Artificial Intelligence

Artificial Intelligence is a decades-old scientific domain which has recently boosted its importance and impact in science, the economy and society in general.

Stemming mostly from Computer Science, AI has strong influences from other scientific fields, namely mathematics, neuroscience, linguistics, psychology, philosophy, and physics. In the 21st century, AI has made major advances, particularly in areas dominated by machine learning and more specifically deep learning. These include natural language processing, computer vision, content generation and recommender systems. Artificial Intelligence is already having a significant impact on many industries, including healthcare, energy, finance, transportation, and manufacturing, and is also playing an increasingly important role in our everyday lives, from virtual assistants to online recommendation systems. The symbolic legacy of AI is also very significant with roots in mathematical logic, linguistics, and psychology. Currently, symbolic approaches open avenues for explainability and transparency in AI systems.
Besides the fundamental need for large amounts of high-quality data (for the correct application), the growing influence of Artificial Intelligence calls for a human-centric approach with advances in the trustworthiness of the delivered tools, chiefly the interpretability of predictions and decisions, generalisation to unseen and even unpredictable situations, and robustness to biased data or unethical results.

Nowadays, Artificial Intelligence has powerful algorithms that can approach very difficult tasks, only doable by humans until little more than five or ten years ago, with astounding quality. Although the success of current neural and statistical approaches is almost blinding, there is a very important legacy of symbolic methods. They matter not only to the human dimension of AI, but also to the possibility of powering non-symbolic solutions with new cognitive layers that can be engineered and designed.

The growing dissemination of AI solutions and AI agents as enhancers of human capabilities, artificial co-workers or artificial experts, boosts the importance of human-AI interaction and of the trustworthiness of AI counterparts. The myriad of different interaction scenarios motivates research along many lines, such as human modelling (including the theory of mind), human-AI collaboration (including human oversight), interaction, usability and user experience, information visualisation and visual analytics, explanations and verification of AI processes and results.

The power of current and future AI also requires the mitigation of AI risks and implications. AI solutions and deployment must be ethical by design, following European and International guidelines that defuse as much as possible any potential harm. The ongoing and foreseen transformation of human tasks and jobs requires anticipation and reflection by all the players.

From an algorithmic point of view, the current moment of AI is strongly influenced by the emergence of large models built using deep and reinforcement learning. These approaches are fundamentally statistical and extremely data-thirsty. At the same time, they can capture refined patterns due to highly powerful estimations and are highly reusable. While their stochastic nature dispenses human intervention and obliterates the knowledge engineering bottleneck, the need for labelled data is still demanding and costly. On the other hand, their statistical nature and complexity make them highly opaque and hard to scrutinise.

Bioengineering

The field of Bioengineering addresses fundamental engineering principles, practices and technologies for medicine, biology, environmental and health sciences to provide effective solutions to problems in these fields. This field includes (but is not limited to) the development of mathematical theories & models, physical, biological and chemical principles, computational models and algorithms, devices and systems for clinical, industrial and educational applications in these domains.

We envision the next generation of advances and high impact of research on bioengineering for prevention, early detection and diagnosis of different types of diseases, ageing-related impairments, rehabilitation, occupational health and wellness, environmental-biology interactions, among others.

- Development of bioengineering novel methods and tools for the prevention, early detection and diagnosis of different types of diseases, ageing-related impairments, rehabilitation, occupational health and wellness, environmental-biology interactions, among others.
- Development of advanced technologies at the frontier of engineering, medicine, biology and other health & environmental sciences and transfer them to the future world market.

Communications

Context-aware, on-demand communications systems using and providing ubiquitous sensing.

Communications technologies, mainly those that are wireless and aligned with the vision for next-generation, are essential for the development of other research areas. Current visions in fields such as industry, energy, smart cities, mobility, health, sea, and agriculture demand well-engineered communications solutions. The current and next generations of communications systems are substantially different from the previous generations. The next generation of mobile and wireless communications will use and provide ubiquitous sensing and localisation capabilities, service-oriented software architectures, autonomous systems for supporting communications equipment such as high-altitude platforms and drones, ubiquitous artificial intelligence, and edge and cloud computing for creating on-demand virtual networks.

Motivated by this vision, the new emerging bandwidth-intensive, latency-sensitive applications, and the need to connect the unconnected, this scientific domain sees as its major challenge the design of communications systems that are more context-aware and deployable on-demand. This means communications systems that can dynamically adapt their characteristics according to the communications context, including the physical environment, energy constraints, the communicating peers, and the users or machines involved in the communication.

Computer Science and Engineering

The field of computer science and engineering is facing significant scientific and technological challenges, especially in the wake of the ongoing digital transformation. The pervasiveness of computer systems brings about new and often unforeseen challenges that defy our knowledge and best practices.

These challenges arise from the sheer complexity and scalability of computer and software systems, and the ever-increasing demand for their performance, interoperability, security, privacy, dependability, and sustainability. The incredible progress being made towards the widespread use of digital sensing and instrumentation technologies along with the sheer computing power at our disposal reinforces our resolve to effectively and efficiently collect, filter, curate, store, process, visualise and analyse the massive volumes of data generated.

As our reliance on information systems grows, there is a rising need for these systems to be trustworthy, fast, always available, and ethically responsible. Software development, verification, and testing have become crucial aspects in the critical path of any digital system, underlining the paramount importance of ensuring quality throughout the entire process.

The whole computing pipeline is becoming more complex, which poses additional challenges in ensuring reliability and performance. Therefore, research on computing architectures and non-functional aspects of software is essential for achieving the scalability, interoperability, and efficiency required for sustainable digital systems.

Power and Energy Systems

Support to the Sustainable Energy Transition.

This Scientific Domain supports the energy transition leading to a reduction of GHG emissions, via the decarbonisation of the energy system, large-scale RES integration, electrification of the society and increased energy efficiency.
This involves the combination of physical representations and data-driven methods for modelling and optimising energy systems, leveraging from emerging technologies like AI, blockchain and interoperability.

Results include concepts, models, methodologies and tools useful for addressing the decision problems of citizens, communities, multi-utilities, system operators, regulators, policymakers and government bodies.

Photonics

The vision for Photonics research at INESC TEC is to explore the potential of photonic-based science in the development of innovative enabling technologies contributing to a smarter, sustainable, and more efficient operation of complex systems such as the human body, the environment or critical infrastructures.
This activity of discovery and innovation subscribes to Optica's core values and is built on accepted scientific methods and engineering practice. It involves:

1. Advancing fundamental understanding of the fundamental physics of light-matter interactions, as well as explore new materials and phenomena that could lead to novel photonic devices;
2. Unlocking the Potential of Light through advancements in technology and applications for information transmission and sensing;
3. Fostering interdisciplinary collaborations to develop innovative solutions to complex problems.

Overall, our vision for photonics research prioritises advancing fundamental understanding, developing new technologies, fostering interdisciplinary collaborations, promoting sustainable development, and advancing diversity and inclusion.

Robotics

Robotics became more intelligent, autonomous, and useful in a wide area of applications. This new paradigm poses new challenges and problems to be solved that require new scientific approaches.

The operation in complex and dynamic environments requires increasing levels of autonomy, with abilities to create and maintain maps of the environment, to react and adapt to unforeseen events, as well as to operate unattended for longer periods.

The increasing interaction between humans and robots poses new, often unforeseen, and risky situations that need to be mitigated. Programming and communicating with robots to assign tasks must be increasingly intuitive and accessible to any operator.

The possibility of acting through forms that did not exist before, such as interacting with flexible objects of manipulating objects from moving platforms, takes robotics to new fields and with new challenges.

New fields of application of robotic systems and novel operational scenarios also require novel design methodologies, simplifying the deployment of these technologies.

Systems Engineering and Management

Systems engineering and management research seeks to advance the design, implementation, and improvement of systems for decision support, human-centred operations, intelligence, technology management, and innovation.

Major challenges arise from optimisation in complex organisations and networks at multiple levels, customer-centric service design, and technology-based innovation management and policy, targeting improvements in business performance, productivity, innovation, resiliency, and economic, social, and environmental sustainability.