility, maritime spatial planning, environmental monitoring, climate change, energy generation and many others
Application sectors	Given that what is needed is an enormous amount of basic research, we are not looking to solve problems in a specific sector. Since the entire research effort is oriented towards the storage, processing and exploitation of complex spatio-temporal (4D) data produced by different sectors, it will be necessary to approach these sectors to understand their needs, the type of data they generate and the processing they need. Thus, among the sectors that can most clearly benefit from this research, we can cite some important ones such as: transport, climate, marine management, air traffic management, logistics, robotics, autonomous driving, etc.
Keywords	spatio-temporal geographic information systems, data engineering, data science, artificial intelligence, data visualization, mobility management, maritime spatial planning

Scientific interest and innovation potential of topic

Describe the state-of-the-art, missing science, and expected outcomes (max 1/2 page). Comment on all items below:

Describe how the topic can support the exploration of bold ideas for radically new technologies based on high-risk / high gain cutting-edge science

Although there have been efforts in recent years to define data models, efficient data structures to store information, query languages, and visualization techniques for three-dimensional and temporal geographic information, these research efforts have not translated into advances in tools for the development of geographic information systems. It is necessary that the ideas proposed by the academic community be taken beyond controlled and limited case studies and address open problems of the productive sectors. Funding research in this field will allow the development of new technologies for the development of geographic information systems in the European context that can compete with stablished companies based in third countries.

In order to fully support geographic information considering three spatial and one temporal dimension (4DGI), complex research efforts must be carried out in several areas:

- Design of conceptual models that allow describing and querying 4DGI.
- Design and implementation of storage techniques and data structures for efficient querying of 4DGI.
- Definition and implementation of data engineering, data science and artificial intelligence techniques and technologies for processing 4DGI
- Definition of visualization techniques for 4DGI
- Implementation of new tools and extension of existing tools for 4DGI management.

- Creation of transnational working groups to address the effort of defining at a European level and in a comprehensive manner usage scenarios requiring the use of 4DGI.

The basic research carried out in these areas will allow for applied research in a number of highly relevant fields, such as:

- Spatio-temporal digital twins: improving digital twins with spatio-temporal knowledge and the ability to interact with the environment will improve fields like urban planning and management.
- Spatio-temporal artificial intelligence and machine learning: adding spatio-temporal information to artificial intelligence and machine learning with improve the results of existing tools and will open new fields of application.
- Spatio-temporal Robotics and Autonomous Systems. Even though robotics and autonomous systems are currently using spatial information, improving the capabilities of spatio-temporal information system will result in better outcomes in fields like agriculture or logistics.
- Spatio-temporal augmented reality and virtual reality. These technologies are changing the way we interact with the world and each other, adding spatio-temporal knowledge and functionalities will increase the fields where the technologies can be used.

Describe how knowledge and communities from different disciplines can be brought together

Research in this field must necessarily be multidisciplinary. The application sectors that would benefit from the inclusion of the third spatial dimension and the temporal dimension in GIS are numerous, so it is necessary that funded projects include multidisciplinary teams that provide the knowledge and specific needs of each sector. Intelligent transport systems is a domain that affects multiple sectors (public administrations, agriculture, logistics and transport, etc.) that must provide knowledge of the domain's problems. Similarly, the domain og Maritime Spatial Planning requires the participation of scientists from different disciplines, as well as experts from the different productive sectors related to marine activities. Finally, the Climate Change domain requires experts from different fields ranging from physicists to biologist and economists.

Describe how scientific and technological performance can be objectively measured in the area (measurement methods, metrics, tools, infrastructures, …)

Scientific performance can be evaluated measuring the number of high-quality publications in relevant journals and conferences. Technological performance in the area can be evaluated measuring the number of existing software artifacts related to the project objective (i.e., allowing the representation, querying and/or visualization of multidimensional geographic information), as well as the TRL of each one of them.

Describe how research results can be transformed into innovations with societal or economic impact

Since the objective of the topic is to improve the tools for GIS development in order to support new fields of application for which there are currently no solutions, the economic and social impact will be achieved by providing the productive sector with tools that allow them to create new applications that efficiently manage the information in their domains at a reduced cost.

Suitability of topic for a CHIST-ERA call

Describe the need for transnational cooperation, complementarity with existing calls, and suitability of topic size (max *<u>1/2 page</u>*).

<u>Comment on all items below:</u>

- *Describe how transnational cooperation in the framework of a joint call can bring added value (complementary national scientific strengths, need for critical mass, need for joint infrastructures, …)*

Transnational cooperation has proven to be highly effective in other initiatives related to geographic information (e.g., the inspire initiative has been an important step forward in the field of geographic information exchange between public administrations). The target sectors of this topic (among others, those related to mobility and maritime planning) have a high need for cross-border collaboration as the problems faced (vehicle mobility and marine environment information) are highly permeable to borders.

Just as the INSPIRE European Directive (Directive 2007/2/EC) and the work carried out by its working groups represented a significant advance in geographic information system technologies and in the implementation of spatial data infrastructures (see https://inspire.ec.europa.eu/), financing projects in the field of 4DGI will represent a significant advance in technology to support transnational application domains in the EU (mobility, marine environment management, climate change, etc.).

- *Describe closest calls (EIC Pathfinder, Horizon Europe, H2020, ERA-NETs, …) and how the topic complements and/or leverages them (the topic should not be redundant with other calls)*

There are currently no planned calls to address this issue. However, the results of this topic, due to its cross-cutting nature, would be applicable to many of the open challenges in the Horizon Europe program.

- *Describe how a significant contribution in the area can be obtained with a call of a few M€, possibly giving indications about the size of the main events, initiatives or structures in the area (conferences, programmes, teams, centres, professional associations, …)*

Considering that this topic focuses on the development of innovative software, a call of a few M€ can yield significant results because the funding can be invested in activities that allow building a network to collaborate, and salaries of software engineers to develop novel technology.

The area of geographic information systems is widely implemented in Europe, reflected in the existence of research laboratory partnerships (AGILE, https://agile-online.org/) and cross-border inter-university masters (e.g., https://mastergeotech.info/), and the high implementation of the INSPIRE initiative and spatial data infrastructures. Moreover, there are scientific congresses dedicated to geographic information (ACM SIGSPATIAL), as well as dedicated tracks in more generalist congresses (VLDB, SIGMOD).

CHIST-ERA Call 2023
Topic suggestion

Please send this form back to era-ict@aei.gob.es

Proposer

Institution / Initiative	University College London (EPSRC)
Contact(s)	c.masouros@ucl.ac.uk

Topic definition

Topic title *(2-10 words)*	Integrating Sensing and Communication in Future Wireless Networks
Short description *(max ½ page)*	With the release of traditional radar frequencies for commercial communications, interference to critical radar systems is on the rise. This caused major disruption already in early 2022 when US airlines would halt their aircrafts in fears of 5G interference to their radar navigation systems. There is rising research interest in technologies to enable the spectrum coexistence between remote sensing and communications. As a further step, initial research is on the way towards integrating communications and radar/sensing technologies to move from their competitive coexistence to their co-design. This is particularly timely, as the expansion of small dense cells in commercial communications, offers profound opportunities to enable pervasive sensing through the cellular infrastructure. This would underpin key emerging technologies, from connected cars, to smart city security, infrastructure monitoring, localisation, among many others. New approaches ranging from signal design, transceivers, all the way to cellular systems redesign tailored to integrated sensing and communications (ISAC).
Application sectors	ICT, smart cities, cellular communications, security, infrastructure monitoring, connected cars
Keywords	Wireless Communications, radar, communications-radar spectrum co-existence, integrated sensing and communications (ISAC), signal processing, RF engineering, wireless network

Scientific interest and innovation potential of topic

Describe the state-of-the-art, missing science, and expected outcomes (around 1/2 page).

- *Describe how the topic can support the exploration of bold ideas for radically new technologies based on high-risk / high gain cutting-edge science*
- *Describe how knowledge and communities from different disciplines can be brought*
- *Describe how research results can be transformed into innovations with societal or economic impact*

For decades communication systems and radar systems have been developed independently. With the growing applications requiring a mix of sensing and communications, such as infrastructure monitoring and security, intelligent mobility, at-home healthcare, the demand for the - already scarce - resources of spectrum, energy and hardware are on the rise. The independent growth of radar and communication systems is not sustainable and will lead to a congestion of devises, emitters and sensors. A new generation of technology tailored for Dual-Functional Radar and Communications systems is needed to address the growing demand for both functionalities. This necessitates the convergence of the two, currently disjoint, disciplines of Radar and Communications research, to address the technological challenges. Key challenges include DFRC waveform and transceiver design, managing interference, resilience to practical hardware, and security.

This research clearly demands inter-disciplinary research, bridging the gap between the research communities of Wireless Communications, Radar Systems and Sensing technologies. Research is required in multiple realms spanning from antenna and transceiver design, signal processing to network level design. Developments in this area would also inform associated disciplines in Free-Space Optical Communications and Lidar. Research in Sensor Networks, Satellite Communications and Remote Sensing would further benefit from this research.

The outputs of the technological advancements in the area could span theoretical research on fundamental limits, signal processing, antenna and RF design, experimentation among others that already communication-only systems involve, redesigning these for the paradigm of communications-and-sensing. Accordingly there is a wide range of measurable objectives; examples include joint radar-communication performance metrics in terms of joint detection probability and data rates, experimental demonstrations of the concept of ISAC, real world benefits in the associated applications of connected cars, safe smart cities among many others.

There are real every day applications associated, such as smart mobility, urban security, remote healthcare among others, that rely on a combination of high accuracy sensing and resilient communications, and with immediate implications on the quality of life of EU citizens. Impact could result from the adoption of such technologies from commercial players such as wireless network operators, device manufacturers, car industries, healthcare stakeholders. Impact can be measured in numbers of start-up activities, market enhancements, and improvement of quality of life.

Suitability for a CHIST-ERA call

Describe the need for transnational cooperation, complementarity with existing calls, and suitability of topic size (around 1/2 page)

- *Describe how transnational cooperation in the framework of a joint call can bring added value (complementary national scientific strengths, need for critical mass, need for joint infrastructures, …)*
- *Describe closest calls (EIC Pathfinder, Horizon Europe, H2020, ERA-NETs, …) and how the topic complements and/or leverages them (the topic should not be redundant with other calls)*
- *Describe how a significant contribution in the area can be obtained with a call of a few M€, possibly giving indications about the size of the main events, initiatives or structures in the area (conferences, programmes, teams, centres, professional associations, …).*

Researchers in wireless communications and those on radar largely work isolated from each other. ISAC requires to break the siloes in the research and also train communication engineers on sensing, radar engineers on communications. There is a need for a new generation of experts in the cross-domain of communications and radar systems. CHIST-ERA level cooperation would increase visibility and awareness of the above needs and ultimately the adoption of the developed technologies.

While there have been traditionally many calls on wireless networks, and a few recent calls on 6G system design (6G-SNS) where sensing as a service has also been identified among other topics, there has been nothing specific on ISAC to gather the academic and research community on this focused topic. There is a clear gap in the funding landscape for this timely and important technology.

The above demands in cross-disciplinary collaboration, cross-disciplinary fertilization of ideas and acquisition of cross-domain skills, mean that a funding initiative on the topic would have significant and long term impact in kicking-off focused research in the area, and producing a new generation of experts to innovate in ISAC for the next generations of cellular networks.

Novelty: While wireless communication calls and remote sensing calls have been the focus of previous CHIST-ERA activity, their integration in the form of systems that can provide both sensing and communication functionalities simultaneously has not been explored in any previous CHIST-ERA call (past years' calls can be found here). Despite some recent calls such as 6G-SNS covering sensing as a service, the area of ISAC is largely unexplored, and importantly the radar sensing and wireless communication communities are still largely working in isolation to date. There is definitely wide scope for research in ISAC which is now at its birth.

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Proposer

Institution / Initiative	Universidad de Sevilla
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Topic definition

Topic title *(2-10 words)*	Intelligent Contracts for Digital Transformation Ecosystems
Short description *(max ½ page)*	The ability of the computational part of an information system to self-adapt to changes in data sources and to take full advantage of the capabilities of its human component is central to software and services science and engineering. However, despite decades of research, such abilities remain limited in practice in the field of digital transformation, more specifically in the automatic processing of contracts governing the use and provision of digital service chains. The main limiting factors lie in the processing and analysis, both manual and automatic, of the contracts and the legislation that govern them. Both are unstructured data sources whose content changes frequently and is highly case-dependent. A new approach is needed that addresses the problem from a more holistic, threefold perspective, namely: 1) from the current notion of contract as a static document to a new notion of intelligent contract as dynamic and machine-readable, 2) to transition to a new type of ecosystem that adapts to changes in i-contracts with minimal human intervention, and 3) new ecosystems endowed with co-evolutionary hybrid intelligence so that both their human and computational parts evolve without friction and taking advantage of the synergies available at any given moment.
Application sectors	All application sectors of digital transformation, especially in public administrations (at all levels: regional, national and international), and smart cities.
Keywords	Digital transformation, digital services, intelligent contracts, hybrid intelligence, coevolution, self-adaptation, model-driven development, service engineering, knowledge graphs, natural language processing, blockchain, information technology law

Scientific interest and innovation potential of topic

Describe the state-of-the-art, missing science, and expected outcomes (max 1/2 page).

Comment on all items below:

- *Describe how the topic can support the exploration of bold ideas for radically new technologies based on high-risk / high gain cutting-edge science*

Service chains have led to digital services being seen not as isolated silos, but as part of a growing ecosystem of co-dependent organizational systems that must interoperate seamlessly to foster a more efficient and responsible digital transformation. The ideas explored in this topic will lead to service chains currently unimaginable. Intelligent contracts (i-contracts) will pave the way for self-adaptive hybrid ecosystems, i.e., ecosystems where the software components that interact with the i-contracts modify their behavior according to the content of the contracts and regulations on which they depend on minimal human intervention, ideally with the minimum that must be maintained for legal reasons. In other words, "the software adapts to the contract and not the contract to the software." Likewise, coevolving hybrid intelligence will ensure that the service chain's degree of automation, efficiency, and reliability increases as the service chain operates. This topic encourages a much-needed methodological change in a field that is ripe for it and would open up possibilities that, when available, will be in high demand.

- *Describe how knowledge and communities from different disciplines can be brought together*

The problems of self-adaptation and coevolution of hybrid ecosystems (computational and human components) and how to deal with i-contracts are far from being solved. Advances in artificial intelligence (e.g., natural language processing, knowledge graphs, automatic reasoning, hybrid intelligence), software engineering (model-driven engineering and autonomic computing), and distributed systems (e.g. digital services, blockchain) that could be applied to this problem have hardly been explored in the field of digital transformation and even less jointly. However, bringing together the knowledge of these three disciplines is strictly necessary to materialize the vision of this topic. But not only experts in these different areas of computer science will be needed, but also experts from other areas such as administrative and information technology law. For example, the ability to interpret contracts by machines enables the improvement of accountability through the tamper-proof monitoring of contract fulfilment, which might require the involvement of legal specialists to devise legally valid solutions.

- *Describe how scientific and technological performance can be objectively measured in the area (measurement methods, metrics, tools, infrastructures, …)*

By construction, a major goal of the topic is to develop techniques to reduce the time needed (ideally eliminate) to interpret i-contracts and to adapt a digital service chain to changes in contracts for any of its services. Performance could be evaluated by computing metrics like percentage, i.e., coverage level, of a contract that was automated, or time needed by humans to answer questions about the content of the contract and response error rate (e.g., what has changed in the latest version of the contract? What would it cost to cancel the contract if I were to request it tomorrow?), about the chain as a whole (e.g. how much would the end-to-end cost of the chain increase if the price of one of its services increased?) and the time needed to make modifications to the software due to changes in the contracts (e.g., to adapt to new penalty clauses for non-compliance with the service level, to adapt to new consumption capacity limits).

- *Describe how research results can be transformed into innovations with societal or economic impact*

Having systems that automatically answer any question that may arise about a contract or a chain of contracts opens the door to highly innovative solutions that will reduce development and operating costs but, above all, will encourage the development of intelligent assistants (bots) for critical activities (e.g., decision making and auditing tasks). These bots will evolve over time based on their own artificial learning model and rules that can be manually incorporated by humans. They will obtain new and explainable knowledge, which previously did not exist and was not available to humans. This knowledge, once validated and supervised, will become part of the ecosystem's knowledge base. As for the societal impact, having these i-contracts in place would bring the undoubted impact that more efficient use of public resources has. In addition, it could also impact on on the line of guaranteeing the right to full transparency and accountability in any process of political participation carried out by technological means.

Suitability of topic for a CHIST-ERA call

Describe the need for transnational cooperation, complementarity with existing calls, and suitability of topic size (max 1/2 page).

Comment on all items below:

- *Describe how transnational cooperation in the framework of a joint call can bring added value (complementary national scientific strengths, need for critical mass, need for joint infrastructures, …)*

This topic encourages the exploration of cutting-edge technology from at least three disciplines (9 communities) from computer science plus one more from IT Law. This fact strongly recommends the launching of several projects in a joint call for several reasons: 1) the number of scientific communities involved would attract teams whose synergy will undoubtedly be of transnational interest, 2) for each challenge to be addressed, it would be advisable to launch several projects and 3) there is an urgent need for data sets and benchmarks of contracts and digital chains. Furthermore, implementing the projects at the CHIST-ERA level brings additional benefits in terms of visibility and adoption, mainly because contracts in different countries may differ from each other due to differences in regulations or legal culture, and all these differences must be considered when developing software for interpretation and analysis of i-contracts.

- *Describe closest calls (EIC Pathfinder, Horizon Europe, H2020, ERA-NETs, …) and how the topic complements and/or leverages them (the topic should not be redundant with other calls)*

This topic is related to the Horizon Europe's Call "World leading data and computing technologies" (Technologies for data management), complemented for a specific scenario, the digital transformation, which requires several enabling technologies not explored in this call.

- *Describe how a significant contribution in the area can be obtained with a call of a few M€, possibly giving indications about the size of the main events, initiatives or structures in the area (conferences, programmes, teams, centres, professional associations, …)*

These notions of i-contracts and self-adaptive ecosystems with coevolving hybrid intelligence in digital transformation are highly novel and can have a relevant impact. A few projects can thus make a significant difference for the topic and will promote and promote seminars and workshops at major conferences in related disciplines.

Proposer

Institution / Initiative	NCN
Contact(s)	Robert Nowak robert.nowak@pw.edu.pl

Topic definition

Topic title *(2-10 words)*	Artificial Intelligence for medicine (focus on trustworthy AI and standardisation)
Short description *(max ½ page)*	Present-day medicine relies more and more on the support of various computer systems. Especially in the field of surgery, in preoperative planning, the procedure itself, and follow-up evaluation, the decision support systems are starting to be essential, if not crucial. Endoscopic, laparoscopic surgery (ELS) is a minimally invasive, extended-port surgical approach for the treatment of specific conditions in the abdominal cavity. Recently, there has been a significant push towards artificial intelligence-based trackers for image-guided systems that incorporate real-time visual overlays of 3D models during surgery to improve surgeon perception during laparoscopic procedures. To meet the demand of the medical field for new supporting techniques, we need to develop systems that understand specific medical data, contain required knowledge, and provide excellent results. Solutions must deal with data that often is multimodal and multidimensional. For example, colour-coded volumetric diagnostic data registered in time. The AI models are complex, and in medicine, especially in surgeon support, it should guarantee a high level of reliability. New methods and tools to measure reliability should be proposed. Such tools return the reliability of complex AI systems depicted above. The tasks in such systems include new database creation, database integration, explainable AI systems creation, standardisation procedures design, and implementation. The standardisation procedures should include visual analysis, signal analysis, artifact detection, segmentation, and generalized object detection measurements. REFERENCES: High-Level Expert Group - Artificial Intelligence, Trustworthy AI, Policy and Investment Recommendations for Trustworthy Artificial Intelligence, 2019
Application sectors	ICT / Clinical medicine / surgical medicine / health
Keywords	Artificial Intelligence, standarisation, thrustworthly AI, augmented reality, deep learning, deep neural networks, decision support system, visualisation, 3D, image tracking

Scientific interest and innovation potential of topic

Describe the state-of-the-art, missing science, and expected outcomes (max 1/2 page).

Comment on all items below:

- *Describe how the topic can support the exploration of bold ideas for radically new technologies based on high-risk / high gain cutting-edge science*

Recently, AI and Augmented reality (AR)-based intra-surgical navigation systems have been increasingly introduced for facial contouring, maxillofacial surgery, bone tumour resection, neurosurgery and so on. It is very acceptable for physicians to enjoy any benefit by applying augmented reality to the clinical workflow without changing the environment too much. It is expected to develop more and more advanced tracking algorithms to support AR systems to provide precise navigation for maxillofacial surgery & other intricate areas like spine surgery. The reconstructed 3D model could be superimposed onto the real environment or anatomy of the patient for effective perception & planning. AI algorithms could provide such methods with high accuracy.

On the other hand, there are no standardization procedures in this field. Therefore there are no standard benchmark databases, standard measurement procedures, etc., to guarantee a high level of reliability of AI support systems. This gap is addressed in this project.

- *Describe how knowledge and communities from different disciplines can be brought together*

This solution requires the expertise of AI engineers, augmented reality researchers, health experts, data scientists, artificial intelligence and machine learning experts and automatic control scientists. At the same time, surgeons, AI specialists, and certification experts are desired to achieve a holistic solution.

To build systems that are safe for people, standardisation procedures should be proposed, and methods and tools should be built to measure AI systems reliability in the medical support area. The results should be acceptable to patients. Therefore psychologists, social scientists, and certification experts will be desired.

- *Describe how scientific and technological performance can be objectively measured in the area (measurement methods, metrics, tools, infrastructures, …)*

The efficiency and safety of novel technologies that can be used in surgery must be assessed using multiple criteria. Computer systems used in medicine are expected to meet very high standards. In particular, decision support systems must guarantee patient safety. They must be efficient and reliable. On the other hand, when decisions are often made online, they must be very efficient due to the use of large amounts of data for calculations. The standards here are essential.

- *Describe how research results can be transformed into innovations with societal or economic impact*

In modern societies, the health of citizens is priceless. It has a significant impact on the level of the country's economy. The complex ICT systems supporting medical doctors decision are common, because training medical personnel is expensive. There is a constant shortage of doctors, especially specialists in surgical medicine. Modern decision support systems make it possible to shorten the time of operations and reduce the number of operating doctors and support staff, as well as the cost of operations. For example, as a diagnostic tool, the simulated 3D reconstruction of organs based on radiological data can provide a more naturalistic view of a patient's appearance and anatomy. Preoperative surgical planning can give a more realistic outcome prediction, especially in craniofacial and aesthetic surgery. Computerised 3D atlases of human anatomy, physiology, and pathology can provide better learning and training systems for plastic and reconstructive surgery. Intraoperative navigation reduces the possibility of significant complications and increases the potential for the best surgical results.

The supporting ICT systems should be certificated in the future using proper standardization procedures, tools, and methods to guarantee the quality of its results.

Suitability of topic for a CHIST-ERA call

Describe the need for transnational cooperation, complementarity with existing calls, and suitability of topic size (max 1/2 page).

Comment on all items below:

- *Describe how transnational cooperation in the framework of a joint call can bring added value (complementary national scientific strengths, need for critical mass, need for joint infrastructures, …)*

Each EU country currently builds its ICT systems to support medical doctors' decisions, and there is a significant need for EU standards for the quality of AI decision systems. Such standards will shorten the development time of new IT systems to support surgeons, speed up, and accelerate their verification. It will be possible to produce stable, reliable, safe tools and systems for modern medicine. It should be noted that within the European Union, IT systems are expected to unify and meet the required standards.

Transnational cooperation is essential. It will allow the exchange of experience, and rapid knowledge transfer will accelerate the work on innovative solutions. The collaboration of teams of scientists and practitioners will be more effective.

- *Describe closest calls (EIC Pathfinder, Horizon Europe, H2020, ERA-NETs, …) and how the topic complements and/or leverages them (the topic should not be redundant with other calls)*

The AI Uptake in Health and Healthcare 2020 calls are already underway. However, the standardisation is not included directly, and there is still a gap regarding the dedicated topics in AI-supported AR solutions in surgery.

Medical technologies, Digital tools, and Artificial Intelligence (AI) analytics to improve surveillance and care at high Technology Readiness Levels (TRL), were focused on COVID-19 detection tools.

Beyond the horizon call: A human-friendly deployment of artificial intelligence and related technologies is focused on explainability and model biases.

H2020, Industrial leadership in ICT has several projects, e.g., empowering next-generation media creation, enrichment, and distribution where the need for standardisation is noticed.

- *Describe how a significant contribution in the area can be obtained with a call of a few M€, possibly giving indications about the size of the main events, initiatives or structures in the area (conferences, programmes, teams, centres, professional associations, …)*

Experienced researchers from European countries should conduct the projects, and teams of IT engineers and medical doctors, have the potential to significantly advance this topic.

There are no previous and ongoing calls, within CHIST-ERA , across HorizonEurope, and at national levels directly focusing on standardisation AI model quality measurements in the medical supporting domain. There are many calls on AI, thrustwortly AI, robots safety, etc. On the other hand many ICT systems support medical doctors' work, and every product is tested (using not standardised procedures). Integrating the existing methods and databases to fund extensions and, more importantly, researching new ways to coalesce the diverse standardisation methods is feasible. For a relatively modest level of funding, we can make this step-change in how a wide range of future practical systems might be constructed.