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Artificial Intelligence and Women Researchers in the Czech Republic

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Abstract: Artificial intelligence as a research area has been continuously growing for several decades. Many applications were developed in various domains. Medicine and health care have attracted more intensive attention thanks to rapid technological development that has accelerated generation of large volumes of data requiring intelligent analysis and evaluation. This article illustrates, through examples of women researchers and selected AI projects in medicine, the wide spectrum of applications developed during the last fifteen years in the Czech Republic, and in particular at the Czech Technical University in Prague. Women researchers played an important and irreplaceable role since the advent of AI research in the Czech Republic. By their example, they motivated many young female students to join the community and start their research career in the AI area. They frequently participated in research projects led by the senior women researchers. The presented overview of projects illustrates the diversity of the medical area and the potential of AI methods that can be used for solving data- and knowledge-intensive problems. We briefly touch on the AI study programs. In conclusion, we point out the future challenges in AI and its applications in medicine and health care.

Keywords: artificial intelligence; machine learning; women; research

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1. Introduction

Artificial intelligence (AI) has been with us for several decades. We can observe both intensive theoretical research and the development of AI applications in various areas. The research and development of AI are growing continuously as technologies generate larger volumes of data that require intelligent analysis and evaluation. One of the application areas that has been developing fast is health care, where rapid technological development during the last two decades of the 20th century and both decades of the 21st century changed the character of the health-care services and many types of medical examinations. Advanced technology was introduced to diagnostics and therapy. As a consequence, thanks to direct connection of devices to computers, the volume of collected data has been continuously and tremendously growing. Better communication channels allow speeding up the exchange and use of data, information and knowledge, and are eliminating geographical and temporal barriers. All these developments increased the importance of medical informatics as a discipline that builds on the results of computer science, artificial intelligence, image processing, etc. The crucial issue is the suitable design of health information systems, in particular electronic health/patient records that should contain all the important data and information about the patient. As has been discussed many times, the critical point is represented by semantic interoperability and satisfaction of standards. Without that, it is difficult to share the data and information properly. The requirements for sharing data are gradually rising as population mobility is increasing and patient data is being accumulated in different places. However, the data needs to be accessible in an organized manner; that means the systems must satisfy defined standards and interoperability requirements.

This approach has been adopted within *the integrated care cycle* (ICC). Its idea is based on the vision of such an environment where the patient-centered approach is applied, where care is personalized, where prevention and maintaining health is central to health-care solutions, where hospitals provide the least-invasive interventions with the shortest length-of-stay for any condition, and where recovery occurs outside the hospital. ICC can enhance both patient centricity and care cycle efficiency through embedded technology and through a holistic approach to integrating health data, health workflows and health systems and devices. ICC may strengthen the health-care ecosystem of hospitals, care providers, health insurers, research institutes and industry in healthcare-embedded systems by bringing people-centric innovations to the market faster. The ICC is built on the following steps: prevention, screening for early detection and diagnosis, discovery to treatment, minimally invasive interventions, management and monitoring, and chronic disease management. Obviously, the activities must be coordinated, and allow for adequate data and information exchange. This requires well-designed data and information models and formats satisfying the interoperability requirements. It is necessary to stress that both data and information need to be accompanied with contextual information. AI methods and systems can contribute to this effort since many appropriate tools and methods have been developed, in particular in machine learning, knowledge representation, image processing, natural language processing and related areas.

The next sections focus on the development of AI in the Czech Republic, the active role of female researchers and examples of research projects that were successfully solved in the health-care area.

2. Women in Artificial Intelligence Research in the Czech Republic

Development of AI in the Czech Republic is similar to that in other European countries. In the 1970s, more intensive activities appeared, including first workshops and conferences. Since the beginning, several women researchers actively participated and successfully developed their research areas and research groups. During the decades they participated in education of new generations of researchers. Through the positive examples they set, they succeeded to attract more women to AI research. Many of them are still active researchers both in the theoretical foundations of AI and applications of AI to various areas. Starting in the early 1990s, a series of textbooks on artificial intelligence In Czech [1–6] was written with the aim to bring the topics to a broader audience. Many women researchers in AI were invited as (co-)authors of chapters in the individual volumes that covered not only theoretical issues but also development of numerous AI applications, including those designed for medical purposes. In the next paragraphs, we present several female personalities from the Czech AI scene. We are well aware of the fact that we cannot accomplish a full list of all AI researchers and research groups in the country.

Eva Hajičová (* 1935) is a professor of linguistics at the Faculty of Mathematics and Physics, Charles University, Prague. She graduated in English and Czech at the Faculty of Philosophy of Charles University and got her PhD degree as well as the highest academic degree of DrSc in general and computational linguistics at Charles University. Her interests cover theoretical linguistics as well as computational applications [7]; she has concentrated on the semantic structure of the sentences, on the discourse phenomena and on different topics in computational linguistics [8].

She is/was a member of a number of editorial boards of international journals (*Journal of Pragmatics*, *Computers and Artificial Intelligence*, *Linguistica Pragensia* and *Kybernetika*) and she was the editor-in-chief of *Prague Bulletin of Mathematical Linguistics*. She was the first president of the European Chapter of the Association of Computational Linguistics (1982–1987) and the president of the international Association for Computational Linguistics in 1998; she was the President of the Societas Linguistica Europaea, 2006–2007, and since 1978 she has been a member of the International Committee of Computational Linguistics.

She was the chairperson of the Prague Linguistic Circle (1997–2006), is a Fellow of the Association of Computational Linguistics and na honorary member of Societas Linguistica Europaea, as well as a member of several Czech scientific societies.

She was awarded the international Alexander von Humboldt Research Prize in 1995, the Medal of the Minister of Education of Czech Republic in recognition of the pedagogical and scientific work in computational linguistics in 2003 and the ACL Life Achievement Award in 2006. In 2017, she received the Josef Hlávka Medal awarded to Czech scientists in recognition of their life-time achievements in science and arts, and in 2018 she received the international Antonio Zampolli Prize for outstanding contributions to the advancement of language resources and language technology evaluation within human language technologies.

Jana Zvárová (1943–2017) graduated in Mathematics in 1965 at the Faculty of Mathematics and Physics of Charles University in Prague. She collaborated in several disciplines offered at Charles University (Medicine, and Mathematics and Physics). She founded the Medical Informatics section of the Czech Society of Biomedical Engineering and Medical Informatics in 1978. She was nominated in 1999 as full professor at Charles University and received in the same year the highest Czech scientific degree of Doctor of Sciences at the Academy of Sciences of the Czech Republic.

She systematically applied new theoretical knowledge in biomedicine, particularly in epidemiology and public health [9]. Since 1994, she chaired the *European Center of Medical Informatics, Statistics, and Epidemiology* (EuroMISE) of Charles University and the Academy of Sciences. Between 2006 and 2011, she was the director of the *Center of Biomedical Informatics*. She was the representative of the Czech Republic in IMIA (the International Medical Informatics Association) and in EFMI (the European Federation for Medical Informatics). She was a member of editorial boards of several national and international journals. The results of her research are documented in 10 monographs and more than 300 articles in peer-reviewed journals.

In the framework of European projects, she started new lines of research and education concerning electronic health records, knowledge representation in clinical guidelines, decision support systems, and methods for evaluation of knowledge. She organized several IMIA and EFMI international conferences and workshops in Prague. Jana Zvárová also initiated the foundation of the EuroMISE Mentor Association focusing on international cooperation in student mentoring activities.

Věra Kůrková (* 1948) graduated from the Faculty of Mathematics and Physics of Charles University, specialization in Topology (1972) and later obtained the Ph.D. degree in the same field from the Academy of Sciences of the Czech Republic (CAS). Between the years 1975 and 1989, she worked as a researcher at the Research Institute of Mathematical Machines. In 1990 she joined the Institute of Computer Science of the CAS, where she remains until now. This position gave her an opportunity to participate in shaping the field of artificial neural networks at the turbulent moment when development of hardware enabled the implementation of algorithms for efficient learning of networks composed of biologically inspired perceptron units that were complemented soon by computational units chosen purely for their suitable mathematical properties. As a mathematician, she focused on theoretical questions inspired by experimental research and worked on building the theory of nonlinear approximation, which involves the approximation of functions of many variables by neural networks of different types, the study of the dependence of network complexity on increasing data dimensionality and the connection between inverse problem theory (which was developed for solving physical problems) and generalization in machine learning.

From 2002 to 2008 she held the position of the head of the Department of Theoretical Computer Science and currently she is a senior researcher in the Department of Machine Learning. Her research interests include the mathematical theory of artificial neural networks and learning, in particular the analysis of the capabilities and limitations of shallow and deep neural networks, the dependence of network complexity on increasing input dimension, optimization of networks computing randomly chosen classifiers [10], the relationship between inverse problem theory and generalization in machine learning and a new branch of function approximation theory involving neural networks. She is a member of the editorial boards of *Neural Networks* (Elsevier) and *Neural Processing Letters* (Springer), and has been a chair or a vice-chair of the program committees of several European conferences. Since 2008, she has been a member of the Council of the European Neural Network Society, of which she is currently President. She was awarded the Bolzano Medal by the Czech Academy of Sciences in 2010.

Iveta Mrazová (* 1966) finished her studies at the Friedrich Schiller University in Jena, Germany, in 1989. She worked on her thesis dedicated to neural nets at the Institute of Informatics of the CAS. In 1996, she was awarded the Annual Prize of the Bolzano Foundation for the collection of original publications on neural networks and a year later she gained a Ph.D. degree. In 2002 she won the Fulbright Commission scholarship, which gave her an opportunity to gain international experience during her stay at the Missouri University of Science and Technology, USA. Since 1992 she has been teaching at the Faculty of Mathematics, Physics and Informatics of the Charles University and in 2007 she became associate professor at the Department of Theoretical Computer Science and Mathematical Logic—she is currently the head of this department. She has received numerous awards for her work in science, including the annual Bolzano Foundation Award and the Prof. Babuska Award, given by the Union of Czech Mathematicians and Physicists and the Czech Society for Mechanics. She has long-term interest in the utilization of neural nets in the context of data-mining. The paper "Enforced Knowledge Extraction with BP-Networks" [11], co-authored by her and Zuzana Reitermanová, obtained the Best Paper Award of the conference Artificial Neural Networks In Engineering (ANNIE) in 2007. Since 2014 she has been cooperating on analysis of data gathered in the Czech Insolvency Proceedings [12].

Vlasta Radová (* 1969) graduated in 1992 from the Faculty of Applied Sciences of West Bohemian University, majoring in technical cybernetics. Here she continued her doctoral studies and subsequently habilitated in 2005. She remained faithful to the Faculty throughout her professional life. She works at the Department of Cybernetics and at the university research center dedicated to new technologies for information society, NTIS. Her research focuses on artificial intelligence, speech technologies, speech processing [13] and speech recognition [14]. She has completed internships abroad in the USA and Hungary, and is a member of several professional societies and committees. In 2009–2014, she represented her alma mater on the Board of the Council of Universities; she is also a longtime member and former chair of the Academic Senate of the Faculty of Arts and Sciences and the Academic Senate of the University of West Bohemia.

Hana Rudová studied mathematical informatics at the Faculty of Informatics, Masaryk University, in Brno, where she obtained a master's degree in 1995 and entered for her doctoral studies, too. In 2001, she gained a Ph.D. degree for her thesis *Constraint Satisfaction with Preferences*. Since then she has been working on various problems broadly related to scheduling and routing, such as educational timetabling, scheduling for distributed environments or transport planning [15]. Her work is inspired by real-life problems coming from practice, and she concentrates on approaches that can contribute to solving practical problems, namely, meta-heuristics, constraint programming or mixed integer programming. She applies her knowledge in problems arising, e.g., during course timetabling in the UniTime system, computer job scheduling in CERIT national infrastructure or vehicle routing [16]. She generously shares her practical experience with students during the courses on Scheduling, Constraint Programming, and Artificial Intelligence. In 2010, she gained the title associate professor in Informatics at Masaryk University, Brno. From 2011 to 2015, she served as the vice-dean of bachelor's and master's studies at her alma mater.

Hana Rudová is a co-author of more than 120 research papers. She is an associate editor of *Journal of Scheduling* and member of the PATAT steering committee. She co-chaired the Novel application track at the ICAPS conference in 2017 and 2018 and co-chaired as well as co-organized the PATAT 2006 conference in her home town. She regularly serves in program committees of conferences such as ICAPS, AAAI, IJCAI, PATAT or MISTA, and co-organizes the ongoing International Timetabling Competition (ITC 2019) with more than 300 registered users from about 60 countries. She spent a half year both at Carnegie Mellon University in 2016 and Purdue University in the USA in 2001.

Jiřina Vejnarová (* 1962) obtained the RNDr. degree (corresponding to M.Sc.) in Probability and Statistics from the Faculty of Mathematics and Physics, Charles University, Prague, in 1986, and the CSc. degree (corresponding to Ph.D.) in Theoretical Cybernetics from the Czechoslovak Academy of Sciences in 1991. Since 1986, she has been with the Institute of Information Theory and Automation at the Czech Academy of Sciences. In 2009, she became the deputy director for research of this institute and in May 2017 its director. Her research interest is in the field of structured multidimensional models in the framework of imprecise probabilities, particularly in possibility and evidence theories [17]. She has authored (and co-authored) more than 50 research publications in these areas. She has been involved in several research projects (both Czech and international ones). Since 1996 she has been teaching at the Faculty of Informatics and Statistics, University of Economics, Prague, and since 2008 at the Faculty of Nuclear Science and Physical Engineering, Czech Technical University in Prague. At present she is responsible for the undergraduate courses on Theoretical Computer Science, Information and Inference Theory and Probabilistic Models of Artificial Intelligence. In 2011, Jiřina Vejnarová was appointed associate professor of the Czech Technical University in Prague. She has been a member of numerous program and organizing committees at international conferences and personally organized the 5th International Symposium on Imprecise Probabilities: Theory and Applications ISIPTA'07 in Prague. She also co-chaired the program committee of this conference. From 2003 to 2010 she was a member of the Board of Czech Society for Cybernetics and Informatics; she is also a member of the Editorial Board of the journal *Kybernetika*.

Barbara Zitová received her Ph.D. degree in software systems from the Charles University, Prague, Czech Republic, in 2000. Her research interests cover all aspects of digital image processing and pattern recognition; particularly, object recognition by invariants [18], degraded image recognition [19], geometric invariants, theory of moments, remote sensing and medical imaging applications and cultural heritage applications. She is a head of Department of Image Processing at the Institute of Information Theory and Automation, Czech Academy of Sciences, Prague. She teaches advanced courses on Digital Image Processing and Wavelets in Image Processing for students of the Faculty of Mathematics, Physics and Informatics at Charles University and of the Faculty of Nuclear Science and Physical Engineering, Czech Technical University. She has authored/co-authored more than 70 research publications in these areas, including two internationally recognized monographs on pattern recognition [20] and image analysis [21]. Barbara Zitová has many editorial and organizational activities. Among others, she has been an Associate Editor of the journal *Pattern Recognition*.

Olga Štěpánková (* 1949) graduated in Theoretical Cybernetics at the Faculty of Mathematics and Physics, Charles University, Prague, in 1972, and received her Ph.D. in Mathematical Logic there later. In 1972, she joined as a researcher The Computer Science Institute of the Czech Technical University in Prague. Since 1988 she has been working at the AI group at the Faculty of Electrical Engineering of the Czech Technical University in Prague (CTU). In 1998 she became professor of technical cybernetics at CTU. During the period 2004–2012 she worked as deputy head of the Department of Cybernetics at CTU. After establishment of the Czech Institute of Informatics, Robotics and Cybernetics at CTU she joined the institute in 2016 and since then she is head of the department of Biomedical Engineering and Assistive Technologies.

When starting her research carrier, she wanted to test the strength of mathematical logic as a tool for accomplishing some of the AI tasks [22]; e.g., goal-oriented action planning for an autonomous agent. That topic led her later to investigation of the properties and limits of the logic programming paradigm and of the reasoning necessary for building distributed systems [23]. Both these research streams share an interest in the efficient performance of the suggested approaches. The sources of inefficiency in a specific solution can be identified through careful analysis of the data produced by the system during its problem-solving activity. She started to search for machine learning tools that could do the job and she became fascinated by their ability to find structure in extensive complex data sets [24–26]. She saw promising potential machine learning offers for data interpretation in the domain of biomedical engineering and since then her team has been cooperating with numerous experts from the medical or biochemical domains, not only to design and implement complex SW solutions for medical data collection and interpretation but also to study how AI and robotics can contribute to better care through the design of novel assistive technologies. She was always aware of the responsibility researchers have towards society and as an active member of the Czech Society Cybernetics and Informatics (CSKI) she promoted utilization of standardized and continuously innovated ICDL/ECDL international certification of digital literacy in the Czech labor market. She supports this concept even now as the CSKI chairwoman.

Lenka Lhotská (* 1961) graduated as Master of Science in Electrical Engineering at the CTU. In 1989 she got her PhD degree in Cybernetics from CTU. In 1984 she joined the Department of Control Engineering, CTU. In 1997 she became associated professor of Cybernetics and head of the Biocybernetic Lab, AI Division, of the Department of Control Engineering. In 2016 she joined the Czech Institute of Informatics, Robotics and Cybernetics, CTU. Currently, she is head of the COGSYS Department (Cognitive Systems and Neurosciences) at the Czech Institute of Informatics, Robotics and Cybernetics and deputy head of the Department of Natural Sciences of the Faculty of Biomedical Engineering, CTU.

Lenka Lhotská joined the AI area in mid 1980s and since that time she has been focusing on decision support systems, knowledge representation, machine learning and multi-agent systems. More than 25 years ago, she started more intensive research and development of the medical applications of AI methods. Currently, her research focuses on following areas: knowledge-based systems, data and knowledge representation, application of artificial intelligence methods to medicine, digital signal processing, machine learning, feature extraction and feature selection, semantic interoperability, mobile technologies in healthcare and electronic health records. She is chair of the Working Group Personal Portable Devices of European Federation for Medical Informatics, member of the Council of the Czech Society for Biomedical Engineering and Medical Informatics, national representative in the International Society for Telemedicine and eHealth (IsfTeH), national representative in International Federation for Medical and Biological Engineering (IFMBE) and Member of the Engineering Academy of the Czech Republic.

She has supervised 20 PhD students (5 of them were women), who all successfully defended their theses. Currently, she is supervising 7 Ph.D. students. She has authored/co-authored more than 100 research publications in the abovementioned research areas, including several book chapters. She was co-chair of the program committee of the 2018 IUPESM World Congress on Biological and Medical Engineering and Medical Physics. She has many editorial and organizational activities. Among others, she has been an Associate Editor of the journal *Health & Technology*.

All these personalities contributed and still contribute to the development of AI methods and their applications. Jana Zvárová († 2017) was among the first who initiated research in medical informatics and decision-support systems. She envisaged the importance of the relation between data, information and knowledge, in particular in medical applications [27,28].

All of these women serve till now as positive role models for students and young researchers. So, there is no wonder that they found their followers, among which many talented female researchers appeared and became members of their research teams or finally organized their own teams.

3. AI Project Applications in Medicine

Modern health care is highly specialized. Complex examination of a single patient involves many expert consultations and laboratory tests. Medical knowledge, examinations and treatment are distributed functionally, geographically and also temporally. There is a need for reliable and consistent information flow among all participating subjects, with the aim to satisfy the global goal—improved health of a patient. Of course, the necessary information flow is not predictable in its extent or structure, but develops and changes in time due to new knowledge and reactions. To satisfy these requirements and provide adequate decision support, the use of flexible intelligent software support is becoming increasingly desirable. Many of these systems utilize artificial intelligence methods as a suitable approach to big heterogeneous multidimensional and multimodal data analysis.

When we look at the topics of our research projects during the past decades we can find several common lines, namely, large multimodal and multidimensional data, continuous data (e.g., signals), machine learning, feature extraction, feature selection using optimization methods and semi-automated classification methods [29–32].

The first application areas in medicine were those that are data intensive. In our case, the collaboration started in cardiology, electrophysiology, neurology and diabetology. Later, rehabilitation was added. With the advancement of the Internet of Things and wearables, new areas opened in home care and telemedicine [33].

In the following, we present the most important relevant projects we have been involved in and their results. We selected as examples those projects in which the principal investigator or even the co-investigator was a woman. This information is shown at each project.

Knowledge-based support of diagnostics and prediction in cardiology (PI female—Lenka Lhotska)

In this project, a set of theoretically well-developed methods and algorithms for knowledge-based support of diagnostics and prediction in cardiology was designed and developed [34,35]. Developed methods were implemented. The implemented system allows to analyze data from multi-electrode records of surface ECG [36], solve inverse problem, integrate results of further methods and suggest diagnosis on their basis [37–39]. A database of interpreted data was developed. The project supported especially interconnection of basic research in the area of artificial intelligence with application of developed methods to medicine. A real-world task provided a platform for verification of both the functionality of the proposed methods and the medical application itself. The project results are used in electrophysiology and constituted a good theoretical platform for a successive project in cardiology, as described in the next paragraph.

Features of electromechanical dyssynchrony that predict effect of cardiac resynchronization therapy (PI female—Lucie Riedlbauchova; co-investigator—Lenka Lhotska)

Impaired coordination between the ventricles or uncoordinated contraction of individual ventricular walls against each other (dyssynchrony) contribute to further heart failure progression in some patients. Reduction or elimination of dyssynchrony through cardiac resynchronization therapy (CRT) is able to slow or even stop pathologic remodeling, improve heart failure symptoms and induce reverse remodeling, leading to a decreased hospitalization rate and mortality. However, our abilities to identify the presence and type of dyssynchrony are still limited and although the primary goal of CRT is to restore the normal ventricular contraction sequence (i.e., to eliminate mechanical dyssynchrony), our current CRT indication criteria are based solely on an electrical dyssynchrony, specifically on assumption that it is present based on a 12-lead ECG. Therefore, the aim of this study was to assess the relationship between electrical and mechanical dyssynchrony, their contribution to ventricular contraction inefficiency and to identify the relevant markers of the presence and extent of mechanical dyssynchrony [40,41]. The main tasks were development of methods for intelligent analysis of body surface potential mapping (128-channel ECG) [42–44] and MRI analysis of heart mechanical activity.

Intelligent methods for evaluation of long-term EEG recordings (PI female—Lenka Lhotska)

In this project, we designed a methodology for automated processing and evaluation of long-term EEG records, based on a set of theoretically well-developed methods and algorithms. Developed methods were implemented and tested on real biomedical signals recorded at a neurology department. The implemented system allows automated detection and classification of specific graphoelements (parts of signals with a characteristic shape and defined diagnostic value) in long-term EEG records [45–48]. A database of interpreted EEG segments was developed. The recorded signals provided a platform for verification of the functionality of the proposed methods as well [49]. The project results were directly applied at several neurology departments of Czech hospitals. Later, we applied the developed methods to processing of a similar type of data from various areas of medicine and technology.

When finishing the project, we found that in some cases it is more suitable to approach the data in a personalized way, namely, in experimental medicine, there are usually complex data of small number of patients, frequently with high interpersonal variability. In such cases, many methods fail or do not give satisfactory results. This was a motivation for us to design a new project Temporal context in analysis of long-term non-stationary multidimensional signal.

Temporal context in the analysis of long-term non-stationary multidimensional signals (co-investigator female—Lenka Lhotska)

The project focused on temporal context-aware approaches in active learning. We hypothesized that the utilization of the contextual information within the query selection or generation can make the active learning more efficient and available for all temporal context-aware methods. This approach is novel, as it transfers a large portion of temporal context handling directly to active learning approaches and thus makes the active learning more efficient and available for any temporal context-aware supervised machine learning method. The proposed research aimed to answer three main questions: (1) How to utilize a given information about temporal context within the active learning approaches? (2) How to utilize a learned temporal context within the active learning approaches? (3) How to extend the application area of the developed approaches?

We consider as the main results the proposal of the methodology of a semi-automatic approach to long-term signal classification utilizing active learning. The designed and implemented methods were tested and validated on real data—polysomnographic recordings.

The proposed semi-supervised method enables fast and objective evaluation of PSG data compared to the gold standard manual scoring done by a certified sleep expert. The undisputed advantage of the proposed method is its independence in the configuration and amount of training data. The method can work with any available PSG recording. The algorithm does not require a specific location of EEG electrodes or montages and has greater resistance to unexpected artifacts in the data; thus, it is robust to noise. We proposed to use the hidden Markov model for the detection of the transitional instances, and proved that it supports the active learning better than the label-based method.

Publications [50–52] present the important results achieved in the area of classification of complex long-term data, tested on real clinical data. They show two different approaches—fully automated unsupervised and semi-automatic supervised. In the first case, active learning can be added as the next step. The other two present advantages of active learning combined with hierarchical clustering and hidden Markov models, respectively. Automated behavioral state classification in intracranial EEG (iEEG) recordings is beneficial for iEEG interpretation and quantifying sleep patterns to enable behavioral state-dependent neuromodulation therapy in next-generation implantable brain stimulation devices. The suggested cluster-based approach can be linked with currently available methods for evaluation of long-term EEG/PSG. It can create a revolutionary and comprehensive tool for the field of experimental and clinical medicine. The active learning outperforms the random sampling in semi-automatic EEG-based sleep scoring in terms of mean class error. Its main conclusion is a solution of the problem of detection of potentially ambiguous data instances that should be not queried for labeling. The method based on the most probable state sequence of HMM can find data instances whose deletion from the training set can statistically significantly improve both the random sampling and the active learning procedure.

Evaluation of cardiotocography using artificial intelligence methods (co-investigator female—Lenka Lhotska)

The aim of the project was a comprehensive computer analysis of intrapartum fetal monitoring. Using artificial intelligence methods and the synergy of technical approach and clinical experience, a system was developed to support the diagnosis of intrapartum fetal hypoxia [53]. A dataset of approximately 10,000 pregnant women was be created containing intrapartum monitors and other data assessing the incidence of hypoxia in the peripartum period. The data were evaluated by independent experts. The final annotated database was verified also internationally and then published on Physionet. The database serves as a platform for data mining and a tool for validation of the methods being developed. Hypotheses were tested as to whether artificial intelligence and digital signal processing algorithms are able to reliably discriminate abnormal CTGs and whether they outperform the results and/or variability of physician decision making [54–56]. Furthermore, the importance of using additional information from medical history and the qualitative impact of individual clinical symptoms on the accuracy of the automatic classification and individual algorithms were tested.

Individual dynamics of glycaemia excursions identification in diabetic patients to improve self-managing procedures influencing insulin dosage (PI female—Katerina Stechova; co-investigator female—Lenka Lhotska)

The aim of the project was interdisciplinary research focused on decision support in diabetic patient treatment. The core is the design of a software prototype (SW)—an application for cell phones—that offers to a diabetic patient treated by an insulin pump an advanced advice on insulin dose based on previous individual experience (self-learning algorithm) [57–59]. Inputs for the SW are (1) complex information on food content (including glycaemia index and reflecting the previous patient's glycaemia reaction to the similar type of food); (2) the amount of active insulin (information available from the insulin pump); and (3) additional information on physical activity and stress (psychic, illness, etc.). The SW uses information about food to be consumed, logbook data analysis and online connection to the food database [60,61]. Improving fitting the insulin dose to real needs improves diabetes stabilization further, with important individual as well as socio-economic impacts. Several project outputs are planned to be applied in other patients requiring precise diet management.

COGAIN project (Computer Gaze Interaction) (co-investigator female—Olga Stepankova)

The COGAIN project was a network of excellence supported by the European Commission's IST 6th framework program from 2004 to 2009, which aimed to study the possibilities of alternative gaze-based tools for interaction with a computer, namely, for persons who could not utilize the classical interfaces for diverse reasons [62]. Various implementations were developed—special attention was given to eye movement recognition and various approaches that can improve the quality of the acquired data. Infra-red illumination is one of these approaches. The project tried to answer questions related to the advantages and dangers related to long-term use of gaze-based solutions. The project started investigating the optical safety of extensive exposure of a human eye to infrared eye trackers and the results of its activity contributed to accepting the corresponding standard by Commission Internationale de L'Eclairage in 2021 [63]. The project founded the COGAIN Association that aims to promote research and development in the field of gaze-based interaction in computer-aided communication and control.

MAS Nanoelectronics for Mobile Ambient Assisted Living (AAL) Systems, EU ENIAC project, No. 120228 (2010–2013) (co-investigator female—Olga Stepankova)

The objective of the MAS project was to develop a common communication platform and nanoelectronics circuits for health and wellness applications to support the development of flexible, robust, safe and inexpensive mobile AAL systems, to improve the quality of human life and improve the well-being of people. In this context, reference architectures were defined in order to enable system development from devices to complete mobile AAL systems, and to enable cooperative clusters of such systems for specific environments and applications. Various approaches to visualization of the data and results were developed and tested on real data [64].

MAS focused on the development of an integrated approach for the areas of health monitoring and therapy support at home, and mobile health, wellness and fitness. The systems were intended for remote patient supervision using multi-parameter biosensors and secure communication networks [65], and health and wellness monitoring in the home environment. Mixed healthcare and consumer markets were targeted with the MAS-platform-based devices, with five application demos: (1) Health and Activity Monitor; (2) Point of Care Terminal and Gateway; (3) Cardiovascular Monitor; (4) Diabetes Monitor; and (5) Mobile Cardiotocography [66].

The key developments addressed mobile, unobtrusive sensor systems with standardized interfaces linked by secure wireless communication to a managing controller. User-friendly interfaces, multiple heterogeneous sensors networks, low power and power management formed key elements of the platform. Seamless connectivity, interoperability and cooperation across mobile AAL systems, health service providers and patients were field tested in different environments.

SPES (Support Patients through E-services Solutions, 2011–2014, 3CE286P2, Operational Program CENTRAL EUROPE) (co-investigator female—Olga Stepankova)

The SPES project demonstrated that technological solutions can improve the quality of life of patients with chronic and serious diseases and of their families. Most of these patients are aged people who have reduced movement capabilities and some difficulties in going to periodic medical examinations to the hospital or medical centers. The technological solutions in the field of telemedicine, such as the patients' home health care, social inclusion tools not only addressed to young people or monitoring systems for non-self-sufficient people, are examples that can be easily evaluated both by decision makers and patients. The SPES project implemented tele-health and entertainment platform in four cities—Ferrara, Vienna, Brno and Kosice—focusing on dementia, handicapped people, respiratory problems and social exclusion. Patients had the opportunity to exploit an easy-to-use telemedicine solution, lowering their displacement costs and the time necessary for going to the care service providers (hospitals, grand physicians and medical centers).

DISTINCT project (Dementia: Intersectorial strategy for training and innovation network for current technology, 2019–2022, EU Horizon 2020 Marie Skłodowska-Curie grant, No. 813196) (co-investigator female—Olga Stepankova)

The rapid growth of the technological landscape and related new services have the potential to improve the cost-effectiveness of health and social services and facilitate social participation and engagement in activities. It is generally believed that well designed and reliable technology has the potential to simplify our daily lives, compensate for disability and promote social inclusion. However, most products available on the market are only ready to support and solve the problems as perceived by an average adult. They do not work for people with cognitive impairment. Even worse, high penetration of technological gadgets throughout all places in society places at high risk the exclusion of all who fail to upgrade or maintain their competencies to manage technology. This risk pertains to daily life at work, in public space as well as at home as the complexity of both realms is continuously increasing. The users' ability to manage products and services has been largely neglected or taken for granted.

The DISTINCT project first identified more than a dozen hot research topics to be resolved within the frame of a Ph.D. study that can contribute to one of the three domains of social health the project is organized around: Technology to enable people to fulfil their potential and obligations; Technology to enable people to manage their life with some degree of independence; and Technology to enable people to participate in social and meaningful activities. Second, the project partners recruited for their topics enthusiastic early stage researchers (ESR) who decided to enter Ph.D. studies at the partner institutions and make from this topic the subject of their dissertation. The main task of the project is to ensure the recruited students have an inspiring, truly international environment; e.g., by offering them a possibility to cooperate for several months with two additional co-supervisors at two different partner institutions. Further, a significant part of the ESR's education is provided in a block format during regular project gatherings (DISTINCT schools) where all the ESRs can share their experience and discuss their recent achievements. The project pays special attention to the top quality content of its schools organized twice a year.

The ESR at our institution is developing a low-cost pet-bot well informed about the activities of its owner through a data stream provided by smart home sensors and their customized interpretation [67]. We intent to use such an interpretation to trigger timely unobtrusive reminders to be provided by a care-bot for patients with dementia.

4. Education in AI

High quality research is very important for successive development of practically applicable solutions. However, research cannot exist without the education of a young generation of researchers. The AI topics penetrated first as topics into existing courses in the early 1990s and gradually developed into separate courses at several Czech universities in study programs of Cybernetics, Computer Science or Information Technology. During the last two decades, artificial intelligence became an independent study program at many universities. At CTU in Prague, there are two study programs explicitly mentioning in their name or in the name of their specializations Artificial intelligence, namely, a bachelor study program in Artificial Intelligence at the Faculty of Informatics and the study program Open Informatics of the Faculty of Electrical Engineering with its bachelor specialization in Artificial Intelligence and Computer Science and master specialization in Artificial Intelligence.

The subject AI is included as a compulsory one also in more study programs. One of these is the study program Biomedical and Clinical Informatics, where the AI-related courses constitute a substantial part of the curricula. This study program stresses the importance of the close connection of the theoretical methods with the large application area of medicine. The students get insight into the terminology, data acquisition, medical procedures and other related topics. They gain knowledge for the design, development and security of biomedical applications. In frame of their projects and finally master's theses, they work on topics coming from the health-care area. After graduation, they are able to implement algorithms for processing, interpreting and evaluating biomedical data, apply their knowledge in the development of mobile and telemedicine applications, and implement personalized solutions for care in medical facilities, etc. The program graduates are also able to analyze biomedical data, design procedures and algorithms for their evaluation and implement them in clinical practice. The acquired knowledge enables the graduates to understand the genesis of biomedical data and to acquire the relevant terminology that facilitates professional cooperation with doctors and researchers.

The next one is the program Assistive Technologies, leading to master's degree and offering education at the doctoral level, too. This study program is accredited at the Faculty of Biomedical Engineering and its first graduates passed their final exams in the year 2021. Design of its curriculum has been extensively inspired by rich experience in the multidisciplinary research to which all the faculty members are highly dedicated. The projects mentioned earlier offer a representative sample of topics that are now further developed by current master's and doctoral students. These students have a solid background not only in signal processing, programming, AI and data mining, but their curriculum covers even user-centered design as well as electronics, health information systems, Healthcare Interoperability Standards and safety issues.

We observe in all the above-mentioned study programs a slow, but gradual, increase in female students, which is a positive sign of change in their thinking about their future career. We are convinced that the positive examples set by successful female Ph.D. graduates also contribute to this trend. The CTU supports the activities of female students. There exists a female student club, wITches, that organizes events for children with the aim to increase their interest in engineering and informatics. We are well aware of the fact that it is a long-distance race. However, we see the first results as more female students have applied for the study of AI at CTU in recent years.

5. Conclusions

The task to describe the artificial intelligence research and most important women in this area in the Czech Republic was not easy. Although there are many personalities that reached excellent results, they are not so known outside the AI community. In addition to the research and educational activities, we see their role in mentoring and supervising young researchers, in particular female researchers, for which they might serve as models of their future career. We tried to select those researchers who were/are active in AI research aiming at medical applications. In the project description we selected a broader variety of our projects to show how colorful and variable the topics in medicine and health care are and how AI methods can be applied.

Health care as an application area has great potential for the implementation of many AI systems to various phases of the care cycle, population and epidemiological studies, and other connected areas. In all cases, data, information and knowledge represent the core of the decision-making process. Decision-support systems were originally intended to be applications for a small group of specialists; in recent years, we can observe a transition to more widely used applications. All applications process data and information. The final result, having the form of a recommendation or even decision, is highly dependent on the quality of the data and information and not only on the quantity of data. That means that the quality must be understood properly and the data and information verified accordingly. The main properties that should be checked are completeness, consistency, validity, precision, redundancy, readability, accessibility, confidence, credibility and usefulness. There are still many open issues that will require our attention in future research as new demands on the functionalities of applications appear. Just to mention a few of them:

- Exchange of data, information and knowledge is desirable; however, it imposes requirements on high-level communication protocols and data structures so that the sender and receiver understand each other. In this context, we speak about interoperability at the data, information, knowledge and process levels.
- Current Health Information systems and electronic patient records place great demands on the time their user has to dedicate to input of all the requested data [68]. It is important to bring into focus a user-centered design of these systems and various possibilities of how this process could benefit from the application of recent AI achievements.
- Last but not least, it is necessary to pay due attention to ensuring data privacy, ethics and the corresponding legal regulations.

Some challenges are directly open in the AI domain; the most significant ones are explainable and trustworthy AI that is fully in line with the requirements already appearing in the medical domain, where an explanation of the proposed solution (diagnosis or therapy) is of utmost importance.

All mentioned issues open new fields for new research projects, topics for Ph.D. theses and finally applications that can find their place in routine practice.

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