Future priorities for Information Research in Europe

This position paper complements the overarching Helmholtz FP10 position from 02/2024.

Introduction

Recent global events such as pandemics and major geopolitical changes have underscored the urgent need for Europe to enhance its technological and digital sovereignty. This sovereignty is essential for fulfilling our basic needs, ensuring prosperity, and our economic strength in a global context. Achieving this goal requires excellent and targeted research activities in key technologies for computing, life, and material sciences, all while aligning with the global sustainability and climate goals described in the UN Sustainable Development Goals and the Paris Agreement.

Helmholtz Information aims to pioneer technologies, methods and digital tools that contribute to sustainable, climate-neutral, and resilient contributions from scientific research for both industry and society. Our overarching goal is to enable the secure collection, storage, processing, transfer, and use of information. We pursue this goal by analyzing natural, artificial, and cognitive information processing systems, exploring and developing novel materials and materials systems, and creating strategies to translate this new knowledge into sustainable materials, resilient and secure algorithms and most powerful next-generation computers. In this context, our interdisciplinary consortia address a broad range of internationally recognized strategic topics like artificial intelligence (AI), digitalization, quantum technologies, advanced computing, future telecommunications, semiconductors, advanced engineering materials, bioengineering and biomanufacturing, and brain research. Helmholtz Information actively collaborates with leading national and international research institutions, thereby enhancing the visibility and strength of the EU in these pivotal fields.

Future Directions

Digital transformation and digital sovereignty: In striving for an ecological significant, economic viable, and social acceptable form of sustainability, Helmholtz Information will be confronted with the question of how large-scale computing and data systems for AI, data analytics, data storage and numerical simulations can be built and operated in an energy-efficient manner over the course of the next decade. Regarding the European Chips Act and the European AI Act, novel and powerful technologies such as trustworthy and explainable AI, quantum technologies and novel, energy-saving and sustainable computing architectures must be developed and mastered independently in Europe. This will help shape international standards and the future commercial application of those technologies, translating their adoption into industrial practices that drive economic growth. At the same time, the application of the FAIR principles for research data and software must be further enforced, as these datasets represent an important value and the most promising foundation for novel, scalable and energy-efficient development approaches. In this context, the EU must recognize the importance of research software engineering and the maintenance of research platforms with software and data to the user communities with dedicated funding. High-performance computing can only reach its full potential through a targeted co-design of hardware and software together with domain scientists. A long-term funding framework should be established for the further development of modular exa- to zetascale, quantum, and neuromorphic computer systems targeted to both simulation and AI training, including funding for building, maintaining and updating the necessary storage capacities. In addition, it is essential to allocate additional financial resources for the education and training programs aimed at developing the skilled specialists needed in this field. Incentives should be given for the integration of high-performance

technologies into practice-oriented funding programs, e.g. in the fields of energy, health and climate research. These factors are critical to ensure the future of Europe's digital computing infrastructures by enhancing their performance, accuracy, security, privacy, and resilience.

Understanding biological information processing and the human brain: Nature has found many ways of low-energy and effective information processing, ranging from the molecular and cellular to the neuronal and brain-level. Understanding those different ways of natural information processing is ultimately a prerequisite for discovering sustainable routes for energy saving, adaptable and reliable computing with the goal to meet Europe's demand for access to advanced modular computing resources. Decoding the mechanisms of biological intelligence and brain organisaton will inspire the development of the next generation artificial intelligence, memory systems, and neurorobotics. Identifying the successful mechanisms and failures of biological information processing constitutes the basis for understanding the origin of diseases and will provide tools for developing corresponding treatments at a multi-scale level, from drug discovery to brain twins and biocompatible and biomimetic man-made systems, i.e. bioengineering. Progressing in this interdisciplinary field is crucial for ensuring Europe's technological and digital sovereignty and it is imperative to strengthen research efforts in this area. Targeted funding of brain-inspired AI and computing technologies such as neuromorphic computing can help Europe to keep the lead in this area, which is not yet widely established internationally. At the same time, funding for the further development of biohybrids, digital twins and implant research can help to take a fundamental step in medical technology towards personalized medicine.

Technological sovereignty: Materials are key to secure technological sovereignty. Overcoming the bottleneck of resource scarcity, developing a sustainable use of materials and consequently evolving an effective circular economy in the accelerated material and materials systems research and design are major challenges in this context. The advancement of state-of-the art technology and biomaterials research is not only vital for addressing sustainable development rules; it is also plays a crucial role in solving global challenges. In line with the European Green Deal, which seeks to eliminate reliance on fossil fuel-based materials and to mitigate economic restrictions, future materials must be more efficient and less harmful in both their production and use. To advance materials systems engineering, the following aspects require development: a) information-driven approaches, including the utilization and management of FAIR data for the design and optimization of highly sustainable materials and materials systems. b) novel correlative, application-oriented and high-impact material characterization methods, that foster deeper insights and advancements in the field. c) more economically and environmentally friendly production processes. The EU should therefore support the further development of the European Open Science Cloud (EOSC), to create stronger incentives for the sustainable storage of material and process data. These data offer unique potential for Europe to succeed in the development of customized materials systems using AI-based data analysis, digitalized processes, and automation. In addition, the EU should provide targeted funding for joint research projects with industrial partners to establish the necessary interfaces for rapid innovation processes in key areas such as photovoltaics, catalysis, energy or biodevice/implant materials to secure Europe's economic stability.

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