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Visegrad Inteligence

AI-Driven Transformation: The state of Artificial Intelligence and its Innovative Potential in V4 Countries

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WWW.POLITIKASPOLECNOST.CZ
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Content

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Introduction: Together we stand, divided we fall

The global digital economic transformation already is and will be driven by megatrends such as AI-supported automation and robotization. Artificial Intelligence, High performance computing (HPC) and cybersecurity technologies are the cornerstones of the Digital Agenda for Europe 2021–2027. To play an active role in the EU and on a global level the V4 group needs the right policies, regional R&D cooperation and strategic international partnerships. The "Visegrad Intelligence" project, conducted by the Institute for Politics and Society, together with partners and supported by the International Visegrad Fund, therefore aims to map and review existing AI policies, R&D centres and strategies in the V4. The main goal is to formulate recommendations for joint policies and projects to help better coordinate resources and efforts, avoid duplicities and formulate joint statements on regional, European and also on the global level (UN, OECD).

Some coordination already takes place e.g. via Strategies Smart Specialisation (RIS3). The countries build on the assets and resources available in specific regions. However, they need more calibrating among V4 countries. A few steps to strengthen cooperation were outlined in the 2017 Warsaw and 2018 Budapest Declarations. On an operational level, a good start is the joint paper on "AI and maximising its benefits" as well as the Memorandum of Cooperation in the Field of Innovation that the V4 signed with Israel. The Visegrad Intelligence project aims at a more efficient and impactful use of intellectual capacity, infrastructure and financial resources, which are now separately streamlined for innovation and AI in all four countries. To achieve that, the V4 first needs to know what is available. Only then, better policies, innovation programs and collaboration can be implemented.

The mission of the Institute for Politics and Society is to improve policy making by means of supporting professional and open discussion among independent experts, government representatives and politicians. Thereby it creates a living platform that identifies key political and economic challenges, analyzes their impact on society and offers evidence-based solutions. This project shall enable V4 to better navigate the needs of partners in the area of AI and innovations. It provides a helpful database of stakeholders, problems and existing regulation of artificial intelligence. The recommendations proposed as part of the project aims to provide framework to create more meaningful work agenda for the upcoming years.

The partners of the Visegrad Intelligence project are:

- Institute for Politics and Society
- AI Center at Faculty of Electrical Engineering, Czech Technical University
- Republikon Institute
- Unico.ai

1. Czech Republic

1.1. Country Summary

- The Czech Republic has the potential to become a European leader in AI. Its technological ecosystem includes all the necessary actors, strong R&D, supporting infrastructure, governmental commitment as well as geographical and economic links to the top European AI research and application centres.
- The main actors in the Czech AI ecosystem are research organisations and private businesses - SMEs counterweighted by large multinational corporations and their own research centres. The Czech Republic has a comparative advantage with excellent research and development, both in primary and applied research. There are more than 1000 researchers of AI (headed by the Czech Technical University) and universities also produce more than a hundred experts in the AI field annually. Approximately 40 AI start-ups operating in the Czech Republic matches are comparable to other EU countries.
- The results of R&D are on par or even above international achievements and R&D application is heading towards sectors with the largest AI impact. Targeted R&D support grows in the long term, 80% is used by universities, the rest by SMEs. The technological focus is diverse, particularly on cognitive skills such as gathering information, logical decision-making and speech processing, some also on creativity, logical thinking, and intelligent systems. These areas give opportunities especially for R&D carried out by research institutions and it is very positive that the projects address up-to-date issues such as robotics, cyber security and transport technologies.
- The topic of digitalisation and AI has become one of the top priorities of the Czech government. It has committed itself to becoming one of Europe's innovative leaders and a country of the technological future within twelve years based on the Innovation Strategy 2019–2030 and the Digital Czech Republic programme. There are efforts not to overregulate the digital sector, to attract foreign talents and the government committed significant money for investments to boost innovations in economy, especially SMEs.
- The government has recently adopted a dedicated National AI strategy and established the AI Council chaired by the deputy prime minister. It wants to build on the strong R&D in AI as well as the technological tradition and support efforts to organize one of the networks of European centers of excellence from Prague and also the cross-border effort to build world class testing facility together with neighbouring countries. It shall be based both on cooperation with the top researchers across Europe and involvement of top researchers from new member states.
- The Confederation of Industry of the Czech Republic has set up a Platform for AI, the AICZECHIA society has been established and the main universities supported by the City of Prague unveiled the prg.ai program to build global AI superhub.
- The Czech economy will be among those significantly impacted by AI in its employment structure. The Government stated that Czech Republic wants to become a model country for automation in Europe and will embrace automation, especially in the SME sector, and push for the transformation of education and social systems.

1.2. Introduction

Artificial Intelligence (AI) is no longer science fiction but has become a part of our everyday life. Due to the increase in computing capacity, data availability, and progress in algorithm development, AI has become one of the strategic technologies of the 21st century. In April 2018, the European Commission launched the "Artificial Intelligence for Europe" initiative [23] to ensure a coordinated EU approach making the most of the opportunities offered by AI and addressing the related challenges. The aim of this initiative is to significantly strengthen the EU's technical and industrial capacities and to support the use of AI throughout the economy, to prepare for the wide-ranging socio-economic changes caused by the development of AI and to provide an appropriate legal and ethical framework for all the related processes. The total public and private AI R&D investment in the EU, estimated between 4 to 5 billion EUR in 2017, should rise to at least 20 billion EUR by the end of 2020, according to the European Commission. The strategies took a concrete form in the Coordinated Plan on Artificial Intelligence issued in December 2018 [24]. The aim of this plan is to maximize investment at the European and national level, to strengthen cooperation between Member States in the field of AI and to identify the main directions of the development of AI in the EU.

The need for an active engagement in the deployment of AI technologies stems from the assumption that the economic growth in the following period will heavily rely on the use of new technologies. Digital technologies and AI have a leading role in this respect. According to the economic model developed by Deloitte for the Czech Republic [14], automation will lead to productivity gains in the production factors, GDP and wages. Assuming full realisation of the technological potential for automation and full workforce adaptation, the average growth rate of the economy could reach 3.9% per year over the next 16 years. Thus, the potential of the economy would increase by 78% by 2033, which is more than double in comparison to the baseline scenario without the use of automation. National studies of other countries, e.g. the Finnish analysis [25] have come to similar conclusions.

Another reason why this topic has been addressed with high urgency in a number of countries is the expected disruptive impact of AI technologies on the labour market. This will impact not only low and mid-level qualification jobs, but practically all types of employment, including high paying jobs that require a high level of qualification. Considering the workforce structure of the Czech Republic and the way the country is involved in the global value chains, it is expected that it will be among the countries significantly impacted by AI in its employment structure (see e.g. [35] and [47]). This will require adaptation not only of the social security and retraining system but also of the whole education process.

The transformation of the education system at all levels is a key task that will have a crucial role both for providing top scientists and researchers and for delivering a high quality and adaptable workforce. The importance of specific knowledge is decreasing in favour of the importance of complex skills, especially so-called 21st century skills[1], along with computational thinking.

As a first step in the systematic approach to AI in the Czech Republic for the future, we can identify the need for a national strategy involving the priorities in the AI field, following the

[1] Sometimes also referred as so-called soft skills, i.e. skills aimed at developing creativity, critical thinking, collaboration and communication with people as well as machines, presentation, project management and problem solving.

Digital Czechia government program [17]. The formulation of this strategy should provide answers to the following questions:

1. How can the public and private sectors ensure that businesses and research institutions receive the necessary support for development and deployment of AI-based innovations so that the AI potential is fully exploited in terms of competitiveness and economic growth?
2. How can the public sector exploit the potential offered by AI in its own activities to provide high quality public services effectively? How can data-oriented businesses benefit from the secondary use of public sector information sources?
3. How will AI influence us as individuals and what impact will it have on the labour market? What will be its wider impact on society and how to prepare for it? How can we ensure that our social structures adapt to the changes brought by AI and that we continue to be a well-functioning, prosperous society?
4. What new ethical and legal issues does AI cause and how should society and the legal system be prepared for their implementation? What regulatory measures should be addressed by the public sector at the time of the rise of AI?

This report summarizes the key findings of three more elaborated studies that analysed the situation in the Czech Republic and offered answers to the aforementioned questions. More precisely, these studies dealt with (i) the analysis of the research, technological, and business background for AI development in the Czech Republic (in the following text as the "technological study"), (ii) the analysis of the expected socioeconomic impacts of AI development (the "impact study"), and (iii) the analysis of the necessary legal instruments and other regulations in relation to the AI development (the "legal and ethical study"). These detailed studies are available only in Czech on the web page of the Office of the Government of the Czech Republic.[2]

In the final stage of the completion of these studies, a workshop was organised at the Office of the Government of the Czech Republic that delivered expert feedback from the public, private and academic sector participants. The main conclusions reached during this workshop were subsequently incorporated in the final studies.

1.3. Research and innovation ecosystem

The wide range of the research required for AI implementation represents a major challenge. Efficient and targeted support to R&D and education may be thus considered as a key factor for underpinning the AI development. The conclusion reached in our study is that public R&D in the Czech Republic is strong and doing fine in comparison with other countries, while covering all the essential technological topics of AI.

Its greatest weakness, however, is its inability to retain capable domestic researchers, who are massively switching to the private sector, coupled with its low ability to attract foreign researchers with good results and reputation to work in Czech public research organizations.

[2] The website of the Office of the Government of the Czech Republic focused on the potential of AI (in the Czech language) https://www.vlada.cz/cz/evropske-zalezitosti/aktualne/jaky-je-potencial-umele-inteligence-v-ceske-republice--170808/

The key findings of the Analysis are summarised as follows:

- **R&D AI is implemented by the entire spectrum of public research institutions,** particularly by major technical universities but also by some institutes of the Czech Academy of Sciences and other institutions that are involved in R&D in the AI field. The research covers the full spectrum of the AI technology research, the institutions carry out both fundamental and applied R&D.
- **A supportive infrastructure for AI research has emerged and AI research centres have been established making use of the European Structural and Investment Funds (ESIF) and additional public resources.** These centres have top-quality research infrastructure allowing them to carry out excellent fundamental research in international cooperation (for example, the national Supercomputing Centre IT4Innovations). In the Operational Programmes (OP) framework RDI OP, RDE OP[3] and a number of national programmes, a number of new application-focused centres were created, which carry out R&D in the field of AI and transfer the research results into the application sphere (centres focusing on AI were newly established making use of financing from these programmes, such as CTU Research Centre for Informatics RCI, Czech Institute of Computer Science, Robotics and Cybernetics CIIRC at the CTU, and New Technologies for the Information Society NTIS in Pilsen, West Bohemia). Instrumentation innovation due to the RDI OP, RDE OP was also implemented at a number of other research institutions that are ready to carry out cutting-edge AI research. There are research labs (Research Centres) at universities and other research institutions specifically focused on R&D in the field of AI. A detailed overview of these important institutions is given in section 6.1 of the technology study. In recent years, Technology Transfer Centres were established in most of the institutions that assist the commercialization of the R&D results and support the cooperation with the application sector.
- **R&D in AI is also implemented by a number of Czech businesses, including the small and medium enterprises (SMEs).** Large companies operating in the field of AI are mostly under foreign control and the R&D results are often used by parent companies abroad. An important part of the research and innovation ecosystem in the field of AI are the start-up companies (start-ups). Currently there are almost 40 start-ups in the Czech Republic operating in the field of AI. These start-ups are focused on the development of products and services with a particular focus on the area of information and communication technologies and the development of support tools for various areas of deployment (for example text search, computer vision, etc.). Some of the start-ups in the AI field have been active in the cyber security, marketing, business management and other sectors. In the Czech Republic, there is a relatively strongly developed network of venture capital investors. However, it seems that there is a lack of projects suitable for financing by venture capital.

1.4. Public support for R&D

A major source for R&D funding in the field of AI are the programs of the Research and Development Operation Programme targeted research. Targeted support has grown in the long term and between 2007 and 2017 it almost doubled (reaching CZK 260 million in 2017), with a large increase which occurred especially in the period 2016–2018. The public support for

[3] RDI OP – Framework Programme Research Development and Innovation, RDE OP – Framework programme Research, Development and Education.

R&D of AI will grow in the coming years and should exceed CZK 400 million in 2018 (according to the national R&D Information system and budgets planned for ongoing projects).

- **In the period 2015-2017 the AI R&D focused projects have been supported by the programs of eight providers, especially by the Grant Agency of the Czech Republic (GA CR), the Ministry of Education, and the Technology Agency of the Czech Republic (TA CR)**. None of these programs, however, were specifically focused on R&D in AI and the technology using it. The closest to the AI topic are specific calls for tenders addressed to the TA CR, favouring sectoral projects in the field of Industry 4.0.
- **Targeted support for R&D is used mainly by universities** which received almost 80% of targeted support granted to AI-related projects in the years 2015-2017. R&D is primarily implemented at major universities such as the Czech Technical University in Prague, the Brno University of Technology, the Technical University Ostrava and Charles University in Prague. Some start-ups received public support as well. Approximately 20% of the targeted support has been used by the commercial sphere, including micro-enterprises and SMEs. Other research institutions are involved in AI-focused R&D to a smaller extent.
- **Businesses and research institutions often work together on the projects supported by public funds**. Some university faculties play the key role in R&D in the field of AI and cooperate quite intensively with other entities of the research and innovation ecosystem. On the other hand, businesses cooperate in AI–focused projects to a lesser extent. Research institutions and businesses, including SMEs, are also internationally involved in AI-focused R&D projects that are supported by the EU Framework Programmes. The involvement of the Czech Republic, however is somewhat lower in comparison to the EU-15 countries.[4]

1.5. Orientation of the technological development

The Czech Republic belongs among the countries with the greatest expected impact from automation and technology using AI, particularly in areas such as manufacturing, retail trade, wholesale trade, health care and social services, education and construction. It can be further expected that automation will have a greater impact in the Czech Republic on employment and jobs (which comes together with the high proportion of manual work suitable for automation), while in other countries the automation will have a greater impact on productivity, safety and quality. It can be assessed that the starting conditions for the implementation of AI technology in the Czech Republic are not optimal. The majority of domestic businesses stand at the lower end of the global value chains (GVC) or is controlled from abroad. Therefore, their foreign headquarters will exert decisive control over the implementation of innovations. For home research institutions and especially for companies providing AI solutions, this means a strong orientation towards partners abroad, where these solutions are supplied.

- **The technological focus of the Czech projects is diverse.** R&D projects focus particularly on cognitive skills such as gathering information and logical decision-making. A relatively high number of projects deals with speech processing. The contemporary technologies in these areas have advanced so much that they are

[4] The EU-15 comprises 15 member countries in the European Union before its enlargement in May 2004, i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom.

comparable with human performance, and therefore suitable for their application. R&D in these areas should be implemented primarily by businesses. Some projects have also been focused on creativity, logical thinking, and intelligent systems. In these areas, the current AI systems fall short in comparison with humans, which gives opportunities especially for R&D carried out by research institutions. It is very positive that the supported projects also address some up-to-date issues such as robotics, cyber security and transport technologies.

- **Orientation of the projects supported by the programs of the targeted applied R&D support is - in terms of expected AI impacts in the Czech Republic – not optimal**. As revealed by the analysis, a relatively high number of supported projects has displayed a general focus (i.e., without connection to the application sector) or has dealt with the use of AI methods only as a supporting tool for solving tasks in some of the engineering sectors. Some of the projects offered solutions for the manufacturing sector, finance, insurance and health and social care sectors, which, except for the manufacturing, have the lowest risk level of societal AI impact. The minimal focus of the projects was in the area of administrative and support activities, mining and extraction, trading, which, in turn, are areas with the highest risk level of the AI impact. Some sectors which will be affected by the deployment of AI and automation to a considerable extent are in the Czech Republic and not yet adequately covered by the applied R&D.
- **Strategic application sectors, technological areas and their support**. Implementation fields and technologies which are listed are of strategic importance for the Czech Republic from the perspective of AI impact and development. These are the sectors in which the SMEs are currently involved, applied research is implemented, and in which the largest AI impact is expected.
- **An important prerequisite for the successful implementation of R&D in relation to the current needs of the Czech Republic is the inclusion of the latter into all relevant strategic-policy documents.** The AI topic, however, has not yet been sufficiently taken into account in strategic-policy documents, especially in relation to the disruptive nature of the involved technologies. The current National Research and Innovation Strategy for Smart Specialisation of the Czech Republic (RIS3) specifies only the general areas which offer opportunities for domestic enterprises to strengthen international competitiveness through the adoption of the AI technology. The Digital Czechia strategy also partially addresses these issues.

1.6. Socioeconomic impacts and their solutions

Based on the current technological level in the field of AI, it can be expected that on the five-year horizon the technology will be able to replace more than 50% of the required skills in 11% of occupations. On the thirty-year horizon, automation can replace over 50% of skills in the vast majority of the current professions. At the same time, new professions will continuously emerge, though they will place different demands on their performers and will require different skills and abilities in comparison to current professions.

- **The benefit of automation lies primarily in taking over of routine and repeatable, as well as strenuous work activities by machines** and in freeing human resources for more creative work activities with a higher value added. At the same time, automation increases efficiency, quality, and effectivity of work activities, where machines can perform better than humans. Automation is also a way to replace

the human workforce missing due to the unfavourable demographic development in developed countries.

- **Occupations with a high proportion of routine skills** in the manual area (machine operators, packaging and palletizing, dosing) as well as knowledge area (accounting, data collection and processing, text and data proofing, measurement of physical quantities, quality control) **are among the professions where the most significant changes in the nature of work due to automation and AI can be expected.** The lower risk of human work replacement is in professions with a higher proportion of non-routine and creative skills in the manual area (repair and renovation, services and personal care) as well as knowledge area (research, analysis, planning, design, rules and procedures, negotiation and training, leadership, entertainment and presentation).
- **Especially professions with middle qualifications and income level are facing a higher risk of replacement.** In low-skilled, low-income manual professions, automation is not worthwhile in many cases. In high-skilled and high-income professions, however, the automation potential is reduced by the limited availability of the necessary technologies to automate the non-routine and the creative activities associated with these professions. The drop-in occupations in the middle-income category caused by automation can therefore lead to a deepening of the economic inequality in society.
- **It is necessary to adapt the whole system of education, lifelong learning and retraining to the changing demands on the skills of the human workforce.** The microeconomic data show the increasing importance of the technical expertise (STEM - Science, Technology, Engineering and Mathematics) and the multidisciplinarity. The weight of specialized knowledge is decreasing in favour of the importance of complex skills, especially so-called 21st century skills[5], along with the computational thinking.
- **Strengthening social security and developing social safety nets**. The speed of retraining and finding new jobs is different for different employments and employers, which can lead to an increase in structural and frictional unemployment. The social safety nets must be adapted to this situation in order to offer effective support of the vulnerable employees seeking retraining and knowledge broadening, skills, and abilities for their prospective professions. It will be necessary to verify experimentally which forms of support will work best (e.g. the right to the educational leave tested in France, or the recently negatively evaluated experiment with the basic unconditional income in Finland).
- **Automation will change the nature of work and will cause organisational changes in companies**. Considering the changes in the nature of work, tasks in production and services will be outsourced more to non-core employees. This implies a new demand for the state to ensure social security for a growing number of self-employed people. Instead of a hierarchical structure, companies will prefer a direct and a flexible networking. Greater expectations will be placed on employees in terms of both time and space flexibility of the jobs, which will require a greater flexibility of the wages

[5] Sometimes also referred as so-called soft skills, i.e. skills aimed at developing creativity, critical thinking, collaboration and communication with people as well as machines, presentation, project management and problem solving.

system. A need will arise to adjust the protection of employees with labour law. It will include the need to modernize the Labour Code.

1.7. Development of the regulatory framework

The development of the regulatory framework is **one of the key conditions for the successful development of AI in the Czech Republic**. It has the potential to significantly contribute to increase the competitiveness of the Czech Republic by providing legal certainty and removing regulatory barriers to the development and use of AI. However, **the Czech law is limited up to a certain degree by its dependence on developments in the field of international and European law**, and by the **unpredictability** of the use of AI and its real social consequences. In the European context, AI has already been widely discussed at the EU level and is also highlighted in the European Commission's work program for 2019.

In the field of **ethics**, the legal and ethical study of the aspects of AI development focuses in particular on the general description of current trends in approaching ethical problems associated with AI, identifies key ethical problems and suggests recommendations that may also affect legal regulation. In the field of **Czech law**, the study assesses its readiness for new AI applications, especially with regard to enabling and protecting innovation while ensuring the effectiveness of law in society.

New ethical problems emerge in connection with the development and use of AI. These are addressed in particular in the field of roboethics, i.e. the area of ethical problems faced by people designing, developing and using intelligent machines, as well as in the field of machine ethics, i.e. the area dealing with situations where machines decide on ethical issues.

- **Ethical problems associated with AI**. These problems are related especially to algorithmic bias, classification of people, limitation of their autonomy, interference with privacy, etc. These problems are in general addressed by the creation of ethical codes of conduct that promote leaving control over fundamental decisions in hands of humans ("human-in-command" approach), reject the possibility of ethical decision-making of machines and transfer of liability to machines, warn against possible discrimination, and demand transparency in the functioning of AI. Ethical solutions and ethical codes of conduct shall influence the interpretation and application of law to cases involving the development and use of AI. This shall become apparent especially in the area of prevention and liability. Drafting these codes of conduct has been initiated at both international and global levels.

The legal study assesses the current regulation primarily with the goal of **ensuring legal certainty and predictability** in legal relations while providing a wide space for innovation. Regulation exerts its effects on several levels, the development of which needs to be promoted as an appropriate and flexible addition to legislation. These levels also effectively enable the involvement of all stakeholders.

With respect to the universal applicability of AI in many areas, the legal study identifies a number of **general and specific legal areas**, including for example the financial and banking sector, antitrust law, research and development, social security, autonomous mobility, or autonomous weapons, in which certain problems emerge.

- **The status and legal nature of AI**. The absence of a generally accepted definition of AI is also reflected in law. In various documents, the EU defines AI by reference to a wide range of technologies and focuses in particular on its characteristic features. However, none of the definitions are legally binding. Depending on the nature of a

particular application, AI can have different definitions from various legal institutes (a computer program, a thing, a product, a service, a computer virus). This will in particular have an impact on a liability regime.

- **Liability for AI**. Liability for AI is a key problem associated with AI as it shall significantly affect economic relations in the future. Contractual liability represents a key tool for regulating individual relationships between providers and users of intelligent systems. Legal certainty would be strengthened by the development of model contractual solutions that would propose a fair distribution of rights and obligations. Liability is also significantly influenced by the duty of prevention, the scope of which is unclear in relation to AI. Therefore, in the future, it will be necessary to specify what is considered the best practice. What regards tort liability, given the current state of use of AI, the existing legal provisions can still be used. However, in order to increase legal certainty, some provisions need to be interpreted specifically with regard to AI (in particular the term "proper oversight" and the reasons for the liberation related to product liability). However, given the increasing interdependence and complexity of intelligent systems, existing regulations may prove not to be sufficient in the future.
- **Privacy protection, electronic communications and non-personal data processing**. The GDPR is the main regulation governing the protection of privacy through the protection of personal data. This regulation does not necessarily limit the research and development of AI but, on the contrary, it stimulates it. However, it is necessary to determine the scope of specific provisions in relation to AI. In the area of electronic communications, there is a strong dependence on European law, which is now undergoing major changes. At European level, rules for processing of non-personal data are also being developed.
- **Cybersecurity**. Czech law provides a high level of cybersecurity with the help of a special law that imposes obligations on certain subjects. Other subjects need to interpret general provisions on prevention and obligations stemming from special legislation to achieve compliance.
- **Intellectual property protection**. Existing copyright does not provide legal certainty about rights related to works generated by AI. As an author can only be a natural person, the question arises up to a which degree an intelligent system can be considered a mere tool to create a work and when it fully replaces an author.
- **Other legal issues related to AI**. With regard to the principle of autonomy, an obligation to inform a person that he or she is dealing with AI (a chatbot, etc.) should be established. At the same time, it is also necessary to address the issue of exercising people's own rights through an AI system that acts on behalf of a user based on the knowledge of his/her preferences.
- **Problems in specific legal areas**. Specific problems appear in various legal sectors. The main obstacle to the development and use of AI is in the field of autonomous mobility. At present, it is not possible to test and operate partially autonomous vehicles with a higher degree of autonomy in the Czech Republic. Existing legislation also does not allow the operation of autonomous drones. Specific rules are set for trading on capital markets with the use of algorithmic trading and high frequency algorithmic trading.

2. Slovakia

2.1. Country Summary

- There are several institutions and experts with strong expertise in AI-related R&D in Slovakia. The overall AI-related R&D development matches the size and overall development of relatively comparable countries.
- AI-related R&D excellence in Slovakia is concentrated dominantly in academia with approximately 200 researchers and 40 companies active in the field of AI. The main specialisation of AI-related R&D in Slovakia is artificial intelligence in general, machine learning, and robotics.
- Academic institutions are the central actors in the Slovak AI ecosystem and are represented by universities and research organisations like the Slovak Academy of Sciences. However, the most important player is the Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology dealing with AI and other AI-related topics such as machine learning and robotics. Slovak.ai research centre for AI was established there. Academic research organisation implement over 80 % publicly granted research projects in AI and related fields. Topics of cybersecurity and machine learning are closely connected to R&D activities.
- Companies play the role of knowledge and technology utilizers, no company in Slovakia had more than one AI R&D project funded by the national body during the last two decades (except for one private R&D organisation), only two companies had more than one R&D project in AI. The main specialisation of the company's projects is on Internet of Things, cloud computing, or cybernetics. In Slovakia, we can also find several start-ups focusing on AI or AI-related fields. However, there is not a dominant specialisation in the start-up scene.
- The Slovak government adopted National Strategy for Digital Transformation of Slovakia 2030 that includes AI and related areas as one of the prioritized technologies. The National Strategy does not provide, nor does intend to provide, the individual ways in which the facts are achieved, but the general framework and vision with a plan on the basis of which concrete measures will be implemented. Slovakia would like to become a model country for EU regulation and government intends to support the business ecosystem and be able to face global competition and produce innovations.
- According to the Strategy, more academics are essential to engage in research and innovation in AI as well as simplifying and promoting access to investment for innovative projects and R&D in this area. The government plans to build a National Center of Excellence for Artificial Intelligence in which experts in the field will work and stipulates simplifying the provision of residence to ensure a sufficient number of experts in the country. It also has the ambition to become the center for testing autonomous vehicles in the V4 region over next three years and create services based on data processing as condition for implementation of new platforms in transport.
- The Slovak economy will be probably significantly affected by automation, it is estimated that AI and robotization will impact 40 percent of jobs.

2.2. Introduction

The main goal of this report is to map research and development (R&D) capacities in artificial intelligence (AI) in Slovakia, to introduce the key organizations focusing on AI, both from academia and business, including their specialization and the key academic staff. Therefore, this report provides an overview of existing capacities in AI R&D in Slovakia with a detailed view on the most active and excellent researchers and organisations.

First, methodology and data are discussed. Second, academic research in AI and AI-related topics are presented. The part dealing with companies and startups operating in AI and AI-related fields follows.

For analysing activities of academic organisations and academic staff in AI and AI-related topics, the participation in R&D projects with state financial contribution was used. This data was obtained from the Central informational portal for research, development and innovation (System SK CRIS). Data from the research program Horizon 2020 managed by the European Commission is included as well. Participation in projects from Horizon 2020 (as a coordinator or as a partner) show technological advancement of the organization be it an academic institution, private company, or other institutions. Patent data from the Orbit database (Questel) are used for identification of the key players with patent activity in AI or AI-related topics (no separate figure resulted from data, because only two players: HighChem and Photoneo were evaluated as companies with core focus on AI or AI-related topics). In addition, startup companies were researched.

2.3. Academic research

Academic research organisations are an integral part of the innovation ecosystem in a developed economy. Their main role in an innovation ecosystem is the generation of knowledge and technologies which are then diffused into other organisations (usually private companies). Academic institutions as one of the central actors are represented by universities and research organisation like the Slovak Academy of Sciences. Academic research organisation implemented over 80 % publicly granted research projects in AI and related fields (companies are only less than 18 %).

Based on research projects, both national and international, the following academic institutions were identified as the most important:

- Slovak University of Technology in Bratislava,
    - Faculty of Electrical Engineering and Information Technology
    - Faculty of Informatics and Information Technologies
- Technical University of Košice,
    - Faculty of Electrical Engineering and Informatics
    - Faculty of Mechanical Engineering
- Institute of Informatics, Slovak Academy of Sciences.

Artificial intelligence (AI) is a core topic especially for the Technical University of Košice, Faculty of Electrical Engineering and Informatics (6 projects), the Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies (3 projects), and the University of Žilina, Faculty of Mechanical Engineering (3 projects). According to the

number of projects, **the most important player in AI and AI-related projects is the Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology** dealing with AI and other AI-related topics such as machine learning and robotics.

Cybersecurity and machine learning are closely connected to R&D activities at the Technical University of Košice, Faculty of Electrical Engineering and Informatics. Data show that robotics is the key domain of R&D activities at the Technical University of Košice, Faculty of Mechanical Engineering, ZTS Výskumno-vývojový ústav Košice, and the Slovak University of Technology in Bratislava, Faculty of Mechanical Engineering (see Figure 1).

Figure 1: R&D institutions in Slovakia according to number of R&D projects in AI and AI-related topics, 1999–2019

		Technical University of Košice, Faculty of Electrical Engineering and Informatics	Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies	Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology	Institute of Informatics, Slovak Academy of Sciences	Technical University of Košice, Faculty of Mechanical Engineering	Comenius University in Bratislava, Faculty of Mathematics, Physics and Informatics	University of Žilina, Faculty of Mechanical Engineering	TOTAL
TOTAL No. of R&D projects		**16**	**12**	**9**	7	7	**5**	**5**	**58***
Key topics	**artificial intelligence**	1	6	1	2	3		1	**14**
	cybersecurity		3						**3**
	industry 4.0	2	2	1			1	1	**7**
	cloud computing	2	1		2				**5**
	IoT	1	1				1		**3**
	machine learning	5	3		2	5	1		**16**
	robotics	5	2	7		1	2	2	**19**
	big data				1			1	**2**
	neural networks	1							**1**

Source: System SK CRIS; notes: institutions with 3 and more R&D projects; projects with public contribution; the sum of the key topics are not equal to a number of projects because some of the projects include more than one of the key topics

*Three projects are shared with other academic partners

Figures 2-6 below show the most active researchers according to their affiliation and participation in R&D projects. Tables also illustrate the top domains of the researchers. At the Technical University of Košice, Faculty of Electrical Engineering and Informatics, 14 experts dealing with 2 or more R&D projects in AI and AI-related topics were identified (Figure 2). Especially, **Ján Vaščák and Peter Sinčák** are among the top researchers with 4 R&D projects in artificial intelligence. According to the topics, R&D in artificial intelligence is a crucial domain for the institution. This fact is also confirmed by the recently established Centre for Artificial Intelligence as a unit of the Department of Cybernetics and AI at the Technical University of Košice. At the Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies, there are many experts focusing on machine learning and AI (Figure 3). Namely, **Daniela Chudá, Mária Bieliková, Marián Šimko, Ivan Srba, Jakub Ševcech, Jakub Šimko or Jarmila Pavlovičová** are the top experts with this affiliation. At the Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology, 10 experts in AI and AI-related topics were found (Figure 4). Robotics or Industry 4.0 were identified as the main domains, they are related to AI in many projects. Among the most active experts, **Marian Kľúčik, František Duchoň, Anton Vitko or Peter Hubinský** stand out. Cloud computing, big data, and machine learning are the key domains that researchers from the Institute of Informatics, the Slovak Academy of Sciences deal with (Figure 5). **Ladislav Hluchý, Emil Gatial, Marcel Kvassay** are the top researchers according to the number of R&D projects. Figure 6 shows other 8 top researchers from other main R&D institutions in AI and AI-related topics according to the number of R&D projects.

Figure 2: Top researchers from the Technical University of Košice, Faculty of Electrical Engineering and Informatics in AI and AI-related topics according to the number of R&D projects, 1999–2019

R&D Institution	Name of Researcher	Number of Projects	Key Topics
Technical University of Košice, Faculty of Electrical Engineering and Informatics	Ján Vaščák	6	artificial intelligence (4); cybersecurity (2); industry 4.0 (2); cloud computing (1); IoT (1); machine learning (1)
	Peter Sinčák	4	artificial intelligence (4); robotics (2)
	Kristína Machová	4	artificial intelligence (3); robot (2); big data (1); machine learning (1)
	Marek Bundzel	4	artificial intelligence (2); cybersecurity (2); industry 4.0 (2); IoT (1); industry 4.0 (1); robot (1); machine learning (1)
	Marián Mach	3	artificial intelligence (2); robot (2); big data (1)
	Rudolf Jakša	3	artificial intelligence (3); robot (2)
	Martin Čertický	3	artificial intelligence (2); robot (2); cybernetics (1); IoT (1); industry 4.0 (1)
	Jozef Juhár	3	robotics (3); artificial intelligence (1)
	Gergely Magyar	2	artificial intelligence (2); robotics (2)
	Jakub Hvizdoš	2	artificial intelligence (2); robotics (2)
	Peter Takáč	2	artificial intelligence (2); robotics (2)
	Ján Buša	2	artificial intelligence (2); robotics (1)
	Matúš Pleva	2	robotics (2); artificial intelligence (1)
	Patrik Sabol	2	artificial intelligence (2); robotics (2)

Source: System SK CRIS; notes: projects with public contribution

Figure 3: Top researchers from the Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies in AI and AI-related topics according to the number of R&D projects, 1999–2019

R&D Institution	Name of Researcher	Number of Projects	Key Topics
Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies	Daniela Chudá	5	machine learning (5); artificial intelligence (2)
	Jarmila Pavlovičová	5	machine learning (5)
	Mária Bieliková	5	machine learning (5); artificial intelligence (2)
	Marián Šimko	5	machine learning (5); artificial intelligence (2)
	Ivan Srba	5	machine learning (5); artificial intelligence (2)
	Jakub Ševcech	5	machine learning (5); artificial intelligence (2)
	Jakub Šimko	5	machine learning (5); artificial intelligence (2)
	Michal Farkaš	4	machine learning (4); artificial intelligence (2)
	Róbert Móro	4	machine learning (4); artificial intelligence (2)
	Pavol Návrat	3	machine learning (3); artificial intelligence (1)
	Peter Lacko	3	machine learning (3); artificial intelligence (2)
	Samuel Pecár	3	machine learning (3); artificial intelligence (2)

Source: System SK CRIS; notes: projects with public contribution

Figure 4: Top researchers from the Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology in AI and AI-related topics according to the number of R&D projects, 1999–2019

R&D Institution	Name of Researcher	Number of Projects	Key Topics
Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology	Marian Kľúčik	8	robotics (6); artificial intelligence (1); industry 4.0 (1)
	František Duchoň	8	robotics (7); industry 4.0 (1)
	Anton Vitko	7	robotics (5); artificial intelligence (1); industry 4.0 (1)
	Peter Hubinský	7	robotics (5); artificial intelligence (1); industry 4.0 (1)
	Ladislav Jurišica	6	robotics (4); artificial intelligence (1); industry 4.0 (1)
	Michal Tölgyessy	6	robotics (5); industry 4.0 (1)
	Jozef Rodina	6	robotics (5); industry 4.0 (1)
	Miloš Oravec	5	machine learning (5)
	Jaroslav Hanzel	5	robotics (4); artificial intelligence (1)
	Andrej Babinec	5	robotics (4); industry 4.0 (1)
	Ľuboš Chovanec	5	robotics (4); industry 4.0 (1)

Source: System SK CRIS; notes: projects with public contribution

Figure 5: Top researches from the Institute of Informatics, Slovak Academy of Sciences in AI and AI-related topics according to the number of R&D projects, 1999–2019

R&D Institution	Name of Researcher	Number of Projects	Key Topics
Institute of Informatics, Slovak Academy of Sciences	Ladislav Hluchý	5	cloud computing (2); artificial intelligence (1); big data (1); machine learning (1)
	Emil Gatial	5	cloud computing (2); big data (1); industry 4.0 (1); machine learning (1)
	Marcel Kvassay	5	cloud computing (2); artificial intelligence (1); big data (1); machine learning (1)
	Martin Šeleng	4	cloud computing (2); big data (1); machine learning (1)
	Štefan Dlugolinský	4	cloud computing (2); big data (1); machine learning (1)
	Zoltán Balogh	4	cloud computing (2); big data (1); machine learning (1)
	Ondrej Habala	4	cloud computing (2); big data (1); machine learning (1)
	Peter Krammer	4	cloud computing (2); big data (1); machine learning (1)

Source: System SK CRIS; notes: projects with public contribution

Figure 6: Top researchers from other top R&D institutions in AI and AI-related topics according to the number of R&D projects, 1999–2019

R&D Institution	Name of Researcher	Number of Projects	Key Topics
Technical University of Košice, Faculty of Mechanical Engineering	Mikuláš Hajduk	6	robotics (6)
	Vladimír Baláž	6	robotics (6)
	Marek Sukop	5	robotics (5)
Comenius University in Bratislava, Faculty of Mathematics, Physics and Informatics	Igor Farkaš	3	machine learning (1); neural networks (1); robotics (1)
University of Žilina, Faculty of Mechanical Engineering	Branislav Mičieta	2	artificial intelligence (2)
	Eva Slamková	2	artificial intelligence (2)
	Peter Macek	2	artificial intelligence (2)
	Ján Rofár	2	artificial intelligence (2)

Source: System SK CRIS; notes: projects with public contribution

Figure 7: European projects of the Institute of Informatics, the Slovak Academy of Sciences in AI and AI-related topics, 2014–2019

Name	City	EC Contrib. (EUR)	Title	Coordinator	Participant Countries	Key Topics
INSTITUTE OF INFORMATICS, SLOVAK ACADEMY OF SCIENCES	BRATISLAVA	339 750	PROviding Computing solutions for ExaScale ChallengeS	LUDWIG-MAXIMILIANS-UNIVERSITAET MUENCHEN (DE)	PL;DE;SK;ES;NL;CH	**big data**
		271 250	Designing and Enabling E-infrastructures for intensive Processing in a Hybrid DataCloud	AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS (ES)	CZ;SK;DE;PT;PL;ES;IT	**neural network; machine learning; cloud computing**
		61 188	Integrating and managing services for the European Open Science Cloud	STICHTING EGI (NL)	FR;CZ;SE;PL;BE;SI;ES;IT;SK;IE;DE;AT;CY;EL;NL;PT;UK;HU;CH;DK;NO;TW;HR;FI	**cloud computing**
		54 750	Engaging the EGI Community towards an Open Science Commons	STICHTING EGI (NL)	CZ;SE;IT;PL;SK;FR;MY;AT;DE;EL;BG;PH;TR;PT;ES;NL;UK;HU;CH;US;ID;TW;HR;BE;FI	**cloud computing**
Total		726 938				

Source: European Commission (Cordis database, Horizon 2020 framework programme)

Figures 7-10 illustrate the main academic institutions according to their participation in the European projects (Horizon 2020). Data confirmed the leading position of the three Slovak R&D institutions that were already mentioned in the national R&D projects. Tables show the key domains in AI and AI-related topics, location, financial contribution from the European Commission, name of the project, name of the coordinator and participating countries.

The Institute of Informatics, the Slovak Academy of Sciences (Figure 7) acquired the biggest budget for its activities, more than 720 thousand EUR. Fields of interest such as cloud computing or machine learning confirm the specialisation of the institution as was showed on the data earlier in the report. More than 550 thousand EUR were gained by the Technical University of Košice for the R&D activities in robotics and industry 4.0 (Figure 8). Additionally, the projects including AI or cybernetics are included in the portfolio. The Slovak University of Technology in Bratislava deals with IoT, cybernetics, and industry 4.0 in the Horizon projects (Figure 9). Financial allocation from the European Commission is approx. 335 thousand EUR. Figure 10 also shows other Slovak academic institutions involved in the Horizon projects dealing with AI and AI-related topics. For example, the National Centre of Robotics acquired almost 150 thousand EUR for its R&D activity in one project.

Figure 8: European projects of the Technical University of Košice in AI and AI-related topics, 2014–2019

Name	City	EC Contrib. (EUR)	Title	Coordinator	Participant Countries	Key Topics
TECHNICAL UNIVERSITY OF KOŠICE	KOSICE	180 000	Industry 4.0 for SMEs - Smart Manufacturing and Logistics for SMEs in an X-to-order and Mass Customization Environment	LIBERA UNIVERSITA DI BOLZANO (IT)	SK;AT	**industry 4.0; cybernetics**
		155 813	Robotics for Infrastructure Inspection and Maintenance	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (FR)	SK;IT;NL;ES;FR;CY;FI;DK;NO;DE;PL;BE;UK;EL	**robotics**
		133 750	Manufacturing Industry Digital Innovation Hubs	EIT DIGITAL (BE)	SE;SK;ES;IE;IT;FI;DE;PL;FR;RS;UK	**industry 4.0**
		73 600	LIFEBOTS Exchange - creating a new reality of care and welfare through the inclusion of social robots.	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU (NO)	SK;PT;RO;EL;BE;CH;IT;NO	**robotics**
		14 671	A European AI On Demand Platform and Ecosystem	THALES SIX GTS FRANCE SAS (FR)	SK;FR;NO;AT;IT;IE;EL;FI;SI;DE;BE;HU;CZ;CH;UK;ES;PT;SE;LV;DK	**artificial intelligence**
Total		557 834				

Source: European Commission (Cordis database, Horizon 2020 framework programme)

Figure 9: European projects of the Slovak University of Technology in Bratislava in AI and AI-related topics, 2014–2019

Name	City	EC Contrib. (EUR)	Title	Coordinator	Participant Countries	Key Topics
SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA	BRATISLAVA	123 970	Flexible FE/BE Sensor Pilot Line for the Internet of Everything	INFINEON TECHNOLOGIES DRESDEN GMBH& CO KG (DE)	SK;AT;NL;ES;DE;BE	**internet of things**
		113 750	High performant Wide Band Gap Power Electronics for Reliable, energy eFficient drivetrains and Optimization thRough Multi-physics simulation	AVL LIST GMBH (AT)	DE;SK;ES;AT;IT;NL;BE;SI	**cybernetics**
		98 000	300mm Pilot Line for Smart Power and Power Discretes	STMICROELECTRONICS SRL (IT)	SK;BE;FI;PL;NL;DE;AT;IL;CZ;FR;IT;IE;RO;ES	**industry 4.0**
Total		335 720				

Source: European Commission (Cordis database, Horizon 2020 framework programme)

Figure 10: European projects of other Slovak academic institutions in AI and AI-related topics, 2014–2019

Name	City	EC Contrib. (EUR)	Title	Coordinator	Participant Countries	Key Topics
NATIONAL CENTRE OF ROBOTICS	BRATISLAVA	147 720	A Pan-European Network of Robotics DIHs for Agile Production	Teknologian tutkimuskeskus VTT Oy (FI)	FR;IT;BE;SI;IE;EE;EL;HR;DE;ES;UK;AT;RO;PL;NL;HU;SK;RS;CZ;PT;BG;DK;LV;CY;LT;SE	**robotics**
SLOVAK ACADEMY OF SCIENCES	BRATISLAVA	87 450	European coordinated research on long-term ICT and ICT-based scientific challenges	AGENCE NATIONALE DE LA RECHERCHE (FR)	BG;AT;EE;LT;RO;TR;IT;ES;FI;PL;UK;CZ;CH;IE;SK;BE	**big data; robotics**
CENTER OF SOCIAL AND PSYCHOLOGICAL SCIENCES, SLOVAK ACADEMY OF SCIENCES	BRATISLAVA	86 950	Encouraging Lifelong Learning for an Inclusive and Vibrant Europe	THE UNIVERSITY OF NOTTINGHAM (UK)	IT;BG;SK;AU;ES;BE;AT;UK;EE	**artificial intelligence**
SLOVAK CENTRE OF SCIENTFIC AND TECHNICAL INFORMATION	BRATISLAVA	77 500	OpenAIRE Advancing Open Scholarship	ETHNIKO KAI KAPODISTRIAKO PANEPISTIMIO ATHINON (EL)	PT;PL;EE;FI;CZ;ES;IE;NL;BE;RO;AT;HU;DE;UY;TR;SK;EL;FR;IL;LU;IT;RS;CH;DK;NO;MT;LV;LT;UK;IS;CY;SE;BG;SI;HR	**cloud computing**
BIOMEDICAL RESEARCH CENTRE, SLOVAK ACADEMY OF SCIENCES	BRATISLAVA	68 750	Life Science Alliance: Closing Research and Innovation Divide in the EU	MASARYK UNIVERSITY (CZ)	CZ;EE;LT;HR;HU;LV;PL;SK;SI	**big data**
UNIVERSITY OF ECONOMICS IN BRATISLAVA	BRATISLAVA	50 000	A FINancial supervision and TECHnology compliance training programme	UNIVERSITA DEGLI STUDI DI PAVIA (IT)	HR;PL;IE;CZ;SI;PT;FI;FR;BE;ES;LU;SK;RO;DE;IT;LT;AT;UK;BG;CH;EL	**artificial intelligence; big data**

Source: European Commission (Cordis database, Horizon 2020 framework programme)

2.4. Companies

Each innovation ecosystem is constituted by the two main parts, knowledge and technology providers, which are mostly represented by universities and research organisation (see above), and knowledge and technology utilizers, represented by companies. Without companies which transform knowledge and technologies into real products and introduce them on the market, no innovation would exist. Therefore, this chapter is focused on the analysis of R&D in companies utilizing AI.

It is important to note that no company in Slovakia had more than one R&D project in AI funded by the national body during the last two decades. Only ZTS Výskumno-vývojový ústav Košice, a.s. had 5 projects, but as it is obvious from the name of the company, it is more a private R&D organisation than a production company. The analysis below is based on participation in European projects, which can be used as an indicator of the quality of research. List of the companies participating in one national R&D project are in Annex (Figure 14).

Figure 11 shows Slovak companies involved in the European projects (Horizon 2020) focusing on IT and data solutions. The companies are coordinators in these projects. In the case of Highchem s.r.o., Edico SK a.s., and Innov8 s.r.o, these subjects were awarded SME instrument project, a very prestigious grant for start-ups for developing their R&D activities; specifically, research in big data, cloud computing, or devices for Industry 4.0. The biggest financial contribution was allocated to EEA s.r.o., 315 thousand EUR.

Figure 11: Company coordinators from Slovakia in AI and AI-related European projects, 2014–2019

Company Coordinator	City	EC Contrib. (EUR)	Project Title	Participant Countries	Key Topics
EEA SRO	Bratislava	315 250	Promoting Financial Awareness and Stability	EL;BE;AT;UK	**big data**
HIGHCHEM SRO	Bratislava	50 000	Big Data of Small Molecules		**big data; cloud computing**
ATOS IT SOLUTIONS AND SERVICES SRO	Bratislava	50 950	Cloud Collaborative Manufacturing Networks (C2NET)	FI;BE;FR;ES; PT	**cloud computing**
EDICO SK AS	Bratislava	50 000	Parallel photogrammetry system for object panoramas		**cloud computing**
INNOV8 S.R.O.	Trnava	50 000	New wearable measurement devices for Industry 4.0 based on gaming motion-capture system		**industry 4.0**

Source: European Commission (Cordis database, Horizon 2020 framework programme)

EEA SRO

- Is a consulting and software development company with expertise in several market segments (banking, telecommunication, industry, pharma etc.) and IT areas (Internet solution, big data, machine learning, digital repositories etc.).

Highchem

- Is a production company developing mass spectrometry solutions that enable chemists, medicinal scientists and biologists to turn complex analytical data into useful answers. They also develop software (also cloud systems and large data collection) for the interpretation, management and processing of mass spectral and chromatographic data in the area of small molecules (inventor and assignee of international patents).

Atos IT solutions and services

- They are a multinational IT company, producing cloud, cybersecurity and high-performance computing, big data, business applications and digital workplace

solutions through its Digital Transformation Factory, as well as transactional services through Worldline, payment industry.

EDICO SK

- Is an IT development company, expertise in data management, data digitalization in culture heritage, state administration and energy industry.

INNOV8

- They are a consulting company for planning and optimization of processes, expertise in production simulation, MTM process standards, designing workplaces/warehouses, digital factory or 3D animation.

Figure 12 shows Slovak companies participating in the European projects (H2020) focusing on AI and AI-related topics. None of the companies included in the Figure is coordinating the project. Very often, these projects deal with the R&D in Internet of Things, cloud computing or cybernetics. We can see that the most successful participants in H2020 with two participations are Mondelez European Business Services Centre s.r.o. and Nano design s.r.o., a multinational company and an SME. Altogether, the projects where Slovak companies participated, received the contribution from the European Commission of over 3,5 million EUR.

Figure 12: Company participants from Slovakia in AI and AI-related European projects, 2014–2019

Name	City	EC Contrib. (EUR)	Title	Coordinator	Participant Countries	Key Topics
BAVENIR SRO	BRATISLAVA	797 563	Open virtual neighbourhood network to connect intelligent buildings and smart objects	TECHNISCHE UNIVERSITAET KAISERSLAUTERN (DE)	NO;EL;SK;PT;ES;UK;SI;DK	**internet of things**
INTERSOFT A.S.	KOSICE	602 125	Open virtual neighbourhood network to connect intelligent buildings and smart objects	TECHNISCHE UNIVERSITAET KAISERSLAUTERN (DE)	NO;EL;SK;PT;ES;UK;SI;DK	**internet of things**
ATOS IT SOLUTIONS AND SERVICES SRO	BRATISLAVA	543 375	Management Of Networked IoT Wearables – Very Large Scale Demonstration of Cultural Societal Applications	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. (DE)	DK;UK;EL;DE;NL;IT;FR;SK;SE	**internet of things; cloud computing**
MONDELEZ EUROPEAN BUSINESS SERVICES CENTRE SRO	BRATISLAVA	315 000	Architecture for EurOpean Logistics Information eXchange	ERTICO – ITS Europe (BE)	DE;EL;FR;NL;SK;AT;UK;SE;IT;ES;CZ;RO;BE;RS	**cloud computing**
BROADBIT ENERGY TECHNOLOGIES SRO	KOMARNO	261 188	NeMo : Hyper-Network for electroMobility	INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS (EL)	SK;FR;IT;DE;ES;AT;EL;BE	**cloud computing**

SAE-AUTOMATION, S.R.O	NOVA DUBNICA	167 081	Prosumer Flexibility Services for Smart Grid Management	Teknologian tutkimuskeskus VTT Oy (FI)	SI;DE;SK	**internet of things; cloud computing**
MICROSTEP-MIS SPOL SRO	BRATISLAVA	158 946	Transforming Weather Water data into value-added Information services for sustainable Growth in Africa	TECHNISCHE UNIVERSITEIT DELFT (NL)	IT;UK;GH;NL;DE;KE;UG;ES;SK;ZA	**cloud computing**
SOLARGIS SRO	BRATISLAVA	152 163	Predictable Flexible Molten Salts Solar Power Plant	ALSTOM POWER SYSTEMS (FR)	SK;PL;CH;PT;IT;DE;ES	**machine learning**
MONDELEZ EUROPEAN BUSINESS SERVICES CENTRE SRO	BRATISLAVA	139 350	Building sustainable logistics through trusted collaborative networks across the entire supply chain	TX LOGISTIK AG (DE)	FR;AT;UK;BE;NL;SK;PL;DE;IT;NO;CH	**cloud computing**
SPINEA SRO	PRESOV	129 500	Predictive Cognitive Maintenance Decision Support System	LINNEUNIVERSITETET (SE)	DE;ES;FR;SK;EL;SE	**artificial intelligence; big data; cloud computing**
VAF S.R.O.	ROVINKA	93 229	Cyber Security Network of Competence Centres for Europe	JOHANN WOLFGANG GOETHE-UNIVERSITATFRANKFURT AM MAIN (DE)	IT;FI;BE;AT;BG;IE;CZ;EE;SK;CH;EL;NO;ES;LU;SI;DE;DK;FR;PT;CY;NL;SE	**cybernetics**
NANO DESIGN SRO	BRATISLAVA	70 500	High performant Wide Band Gap Power Electronics for Reliable, energy eFficient drivetrains and Optimization thRough Multi-physics simulation	AVL LIST GMBH (AT)	DE;SK;ES;AT;IT;NL;BE;SI	**cybernetics**
POWERTEC SRO	BRATISLAVA	55 188	Flexible FE/BE Sensor Pilot Line for the Internet of Everything	INFINEON TECHNOLOGIES DRESDEN GMBH& CO KG (DE)	SK;AT;NL;ES;DE;BE	**internet of things**
NANO DESIGN SRO	BRATISLAVA	42 500	300mm Pilot Line for Smart Power and Power Discretes	STMICROELECTRONICS SRL (IT)	SK;BE;FI;PL;NL;DE;AT;IL;CZ;FR;IT;IE;RO;ES	**industry 4.0**
ELCOM SRO	PRESOV	-	Industry 4.0 for SMEs - Smart Manufacturing and Logistics for SMEs in an X-to-order and Mass	LIBERA UNIVERSITA DI BOLZANO (IT)	SK;AT	**industry 4.0; cybernetics**

			Customization Environment			
Total		3 527 706				

Source: European Commission (Cordis database, Horizon 2020 framework programme)

bAvenir

- They are a technology start-up, active in the fields such as IoT and Distributed Ledger Technologies.

InterSoft

- Is a software development company. They have expertise in the areas of web technologies, knowledge management or E-government solutions.

SAE-Automation

- They work on the development of industrial software and database systems, web design and complex turnkey projects in many areas such as control and monitoring of technological processes, devices, buildings and computer networks, remote alerts, remote measuring, diagnostics, WiFi, GSM and GPRS communication, support, download, logging, SCADA; IoT and cloud; wired or wireless computer networks; wireless sensor networks using ZigBee technology.

MICROSTEP-MIS SPOL

- They specialised in development and manufacturing of monitoring and information systems, processing of acquired data, research and numerical modelling for weather and environment products and solutions (meteorology, aviation weather, hydrology, marine, radiation etc.).

Solargis

- They are a provider of reliable and accurate solar, weather and solar electricity data that is used in the whole lifecycle of solar power plants, from prospection to development and operation.

VAF S.R.O.

- Is a consulting company offering services in the area of cybersecurity, information security and privacy protection.

NANO DESIGN

- Is a spin-off of the Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology, R&D in IoT technologies and SMART sensors.

POWERTEC

- They are focusing on the design of progressive organic and hybrid structures and devices for power electronics and IoT systems in relation to SMART sensor devices.

2.5. Start-ups

In Slovakia, there are technological start-ups focusing on IT and data solutions. Below is the list of selected start-ups focused on AI and AI-related topics. Data for startups is based on www.eu-startups.com, the Orbit patent database by Questel and our own research. Start-ups develop their products using different technologies related to AI.

YesElf

- YesElf is an onboarding platform that facilitates the training and retention of new employees. The startup, founded in Bratislava in 2016, uses AI to monitor the work of experienced employees, analysing their activities using corporate software. YesElf has raised €405k to 2019.

Nettle.ai

- Nettle.ai builds conversational AI systems to help enhance e-commerce businesses. The objective is to create outstanding user experiences at scale by leveraging Natural Language Processing and Machine Learning to analyse, understand and derive meaning from an unstructured text. Nettle launched in 2018 and is based in Bratislava.

eDocu

- eDocu puts things on the internet using iTags: QR-codes, NFC chips, and, of course, the Internet of Things. There use ranges from the inventory management and ordering of pharmaceutical supplies to managing municipal garbage pickups by the pound. Founded in 2014, eDocu was named Best IoT Central European Startup in 2018.

Photoneo

- The company deals with 3D scanning technology to industry segment to advance computer vision to a higher quality. Founded in 2013, Bratislava, the company is an inventor and an assignee of several international patents.

PredictiveDataScience

- This company is from Bratislava and is cooperating with the Slovak University of Technology in Bratislava. Their expertise is in preparing many solutions to ensure the continuity of industry production, such as Failure prediction, Anomaly detection, AI, data transfer, integration and visualisation and IoT analysis.

Exponea

- This fast growing company is in the field of AI-Enabled Marketing Automation & Data Analytics.

2.6. Conclusion

This report presented R&D capacities in Slovakia with the ambition to identify the leading organisations and researchers in AI-related R&D. Innovation ecosystems in developed countries consist both of academia and business. Therefore, the report was focusing on universities, research institutions, and companies, including start-ups, SMEs, and large companies. Data on the national and international R&D projects and patent were used. The business sector was analysed through market research.

AI-related R&D excellence in Slovakia is concentrated dominantly in academia, especially at the Slovak University of Technology in Bratislava, the Technical University of Košice and the Institute of Informatics, and the Slovak Academy of Sciences. At these institutions, there are

leading researchers such as, Ján Vaščák and Peter Sinčák from Technical University of Košice, Faculty of Electrical Engineering and Informatics, Daniela Chudá, Mária Bieliková, Marián Šimko, Ivan Srba, Jakub Ševcech, Jakub Šimko or Jarmila Pavlovičová from Slovak University of Technology in Bratislava, Faculty of Informatics and Information Technologies, Marian Kľúčik, František Duchoň, Anton Vitko or Peter Hubinský from Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology and Ladislav Hluchý, Emil Gatial, Marcel Kvassay from Institute of Informatics, the Slovak Academy of Sciences.

The main specialisation of AI-related R&D in Slovakia is artificial intelligence (mostly Slovak University of Technology in Bratislava), machine learning, and robotics (dominantly Technical University of Košice). On the other hand, it is important to note, that none of the analysed organisations participated in more than 10 projects in AI-related fields over the last two decades.

The most active company in AI-related R&D is ZTS Výskumno-vývojový ústav Košice a.s., which is a private R&D institute not a production company. Only two companies had more than one R&D project, Mondelez European Business Services Centre, s.r.o. and Nano Design, s.r.o. The main specialisation of the company's projects (based on H2020 projects topics) is on Internet of Things, cloud computing, or cybernetics. In Slovakia, we can also find several start-ups focusing on AI or AI-related fields. However, there is not a dominant specialisation in the start-up scene.

Generally, there are several institutions and experts with strong expertise in AI-related R&D. On the other hand, the AI-related R&D in Slovakia is still less developed compared to Czechia and other relatively comparable countries.

3. Poland

3.1. Country Summary

- Development of AI in Poland is primarily driven by companies, the sector has very close ties with academic teams and the size of the ecosystem is the biggest market among the V4 countries. It comprises of 110 companies and 59 investors and many foreign AI R&D centers which were opened in Poland by global giants like Google, Samsung, IBM or TCL. However, the Polish companies working on AI develop their solutions primarily for foreign buyers and partners.
- AI investment in Poland is mainly driven by venture capital and grants. The penetration of giant global tech companies has also significantly stimulated the growth of AI and related technologies.
- The major field of AI application is image processing and recognition, other popular applications are data exploration recommender systems and natural language processing. There are four leading industry groups where most of AI technologies develops: Healthcare, Media and entertainment, transportation and infrastructure and Information Technology and Services and Computer Software, where solutions for sales and marketing, especially recommendation systems and chatbots for client support. Polish companies are active in many areas such as, Big Data, predictive analytics, ML tools, robotics, FinTech, Industry 4.0, or IoT.
- Polish universities are active in AI R&D and opened specialized research centres in AI. The government stipulated support for building of national AI research centre (DFKI model) and marked it as one of their priorities. Overall, AI is the domain of large metropolitan areas in Poland. 85 percent of AI is located in six major urban areas and Warsaw itself accounts for more than 40 percent.
- The Polish government has begun working on the development of the national AI development strategy in 2018 under the leadership of the Ministry of Digital Affairs, Entrepreneurship and Technology as well as Science and Higher Education. It shall be based on broad cooperation with private experts. The Government has already stipulated that the national strategy is to make Poland one of the leading global digital innovation hubs. According to government, the main aim of the Polish AI strategy shall be to help businesses to obtain state and the European funding easier and encourage more entrepreneurs to invest in AI. The Poland's AI plan shall include solutions for many areas, including the future of health care, public administration, education and cybersecurity.
- Among private and business-oriented stakeholders, The Digital Poland Foundation (created according to the DigiSwiss model as nationwide industry coalition) is quite active in the area of AI and digital transformation.
- Polish Initiative for the Advancement of Artificial Intelligence was formed by five major Polish societies to coordinate the effort to further develop the AI sector (PP-RAI, Polskie Porozumienie na Rzecz Rozwoju Sztucznej Inteligencji). The first conference of PP-RAI took place in October 2018.

3.2. Introduction

The goal of this report is to briefly provide the current landscape of Artificial Intelligence (AI) in Poland. The majority of the data is collected from findings of studies by the Digital Poland Foundation publications and subsequent reports in relation to AI in Poland. The Foundation's main purposes of publishing the Map of Polish AI, 2019, "is to support the creation of the national AI development strategy and to present a reliable and up-to-date picture of the state of AI technology in Poland".[6]

Other objectives of this report are to describe the state of research of AI in Poland at a macro-level, as well as discuss its current academic research community. This report should be used for the evaluation of the current state of AI research with a focus on the broad trends within the field rather than on specific technologies, the aim is to summarize the work that is currently completed by individual institutes and universities within the Polish IT industry, in a manner that is more accessible for the general public.

Experts in the industry had raised alarm for the creation of a Polish Strategy for the Development of Artificial Intelligence as a must. Without it, Poland might not be amongst one of the most highly sophisticated nations.[7]

As the advent and the importance of AI have become more important on the global stage in terms of economic growth and technological advancement in the 21st century. As with the growing trend of AI, it came as no surprise as the government of Poland held talks on the development of a Polish AI strategy in May 2018. The meeting was attended by senior government officials and representatives of the scientific community and related institutions.[8] Notably, attended by the Vice-President of the Council of Ministers, the Minister of Science and Higher Education Jarosław Gowin, the Deputy Minister of Digital Affairs Karol Okoński, among others.[9]

Chair of Management in Networked and Digital Societies at the Kozminski University, Prof. Dariusz Jemielniak stated that the development of AI in Poland would require a "clear strategic decision", which would include elements such as strong funding for research in this area, development of study programs and prevention of brain drain.[10]

Among them, the Map of Polish AI is a comprehensive undertaking of AI in the Polish market.[11] As with the growing trend of AI, the Digital Poland Foundation wants to make Poland one of the global digital innovation hubs.[12] Many key activities include educating and running a series of initiatives promoting digital technologies in Poland. Of which includes events, but not limited to, programs as Digital Festival, Digital Shapers, Digital Summit, AI Academy, and Digital Compass.[13]

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[6] Borowiecki, Łukasz, and Piotr Mieczkowski. *Map of the Polish AI*. I ed., Digital Poland Foundation, 2019.
[7] Suwart, Krzysztof. "Rewolucyjny Plan Dla Polski. Powstaje Pierwsza w Kraju Strategia Rozwoju Sztucznej Inteligencji." *Www.money.pl*, 21 May 2018.
[8] Dutton, Tim. "An Overview of National AI Strategies." *Medium*, Politics + AI, 25 July 2018,
[9] Ibid
[10] Florencka, Katarzyna. "Expert: Implementing an AI Development Strategy Is a Must." *Nauka w Polsce*, Science in Poland, 11 Aug. 2018.
[11] Ibid
[12] Borowiecki, Łukasz, et al. *Map of Polish Science in the Field of AI*. 2019. Digital Poland Foundation, 2019.
[13] Ibid

As of late 2019, the development strategy of AI for Poland is being prepared based on four basic pillars: knowledge and competence, an appropriate infrastructure, legal provisions (to ensure that the technologies will be safe for people) and financing for research and implementation as stated by the Minister of Digital Affairs Marek Zagorski at a talk given at "Dimensions of Artificial Intelligence. NASK – Cyber Reality – Poland" conference held in Warsaw. The minister added that a development strategy for AI "In its new financial perspective, the European Commission has allocated nearly EUR 9 billion to areas related to artificial intelligence and the entire Digital Europe programme. We want to get the most of this programme, as Poland, and together with our partners from the EU," added the minister.[14]

3.3. Academic Research and Companies

Academic research by PhDs and universities and collaboration between various institutions plays a role in growing AI research-based programs. According to Digital Poland Foundation, there are over 200 companies dealing with AI in Poland. These companies cooperate heavily with the scientific community, with half them hiring at least one PhD. Additionally, there are over 40 companies that invested in R&D centers developing AI, big data and software products in Poland.[15]

A 2018 report on the global talent pools in AI, showed there were growing trends in the Global AI talent and the demand for AI experts has grown exponentially over the last few years.

In Europe, the United Kingdom and Germany had significant numbers of experts. Overall, it is fairly clear that in recent years, Europe has steadily become a competitive location for finding AI talent.[16]

Globally there are close ties with academic teams and the AI sector. Which is also the case among Polish companies, with half of them employing PhDs on their teams. Depending on the size of the AI team within a company, nearly 77% cooperate with the scientific community.[17]

From 2013-18, roughly 6.5 thousand Polish researchers published 12 thousand scientific papers on AI. A major contribution was that by computer scientists that published 5.3 thousand publications amongst 1.5 thousand computer scientists.[18]

- Institutions: AGH in Kraków has the largest number of researchers who published articles on AI (524 people). As for faculties – the Faculty of Electronics and Information Technology, at the Warsaw University of Technology, is leading with 153 researchers.
- Scientific societies: In order to coordinate the effort, in 2018, five major societies have formed a new structure – Polish Initiative for the Advancement of Artificial Intelligence.
- Regions: Mazowieckie region has a strong lead in the number of AI researchers with 1 956 people publishing in the field. Two other regions with a considerable number of researchers are Małopolskie (969 people) and Śląskie (895 people).

[14] Obara, Marcin. "Poland Must Make Use of Artificial Intelligence." *The First News*, 9 Sept. 2019
[15] Borowiecki, Łukasz, et al. *Map of Polish Science in the Field of AI*. 2019. Digital Poland Foundation, 2019. Pg. 19
[16] Karmanov, Fedor, and Simon Hudson. "Global AI Talent Pool Report 2018." *Jfgagne*, 2 Apr. 2019.
[17] Borowiecki, Łukasz, and Piotr Mieczkowski. *Map of the Polish AI*. I ed., Digital Poland Foundation, 2019.
[18] Borowiecki, Łukasz, et al. *Map of Polish Science in the Field of AI*. 2019.

- PhD students: Out of 43 thousand PhD students in Poland 2,6 thousand study mathematics heavy disciplines with potential for AI. Five universities educate 46% of these PhD students.
- New students: Each year about 20 thousand students start their education in computer science.
- Graduates: Each year about 28 thousand technical sciences and 4 thousand mathematical sciences students graduate from Polish universities.[19]

AI companies generally accept and cooperate with the scientific community in order to involve researchers and students in the everyday operations of the company. 48% engage individuals from the scientific community in the advancement of their own AI services and also 31% produce internships.

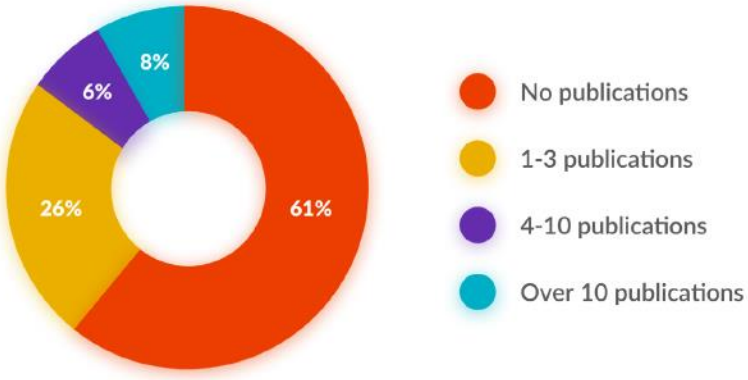
Only 13% of companies are associated with supplying training courses or studies as well as 11% engage in student research group.[20]

The importance of academia and in the AI ecosystem cannot be overstated in the field. Academia has played an important role and is closely tied with AI.[21] According to the Map of Polish Science in the Field of AI, in cooperation with Digital Poland and the National Information Processing Institute (OPI PIB), between the years 2013-18, there were 12 thousand publications covering research on AI and related topics registered in Polish Scientific Bibliography database. [22]

The AI community is transparent, working across various platforms such as GitHub and Kaggle, sharing open source codes and publications. According to the Map of Polish AI, local Polish participate in the research community. Surveys also found that 26% of them take part in Kaggle competitions and 20% publish their projects in an open source standard, mostly on GitHub. Maybe more importantly, 39% of companies have published articles in research journals. A small group is very active in this area – 8% of companies have over 10 publications. Showing the correlation of how important the scientific community is in the development of the Polish AI sector.[23]

[19] Ibid
[20] Borowiecki, Łukasz, and Piotr Mieczkowski. *Map of the Polish AI*. I ed., Digital Poland Foundation, 2019.
[21] Ibid, pg.44
[22] Borowiecki, Łukasz, et al. *Map of Polish Science in the Field of AI*. 2019
[23] Ibid, pg. 45.

Chart 1: Number of papers published as a result of work in the area of AI



Source: Map of the Polish AI. I ed., Digital Poland Foundation, 2019

Amongst Polish companies only one in four (27%) do not run any type of cooperation with the scientific area. Those that do, have actually picked various means of including people from academic community: 43% directly utilize researchers, 32% have actually formed a teamwork with an academic group as well as 43% accept a solitary researcher.[24]

Outcomes have shown that "companies which chose to develop particular strengths in the area of AI relied heavily on the scientific AI community."[25] Reiterating that academia plays a key role in the development of AI sectors and opportunities. Additionally, correlations were found between the size of an AI team and its tendency to contribute or cooperate with the scientific AI community. Companies with smaller groups were less likely to contribute academically as those with larger groups. Larger groups were more likely to contribute due to the majority of those groups having affiliations to academia. In respects to PhDs and various researchers in the field of computer sciences and mathematics.

It was also noted that companies need to be more involved in the development of a more opportunities and cooperation with universities. It was shown as a worrying trend. Rather than expect universities to provide fresh graduates and experts researchers, companies do not usually undertake the effort to help the scientific community grow their teams within the universities.[26]

Alternatively, there are a number of scientific societies in Poland which focus their attention on data science, artificial intelligence and machine learning. Some, such as the Polish Neural Network Society, was founded in 1995 and have already been operating for a certain time.[27]

In order to coordinate the effort of developing the AI sector, five major societies have formed a new structure in Poland – Polish Initiative for the Advancement of Artificial Intelligence (PP-RAI, Polskie Porozumienie na Rzecz Rozwoju Sztucznej Inteligencji). The first conference of PP-RAI was held in October 2018.[28]

[24]Ibid, pg. 45.
[25] Ibid, pg. 45.
[26] Borowiecki, Łukasz, et al. *Map of Polish Science in the Field of AI*. 2019
[27] Ibid
[28] Ibid

Figure 13: Polish Initiative for the Advancement of Artificial Intelligence (PP-RAI, Polskie Porozumienie na Rzecz Rozwoju Sztucznej Inteligencji)

Organisation	Foundation	President
Polish Initiative for the Advancement of Artificial Intelligence (PP-RAI: Polskie Porozumienie na Rzecz Rozwoju Sztucznej Inteligencji)	2018	Coordination committee consists of 9 members who represent each of 5 founding societies
5 PP-RAI societies:		
Polish Artificial Intelligence Society (Polskie Stowarzyszenie Sztucznej Inteligencji)	2009	Grzegorz J. Nalepa, AGH University of Science and Technology
Polish Neural Network Society (Polskie Towarzystwo Sieci Neuronowych)	1995	Leszek Rutkowski, Częstochowa University of Technology
Polish Special Interest Group on Machine Learning (Polska Grupa Systemów Uczących się PL SIGML)	2013	Jacek Koronacki, Polish Academy of Sciences; Jerzy Stefanowski, Poznań University of Technology; Michał Woźniak, Wrocław University of Science and Technology
Polish Chapter of the IEEE Systems, Man, and Cybernetics Society		Piotr Jędrzejowicz, Gdynia Maritime University
Poland Section of IEEE Computational Intelligence Society		Joanna Kołodziej, Warsaw University of Technology
Other societies:		
IEEE Robotics and Automation Society Polish Section		Krzysztof Kozłowski, Poznań University of Technology
Association for Image Processing (Polish Member Society of the IAPR logo International Association for Pattern Recognition)	1998	Leszek Chmielewski, Warsaw University of Life Sciences
Network Science Society (Polish Chapter)		Przemysław Kazienko, Wroclaw University of Technology
Poland Chapter of IEEE Signal Processing Society		Piotr Samczyński, Warsaw University of Technology
International Neuroinformatics Coordinating Facility Node of Poland	2007	Tomasz Piotrowski, Nicolaus Copernicus University

Source: Borowiecki, Łukasz, et al. Map of Polish Science in the Field of AI. 2019

3.4. AI Start-ups

A number of startups have made home in the capital city of Poland, Warsaw, although they may not be as visible on the global stage according to Nanalyze consulting with investment roster of Berlin-based VC investor Asgard Capital and Crunchbase. The following startups are a list of the ten most funded AI startups in Poland based on disclosed funding were brought forward by Nanalyze consulting with investment roster of Berlin-based VC investor Asgard Capital and Crunchbase.[29]

[29] "Top-10 Artificial Intelligence Startups in Poland." *Nanalyze*, 11 May 2019.

- **Creamfinance**: Founded in 2012, Warsaw startup Creamfinance has raised $30.1 million to develop a consumer lending platform that utilizes AI-based credit scoring. The startup feeds a mix of online data and traditional credit intelligence to its machine learning algorithms to decide whether a customer is eligible for a loan. Applications are made online and the approval process is automated with the company aiming to become a one-click loan provider. Creamfinance provides short-term microloans and credit lines to its mainly millennial customer base and is present in Poland, Latvia, Czech Republic, Georgia, Denmark, Mexico, and Spain.
- **Synerise**: Founded in 2013, Krakow startup Synerise has raised $6.7 million to develop a marketing automation and customer personalization platform powered by AI. The startup's software consumes customer data in real time to display relevant search results and product recommendations to e-commerce visitors. Algorithms that crunch behavioral data tell users when to launch marketing campaigns, project sales numbers, and analyze the performance of different marketing channels like mobile, web, and physical retail. The company has a handful of large corporate clients including Microsoft, Orange, and Carrefour, and is present in America, Europe, and the Middle East.
- **Nethone**: Founded in 2016, Warsaw startup Nethone has raised $6 million to develop an AI platform for business intelligence and fraud prevention. Nethone's algorithms record and identify every device interacting with a website and derive actionable insights based on these interactions. These can be customer behavioral analytics, predictions, returning user forecasts, or fraud event detection. Everything a visitor does on a client website is recorded and integrated into the "know your customer" process.
- **Elmodis**: Founded in 2015, Krakow startup Elmodis has raised $5.2 million to develop an Internet of Things (IoT) platform for the predictive maintenance of industrial machines. The company offers a combination of hardware sensors and software to monitor the health of machines and flag necessary maintenance work in advance. The application can be used in conjunction with electric motors, conveyors, pumps, and industrial fans, machinery that is present in energy, manufacturing, and heavy industries. Benefits include longer lifetime, lower maintenance costs, and prevention of unscheduled production stops. Elmodis is also running a project in partnership with the European Union focusing on the monitoring of power generation equipment.
- **Applica.ai**: Founded in 2013, Warsaw startup Applica.ai has raised $3.5 million to develop algorithms that process unstructured text. The company has applied neural networks to language modeling in order to locate, extract, and compare relevant information in large amounts of documentation. By applying Applica's algorithms, customers can reduce human effort by 75% and human errors by 90% while speeding up document turnover to under one second. The service is used in credit verification processes, customer service claims, and debt collection – all of which require the understanding, classification, and comparison of large bodies of text. Applica's proprietary machine learning technology requires one-tenth less data for supervised learning when compared to typical machine learning models.
- **Liber**: Founded in 2014, Warsaw startup Liber Finance Group has raised $2.2 million to develop marketplaces that match borrowers and lenders in real-time using big data analytics. Liber Finance uses AI algorithms to find lenders matching

borrowers' required terms, and also performs instant credit scoring based on customers' social data, online behavior, and interactions with the startup's lending platforms. The company aims to provide fast and automated loans to private individuals and small and medium enterprises, not unlike Creamfinance.

- **Digital Fingerprints**: Founded in 2017, Katowice startup Digital Fingerprints has raised $2 million to develop online authentication solutions that use behavioral biometrics. According to Digital Fingerprints, PINs and passwords are antiquated and easy to breach and biometric checks like fingerprints, facial recognition, or iris recognition can also be copied, although they are much more difficult to replicate.
- **Airly**: Founded in 2016, Krakow startup Airly has raised $1.2 million to develop a platform that monitors and forecasts air quality using sensors and AI. The company currently has 2,500 working sensors located mainly in Poland and a number of big European cities. These sensors measure levels of pollution by looking at air composition in real-time and Airly's algorithms analyze the data to come up with insights about pollution in areas of coverage. The startup uses AI to model air quality and predict how pollution levels are going to change. Airly has been working with Cisco on the corporation's smart cities strategy since the early stages of the startup.
- **Senuto**: Founded in 2014, Warsaw startup Senuto has raised $540,000 to develop Search Engine Optimization (SEO) tools that utilize AI. Senuto's software-as-a-service provides search result rank tracking, semantic keyword search in all languages, and content planning, optimization, and performance analysis. The company also does custom SEO consulting and big data projects related to SEO. According to Senuto, the basic rules of SEO copywriting are choosing to include the right keywords, delivering informative and error-free content that's well structured, and refraining from automatic content generation or copying other websites.
- **CTAdventure**: Founded in 2013, Gdansk startup CTAdventure has raised $300,000 to develop tools for image processing and Augmented and Virtual Reality (AR and VR). The startup is involved in four types of projects spanning four different industries. The first application assists doctors performing capsule endoscopy, a diagnostic procedure where a capsule the size of a large pill equipped with cameras slides down the digestive tract and records the inside of internal organs. Machine learning algorithms automatically analyze this footage and reduce the time spent on analysis and evaluation by 70%. The second application, called FashionTagger, detects and classifies apparel on pictures, helping shoppers search e-commerce stores using detailed attributes of clothes like pattern, hemline, and neckline. The company's VR division delivers interactive training to professionals in the petroleum and energy industries, and soldiers in the army. CTAdventure is also involved in custom mobile and web application development involving AR.

3.5. Conclusion

The goal of the report was to briefly provide the current landscape of Artificial Intelligence (AI) in Poland. The breakdown included the correlation and cooperativeness of companies and the academic community. Among the reports reviewed, the Map of Polish AI proved to be comprehensive in undertaking of AI in the Polish market.[30]

[30] Ibid

The experts who were consulted for the report point to a mismatch between the availability of AI specialists and the demand for their skills. This mismatch may be an important bottleneck in the development of the AI sector in Poland. In order to bridge this gap, there should be more education of specialists and non-experts. The latter means training managers to understand AI and being able to identify areas were the technology can be applied. [31]

However, in order to increase the effectiveness of research efforts, there should be greater understanding of the existing research literature and understanding of potential solutions to the potential shortages. The next step can be the inclusion of AI expert specialists to the workforce, because research in the AI sector is continuously evolving.

Additionally, there is optimizing and investing opportunities in AI dominated and related start-ups. Entrepreneurs have capitalized on the wave of AI and the need for innovative solutions. The official government strategy being prepared shall be based on four basic pillars: knowledge and competence, an appropriate infrastructure, legal provisions (to ensure that the technologies will be safe for people) and financing for research and implementation.

According to the Observatory of Public Sector Innovation, co-funded by the Horizon 2020 Framework Programme of the European Union, the government of Poland has not yet published an AI strategy. The Ministry of Digitization published *Assumptions for the AI strategy in Poland* in November 2019, as an action plan towards developing an AI strategy. It includes provisions for the management and opening of government data, participation of public sector companies in the development of AI projects. It is not clear when the final strategy will be issued. The development of an AI policy would provide a framework for the development of AI in Poland.

[31] Borowiecki, Łukasz, and Piotr Mieczkowski. *Map of the Polish AI*. I ed., Digital Poland Foundation, 2019.

4. Hungary

4.1. Country Summary

- The foundation of Hungarian AI research lies in the very strong mathematical research traditions especially in the field of graph-theory, number theory, combinatorics, algorithms and networks. One of the most prominent Hungarian mathematicians of the 20th and 21st century in these fields was John von Neumann. There are several research centers in Hungary dealing with the basic research of different aspects in AI, three of them are internationally acclaimed, winners of several European Research Council (ERC) grants (all located in Budapest). The most significant applied research center in the field of AI is the Institute for Computer Science and Control Institute (MTA SZTAKI) of the Hungarian Academy of Sciences.
- Quite a number of multinational companies have established R&D centers in Hungary, due to the high number of well qualified and in the past also relatively underpaid engineers, IT specialists and scientist. However, the salary levels have risen significantly, and a large number of professionals moved to Western Europe, causing a shortage in the STEM field. Nevertheless, the most important multinational R&D centers are extending their operations and in several cases this extension is related to newly established AI R&D research entities. The large automotive production plants (mostly German companies) are significant users of robotics based production and they are often early adopters of Industry 4.0 solutions.
- AI and Big Data related startups play a significant role on the Hungarian startup scene. There are about 40 AI, Big Data related startups that accounts roughly to 5% of all startups. Another factor related to the relative high number of startups is the abundance of financing due to earlier Jeremie Funds and a very large government VC fund (HiVentures) with over 220 million Euros of funding.
- The Hungarian AI Coalition was formally created under the auspices of Laszlo Palkovics, Hungary's Minister of Innovation and Technology (ITM), and at the founding it was joined by about 78 academic research centers, universities, businesses, and state offices with interests in the future of AI. Since its founding the number of members has more than doubled. Apart from the Ministry of Innovation and Technology, a dozen ministries and government offices have joined the coalition, including the Ministry of Interior, Ministry of Human Capacities, Central Statistical Office, National Bank and Tax Authority.
- The government decided to formulate a national vision for AI based on the existing centers, competences, research projects and international cooperation together with the AI Coalition. It shall identify specific use cases, access to HPC capacity and strengthening of startup ecosystem. The National Brain Research Program, an earlier RDI government initiative, can serve as example to a new AI flagship program.
- There are two main areas of AI application in the public sector: security and healthcare. A special government initiative for autonomous driving with cca. 150 mil. Euro investment for an automotive industry test track on 265 hectares is getting close to its completion in Zalaegerszeg in Western Hungary and includes a smart city segment.

4.2. Introduction

The foundation of **Hungarian AI research** lies in the very strong mathematical research traditions. Three institutions are internationally highly acclaimed and winners of several European Research Council (ERC) grants:

- Hungarian Academy of Sciences – Alfred Rényi Institute of Mathematics
- Eötvös Loránd University of Sciences
- Budapest University of Technology and Economics

The most significant applied research center in AI is the Institute for Computer Science and Control Institute (MTA SZTAKI) of the Hungarian Academy of Sciences, founded in the 1980s.

Three multinational companies have established large R&D centers in Hungary with a significant AI focus:

- Continental
- Ericsson
- Bosch

Despite the activities of these important centers, AI application development is lagging behind in basic research; the "European Paradox" of RDI is true in this case as well.

AI and Big Data related **startups play a significant role** in the Hungarian startup scene. This can be attributed to the relatively high level of research and also to the spillover effect of the success of some startups. According to estimates there are about 40 AI, Big Data related startups that accounts roughly for 5% of all startups. Most startups are from the biotech and fintech industry segments, but the largest investment is in an AI startup, close to 40 million USD, went to AI Motive, in the autonomous driving field.

There are two main application fields in the **public sector** currently: security and healthcare. The former one focuses on fast video recognition and analysis, the latter one primarily on big data applications. Several universities are included in the creation and application of healthcare solutions.

The **Hungarian AI Coalitio**n was formally created in 2018, under the auspices of Hungary's Minister of Innovation and Technology, currently with over 150 members including government offices, research entities and industry. The AI Coalition is a permanent forum for cross-sector cooperation in research and in industrial and public sector application. The coalition has established six task forces: Applications and market development; Technology and security; Data industry and data management; Regulation and ethics; International relations; Education and awareness.

The government has invested heavily in an autonomous driving test-track to make Hungary an important center of RDI in this field.

The last chapter of the overview summarizes some policy recommendations that proved to be efficient in the AI field as well.

4.3. Excellent AI Research

Basic research

The foundation of Hungarian AI research lies in the very strong mathematical research traditions especially in the field of graph-theory, number theory, combinatorics, algorithms and networks. Some of the most prominent Hungarian mathematicians of the 20th and 21st century in these fields are: Pál Erdős, John von Neumann, Pál Turán, László Lovász (currently, the president of the Hungarian Academy of Sciences), Endre Szemerédi, and Albert-László Barabási.

Specific AI research in Hungary goes back more than 40 years. Within the Hungarian Neumann János Computer Society existed an Artificial Intelligence Group (AI Group) and an Image Processing Group (IP Group) and there was a separate Hungarian Robotics Association (HRA) with over 40 institutional and two hundred individual members as early as the middle of the 1980s.

Currently there are several research centers in Hungary dealing with the basic research of different aspects of artificial intelligence. Three of them are internationally highly acclaimed, winners of several European Research Council (ERC) grants:

- Hungarian Academy of Sciences – Alfred Rényi Institute of Mathematics
- Eötvös Loránd University of Sciences
- Budapest University of Technology and Economics
- Central European University

Details about their research activities:

a) Hungarian Academy of Sciences – Alfred Renyi Institute of Mathematics

Recently, the Institute has established an Artificial Intelligence Research Group, led by Balázs Szegedy, who is also the winner of an ERC Consolidator Grant with the title The Limeses of Discrete Structures. This theoretical topic is related to the generative neural networks and stochastic residual networks. The applications possibilities include deep learning, semantic compression methods and 2-dimensional Gauss auto encoders.

László Lovász, Albert-László Barabási (CEU and Boston) and (Jaroslav Nešetřil, Charles University, Prague) won a close to 10 million Euro ERC Synergy Grant[32] for the research of dynamic networks for 2019-2023 period. The "synergy" in this case is between network science and graph-theory, including many potential AI applications.

Rényi Institute was awarded with a 1 billion Ft (3.1 million Euro) grant funded by the Hungarian National Excellence Program for the research of "mathematical foundations of artificial intelligence", in 2018. This program involves researchers from ELTE, the Institute for Computer Science and Control of the Hungarian Academy of Sciences, Szeged University and Pázmány Péter Catholic University. The amount was among the two top highest grants.

b) Eötvös Loránd University of Sciences (Budapest)

The Artificial Intelligence & Data Science research group of ELTE was established to provide a knowledge and know-how center at the Eötvös University in the state-of-the-art AI techniques. This initiative is a joint effort of the Department of Computer Science, Eötvös Loránd

[32] The most prestigious ERC grant

University and the Alfréd Rényi Institute of Mathematics, Hungarian Academy of Sciences. The main research fields are the following:

- Deep learning
- Data science
- Network science
- Visual analytics

ELTE runs a four semester Computer Science MSc program with Artificial Intelligence specialization and a Computer Science for Autonomous Systems MSc program. Both programs are in English.

c) Budapest University of Technology and Economics (BME)

There are 26 research teams at BME dealing with specific aspects of AI. In the following there is a list of the more significant scientific topics:

- Development of a new data-security system based on the transformation (anonymization) of the learning data-set. The proof of the efficiency of the new data-security method in the Differential Privacy model. Analyzing the inversion of distributed neural networks.
- A model was developed for robust cyber-physical systems to describe architectural reconfiguration and sensor fusion.
- In the field of robotics and intelligent manufacturing the research topics include robust control systems, AI-based fault location and intelligent production based on machine-robot cooperation.
- In the field of autonomous driving and related communications a “virtual cockpit” and LiDAR based collision avoidance system was developed. Modelling of the different driving “styles” was developed that can be used in the autonomous vehicle control.
- In the case of data-mining of financial time-series the Autoregressive Hidden Markov Models (ARHMM) were used for algorithmic trading. It was proved that using parallel MCMC algorithm, significant profit can be achieved by options trading.
- A validation system was developed for the cybersecurity risks of vehicle communication.
- Data integration methods were developed for simultaneous LiDAR and different camera-based visual representations. Methods were developed for the analysis of algorithm robustness.

BME was awarded with a 300 million Ft (1 million Euro) grant funded by the Hungarian National Excellence Program for the research of “Technologies to increase the safety of IoT (Internet of Things) systems” in 2018. This program involves researchers from Debrecen University and Szeged University.

The Faculty of Electrical Engineering and Informatics runs quite a few academic subjects in AI: Artificial Intelligence (BSc), Applied Artificial Intelligence (BSc), Autonomous Robots and Vehicles (BSc), Big Data Analysis Techniques (MSc), Artificial Intelligence Based Control (MSc).

d) Central European University

In the field of AI education, the Central European University has an important role. Courses like "HelloAI" a Summer School about Artificial Intelligence in Healthcare or CEU Business School's Big Data Insights Course attract large number of students and even industry experts.

CEU also has significant research in the field of networks at the Department of Network and Data Science led by Albert-László Barabási. His joint research with Nima Dehmamy and Soudabeh Milanlouei was on Nature's cover (November 29, 2018): "A structural transition in physical networks". This research is fundamental among others in understanding the deep learning methods. On a lighter note, a CEU PhD Student Mr. Janosov made an AI-based prediction model regarding who dies next in Game of Thrones.

e) Additional education centers

Apart from the above-mentioned universities, Szeged University is a significant institution in AI education, its Department of Algorithms and AI offers a number of courses on all levels.

There are also a number of private training companies offering programs in the field of AI. E.g. NobleProg offers courses in practically all areas of AI (neural networks, machine learning, computer vision, face recognition, image analysis, predictive analytics, etc..)

Applied research

a) MTA SZTAKI

The most significant applied research center in the field of Artificial Intelligence is the Institute for Computer Science and Control Institute (MTA SZTAKI) of the Hungarian Academy of Sciences. The institute has been active in the field of AI since the 1980s, primarily in applied research, in many cases based on concrete industrial needs. Their main field in AI is robotics, human-robot interactions, logistics and Industry 4.0. The institute has significant research competences in the following areas:

- Engineering and business intelligence
- Machine perception and interaction
- Vehicle and transportation systems.

SZTAKI has a longstanding and strong partnership with the German Fraunhofer Gesellschaft the umbrella organization of about 60 research institutes. In 2010 the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA), Stuttgart, MTA SZTAKI, and Fraunhofer Austria established the Fraunhofer Project Centre for Production Management and Informatics at SZTAKI. The main research activities of the Project Center are the cyber-physical production systems aimed at developing models, methods and techniques that are capable of handling complex production and business systems working in an uncertain, changing environment.

b) Continental

The German technology company, Continental has opened a Deep Machine Learning Competence Center in Budapest in February 2019. According to their press release "Artificial intelligence is a core competency in the development of automated driving. We are expanding our expertise in the area of Deep Machine Learning to enable automated driving and to support our Vision Zero – a future without accidents." Continental is hiring about 100 software and

hardware engineers for the new center. The focus topic in the new site will be Deep Machine Learning for embedded and safety-critical real-time software applications. “Our competence center will develop solutions for mastering complex driving situations using this rapidly evolving technology.”

According to Continental, the main factors in the choice of Budapest was the existing active automotive environment, a large number of universities and research institutes as well as the availability of the required specialists, including Machine Learning specialists, Big Data engineers, Hardware/Software co-designers and Application engineers.

c) Ericsson

Ericsson has its largest R&D center outside of Sweden in Budapest with over 1500 engineers.

Their main research fields are 5G service development and cloud based systems. AI related activities are mainly in the field of IoT R&D and smart city applications. Ericsson Hungary has a strategic cooperation agreement with the Budapest University of Technology and Economics (BME) in R&D and education. The CEO of Ericsson Hungary is the president of the IO coalition (see in 3.1.).

d) Bosch

Bosch Hungary invests in R&D with approximately 20 million Euros. In their Budapest center they have an autonomous driving research group and sensor and radar R&D.

International cooperation

a) EIT (European Institute of Technology and Innovation) Digital has a co-location center in Budapest, jointly run by Eötvös Loránd University (ELTE) and Budapest University of Technology and Economics (BME) in cooperation with a number of companies. Artificial Intelligence is one of their main competence fields, even industrial PhD programs are run in the AI field. The University of Ljubljana is also involved in the activities of EIT Digital’s Budapest co-location center.

   The European Union selected the AI4EU consortium from 7 applicants to receive a total funding of EUR 20 million in a research and innovation project related to artificial intelligence. AI4EU includes leading European industrial companies, research centers, small and medium-sized enterprises, higher education institutions and, from Hungary, researchers from the Budapest University of Technology and Economics and ELTE who will work together to establish the European Union’s mega platform. The stated goal of the project is to “build a comprehensive European AI-on-demand platform to lower barriers to innovation, to boost technology transfer and catalyze the growth of start-ups and SMEs ..."

   The National Contact Point for Hungary will be Géza Németh, the head of the Speech Communication and Smart Interactions Laboratories at BME’s Department of Telecommunications and Media Informatics. The platform will act as a broker, developer and one-stop shop providing and showcasing services, expertise, algorithms, software frameworks, development tools, components, modules, data, computing resources, prototyping functions and access to funding.

b) Alfred Rényi Institute of Mathematics of the Hungarian Academy of Sciences has strong contacts with the Charles University, Prague, Rutgers University (New Jersey, US), University of Pisa (IT).

c) There are many Hungarian contacts and cooperation with the German Fraunhofer network. The Fraunhofer Project Centre for Production Management and Informatics was already mentioned as an organizationally established and ongoing cooperation. Three Hungarian entities with three Frauenhofer Institutes have won a H2020 Teaming grant from the European Commission. The Hungarian members are: SZTAKI and two faculties of the Budapest University of Technology and Economics (BME) (Faculty of Mechanical Engineering and Faculty of Transportation Engineering and Vehicle Engineering). The German partners are: three Fraunhofer Institutes (IPA-Stuttgart, IPK-Berlin, IPT-Aachen). The consortium includes Fraunhofer Austria as well. The applied research / innovation objective of the proposal is to transfer the results achieved by SZTAKI and BME into the industry with the support of the Fraunhofer Society (FhG). The Teaming project received about 20 million Euro funding (1/3 from Hungarian resources) for R&D and industrial application of cyber-physical production and logistic systems.

d) An AI workshop was organized in March 2019 by the British Embassy and the Ministry for Innovation and Technology with the aim to „discover dos & don'ts of how the UK government & private organizations build, incentivize, promote, internationalize and measure AI as a tool in their products & services and their relevance to Hungarian AI policy". Representatives of the Alan Turing Institute (UK) and the Hungarian AI-coalition (see below) held discussions on concrete areas of cooperation.

e) A similar workshop was organized by the French Embassy in May.

4.4. AI Applications

National and international companies

Quite a number of multinational companies have established R&D centers in Hungary, due to the high number of well qualified and relatively underpaid engineers, IT specialists and scientist. This situation has started to change, the salary levels have risen significantly and a large number of professionals moved to Western Europe, causing a shortage in the STEM field. Nevertheless, the most important multinational R&D centers are extending their operations; they can more easily compete with salaries. In several cases this extension is related to newly established AI R&D research entities. (See detailed in 1.2.)

The large automotive production plants (mostly German companies) are significant users of robotics based production and they are often early adopters of Industry 4.0 solutions.

The startup scene

AI and Big Data related startups play a significant role in the Hungarian startup scene. This can be attributed to the relatively high level of research in this field and also to the spillover effect of the success of some startups. According to estimates there are about 40 AI, Big Data related startups that accounts roughly to 5% of all startups[33]. According to European Artificial Intelligence report[34], this would mean they rank behind Sweden and Finland, but ahead of the Netherlands and Italy (the new member states were not listed…).

[33] These numbers are estimates as there is no reliable database of startups, partly because of the volatility of these companies. Source: Hungarian Trading House

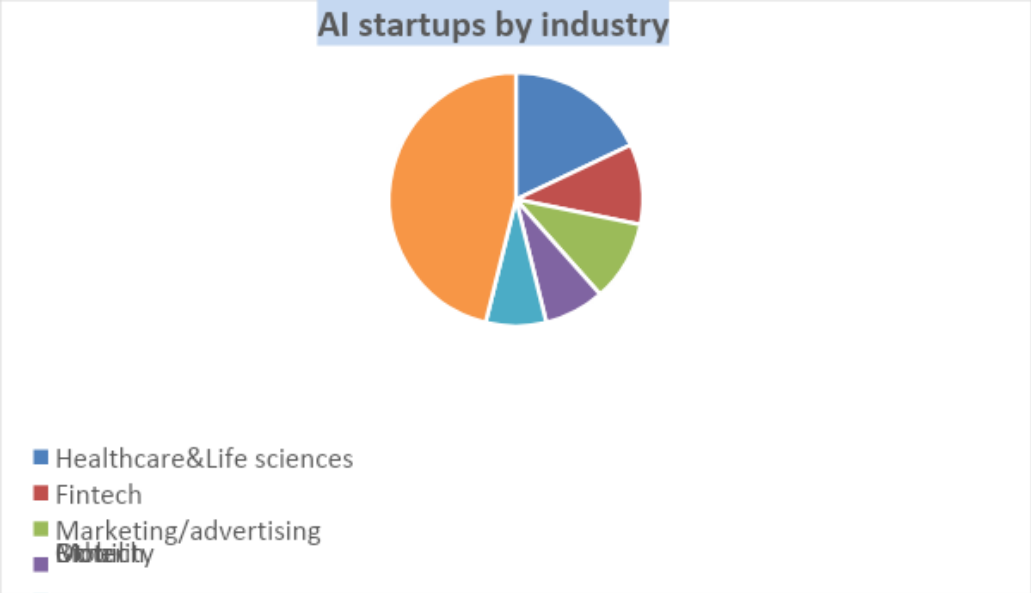
[34] Roland Berger: Artificial Intelligence – a Strategy for European Startups (Asgard, 2018)

Another factor related to the relatively high number of startups is the abundance of financing due to earlier money from the Jeremie Funds and a very large government VC fund (HiVentures) with over 220 million Euros of funding.

Figure 14: Some statistics about the Hungarian AI startup population

Phase	Proportion
Startup	65%
Scaleup	35%

No. of Employees	Proportion
1-10	72,5%
11-50	25,0%
101-250	2,5%



Success stories

Success stories are important as they have a spillover effect in attracting others to the field, as we can see in the Hungarian case already.

a) **AIMotive,** https://aimotive.com/

This startup is an internationally acclaimed player in the field of developing software solutions for autonomous driving. Using cameras as primary sensors their solutions mimic the visual capabilities of human drivers.

The company received the second largest investment after Prezi in 2018. According to the company's press release they will use the close to 40 million USD investment for camera sensors and for the development of AI-based image processing. According to the company plans they will start testing their solutions in Japan, China and in the United States. They have over 180 employees.

b) LynxAnalitics, https://www.lynxanalytics.com/

With their proprietary big data graph analytics tool and solution platform they can solve complex business problems. The graph engine can dramatically accelerate deep learning algorithms.

Their strategic investor and prime business partner is Hong Kong Telecommunications (HKT) with a 10 million USD investment in 2016.

c) Turbine.AI, http://turbine.ai/

Born from a marriage of bioinformatics, network medicine and artificial intelligence at Semmelweis University, Turbine was founded to start a new paradigm in cancer research. Turbine's "in silico" experiments can test an almost infinite number of interventions on a Simulated Cell that reflects the molecular diversity of cancer cells accurately. Turbine takes laboratory trial and error out of drug discovery and tackles it with scalable power on their servers.

Among their customers there is Bayer and two other pharma multinational companies. They have over 40 employees.

4.5. AI application in the public sector

There are two main areas of AI application in the public sector: security and healthcare. Regarding security, we can only deal with public domain information.

Security

In Q3 2018 the Hungarian Rapid Response and Special Police Service (Készenléti Rendőrség) issued an open call for the public procurement of a number of analytical software and hardware tools. One lot is about fast video recognition and analysis of persons, objects, situations covering all possible attributes (size, velocity, direction, color, etc.). As of the writing of this document there was no decision made regarding the call.

Healthcare

There are a number of initiatives using big data as a foundation for AI-based improved quality healthcare delivery, better patient outcome and higher productivity. Unfortunately, in the health-sector there are a number of hindering factors:

- database issues (standardized data structures, interoperability, sensor based personal data integration, etc.),
- data reliability,
- legal, ethical issues,
- GDPR, cybersecurity.

In most cases the solutions are a combination of big data, AI, imaging (digital health/e-health). The precondition of any AI deep learning solution is the availability of high quality, manageable data.

There are a number of large projects currently in progress:

a) A consortium led by the State Healthcare Center funded by Structural Funds (over 70 million Euro) aims simultaneously at creating the necessary data bases and developing expert systems for diagnosis, health management and scientific research. The project

is also about the development of value added services, telemedicine, etc., including their implementation in the sector.

b) The University of Pécs is the consortium leader of another Structural Fund funded (6 million Euro) project to develop an augmented reality solution for combining the visualization of 3D medical images with reality, to be used for diagnostic expert systems and education.

   The project includes the development and implementation of a new database concept, called "Data Lake". The implementation will take place at Pécs University to improve the healthcare service at the university and later in the region. The project goes far beyond the "traditional" e-health application in the direction of AI.

c) Semmelweis University Health Services Management Training Centre is the Hungarian partner of the EU e-health regulatory taskforce (eHaction), leading the BigData work-group.

   Semmelweis University is also involved in the Data Lake concept by defining the application layers, including AI.

4.6. AI Policy environment

AI Coalition

The Hungarian AI Coalition was formally created on October 9 under the auspices of Laszlo Palkovics, Hungary's Minister of Innovation and Technology (ITM), and at the founding it was joined by about 78 academic research centers, universities, businesses, and state offices with interests in the future of AI. Mr. Roland Jakab, the CEO of Ericsson Hungary was elected as the president of the AI Coalition. Since its founding the number of members has more than doubled.

The aim of the AI Coalition is to support Hungary in the international competition and in becoming a reference point for the international AI community by defining the directions and framework of the AI-based developments. Furthermore, the Coalition would like to strengthen the competitiveness of domestic businesses by the wide spreading and extensive application of AI with special attention to Hungarian start-ups and SMEs. Also, the Coalition will focus on the efficient, fair and regulated utilization of public data.

Underscoring the global nature of AI research and the opportunities to be had, national business chambers such as the American or German Chamber of Commerce Hungary and international consulting and law firms are among the founding members of the coalition, which according to one signatory is focused on creating "a framework for cooperation in order to bring Hungary to the forefront of Europe in the field of this technology." The AI Coalition is a permanent forum for cross-sector cooperation in research and in industrial and public sector application.

The coalition has established six task forces:

- Applications and market development
- Technology and security
- Data industry and data management
- Regulation and ethics
- International relations

- Education and awareness

In the wake of the October 2018 founding of Hungary's AI Coalition the coalition is working towards drafting a comprehensive AI strategy for the future, which industry leaders hope will establish this country as an AI innovator.

In addition to formulating a national strategy, the Coalition is studying the social and economic effects of AI on society as this technology becomes increasingly more important in everyday life.

Government activities

Apart from the Ministry of Innovation and Technology that was instrumental in the founding of the AI Coalition, a dozen of other ministries and government offices have joined the coalition, including the Ministry of Interior, Ministry of Human Capacities, Central Statistical Office, National Bank and Tax Authority.

On April 2018 the Hungarian government signed the EU Declaration on Artificial Intelligence, a cooperation agreement among 24 member states for research, implementation, and regulation of AI with the ultimate aim of increasing the EU's global competitiveness in this sector.

Hungary's decision to formulate a national vision for AI comes as Brussels works to develop an EU-wide AI strategy in response to US and Chinese dominance in this sector. This vision is based on the existing centers, competences, research projects and international cooperation. To formulate the strategy, the government (ITM) is cooperating with the AI Coalition. In this vision/strategy specific use cases will be identified, access to high-performance computing capacity has to be dealt with and the strengthening of this segment of the startup ecosystem will have to be taken care of.

The National Brain Research Program, an earlier RDI government initiative in Hungary, can serve as a successful example to a new AI flagship program.

A special government initiative for autonomous driving – Zalazone

With a cca. 150 million Euro investment an automotive industry test track is getting close to its completion in Zalaegerszeg (Western Hungary). The test track is designed primarily for autonomous cars and it will include a smart city segment as well. The primary potential users of the 265 hectares test track are R&D units of the automotive industry including their Tier1 and Tier2 suppliers, and also companies from the communication technology sector.

4.7. Policy recommendations

We will cover briefly five areas where right government policies can help significantly in strengthening the AI capabilities of their respective countries:

a) public procurement

b) government data as the fuel of Big Data and AI applications

c) support of EU and other international R&D consortium building

d) startups

e) multinational companies

a) Public procurement.

It is generally accepted that the public procurement of RDI can serve as a significant stimulus to a country's innovative companies. Despite the fact that the EU has put a lot of effort into creating legislation (e.g. PCP, Pre-Commercial Procurement directive[35]) and disseminating best practices in this field, most member states are not ready for using it as a tool for boosting innovations. The Swedish "Functional Procurement for Innovation" is very positive exception, which is worth considering its implementation. The GovTech initiative in Poland is also a good practice. AI is a typical field where governments can use PPI (Public Procurement of Innovation).

b) Regulating the use of government collected data

Governments collect extremely large amount of data, in relation with this data collection the focus is more on the privacy and protection issues. With the right legislation and procedures in place, these databases can be used as a fuel for big data and AI applications.

In Israel the government on 25 March 2018, approved a five-year national digital-health program that is designed to personalize medicine, improve medical procedures and keep Israel at the forefront of the medical-tech field As part of this program the Israeli government will regulate the digitization and sharing of health data and will promote and finance collaboration with commercial companies, including startups, focused on digital health. It must be stated that some controversies were also generated by this decision in Israel.

c) Supporting of EU and other international R&D consortium building

Consortium building can be a costly exercise both for the individual researchers and the institutions. On the institutional side travel expenses, on the individual's side the significant amount of time invested can prove to be a risky investment because of the fairly low success rate. Some kind of partial governmental contribution to these activities and costs can increase the willingness of both the institutions and that of the individuals to participate in the preparation of such bids. This can increase the low participation rate that is an unfortunate fact in the CEE region.

d) Startups

AI/Big Data is one of the fastest growing segments of the startup ecosystems[36] world-wide, the total funding value growth was over 190% comparing 2013-14 to 2018-19. One of the reasons of this fact is that developing AI-based solutions, applications are not traditionally the territory of the well-established companies. Thus, startups are among the most successful companies in this field. Instead of direct governmental support to startups, an indirect co-financing support scheme to technological incubators, accelerators can bring much better results. The Israeli technological incubator model can serve as a best practice that was adopted in several countries[37], including Hungary.

It is important that even if successful startups move their HQs to the US or London, Berlin, etc. that they leave their R&D activities in their country of origin. Appropriate financial and regulatory circumstances can help a lot in achieving this goal.

[35] Directive 2014/23/EU
[36] Global Startup Ecosystem Report 2019
[37] Singapore, Finland

e) Multinational companies

Government policies should encourage international companies to move or create R&D activities together with the move of production facilities.

This is not just a question of financial incentives, but with the availability of highly trained and creative workforce, attractive living conditions and good foreign language schooling are at least as important factors.

Hungary was quite successful in this aspect in the case of a few ICT company, (most of these have appeared in the report: Bosch, Ericsson, Continental) and less successful in the case of automotive companies.

Conclusion and Summary of Recommendations

- AI and automation trends should not be seen as a threat, but as an opportunity for the V4 countries to modernize their economies, raise wages and overall welfare. It can play a unique role in restructuring and boosting productivity gains, supporting countries' convergence with EU income levels and preventing the risk of slowing down.
- V4 countries have huge research and business potential in AI. Yet, when acting on their own, they can neither implement globally relevant commercial projects, nor can they properly prepare for the political and economic impact of AI on our societies. V4 needs more common AI projects, both in R&D and policy, to remain competitive and better prepare for the transformation that will affect young generations.
- Public policy and R&D efforts are scattered among too many public and private stakeholders in V4 countries. Public and private R&D centres work on similar projects and politicians only recently started to reflect the political importance of AI and automation. This will change the structure of labor markets and supply chains, which by itself is a regional issue. The governments should therefore set clear rules and an overall framework for cooperation on regional basis on the grounds of V4/CEE.
- To fully utilize this opportunity countries need to invest in and cultivate innovation. Unlike Lisbon or Stockholm, none of V4 major cities are listed in global rankings of startup hubs. V4 needs strong ecosystem based on AI, HPC and cybersecurity. The support for concentration of R&D shall be coordinated to the regional hubs and mutually supportive networks to maximize V4 competitiveness.
- V4 countries shall get fully involved in all EU activities in AI and the V4 coordination shall be in line with building of the European AI ecosystem. The Czech V4 Presidency 2019-2020 is a very good opportunity to articulate and coordinate priorities in AI, including all V4 working groups, and high-level meetings that deal with innovation and AI. It shall serve also as a preparation for the Czech presidency of the EU Council (2022), followed by the Hungarian presidency (2024) and Polish presidency (2025).
- The European Commission outlined specific actions for investments in AI in the Coordinated plan, including talent, skills and life-long learning that are very important for V4 countries. The current focus is primarily on testing and the transfer of technologies to businesses is very valuable, however, the EU should support the whole ecosystem to strengthen its global and regional competitiveness in AI. Therefore, it should be covered in Horizon 2020, but also in new the Digital Europe Program to support the building of the whole ecosystems on this basis.

The challenges of automation for V4 economies are often underestimated. Not only will low-income professions face higher risk of replacement, but those with middle-level qualifications also. This can lead to a deepening of economic inequality in society. The governments shall play an important role in reshaping the educational system and in supporting the adaptation of workers and businesses to new conditions. They should include policies that can be initially unpopular or difficult to implement but may create a significant competitive advantage for the whole economy in the long run.