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COUNCIL FOR TECHNOLOGICAL SOVEREIGNTY

Discussion paper

Adapting technology to humans to promote technology adoption and technological sovereignty

Significance in a modern society on the example of robotics

Council for Technological Sovereignty

Introduction

Measures to secure technological sovereignty[1] are increasingly at the centre of political discussions[2]. Priority is given to concepts aimed at reducing one-sided international dependencies, classified as critical, and ensuring competitiveness in key technologies such as microelectronics, communication technologies, energy technology and artificial intelligence (AI). Their criticality for current and future location-specific fields of application is an important argument[3]. In order for technologies to unfold their intended socio-economic impacts and contribute to securing technological sovereignty, availability alone is not enough. A modern economy must have the ability to adopt new technologies in work and living environments. This includes the acceptance, integration and utilisation of a new technology in a specific domain. In addition to technology acceptance, which has already been extensively addressed, a modern economy also includes its value-adding utilisation. The Council for Technological Sovereignty points out that the ability of a society to adopt technology against the backdrop of technological sovereignty has not yet been sufficiently analysed. Especially in the crucial application field of robotics, in addition to the strategic development of competences, the ability to adopt technology in work and living environments can be of great significance. Essential to this is the process of active adaptation, more specifically the ability of technology to adapt to humans. The design of this process is important for adoption and can thus contribute to achieving technological sovereignty in robotics applications in work and living environments (see Figure 1). The adaptation of technology to humans is to be understood as an active process that starts from the technology itself.

TECHNOLOGY ADOPTION

Technology adoption refers to the acceptance, integration and utilisation of a new technology in a specific environment.

ADAPTATION

The adaptation of technology to humans is to be understood as an active process that starts from the technology itself.

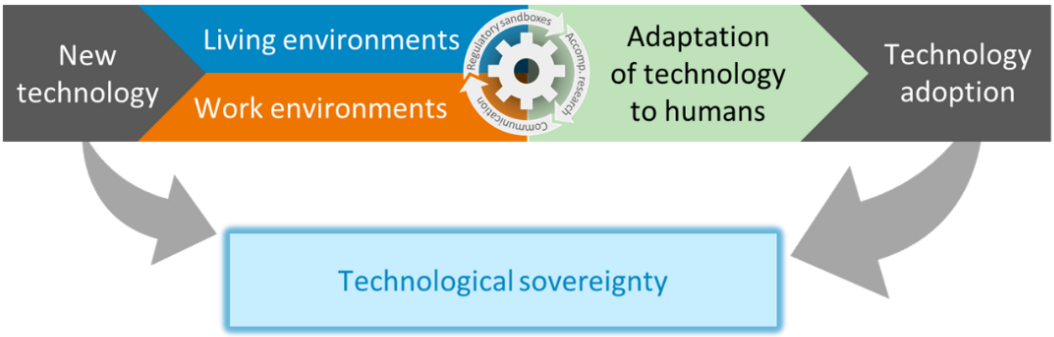

Figure 1: Introduction of new technologies and technology adoption toward technological sovereignty, dependent on processes of adapting technology to humans.

Importance of the adoption of technologies

In some areas, technological development has increased significantly: While it took 75 years to reach 100 million users with the landline network, it only took 16 years to reach the same number of users in mobile networks. ChatGPT achieved this in just two months[4]. To be effective, the adoption of technology must keep pace with the speed of technology development. However, it is not only the speed of adoption that has increased, but also the dynamics. This is increasingly crucial for the realisation of intended socio-economic impacts[5]. In the past, new fields of application were often driven by what was technically

feasible; today, the success of many applications, and often their underlying technologies, is determined by their adoption. Against the backdrop of significant investment in new technologies and applications, it is therefore essential to take technology adoption into account in order to achieve the associated socio-economic goals. The importance of adoption is seen as central to socio-economic change in numerous disciplines, for example in economics[6], health research[7] and energy research[8].

Technological sovereignty is an important strategic goal of many governments, whereby they address a bundle of key technologies[9]. There are various aspects to be considered in the adoption of technology. In application fields such as robotics, in which people interact directly with technology, the adaptation of technology to humans is a key aspect.

Adapting technology to humans– today and in the future

The increasingly widespread availability of many technologies, coupled with rapidly growing capabilities in the field of machine learning, favour the trend of technology being used in ever closer proximity to people and becoming more closely intermeshed with human activities. The trend is towards a sharp increase in interactive and collaborative co-operation between humans and technology. Human-driven approaches such as user-centred design (UCD) – which aims to ensure that a future product meets the requirements, expectations and needs of an assumed end user in terms of structure, content and design – must be supplemented by approaches in which adaptation starts from the technology itself. In this technology-driven approach to adaptation, technology adapts independently to the needs and requirements of humans. To this end, research is being conducted into specific interfaces, and solutions are being developed that allow humans to control and interact with (technical) systems without prior knowledge and with low access thresholds. Natural language interfaces and interfaces such as chatbots are notable examples. The computer programme ELIZA[10], which was developed in the 1960s, showed that interaction with computer programmes in natural language leads to an enormous increase in acceptance. The foundation for a high level of acceptance of potentially socially transformative technologies, such as large language models (LLMs), is also based around the use of chatbots, which allow natural language input and have thus made this advanced technology widely available.

Interaction between humans and machines is not limited to linguistic communication, but already relies on a wide range of sensory technology[11]. Sensory technology and signal processing enable multimodal perception and analysis of human behaviour. This is the basis for the now widespread adaptation of (technical) systems to humans. It is therefore necessary for a technical system to recognise humans and their situation during the interaction. This will very often be the case, for example, with robots that have multimodal sensors enabling them to perceive the needs of humans and their situation and thus recognise requirements in an interaction, among other things. Multimodal sensory technology therefore plays a decisive role in improving human-machine interaction (HMI).[12] It also enables more natural and intuitive communication[13,14] and in that sense it adapts to people's need to communicate in the manner they are accustomed to.

Together with AI approaches, multimodal sensor systems are a prerequisite for systems that adapt to humans during the interaction by learning from them.[15] 'Active learning', for example, enables learning of the individual capabilities of a system, such as a personal robotic assistant, in order to address the very individual requirements of the user. Humans act as teachers without having any knowledge of machine learning or robotics. The robot requests suitable examples from a human partner in order to solve the learning task efficiently. This request for examples must be as natural as possible[16]. However, there is a risk of the teacher (user) becoming tired of giving explicit instructions. To counteract this, robots also use implicit “signals” from humans. One example is intrinsic interactive reinforcement learning, which can even use brain data as learning signals during human-robot interaction (HRI)[17].

Learning that takes place during the interaction enables the current and continuous adaptation of technology to humans, leading to highly individualised solutions. Using this example from HRI, it is also important to emphasise that it is not only the system's sensory interfaces that are relevant, but also its ability to manipulate objects in the collaboration in a human-like[18,19] and safe[20] manner, or to behave generally as expected by humans. This in turn requires an understanding of human needs and the ability to adapt to those.

The relevance of adapting technology to humans is therefore addressed at various levels and is receiving a great amount of attention in product and solution development as well as research. It also addresses overarching

issues relating to prerequisites such as technology acceptance and society's openness to technology, which are intensively promoted, for example, through accompanying research measures and the development of communication strategies. The creation of real-world laboratories serves to test new technologies in realistic scenarios in order to promote safe and efficient (natural) interaction in work and living environments. It is also recognised that highly interdisciplinary research (sensor technology, AI, robotics, neurology, psychology, ethics, law and others) is required for implementation. In particular, there is significant potential in approaches that serve the development of intuitive interfaces and learning in systems for adaptation to humans through the use of multimodal sensor systems and AI methods: They promote technology adoption in industry and society. The aforementioned example of ChatGPT illustrates the potential of technology's ability to adapt to humans. Here, for example, the combination of different technologies – in this case LLM and a chatbot – enables complex technology to be utilised by a broad cross-section of society, by responding to people's need to operate and control technology naturally, using language. Adapting technology to humans in this way promotes the development of new value-creation opportunities and allows for easy implementation in industry. The use of modern technologies will become essential in many economic sectors in which they do not yet play a major role. At the same time, the threshold for using these technologies is lowered – a contribution to solving the shortage of skilled labour. There is growing recognition of the importance of such approaches to adapting technology to humans in order to satisfy human needs or increase productivity, and even their relevance to technology adoption, i.e. making new technologies one's own. Nevertheless, their relevance to technological sovereignty is currently not being sufficiently addressed.

Action Points

In recent history, it has often been necessary for humans to adapt to new technology. Complex functionalities of technology had to be painstakingly learnt from technical experts before they could be implemented. This process is now being reversed in many areas of application. Robotics is an important example of this. Technology is adapting to humans in many new areas of development. This is made possible, for example, by approaches such as Large Action Models (LAMs), which allow a human to give a robot complex instructions in natural language, which can then be implemented right through to the execution level.[21] This greatly facilitates the adoption of new technological solutions, in this case in robotics, and is therefore also highly relevant in socio-economic terms.

Only technologies that are adopted can prevail in the long term. Adaptation to humans is a crucial lever here (see Figure 1). This is relevant to all kinds of investment in new innovative solutions and means that research policy and funding **need to consider the relevance of technology adoption in debates and implementation strategies for technological sovereignty**. **The adaptation of technology to humans as an implementation option in the field of robotics, alongside other areas of application with significant interaction with humans, must be considered from the outset**.

It is a matter of great urgency not only to intensify research into new ways of adapting technology to humans, but also to investigate its effect on the success of technology adoption. Relevant technical developments include, for example, new types of human-technology interfaces, multimodal sensor systems for improved perception of humans and the environment by the machine in a wide variety of scenarios, and the implementation of AI methods for adapting technology to people during use. There should also be research into solutions that make interaction between technology and humans more pleasant, for example through natural behaviour or intelligent, sensitive robots. Last but not least, ethical, legal and social issues around the use of AI for continuous learning during utilisation must be addressed, as learning during use is becoming increasingly relevant.

In this research, communication between researchers and society at large as a potential user base is essential. Real-world laboratories and accompanying research projects are exemplary tools for the concrete feedback of experiences, needs and challenges in the use of technology in the human environment. This promotes the general social acceptance of the new technologies, but in particular also their safe and efficient use to create added value.

[1] A definition of 'technological sovereignty' can be found on the Council's website: www.bmbf.de/rat4ts
[2] Dow Jones Factiva 3 May 2023–3 May 2024
[3] O. Falck, S. Falk for the Council for Technological Sovereignty, 2024, Focus on Critical Technologies: The Race for Leadership in Industry and Technology Policy – "Technological Sovereignty" in International Comparison
[4] The Economist Times News, 2023, ChatGPT witnesses massive rise, chatbot gains 100 million users in two months
[5] World Economic Forum, Digital Transformation Initiative, 2018, Maximising the Return on Digital Investments
[6] Digital technologies and productivity: A firm-level investigation - ScienceDirect
[7] S. Renukappa, P. Mudiyi, S. Suresh, W. Abdalla, C. Subbarao, 2022, Evaluation of challenges for adoption of smart healthcare strategies
[8] E. Fleiß, S. Hatzl, J. Rauscher, 2023, Smart energy technology: A survey of adoption by individuals and the enabling potential of the technologies
[9] O. Falck, S. Falk for the Council for Technological Sovereignty, 2024, Focus on Critical Technologies: The Race for Leadership in Industry and Technology Policy – "Technological Sovereignty" in International Comparison
[10] J. Weizenbach, 1966,ELIZA—a computer program for the study of natural language communication between man and machine (acm.org)
[11] E-J. Rechy-Ramírez, A. Marín-Hernández, H.V. Ríos-Figueroa, 2018, Impact of commercial sensors in human computer interaction: a review, in: J. Ambient Intell. Humaniz. Comput.
[12] N. S. Sreekanth, N. Varghese, C.H. Pradeepkumar, P. Vaishali, R.G. Prasad, N.K. Supriya Pal, 2016, Multimodal Interface for Effective Man Machine Interaction, computer science
[13] A. Bonci, P.D. Cen Cheng, M. Indri, G. Nabissi, F. Sibona, 2021, Human-Robot Perception in Industrial Environments: A Survey.
[14] M. Javaid et al, 2021, Significance of sensors for industry 4.0: Roles, capabilities, and applications
[15] N. Huchler et al. (eds.), 2020, Kriterien für die menschengerechte Gestaltung der Mensch-Maschine-Interaktion bei Lernenden Systemen – White paper from Plattform Lernende Systeme
[16] C. Chao, M. Cakmak and A.L. Thomaz, 2010, Transparent active learning for robots.
[17] S.K. Kim, E.A. Kirchner, A. Stefes et al., 2017, Intrinsic interactive reinforcement learning – Using error-related potentials for real world human-robot interaction
[18] K. Mülling, J. Kober, O. Kroemer, J. Peters, 2013, Learning to select and generalize striking movements in robot table tennis9
[19] L. Gutzeit, A. Fabisch, M. Otto, J.H. Metzen, J. Hansen, F. Kirchner, E.A. Kirchner, 2018, The BesMan Learning Platform for Automated Robot Skill Learning
[20] E.A. Kirchner, S. Fairclough, F. Kirchner, 2019, Embedded Multimodal Interfaces in Robotics: Applications, Future Trends, and Societal Implications
[21] e.g. Figure one robot: https://www.figure.ai/

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