KI-SIGS: Artificial Intelligence for the Northern German Health Ecosystem

Stefan Fischer, Martin Leucker, Christoph Lüth, Thomas Martinetz, Raimund Mildner, Dirk Nowotka , Frank Steinicke

KI-SIGS ("KI-Space für intelligente Gesundheitssysteme", engl.: AI Space for Intelligent Health Systems), is an initiative to strengthen the Northern German health ecosystem to meet the challenges it is facing due to the rise of AI technologies. We present KI-SIGS by first describing the current state of the health ecosystem and the challenges it is facing. Then, we present our approach to meet those challenges, which basically consists of the interplay of three components: (i) an adaptive AI platform, (ii) an R&D (research and development) program using this platform, and (iii) the ecosystem itself. The initial partners of KISIGS are described, and finally, an outlook on sustainability options is given.

1 Introduction

Shaping the structural changes in the economy, labour market and society associated with digitisation and AI technologies represents a major challenge. This is especially true for the health care industry in Germany which traditionally has an SME-sized structure while being simultaneously exposed to strong international market competition. This challenge has been characterised by three decisive technological developments over the last ten years: major advances in machine learning, a rapid increase in data volumes and a massive increase in available computing power [1]. Taken together, these three developments lead to the breakthrough of AI and to disruptive innovations in our networked society, not only, but also and especially in the healthcare sector [2]. This in turn leads to considerable pressure for innovation in the industry. The increasing digitalization in the health care industry, medicine and medical technology leads to a rapid growth of the number of large, heterogeneous, complex and partly unstructured data sets in all areas of the life sciences. These data sets hold great potential for intelligent healthcare systems and adaptive selflearning AI technologies [3]. Moreover, comprehensive data exchange within and among institutions generate a multitude of new data-driven applications. The interoperability of medical devices and combining health data from distributed data sources of care and research open up a variety of possibilities for the exploitation of learning algorithms and adaptive AI systems. Intelligent assistive health technologies, robotic systems with assistive components up to humanoid robots and mobile health applications open up new fields of application also in nursing and rehabilitation.

The development AI in the healthcare industry must focus on people in order to comply with the regulatory framework of the industry. The high data protection requirements with regard to personal interests and the ethical requirements for the use of health data, which arise from the debates in our society, is particularly sensitive in the medical field. Medical technology companies and healthcare institutions are also faced with the question of new business models and their application in the situation of an ageing society [4].

First AI applications in the field show that their benefits are enormous (for a recent survey see [5], for a more general state of the art see [6]). Ranging from a better understanding of disease mechanisms through optimized diagnostics and therapy, increased efficiency in medical care, these applications cover a broad spectrum of value creation opportunities. However, there is a need for clarification as to how these benefits can be reconciled with the industry-specific challenges with regard to approval/regulation, data protection/ethics and financing/busi-

ness models under the conditions of international competition. This applies in particular to the explanation and transparency of the results, decisions and actions of AIsupported systems required in the healthcare sector.

With a gross value added of over 350 billion euros (2018), the core area of the healthcare industry is of considerable economic importance for Germany. This applies in particular to the North German economic area of Bremen/Hamburg/Schleswig-Holstein, in which the health industry plays an outstanding role as one of the central key industries. The industrial health sector makes a strong contribution to value creation and employment in the federal states (29.1% in Hamburg, 21.2% in Schleswig-Holstein and 16.9% in Bremen). With an annual growth rate of 4.1 percent, the sector has grown significantly faster than the gross domestic product over the past ten years (BMWI Health Economics Facts & Figures 2018). This strong starting position was created by decades of close cooperation between science and industry, which is reflected especially by the successful cluster network "Life Science Nord" (LSN) across the federal states. In recent years, this has resulted in a pulsating innovation ecosystem, from which numerous successful start-ups benefit in addition to regional universities and research institutions and large regionally based medical technology manufacturers such as Dräger, Philips, Söring, and Olympus.

Due to this favourable starting position, an AI-oriented strengthening of the North German health ecosystem offers the participants excellent opportunities to expand their position on the world market and to open up new business areas. Moreover, this may also serve as an example for other regions.

In the rest of this paper, we present the main conceptual ideas of KI-SIGS (Section 2) and present the partners participating in the project (Section 3). Section 4 looks at sustainability issues, always an important question for major infrastructural projects. Section 5 concludes and gives an overview of the future time plan.

2 KI-SIGS Concept

2.1 Objective

An AI facility focussed on intelligent health systems has not yet been established in Germany, despite its importance. In Northern Germany, however, there is a clear focus on AI-related R&D as well as application and start-up competencies in the field of health management, which form the basis of a cooperative initiative on the spatial axis Bremen/Hamburg/Schleswig-Holstein as the basis of a North German AI network in the sense of a critical mass of AI competence and market penetration. In KI-SIGS, the excellent competencies of the North German universities (in particular the universities in Bremen, Hamburg, Kiel and Lübeck) and research institutes (DFKI and Fraunhofer MEVIS) in the field of symbolic and statistical AI are to be brought into play in order to work together with the large regional companies (Philips, Stryker and Dräger) as well as small and medium-sized enterprises (e.g. Söring, Hugo Rost and apoQlar) from the health and AI sector to develop, test and deploy clinical-medical applications with the North German clinics (in particular UKSH and UKE).

Successful innovations in the high-technology sector require that in strongly connected research and development processes, with close involvement of users and in-depth knowledge of operational process framework conditions, different ideas and perspectives of a majority of participants and affected parties are implemented in new solutions. The solution approach to be developed in KI-SIGS and presented in the following therefore focuses on a decentralized AI network with a focus on knowledge gain, method competence, technology development, transfer and evaluation in the area of AI methods in the health care system. On the other hand, the focus is particularly on the challenges that the health sector brings with it, such as the problem of providing sensitive medical patient data across different locations, regulatory, approval and ethical issues.

2.2 Overall architecture

The above objectives are to be achieved through three main components to which all partners contribute in different ways:

1. development and deployment of the AI platform KI-Space with a variety of technical and nontechnical services for use by projects and ecosystems
2. definition of an R&D roadmap and its implementation in cross-location cooperative R&D projects that are constantly growing out of the ecosystem by partners from business, science and clinics using the AI platform and continuously improving it in a feedback process
3. improvement of the already excellent ecosystem in the North German health economy for the purpose of further strengthening its AI competence through the close cooperation of the project partners and the integration of further associated partners and external stakeholders on the basis of the platform, with the aim of repeatedly and increasingly producing AI-based innovations in new R&D projects and quickly translating them into products and services

All in all, the project will result in an interaction between the three components as shown in Figure 1. The platform and the R&D roadmap have to meet considerable requirements, because the roadmap must take the needs of the market and the competencies of the partners into account as much as possible, while the platform must support the development of the ecosystem - which in turn is to ensure the creation of new projects - and the most efficient implementation of the R&D projects. The design of the platform and the R&D program was therefore analysed in detail before the implementation; this process is described in the following section.

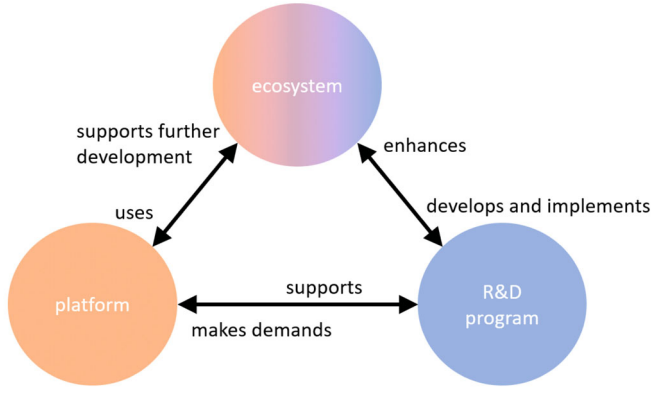

Figure 1: Interplay of the components

2.3 Requirements Analysis for R&D Program and the Platform

In order to identify and collect the requirements of the North German healthcare industry for an AI platform as well as the AI competencies and requirements of the North German healthcare industry in general, a comprehensive analysis was carried out before the implementation. In workshops, online surveys, interviews and focus groups, more than 80 companies, research institutes, universities and clinics were interviewed and the competencies and requirements of the relevant stakeholders from the economy and science of the health industry as well as the clinics in Northern Germany were collected and analysed in discussion rounds. The results make it clear that the topic of AI is already important or very important for the majority (approx. 55%) of the companies surveyed and that more than 67% assume that the topic will become significantly more important in the next 5-10 years. From the perspective of AI topics, the need to improve multimodal diagnostics through modern AI procedures, especially by means of biomedical signal processing as well as image and video processing (approx. 78%), is mentioned above all. Furthermore, the companies see a great need in the field of prediction and prognosis through better forms of data analysis but also through improvement of data management and access (approx. 78%). In addition, the companies see great potential for product innovations in the field of medical assistance systems, for example through new forms of human-machine interaction (approx. 67%), autonomous systems and robotics (approx. 57%), speech and text processing (approx. 57%) as well as virtual and extended reality (approx. 45%). While all the universities and research institutes surveyed are currently carrying out at least one AI project, less than a third of the companies surveyed have experience or expertise in the field of AI. Approximately 86% of the respondents stated that they currently have fewer than five employees working on AI projects. On the other hand, more than 71% of the companies surveyed currently have an immediate need for up to five additional employees in the field of AI. Less than 30% currently see no need or have no vacancies to fill. All respondents consider a regular exchange of knowledge to be important and would like to participate in workshops (100%), lectures (67%) and conferences (56%). 67% of the scientific partners already have or have access to specialized AI hardware, while less than one third of the SMEs have such access. Accordingly, the demand for further AI hardware is large (56%) to very large (23%), whereby GPUs and computing servers for training AI algorithms are particularly important. In the consortium, 89% of the partners would be willing to share their AI hardware.

Access to medical and clinical data as well as data sovereignty in the institutions themselves is considered essential for an AI platform. More than 78% of the partners already share data themselves or access shared data, primarily speech data, challenge data, measurement data, medical image and volume data, bio-signal and clinical data. All partners surveyed have a need for larger data sets, with anonymization and security of patient-related data as well as ethical issues having priority in the collection and processing of personal data.

2.4 R&D-Roadmap and Projects

For a targeted approach to the development of new products and services within the framework of a network, it is crucial to formulate content objectives and the path to achieving these objectives in an R&D roadmap. On the basis of the existing competencies and the requirements of the North German health sector described above, the following three future fields for R&D tasks in intelligent health systems were identified:

- Prediction and prognosis: The use of AI systems for clinical prediction and decision support benefits society and the healthcare industry equally. The application of predictive analysis functions to patient populations shows possible preventive measures, contributes to the reduction of health risks and helps to avoid unnecessary costs.
- AI-based multimodal diagnostics: With the help of AI-based multimodal diagnostics, large amounts of medical and clinical, but also behavioral, social and mobile health and care data can be combined to gain a holistic view of the patient. This supports the entire hospital and nursing staff in making diagnoses and decisions and optimizes the success of treatment.
- Medical assistance systems: Demographic change is leading to a growing demand for health services and support for nursing services. These include, for example, virtual support and robotic assistance systems that improve and facilitate training, therapy, rehabilitation or living at home in old age.

In this framework nine initial projects have been selected as the starting R&D program of KI-SIGS. Project 1 develops homecare devices for eye diagnostics for disease prevention as well as aftercare. Here, two start-up companies from the ecosystem are supported who develop and market an Optical Coherence Tomography (OCT) based measurement of macular degeneration as a homecare device.

In Project 2, both conventional X-ray images and 3D images from so-called Time-of-Flight cameras are analysed and evaluated using deep learning methods. An X-ray assistant is to be developed that also allows less qualified personnel to take high-quality X-ray images. Two highly innovative and globally active SMEs from the North see a high market potential here and are committed accordingly.

Patient data management systems (PDMS) in hospitals are increasingly recording essential patient data, which is to be evaluated and made usable with the help of AI. In Project 3, risk indicators for cardiopulmonary decompensation on intensive care units are derived from PDMS by monitoring vital parameters. In addition to the special methods for time series on the time scale of minutes, hours and days, the regulatory requirements for patient data management systems in connection with AI and the special needs of intensive wards will be incorporated into the platform.

Project 4 is a central project around AI for radiological imaging, especially in emergency and intensive care medicine. Radiological imaging is one of the main fields of application for AI because deep learning methods have been particularly successful on images. In emergency and intensive care medicine, AI-based diagnostic support systems are of greatest use, because they have to be diagnosed particularly quickly and carefully at the same time. For emergency and intensive care medicine, the regulatory system is also special and an exchange on the platform is particularly beneficial.

In Project 5, recurrent neural networks are used as in Project 3, but in a completely different context. This involves intelligent

Stefan Fischer

Stefan Fischer is a full professor in Computer Science at the University of Lübeck, Germany, and the director of the Institute for Telematics. He is also a Vice President of the university, responsible for technology transfer and digitization. His research interest is currently focused on network and distributed system structures such as ad-hoc and sensor networks, Internet of Things, Smart Cities and nano communications. He has (co-)authored more than 200 scientific books and articles.

Martin Leucker

Martin Leucker is currently a professor at the University of Lübeck, Germany heading the Institute of Software Engineering and Programming Languages. He obtained his Ph. D. at the RWTH Aachen, Germany and afterwards, he worked as a Postdoc at the University of Philadelphia, USA and at the Uppsala University, Sweden. He pursued his habilitation at the TU München, Germany. He is the author of more than 100 peer reviewed conference and journal papers ranging over software engineering, formal methods and theoretical computer science.

Christoph Lüth

Christoph Lüth is vice director of the rCyber-Physical Systems group at the German Research Centre for Artificial Intelligence (DFKI) in Bremen, and professor for computer science at the University of Bremen. His research covers the whole area of formal methods, from theoretical foundations to tool development and applications in practical areas such as robotics. He has authored or co-authored over eighty peer-reviewed papers, and was the principal investigator in several successful research projects in this area.

Thomas Martinetz

Thomas Martinetz is full professor of computer science and director of the Institute for Neuro- and Biocomputing at the University of Lübeck. He studied Physics at the TU Munich and the University of Illinois at Urbana-Champaign. Prior to Lübeck he developed Neural Networks for automation control at the Corporate Research Laboratories of the Siemens AG, was Managing Director and co-owner of the leading face recognition company in Germany, and professor for Neural Computation at the Ruhr-University of Bochum.

ultrasound aspirators, the online determination of the tissue type during the resection of brain and liver tumours. During resection, the aspirator becomes an intraoperative probe with the help of AI-based signal pattern recognition, which can be used to increase the extent of resection in tumour diseases and thus the life expectancy of cancer patients.

Project 6 is methodologically/technically closely related to Projects 2 and 9. 3D-Time-of-Flight cameras are used in all three projects. There will be an intensive exchange via the platform, also with Project 1, since this is also about the acquisition of time series of vital parameters, here especially about the acquisition of visual context information for the optimization of ventilation therapy. The patient's position is recorded with 3D cameras in order to be able to optimally adjust ventilation together with vital parameters.

Project 7 helps the surgeon in the OR by providing intervention support for the repositioning of bone fragments in pelvic fractures. The optimal repositioning of bone fragments in pelvic fractures shall be based on intraoperatively acquired 2D layer images and replace the time-consuming conventional 3D procedures. This requires learning how to map 2D layer images to 3D images.

With Project 8, we are slowly moving from therapy to aftercare. With the aging society, the number of hearing-impaired people who need hearing aids is constantly increasing. Hearing aids have to be adapted to the individual's specific hearing loss and preferences, which is difficult and time-consuming. An AI for individualized hearing aid fitting can therefore be of enormous benefit. Especially speech comprehension in acoustically challenging environments can be improved, which in turn increases wearing time and spontaneous acceptance. AI-methodically, it is closely related to Projects 4 and 6 and accordingly linked via the platform.

In cooperation with patients, therapists, physicians or nursing staff, intelligent virtual agent and robot systems for assistive movement training will be developed in Project 9. The movements are analysed by (depth) sensors and multimodal instructions (e.g. via speech and gestures) are given by agents/robots. If movements are detected correctly, human experts instruct and continuously improve the system using supervised learning.

2.5 The Platform of KI-SIGS

AI has the potential to play a decisive, even disruptive, role in the healthcare industry. This potential cannot be exploited by isolated projects in specific application areas. Rather, a uniform conceptual framework is needed that will tackle the following challenges common to all AI medical projects in a goal-oriented manner and pave the way for sustainable solutions:

• AI applications are usually data-driven, because the potential of these methods lies precisely in the discovery of unexpected, i.e. not hypothesis-driven, ideas through unsupervised learning methods. The latter, however, require large amounts of training data. Especially in health care, however, the explosive question arises as to who has sovereignty over patient data in which role. For understandable reasons, the authorities responsible for data processing (usually the clinics) are very reluctant to grant access to the data. Here, the AI space creates a framework that allows legally compliant access to patient data (data compatibility, security of access), supports its exchange between stakeholders

and creates incentives for the provision of data.

- In medicine, applications are subject to strict regulatory requirements (such as legally compliant implementation in accordance with the applicable data protection regulations and the Medical Devices Act). The KI-Space supports developers in regulatory questions and helps to develop concepts for approval.
- Beyond the observance of legal rules and regulations, acceptance is also an obstacle to application that should not be underestimated, namely acceptance by the individual patient as well as by doctors, nursing staff and society as a whole. The KI-Space thinks about the ethical and social effects of the new development from the beginning.
- Furthermore, an interdisciplinary, collaborative framework must be created in which users, developers and users can build up the necessary competencies together to support a broad application and later enable the introduction into clinics.

KI-Space, the AI platform for intelligent healthcare systems, addresses these challenges and enables appropriate solutions. The AI Space has several components that address the above challenges:

- Central to the KI-Space is the collaboration platform, which on the one hand connects the participants with each other using technical aids such as portals and repositories, but on the other hand presents the KI-Space to the outside world with workshops, competitions and integration into other networks, thus making a massive contribution to the development and expansion of the ecosystem.
- On the one hand, the technical platform defines uniform communication standards, standardizes data access and provides the technical framework for services on this platform, and on the other hand it offers an application module which realizes hospital-based data processing "on premise".
- The regulatory platform ensures the conformity of the applications to be developed with legal, normative and other regulations and specifications.
- The responsible innovation platform explicitly addresses the ethical and social impacts of the use of AI technologies in the medical and health sector.

3 Partners

The following criteria have been used for the composition of the initial partner group:

1. Coverage of all links of the scientific-economic value chain in the North German health care industry
2. Integration of the main AI-competent scientific partners (universities and research institutions) with already transferable research results
3. Compilation of the economic partners as a prototypical image of the North German health care industry from corporations, SMEs and start-ups as well as clinics with high chances of success for the transfer of research results "onto the street".

The following partners have then been selected, according to the criteria:

- Universities: Bremen, Hamburg, Kiel, Lübeck
- Applied Research Institutes: DFKI Bremen, Fraunhofer MEVIS Bremen/Lübeck, UniTransferKlinik Lübeck
- Industry: Advanced Bionics (Hannover), apoQIar (Hamburg), Cellmatiq (Hamburg), Dräger (Lübeck), Gesundheit Nord (Bremen), Hugo Rost (Kiel), Image Information Systems (Rostock), mbits (Heidelberg), Philips (Hamburg), Söring (Quickborn), Stryker (Kiel), szenaris (Bremen)
- Hospitals: Universitätsklinikum Hamburg-Eppendorf, Universitätsklinikum Schleswig-Holstein Kiel/Lübeck

Raimund Mildner

Raimund Mildner is an Economist and Social Scientist. He currently is Project-Consultant to the University of Lübeck for diverse AI- and other technology- related projects, mainly in the clinical application domain of Medical Devices as well as in Logistics and Industry4.0. Before he was longstanding CEO of the Technology/Science-/StartUp-Center Lübeck and UniTransferKlinik Ltd. He has hold several supervisory board seats in companies and scientific institutions.

Dirk Nowotka

Dirk Nowotka leads the Dependable Systems group of the Computer Science department at Kiel University, Germany. Prior to joining Kiel as a HeisenbergProfessor in 2011, he was a research scientist at the Stuttgart University (2004-2011), Germany, where he gained his habilitation, and the ETH Zürich (2004), Switzerland. He completed his PhD in mathematics from the University of Turku (2004), Finland. Dirk's primary field of research is the theory and practice of automated mathematical and logical procedures for the safety and security analysis of software systems. One particular research interest of him is safety in the field of artificial intelligence.

Frank Steinicke

Frank Steinicke is full professor for Human-Computer Interaction at the Department of Informatics at the Universität Hamburg, and since 2018 he is head of the Department of Informatics. Before he joined Universität Hamburg, he was Professor at Julius-Maximilians-Universität in Würzburg (2011-2014), and Guest Associate Professor at the University of Minnesota (2009). His research is driven by understanding the human perceptual, cognitive and motor abilities and limitations in order to reform the interaction as well as the experience in computer-mediated realities.

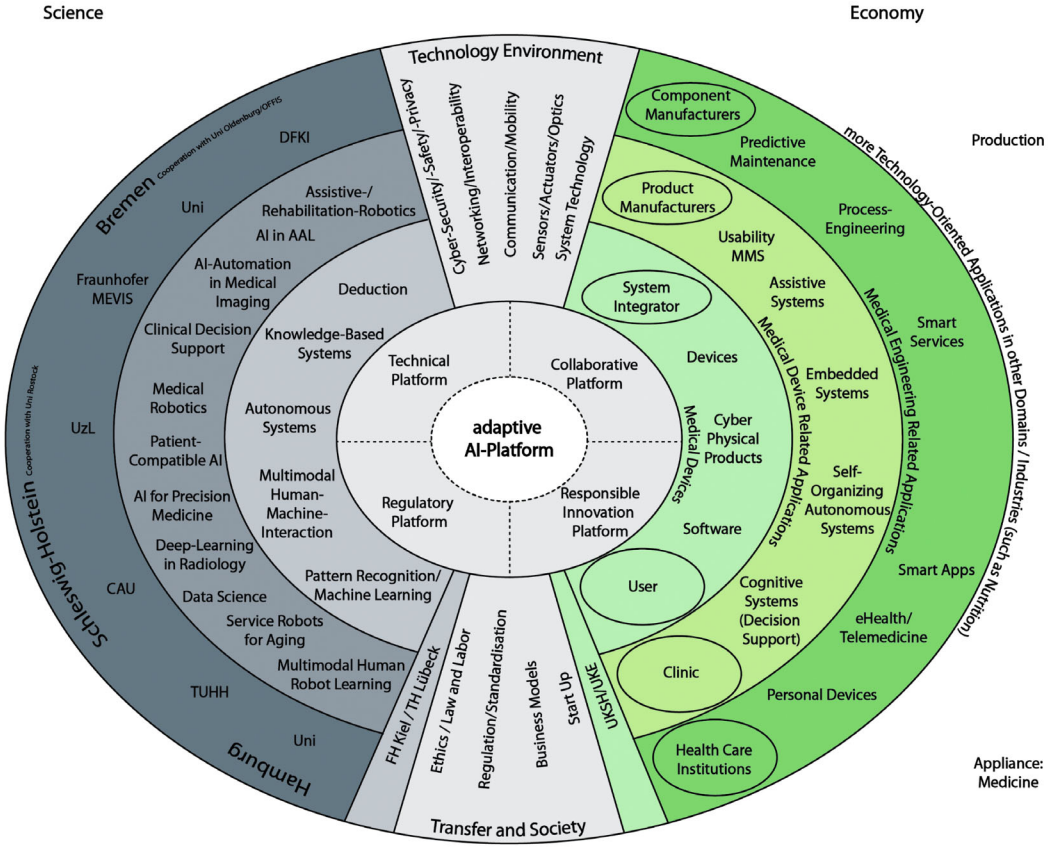

Figure 2: The ecosystem of KI-SIGS

The goal of KI-SIGS is the establishment of an ecosystem for the Northern German health system as it is depicted in Figure 2.

4 Sustainability

KI-SIGS requires considerable efforts on the part of the partners involved and the donors. It therefore pursues the objective of gradually consolidating itself in the form of a stable, permanent organisational form after a successful trial and funding phase lasting several years. This could, for example, be realised as a supra-regional (transfer) centre for innovations in the health industry, for example in the form of an R&D institution institutionalised by a sponsoring association or a non-profit limited liability company. The mandatory supra-regional cooperation then requires local transfer points as service and consulting facilities on site in order to guarantee short distances and fast reaction times for cooperation partners and customers. The costs of such a permanent network can be met in part by the contributions of the participating partner institutions (companies and scientific institutions) and by their own revenues (service revenues, workshops, training and further education), and will also require permanent co-financing from the public sector. This will provide the prerequisites for successful third-party funding by national and international funding providers. Taken together, the activities to be started now form a long-term perspective with prospects of success and enable the establishment of a sustainable transfer network for artificial intelligence in the health care system far beyond the North German region.

5 Conclusion and Outlook

In this paper, we have presented the project KI-SIGS the goal of which is the introduction of AI technologies into the products and services of the Northern German health industry in order to keep and extend the competitive advantages it has gained over the last years. We have introduced the major ideas as well as the consortium which is a nice representation of the Northern German health industry ecosystem. KI-SIGS has just recently been announced to be one of the 16 winners of the "Artificial Intelligence Idea Challenge for economically relevant ecosystems" of the German Ministry for the Economy [7]. The project will thus soon start its operational phase and will very quickly have a first version of the AI platform available. This will be the major base for a quick implementation of the R&D projects which are to start in mid 2020.

References: **[1]** LeCun Y, Bengio Y, Hinton G. Deep Learning. Nature 521, 436-444 (2015). **[2]** Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., Cui, G., Corrado, G., Thrun, S., Dean, J. A guide to deep learning in healthcare. Nature Medicine, Volume 25, pp. 24–29, (2019). **[3]** Yu, K.-H., Beam, A. L., and Kohane, I. S. Artificial intelligence in healthcare. Nature Biomedical Engineering 2(10), 719-713, doi: 10.1038/s41551-018-0305-z (2018). **[4]** Strickland, E. IBM Watson, heal thyself: How IBM overpromised and underdelivered on AI health care, IEEE Spectrum, 56(4), 24-31 (2019). **[5]** Jiang F, Jiang Y, Zhi H, et al. Artificial intelligence in healthcare: past, present and future. Stroke and Vascular Neurology 2017;2:doi: 10.1136/svn-2017-000101, 2017. **[6]** Wang, F., Preininger, A. AI in Health: State of the Art, Challenges, and Future Directions. Yearbook of Medical Informatics, 28(01): 016-026 (2019) **[7]** Bundesministerium für Wirtschaft und Energie. Gewinner des KI-Innovationswettbewerbs stehen fest. [Online] 19. September 2019. https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/ 2019/20190919-gewinner-des-ki-innovationswettbewerbs-stehen-fest.html (2019).