SCIENCE AND TECHNOLOGY FORESIGHT PROJECT KK.01.1.1.03.0001

ANALYTICAL REPORT OF THE CONDUCTED SCIENTIFIC AND TECHNOLOGICAL MAPPING

ARTIFICIAL INTELLIGENCE

Inovacije i razvoj d. o. o., Zagreb

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AUTHORS

- Bojan Bajić, MEc, principal adviser
- Vedran Đidara, MEc, expert in the field of research and/or innovation policy
- Prof. Kristian Vlahoviček, PhD, expert in the field of artificial intelligence
- Prof. Hrvoje Buljan, PhD, expert in the field of space technologies
- Lidija Gruber, MEc, expert associate
- Maja Jakšić, MEc, expert associate
- Ana Podnar, expert associate

Table of Contents

1 Introduction

The Ministry of Science and Education (hereinafter: the Ministry), in cooperation with the University Computing Centre of the University of Zagreb (Srce), is implementing a strategic project titled 'Science and Technology Foresight', co-financed by the European Regional Development Fund. The overall objective of the project is to create a coherent and comprehensive system for determining the priorities of research, development and innovation policies in the Croatian scientific space. This will be achieved by implementing three main project elements: 1) establishing a legal framework, 2) creating the Croatian Research Information System, CroRIS, and 3) implementing scientific and technological mapping and foresight activities. The project will facilitate the cooperation among the representatives of the relevant ministry, the scientific community, the economic sector and civil society for the purpose of creating a comprehensive system for research, development and innovation. More about the project can be found at https://mzo.gov.hr/istaknute-teme/eu-fondovi/operativni-program-konkurentnost-i-kohezija-2014-2020/strateski-projekt-znanstveno-i-tehnologijsko-predvidjanje/851.

As part of the third project element, titled Implementation of Scientific and Technological Mapping and Foresight, the second phase of the mapping activities has been carried out for two new areas: Artificial Intelligence and Space Technologies. The objective of carrying out this mapping activity is to establish a comprehensive database of research competence, innovation capacity of scientific institutions and private sector entities operating in the new areas of artificial intelligence and space technologies. An in-depth analysis of the data collected from these two areas will indicate the strengths of the research sector and the overlap areas for potential identified in the said areas. This will help determine the priorities for the development of science and innovation in the Republic of Croatia and to align with the relevant policies at the EU level. This mapping activity will enable the identification of productivity, skills, expertise, strengths and weaknesses of the Croatian science and technology system with a focus on human potential, technology transfer, synergies, strengthening participation in EU framework programmes, internationalisation, inclusion in the European Research Area and innovation as well as financial operations in the selected thematic areas. A comprehensive insight into the areas of concentration of Croatian scientific and innovation excellence in the two mapped areas will enable the modification and expansion of strategic documents in the field of research, development and innovation (RDI).

This document presents the mapping of the Artificial Intelligence area.

The methodological framework established by previously conducted mapping in the Energy and Sustainable Environment area within the Scientific and Technological Mapping Project is the starting point for the implementation of mapping and the establishment of methodologies for new areas. This document presents an analysis of the new Artificial Intelligence area and the mapping of stakeholders under it using a professional review of their activities.

The process of collecting and processing data for this study was harmonised with the regulations related to personal data protection (the General Data Protection Regulation — Regulation (EU) 2016/679 and the Act on the Implementation of the General Data Protection Regulation (NN 42/18).

1.1 Context of Mapping

The field of artificial intelligence has seen a significant increase in scientific activity in the last ten years. A number of causes have contributed to this growth. Progress in the development of computer circuitry elements, particularly graphics processing units (GPUs) used for deep learning, has led to the development and application of deep neural network (DNN) algorithms and other complex machine learning models, making it possible to perform complex operations with big data more quickly and easily. Large and well-described datasets, such as image sets with high-quality metadata, have enabled complex machine learning models to be produced. In addition, generative models as well as machine recognition and learning have been developed, as well as other new analytical approaches that have made it possible to solve new problems. Perhaps the most important cause of the development of AI is the great need for practical solutions in various sectors, such as autonomous driving, the health care sector (diagnostics), image and speech recognition, etc., which has greatly incited large investment in AI research and led to strong growth in this field. There is thus a great need to carry out mapping activities.

1.2 Basic Terms in the Report

Researchers in public scientific institutions and business entities (companies) are employees of these legal entities, who are engaged in research, publishing scientific papers and implementing projects as part of their work. The quality of research at scientific institutions and companies was evaluated by analysing three types of indicators:
(1) number of publications indexed in the SCOPUS database and number of citations standardised to the age of the publication;
(2) project activity, i.e. project management and participation; and
(3) different forms of collaboration within projects and research activities.

Mapping, in the context of this project and throughout the entire report, implies the identification of researchers and public scientific institutions as well as business entities (companies) operating in the Artificial Intelligence area on the basis of an analysis of the scope of their activities, such as:
(1) participation in various projects within the S3 implementing policy instruments, S3 additional policy instruments as well as in selected EU programmes;
(2) number of published scientific papers (in the SCOPUS database) and citations of these papers;
(3) collaboration with other institutions;
(4) commercialisation of research results; and
(5) use of equipment supporting the work of researchers.

Projects — the subject of interest of this report is the participation of Croatian scientists and entrepreneurs in projects falling under a portion of the Smart Specialisation Strategy (hereinafter: S3) and the participation of Croatian scientists and entrepreneurs in projects under some of the EU programmes related to the topics of artificial intelligence that are not classified under the Smart Specialisation Strategy programmes. The projects of scientists and entrepreneurs under the following programmes were taken into account: the Seventh Framework Programme of the EU — FP7, Horizon 2020, Horizon Europe, Croatian Science Foundation programmes and projects from the programmes implemented by HAMAG-BICRO: Knowledge-Based Companies Development — RAZUM, Research and Development Programme — IRCRO, Increasing New Product Development and Services Arising from Research and Development Activities — RDI1 and RDI2, Proof of Concept — PoC from the seventh and eighth calls, the EUREKA and EUROSTARS programmes, Innovation Commercialisation, Innovation Vouchers, Innovation at Newly Established SMEs, Integrator, Innovation in S3 and European Space Agency (ESA) projects. The aim was to identify projects where solutions within artificial intelligence were developed but not those where finished solutions with some basic purpose were installed.

The Smart Specialisation Strategy (S3) is a strategic document that defines priority areas for stimulating investment in research, development and innovation (RDI) using public funds and is a key document for directing EU funds earmarked for this purpose. The Smart Specialisation Strategy of the Republic of Croatia was initially adopted in 2016 with the aim of using the structural funds of some of the EU funds.
The new Smart Specialisation Strategy by 2029[1] takes into account experience obtained, understanding gained and evidence available from the implementation of the Smart Specialisation Strategy 2016–2020 in order to achieve significant improvements in the next implementation cycle of the smart specialisation programme. The aim of the programme interventions planned under the new Smart Specialisation Strategy by 2029 is to improve Croatia's overall innovation efficiency and capacities to strengthen competitiveness and promote industrial digital and green transformation.

The following is to be achieved through the three specific objectives of the Smart Specialisation Strategy[2]:

- improving scientific excellence;
- bridging the gap between the research and business sectors; and
- increasing innovation efficiency.

Under S3 by 2029, the following thematic priority areas are defined:

- Personalised Healthcare;
- Smart and Clean Energy;
- Smart and Green Transport;
- Security and Dual Use — Awareness, Prevention, Response, Remediation;
- Sustainable and Circular Food Systems;
- Adapted and Integrated Wood Products; and
- Digital Products and Platforms.

1.3 Mapping Methodology

The methodological framework for the mapping of the artificial intelligence area was developed in several key steps:

[1] The Smart Specialisation Strategy has not yet been formally adopted.
[2] https://mzo.gov.hr/pristup-informacijama/e-savjetovanja-koja-je-pokrenulo-ministarstvo-znanosti-i-obrazovanja-2022/zavrseno-21-prosinca-2022-o-prijedlogu-nacrta-strategije-pametne-specijalizacije-do-2029-s3/5202

1.3.1 Defining the Scope of the Artificial Intelligence Area

Defining the key technologies, i.e. the engineering, scientific and computer disciplines within the field of artificial intelligence was conducted to achieve the following objectives:
(i) build a database of institutions and researchers from the public sector and private business entities;
(ii) define the keywords (i.e. technologies, research topics, products and services) by which databases will be searched (SCOPUS, project applications for calls defined in Chapter 1.2.);
(iii) prepare an adequate survey questionnaire for primary data collection; and
(iv) create a landscape of institutions and researchers from the public sector and private business entities active in the artificial intelligence thematic area.

In view of the above objectives, the keywords were selected with the purpose of building a database of stakeholders with existing research and development capacities in the field of artificial intelligence. In this context, specific technologies as well as engineering, scientific and computer disciplines for this area have been defined. During the research of secondary data, the set of keywords was chosen iteratively, i.e. it was checked whether a keyword was retrieving scientific papers and/or projects exclusively related to artificial intelligence or only partly from that area and partly from other areas. The keyword selection was then adapted over several cycles so that the final set would contain the keywords that best represent the area and retrieve the best and most representative dataset in the database searches. The list of keywords is presented in Chapter 2.1., which also explains, by using an example, the procedure for selecting them.

ARTIFICIAL INTELLIGENCE

Artificial intelligence covers a wide range of uses of computers and computer systems for **solving problems autonomously or semi-autonomously through collecting, synthesising and distinguishing information and creating knowledge to**:

- plan and make decisions or assist in planning and decision-making;
- display data and knowledge;
- learn and perceive;
- process natural language and script; and
- move objects and perform orientation in space.

Procedures classified as falling under the field of artificial intelligence include mainly the application of one of the **machine learning methods** in supervised and unsupervised **clustering, classification or regression,** such as:

- k-nearest neighbours method;
- support vector machines;
- decision trees and random forests; and
- neural networks and deep neural networks.

The areas of application of artificial intelligence include:

- big data collection systems (image, voice or text);

- planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources);
- text recognition and processing systems (digitalisation and processing of archives);
- image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth);
- search systems (contextual search engines);
- automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines);
- expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.; and
- game development systems (logical games such as chess or the development of virtual or augmented reality environments).

Artificial intelligence mapping also included the collection of data on legal and/or ethical standards and principles for the operation of artificial intelligence. The above list of methods and technologies was merged into a list of keywords for searching secondary data sources, as well as a basis for the classification and mapping of the areas of activity of Croatian stakeholders (scientific organisations and business entities) in the field of artificial intelligence. Due to the great expansion of systems based on artificial intelligence into all areas of human activity, this report primarily covers researchers and companies that:

- **develop new artificial intelligence methodology and algorithms** using new statistical and computer approaches to data analysis; and
- **use existing** machine learning **methods and algorithms** in the development **of their own systems and products**.

Therefore, in order to better map the potential of the Artificial Intelligence area, this methodological approach would not include entities that use commercially obtained computer programmes or machines and apply them in their activities.

1.3.2 Creating a Database of Researchers in Public Scientific Organisations under the Artificial Intelligence Area

The researchers database was created on the basis of queries sent to relevant scientific institutions. The list of scientific institutions to which the query was sent was made on the basis of the secondary data collected and taking into account the professions (e.g. technical professions) present in these institutions.

1.3.3 Creating a Private Business Entities Database for the Artificial Intelligence Area

The database of private business entities was created on the basis of an analysis of the secondary data collected from the considered funding programmes to which the business entities applied in the period from 2016 to the end of 2022 and the identification of business entities through relevant professional association membership.

1.3.4 Collection of Primary and Secondary Data on Projects under the Artificial Intelligence Area

The primary data comprises the responses of target groups (researchers and companies) collected through a survey questionnaire sent to their electronic addresses, while the secondary data was obtained from available databases and secondary data sources of certain ministries, agencies and/or institutions related to different programmes in which the researchers and business entities from the target area participate.

The questionnaires were sent to all the listed researchers and business entities in the field of artificial intelligence.

1.3.5 Analysis of Collected Data

The quantitative and qualitative data collected was processed in the following ways:

- descriptive data analysis: it involves summarising and describing the collected data (use of measures such as mean value, median, mode, standard deviation and frequency distribution);
- qualitative analysis: includes the analysis of collected non-numerical data, such as answers to open-ended survey questions (e.g. categorisation of answers and searching for patterns or topics);
- content analysis: includes the analysis of text data to identify patterns or topics as well as text machine processing techniques to recognise relevant topics; and
- inferential analysis: it involves drawing conclusions from the collected data sample.

1.3.6 Database Updates and Building the Landscape of the Artificial Intelligence Thematic Area

- It includes an estimate of the number of active researchers, i.e. scientists and entrepreneurs, in the Artificial Intelligence area;
- the identification of key institutions dealing in artificial intelligence and distribution of authors by institution; and
- the distribution of research activities by types of artificial intelligence.

2 Analysis of Secondary Data Regarding the Research and Project Activities of Croatian Scientists and Entrepreneurs in **Artificial Intelligence** Topics

2.1 Introduction

Croatian public higher education institutions and public scientific institutes have actively participated or are currently participating in a number of programmes for funding research, development and innovation. In carrying out this and other research, they publish scientific publications in the form of scientific and conference papers, professional papers, books, chapters in books and other forms of publications. **In this part of the analytical report, based on the available secondary data, those projects, i.e. publications, related to the Artificial Intelligence thematic area, were selected and then analysed.**

The potential databases for processing scientific publications were Web of Science and SCOPUS. Since the overlap of information contained in these two databases is extremely high, the **SCOPUS** database was analysed in this report, with a restriction to the period of the last 10 years (2012 –2022), depending on the available data.

This chapter analyses the activity of Croatian researchers in the following EU programmes:

- Seventh Framework Programme for Research and Technological Development (FP7);
- Horizon 2020 (H2020); and
- Horizon Europe.

Furthermore, the contracted projects of the Croatian Science Foundation, as well as the projects and project applications submitted to calls by the Croatian Agency for SMEs, Innovation and Investments (HAMAG-BICRO) were also analysed. Specifically, the following calls were analysed:

- Knowledge-Based Companies Development — the RAZUM programme in 2015;
- Research and Development Programme — the IRCRO programme in 2015;
- the Increasing New Product Development and Services Arising from Research and Development Activities programme — RDI1 and RDI2;
- the Proof of Concept programme or PoC (seventh and eighth calls);
- the Innovation in Smart Specialisation Strategy Areas programme;
- the Innovation Commercialisation programme;
- the Integrator programme;
- the Innovation Vouchers programme;
- the Innovation at Newly Established SMEs programme — 2019;
- the EUREKA programme; and
- the EUROSTARS programme.

Finally, the projects submitted following the call by the European Space Agency (ESA) and implemented in cooperation with the Ministry of Science and Education were analysed:

- European Space Agency (ESA) projects.

This selection of co-financing programmes is a comprehensive framework as the vast majority of Croatian researchers, scientists and entrepreneurs who were active in projects under the Artificial Intelligence area participated in the above mentioned programmes. The term *active* means a researcher who has submitted a project or participated in an approved or submitted project as a principal researcher or research associate.

The selection of the scientific papers, i.e. projects, falling within the thematic area was done using an appropriate set of keywords. The keywords used to filter data related to artificial intelligence are given in Table 1. In the first iteration, a large set of keywords was selected which, in addition to those listed in Table 1, contained words such as *classification*, *regression analysis* and *logistic regression*. All papers from the period between 2012 and 2022 with at least one address of the co-authors (affiliation) being from the Republic of Croatia were then filtered out. From these papers, a table with the names of the authors, their associated affiliations and keywords mentioned in their papers was derived.

Then, for each keyword, the sample of authors and their papers was analysed to see if the keyword included papers from the field of artificial intelligence or also papers from a different field, since some keywords related to artificial intelligence also appear in entirely different fields. For example, *regression, regression analysis* and *classification* are common terms in scientific papers in medicine that are not related to artificial intelligence. With keywords that would retrieve papers that do not fall within the thematic area, the word was either modified or was completely removed from further analysis (e.g. *regression*).

After several iterations, the final set of keywords was obtained that indexed papers related to the field of artificial intelligence. The final set of keywords, yielding a high-quality and comprehensive signal, is given in Table 1.

Table 1 — Keywords used to filter the databases for the field of artificial intelligence. When searching the databases of project applications and reference sources, the English keywords were used. The table also lists their translation into Croatian.

English	**Croatian**
ai	*ai*
artificial intelligence	*umjetna inteligencija*
machine learning	*strojno učenje*
automatic classification	*automatsko razvrstavanje*
automatic prediction	*automatsko predviđanje*
decision support	*podrška pri odlučivanju*
decision support system	*sustav podrške odlučivanju*
support vector	*vektor podrške*
support vector machines	*potporni vektorski strojevi*
support vector regression	*regresija potpornog vektora*
image classification	*klasifikacija slika*
image recognition	*prepoznavanje slike*
image processing	*obrada slike*
natural language processing	*obrada prirodnog jezika*
swarm intelligence	*inteligencija roja*
markov chain	*Markovljev lanac*
markov chains	*Markovljevi lanci*
deep learning	*duboko učenje*
reinforced learning	*pojačano učenje*
neural networks	*neuronske mreže*
deep neural networks	*duboke neuronske mreže*
adversarial networks	*suparničke mreže*
convolutional neural networks	*konvolucijske neuronske mreže*
gpt	*gpt*

An informative display of the incidence of the keywords is given using a word cloud. This keyword cloud, where the size of a word corresponds to its frequency in the SCOPUS database, is shown in Figure 1.

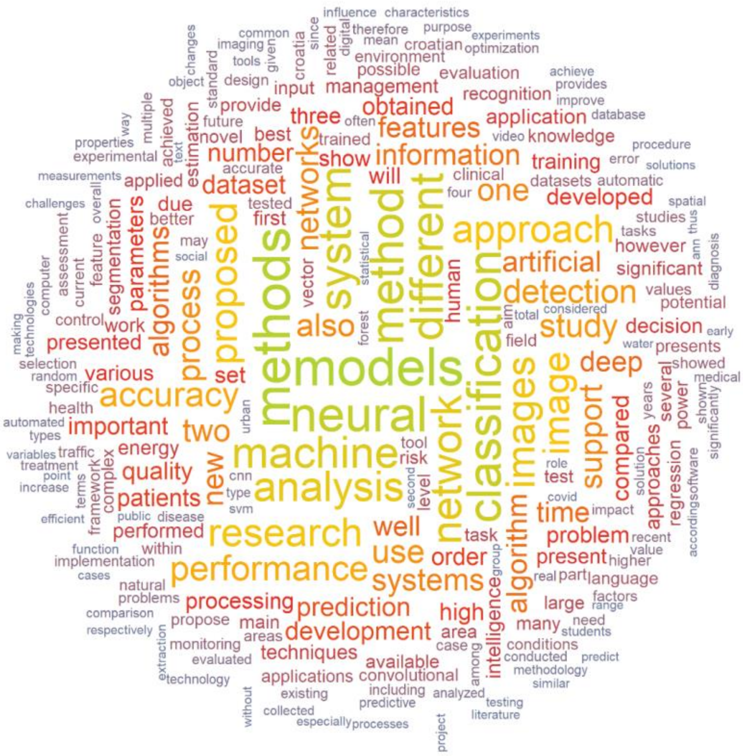

Figure 1 — A cloud display of keywords and words associated with them in the papers. The number of repetitions, i.e. frequency, is proportional to the term size in the display.

2.2 Research Activities: Overview of Scientific Publications Related to Artificial Intelligence Topics in the SCOPUS Database

Croatian public higher education institutions and public scientific institutes directly participate in the development and application of artificial intelligence methods. Figure 2 shows the number of publications by Croatian researchers indexed in the SCOPUS database in the field of artificial intelligence in the period between 2012 and 2022 retrieved by using the keywords defined above. It is to be noted that the SCOPUS database contains papers by researchers from public scientific institutions but also those by researchers from private companies. In the chapter on the SCOPUS database, in addition to the word researchers, the words authors or scientists and entrepreneurs are also used, bearing in mind the stated fact.

Publications in the SCOPUS database include scientific papers, conference papers, book chapters, review papers, editorial reviews and other types of publications. Of the data in the database, the title of the publication, the summary of the publication and the keywords that can be found alongside each publication in the database was the data taken for analysis. If one of the keywords defined in Table 1, appeared in the title, summary or annotated keywords, the publication was added to the analysis dataset. Only publications where at least one affiliated institution had its address in the Republic of Croatia were taken into account.

Authors or related institutions (whether public institutions or private entities) with Croatian addresses were retrieved from publications related to artificial intelligence via keywords. In this way, all the authors from the Republic of Croatia with at least one publication in the past 11 years that mentions a keyword related to artificial intelligence were found.

Since adequate hardware, large datasets needed for learning and all the other factors in the development of artificial intelligence globally are available to Croatian scientists, it is logical that our scientific production in this field has followed world trends, as evident in Figure 2. While in 2012, the number of scientific papers in the field of artificial intelligence was around 180, in the last three years, this number has grown to over 500 papers per year. It is concluded from the chart that the number of articles has not yet reached its peak (i.e. that the human potential and scientific capacities have not yet been exploited to the maximum) and further growth is predicted.

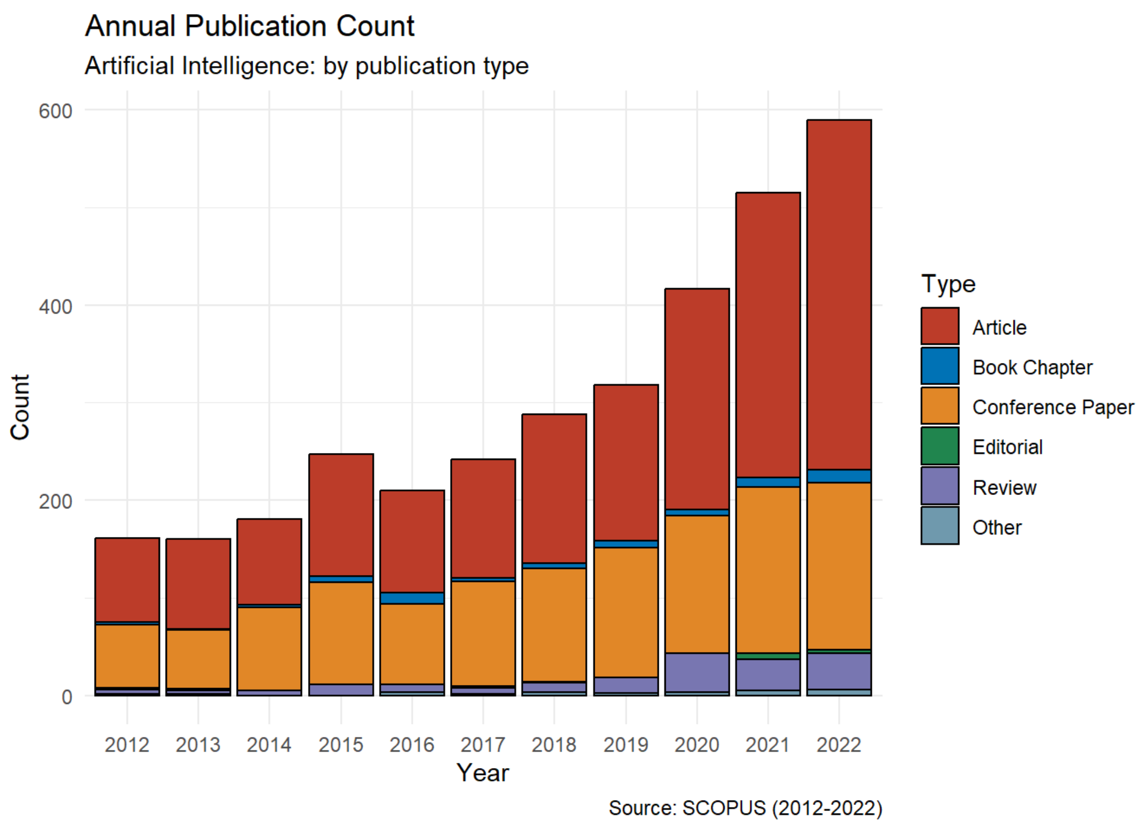

Figure 2 — Number of publications by Croatian scientists and entrepreneurs in the field of artificial intelligence from 2012 to 2022. Different colours are used for scientific papers, books, chapters in books, conference papers, editor letters, letters, review papers and corrections.

Figure 3 shows the number of publications on artificial intelligence in the period from 2012 to 2022, by scientific field. In other words, all papers from a period of 11 years that fall within a certain scientific field, for example computer science, are shown. The fields are classified according to the All Science Journal Classification Codes (ASJC) scheme. It is evident that the highest number of publications is from the fields of computer science and engineering, while materials science followed by medicine rank third and fourth in terms of prevalence. Artificial intelligence, and especially image recognition and analysis algorithms, plays an increasing role in diagnostics and analysis of images obtained through standard diagnostic procedures, e.g. using an NMR (Nuclear Magnetic Resonance) device. Since AI has seen great expansion into all areas of scientific and research activity, it is expected that the number of publications from other fields, e.g. physics and astronomy, neuroscience, etc., will also increase.

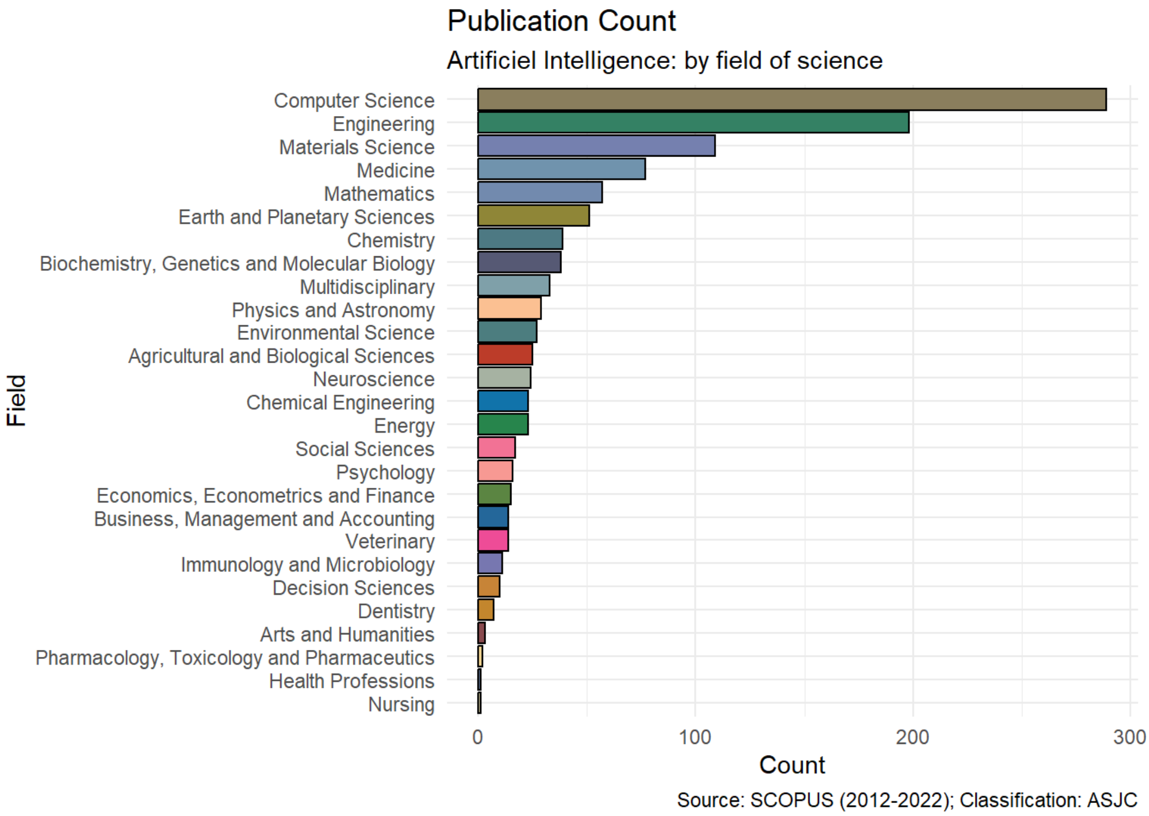

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Figure 3 — Number of publications on artificial intelligence from 2012 to 2022, by scientific field.

Figure 4 shows the number of publications on artificial intelligence between 2012 and 2022 for different institutions. In this way, one can see which public scientific institutions or companies are most active in this field, i.e. where the critical mass of researchers dealing with topics related to artificial intelligence can be found. The Faculty of Electrical Engineering and Computing from Zagreb takes first place. The University of Osijek holds second place. The number of publications is not standardised to the number of scientists employed at the institutions, i.e. the number of papers is not divided by the number of employees. Furthermore, scientists do not state the addresses of their institutions in their scientific papers unambiguously, which creates a certain problem in the retrieval and interpretation of data. The number of publications shown in this figure does not provide information on the quality of the research; however, based on Figure 4, it can be concluded that the concentration of the scientists working in artificial intelligence is approximately equally distributed across our large science centres of Zagreb, Rijeka and Split, with a minor prevalence of Osijek.

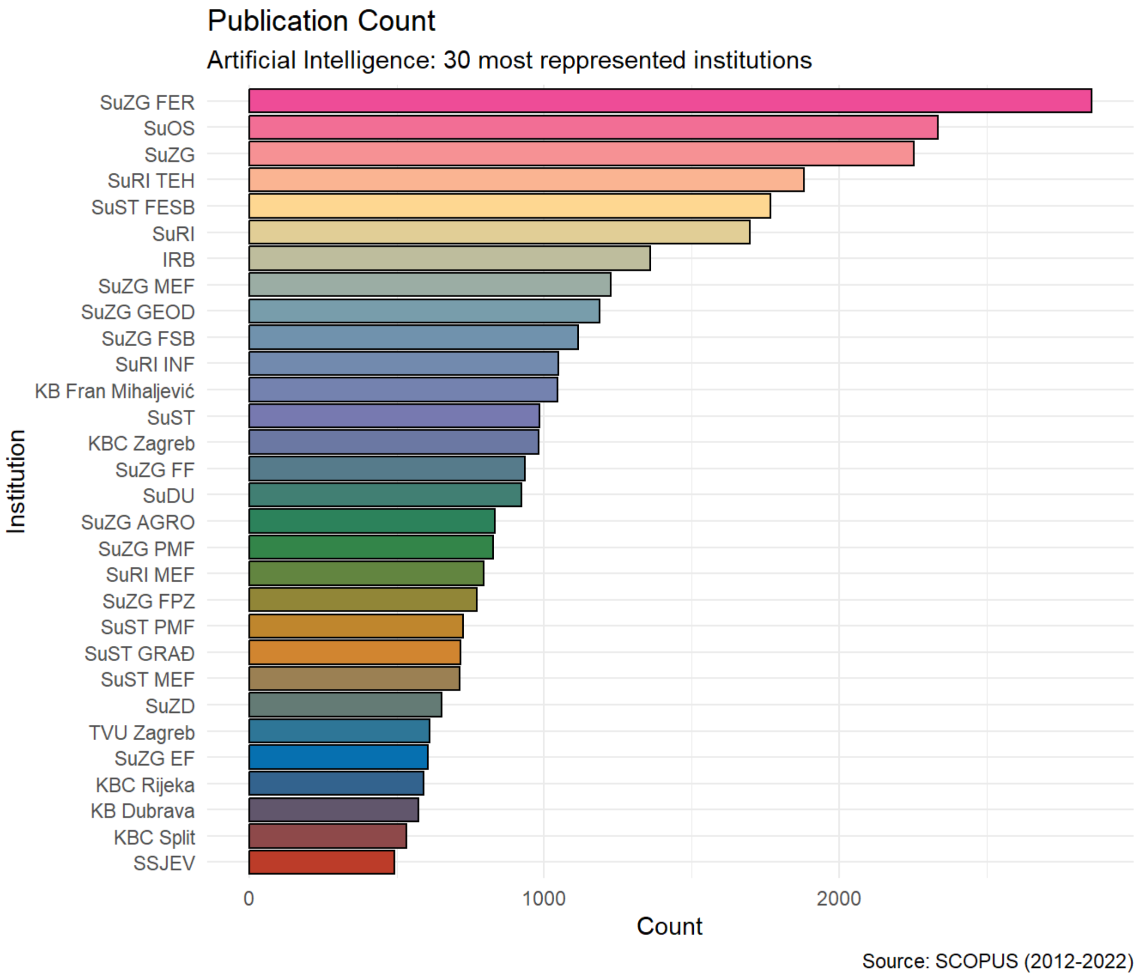


Figure 4 — Number of publications on artificial intelligence from 2012 to 2022 for the 30 institutions with the highest number of publications found in the database.

In order to understand, from the secondary data, which methods of artificial intelligence are studied by Croatian scientists, i.e. to assess their level of knowledge of this field, Figure 5 and Figure 6 are of notable importance. Figure 5 shows the prevalence of the keywords in the publications, and Figure 6 the evolution in the frequency of the keywords in the publications over the years. The keywords *neural networks, image processing* and *machine learning* are primarily prevalent. About 300 publications mention *deep learning.* There is an apparent increase in the use of deep learning and machine learning techniques, which means that Croatian scientists are keeping up with the global development of artificial intelligence and the global trends.

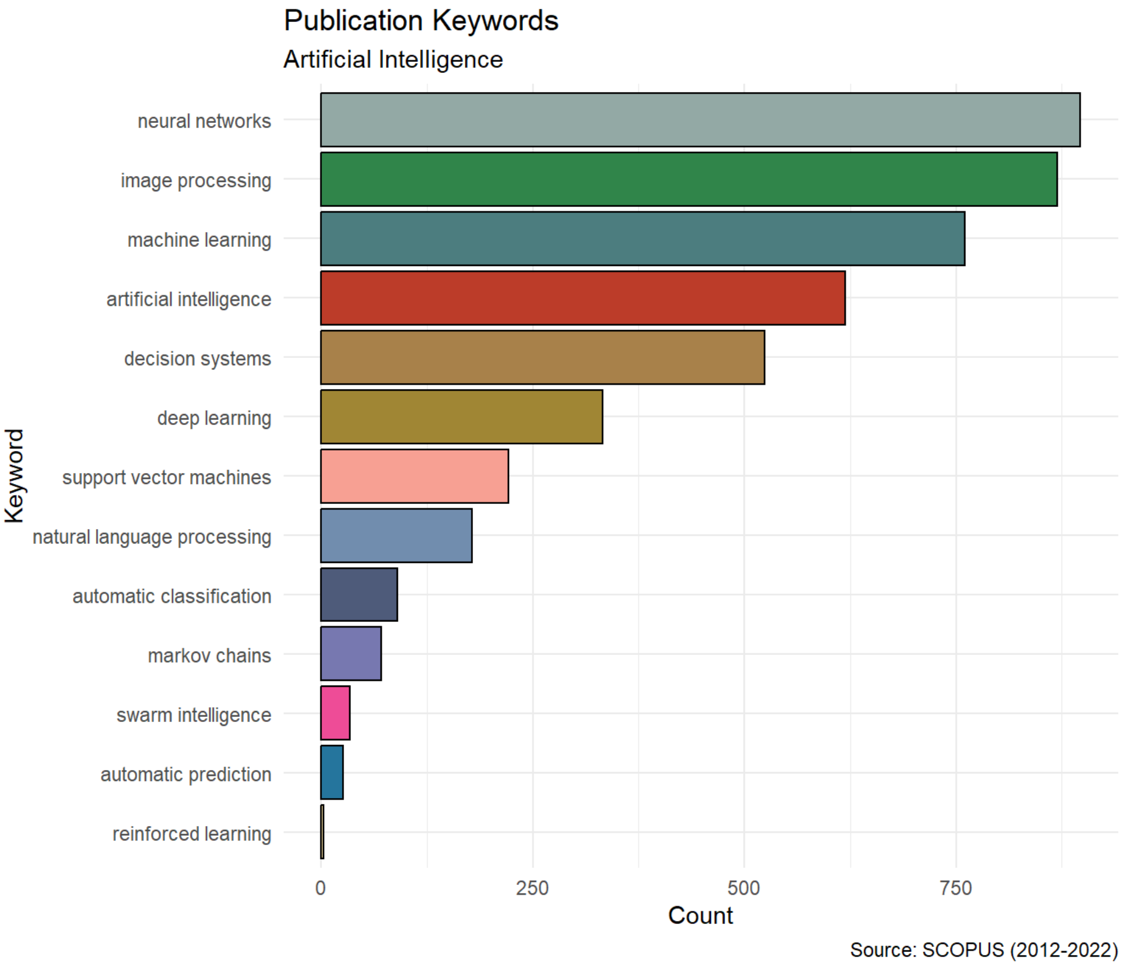


Figure 5 — The frequency of keywords in publications. The number of publications containing a specific keyword is shown; e.g. neural networks are mentioned in approximately 900 papers.

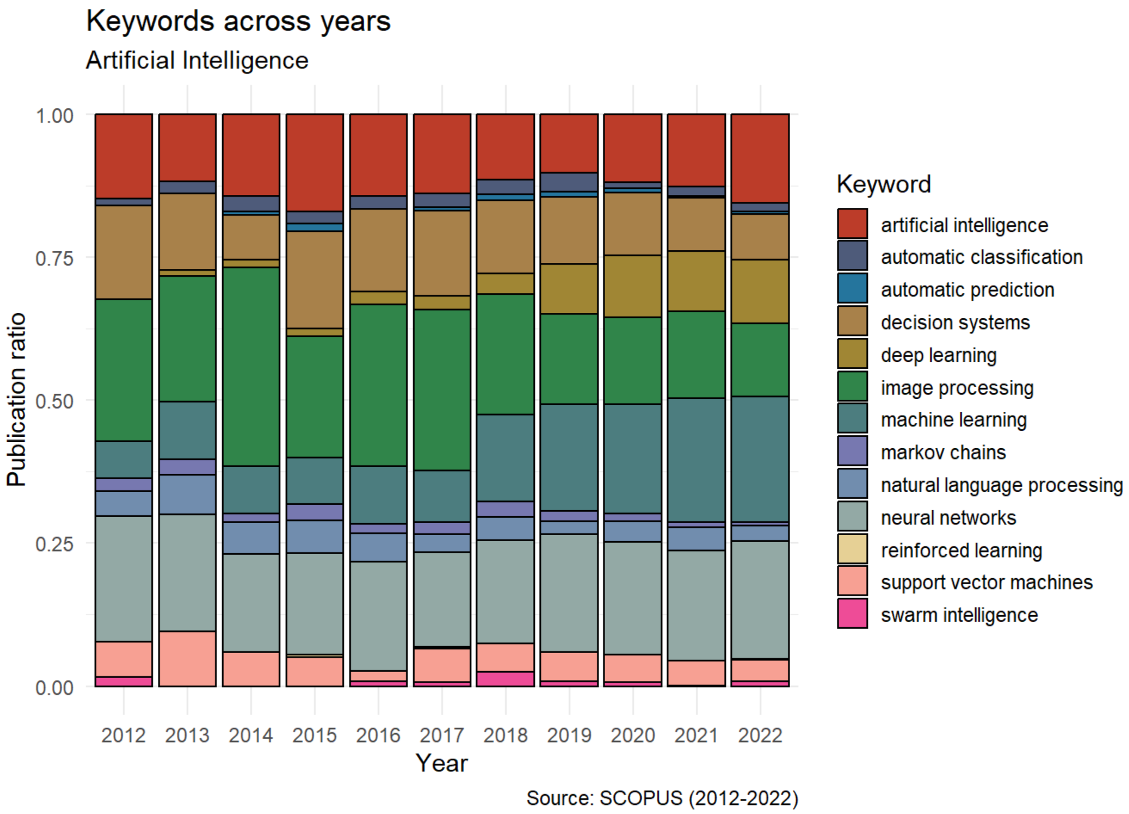


Figure 6 — The frequency of keywords for the period from 2012 to 2022.

The number of publications and the number of authors provide information about the prevalence of artificial intelligence in published research where the researchers have a Croatian address. However, the number of publications does not indicate directly what influence Croatian authors and their publications have on the development of this scientific field globally. This information is provided by citation data. Citation data tells us how papers by Croatian authors are received internationally, i.e. how many other authors rely on the work of our scientists and entrepreneurs. If a paper has a very low number of citations, it does not have a major impact on the development of a scientific field. Figure 7 shows the citation data for publications from 2012 to 2022, adequately standardised to the age of the publication, while Figure 8 shows the average citation rate classified according to the keywords and standardised to the age of the publication. Since publications published at an earlier date can accrue more quotations than those published at a later date, standardisation to the age of the publication is carried out by dividing the total number of citations by the number of years gone by from the date of publishing until today (the age of the publication). The average citation rate of the papers is relatively low, which to some extent indicates that there is room for improvement in the quality of research.

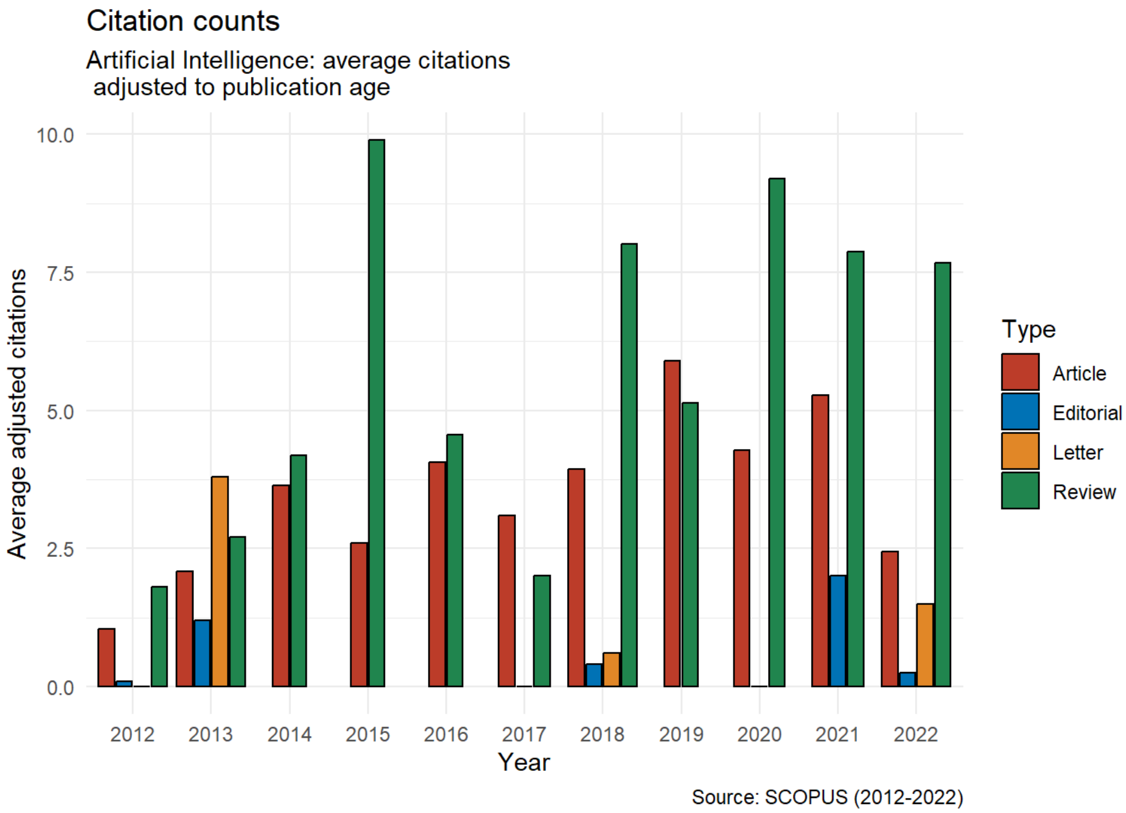


Figure 7 — Citation data for publications from 2012 to 2022, standardised to the age of the publication.

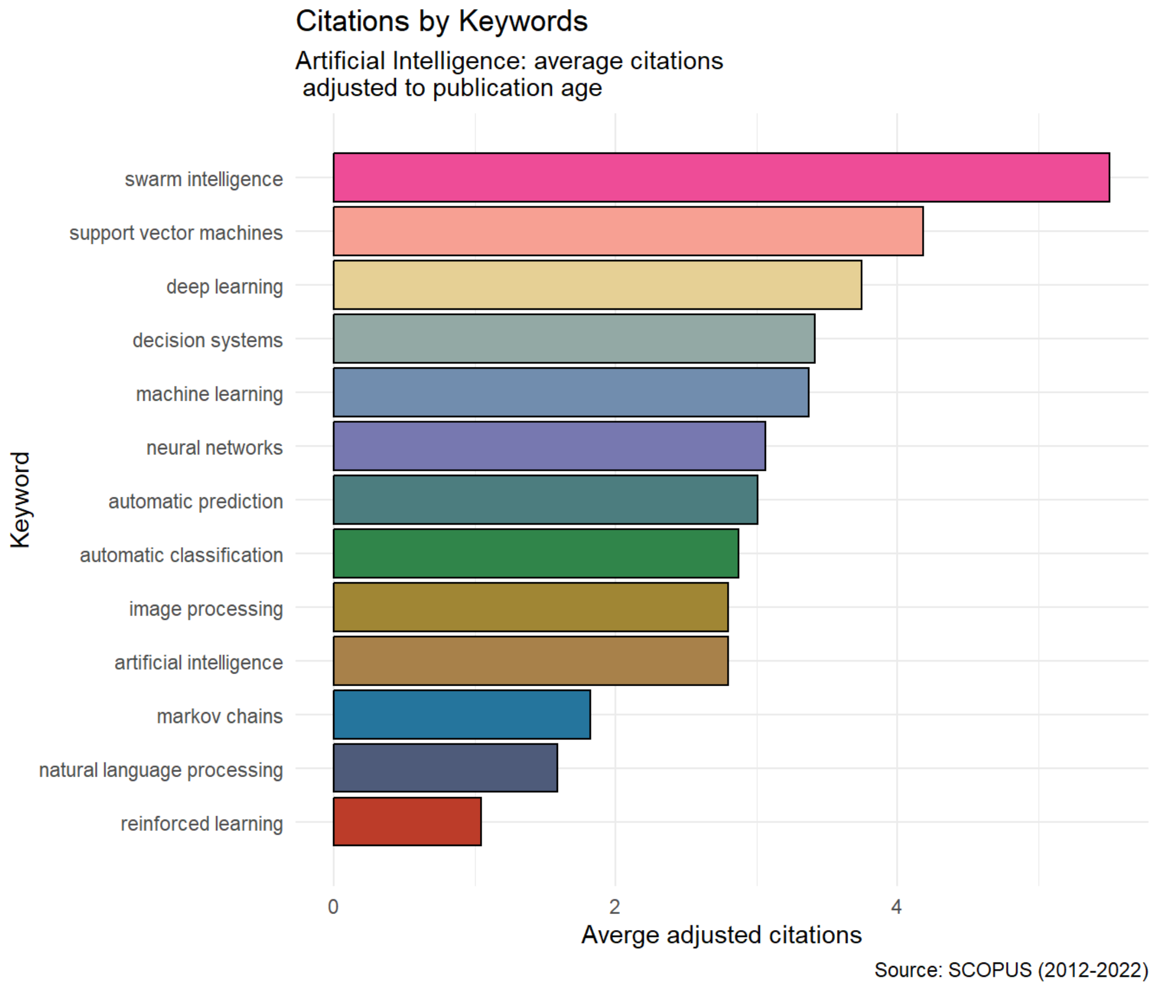


Figure 8 — Citation average classified by keywords, standardised to the age of the publication.

In conclusion, in order to map the potential of Croatian public scientific institutions and private companies in the field of artificial intelligence, Figure 9, which shows the number of scientists working in this field by institution, is particularly important. In it, the number of scientists indicates the number of persons who have at least once published at least one paper that contains at least one keyword with the affiliation of a given institution. In addition to permanent placement employees, this also includes students, doctoral students, postdoctoral students, external associates, etc., i.e. authors who are currently no longer working at a given institution.

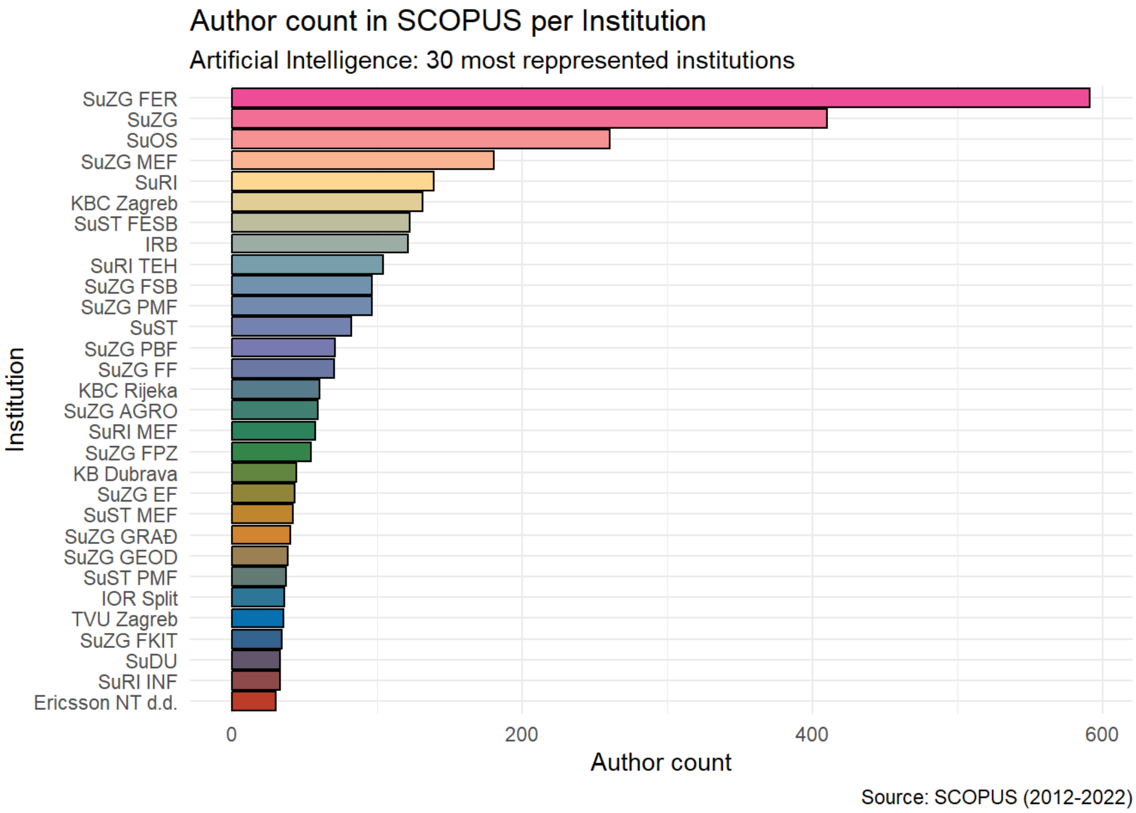


Figure 9 — Number of authors, by institution, who published papers in the SCOPUS database in the period between 2012 and 2022 containing at least one of the keywords.

The leading institutions were the University of Zagreb, within which the most represented institution was FER with more than 500 scientists, followed by the University of Zagreb (papers with no specific faculty stated; see above) and by Josip Juraj Strossmayer University of Osijek with 250 scientists. A total of 4,137 names were filtered from the secondary data. This number needs to be interpreted as the upper limit because it includes each and every author who published, within the eleven-year period, at least one article with at least one keyword within the title, summary or list of keywords. Furthermore, for the correct interpretation of these figures, it is necessary to take into account that this is cumulative data for a period of 11 years (and so includes scientists who have retired as well as graduates and doctoral students who have completed their theses and work at other institutions or companies).

In order to more precisely estimate the exact number of scientists in this field, and by **taking into account only those authors with papers containing at least two keywords, a figure of 1,966 active authors in the field of artificial intelligence for the period of 11 years is obtained.** Taking into account that the average working life is about 40 years and assuming a uniform distribution of scientists and entrepreneurs by generation, it can be estimated that, in the 11 years, about 25% of these researchers have retired, so around 0.75 × 1,966 = 1,474 authors are currently active. The exact number of authors (the lower and upper limits) was estimated and is commented on in the conclusion to this document, taking into account the primary data. Alongside the estimation of the upper limit, the administrations of the public institutions identified the scientists currently employed in the field of artificial intelligence, and the lower limit of the number of scientists was thus derived after the survey questionnaires were processed.

2.3 Overview of Participation of Croatian Scientists in Selected Programmes Related to Artificial Intelligence

2.3.1 Horizon 2020

Horizon 2020 (H2020) is the European Union's research and innovation programme for the period from 2014 until 2020. The programme was conceived as an instrument to strengthen the competitiveness of the EU through support for research, development and innovation. The aim of the programme is to provide funding to support excellence in research, strengthen European industry and address societal challenges. Horizon 2020 had a budget of almost EUR 80 billion. The programme is divided into three main priority areas: (i) excellent science, (ii) competitiveness of European industries and (iii) societal challenges. Climate change, health and well-being, energy, transport, food security, digital technologies (including artificial intelligence) and space technologies are some of the areas highlighted under the programme. The current Horizon Europe programme succeeded Horizon 2020.

This section analyses the submitted and contracted Horizon 2020 projects in the Republic of Croatia. The secondary data available for this study contained all the submitted projects, their titles and summaries as well as their associated institutions. Furthermore, the data contains information on the status of the institution (coordinator or partner) and the status of the project application (rejected or accepted for funding and contracted). Using the keywords, all the project applications related to artificial intelligence under this programme were identified. If the keyword was in the title, keyword list or summary of the project or project application, then it was concluded that the project belonged to the field of artificial intelligence. Figure 9 shows the number of all the applications classified by institution, and the contracted projects are marked in blue.

A total of **406 applications related to artificial intelligence** were identified, and **42 projects were contracted**; the success rate of the applications was slightly higher than 10%, which is close to the national average for Horizon 2020. On the 42 contracted projects, **27 beneficiaries were from public institutions (public higher education institutions, public institutes, ministries, etc.), i.e. around 50%, while the beneficiaries of 24 of the contracted projects were entrepreneurs from Croatia**. In total, more than one Croatian partner participated in seven of the contracted projects, and two of those projects had three participating partners. Out of the 42 contracted projects, **Croatian public institutions were the coordinators,** or the main beneficiaries, **on three of them**. The coordinators were the Faculty of Electrical Engineering and Computing and the Faculty of Transport and Traffic Sciences, both from the University of Zagreb, and the Croatian Agency for SMEs, Innovation and Investments.

The first four spots in terms of the number of applications were occupied by the Faculty of Electrical Engineering and Computing (SuZG FER), the Faculty of Civil Engineering (SuZG GRAĐ) and the School of Medicine (SuZG MEF) of the University of Zagreb (SuZG), as well as the Ruđer Bošković Institute (IRB) from Zagreb (Figure 10). SuZG FER had 36 project applications, SuZG GRAĐ and SuZG MEF each had 16 applications, and IRB had 15 applications. Since this programme lasted for seven years, it is evident that the number of applications related to artificial intelligence by the leading public scientific organisations from the Republic of Croatia to this programme was around two to five applications per year.

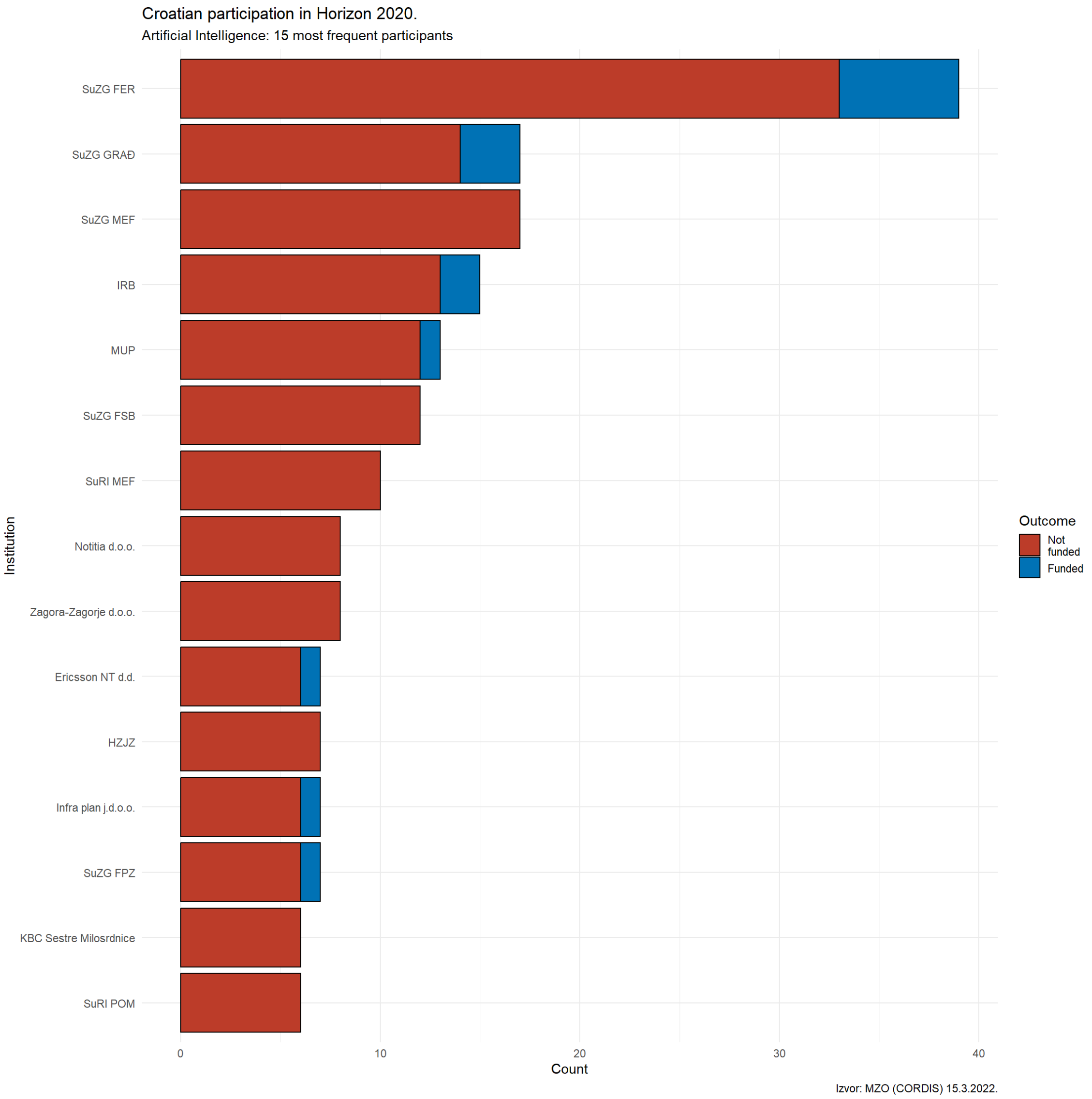


Figure 10 — Number of applications for Horizon 2020 classified by institution. Successful project applications are marked in blue and the unsuccessful ones are marked in dark red.

Figure 11 shows the number of Horizon 2020 applications divided by specific objective. Most applications related to artificial intelligence fall under the specific objective *health*, followed by the specific objectives *competitive industries (ICT)*, *climate and the environment*, *secure societies* and *food security*.

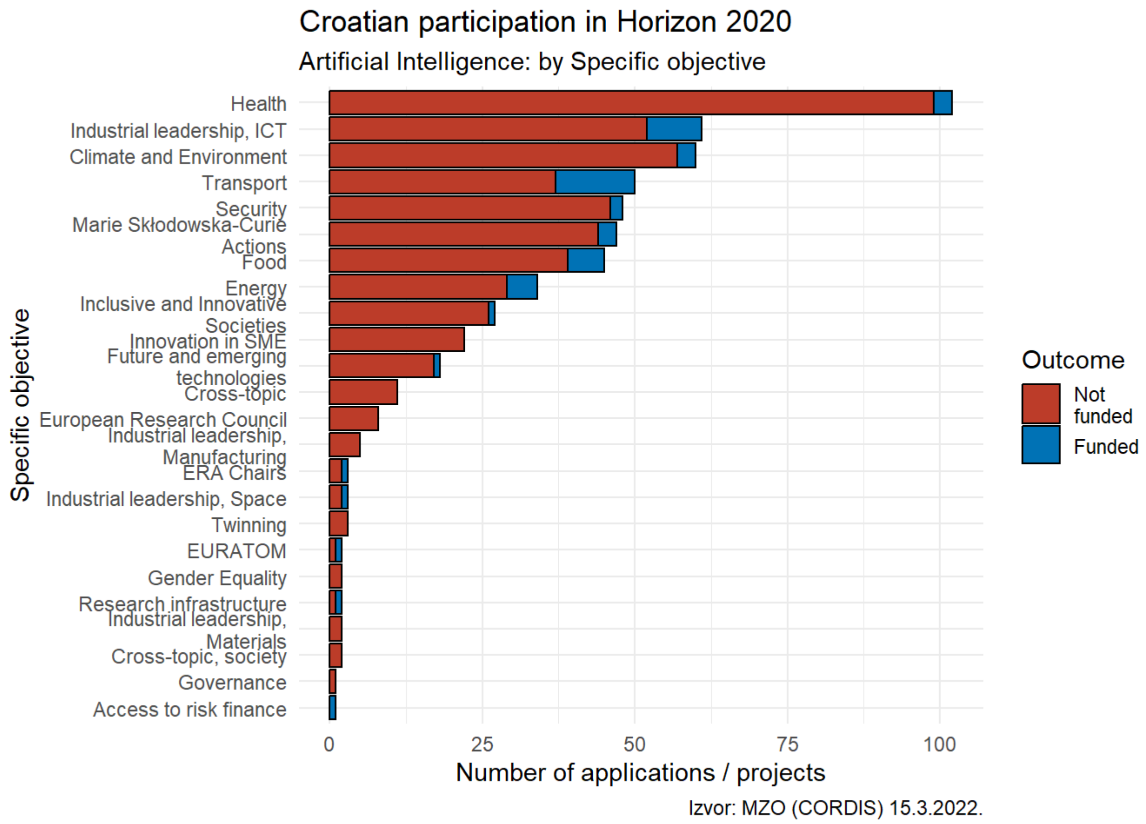


Figure 11 — Number of Horizon 2020 project applications classified by specific objective. Successful applications are marked in blue and the unsuccessful ones are marked in dark red.

2.3.2 The Seventh Framework Programme and Horizon Europe

The Seventh Framework Programme (FP7, i.e. the Seventh Framework Programme for Research and Technological Development) of the European Union was implemented from 2007 to 2013 with a budget of EUR 50.5 billion, while Horizon Europe is the EU research and innovation programme to be implemented from 2021 to 2027, with a budget of EUR 95.5 billion. The secondary data available for these two programmes did not include unsuccessful project applications but only the successful (contracted) ones. More specifically, the titles and summaries of the contracted project applications, the associated partner institutions and information on the status of an institution under the project (coordinator or partner) were available.

Since the number of contracted projects proposed by Croatian scientists relative to the total number of contracted projects within the mentioned EU programmes is relatively small, and since the secondary data collected for the FP7 and Horizon Europe programmes has the same structure, they are presented here in parallel. This display also provides a visual comparison of the applications over more than six years, which was the duration of Horizon 2020.

The aim of the FP7 programme, i.e. the 7th Framework Programme for Research and Technological Development, was to foster scientific research and development projects in Europe. Its aim was to boost research and innovation in several key areas, including information and communication technologies, health, the environment, energy and transport. FP7 was the largest R&D programme in Europe, with a budget of EUR 50.5 billion. In total, more than 7,000 projects were funded.

Under the **FP7 programme, a total of ten projects that can be classified under artificial intelligence were contracted**. On all of the projects, Croatian institutions were only partners.

FP7 was later replaced by Horizon 2020 and then Horizon Europe.

With regard to the thematic area considered here, Horizon Europe funds research in the field of artificial intelligence under the key objectives of the following programmes: Health, Civil Security for Society and Digital, Industry and Space, found under Pillar 2 of the programme. Artificial intelligence research can also possibly be funded under Pillar 1, under Excellent Science through research projects and under Pillar 3, under Innovative Europe through innovation activities. Different aspects of AI are funded, including the development of ethical and social aspects of AI.

As Horizon Europe is still current, the data refers to the period until April 2023. Under the Horizon Europe programme, a total of 18 projects that can be classified under artificial intelligence were contracted. On **two of the projects, Croatian institutions were the coordinators**, while they held partner roles on the rest of the projects. The coordinators were the Faculty of Electrical Engineering and Computing of the University of Zagreb and Agrivi d. o. o. Since Horizon Europe has so far only gone on for two years, with assuming the same rate of contracting and implementing projects, it can be predicted that Croatian institutions and companies will contract a total of about 60 projects, but given the growth and development of artificial intelligence, this number will probably be slightly higher. This is a very significant increase compared to the FP7 programme, where ten projects were contracted.

Figure 12 shows the number of all the contracted projects by organisation, with the contracted FP7 projects marked in dark red and Horizon Europe projects marked in blue. This figure shows the organisations that were the most active in attracting project funding during the duration of the FP7 programme and that have so far demonstrated activity in the currently active Horizon Europe programme.

Under the FP7 programme, the private company Inetec d. o. o. stands out with two contracted projects. It is also interesting that most of the projects were carried out in private companies, specifically in 11 companies, as opposed to four public institutions and one public administration body (City of Rijeka). It is important to note that some projects involved more than one participating partner from Croatia (with three Croatian partners at most).

Under Horizon Europe, the number of participants from the public and private sectors was somewhat equalised (out of 19 partners, 12 were from the public sector), meaning that, during Horizon 2020, the scientific community from public institutions stepped up their project activity under European programmes. Of the public institutions, the Faculty of Maritime Studies, University of Rijeka, the Faculty of Agriculture, University of Zagreb and the Faculty of Electrical Engineering and Computing, University of Zagreb are the ones that stand out. The last faculty from that list is the coordinator of the prestigious project *Twinning Action for Spreading Excellence in Artificial Intelligence of Things*, which lends great international visibility to the institution at which it is implemented as well as to the project leader and associates.

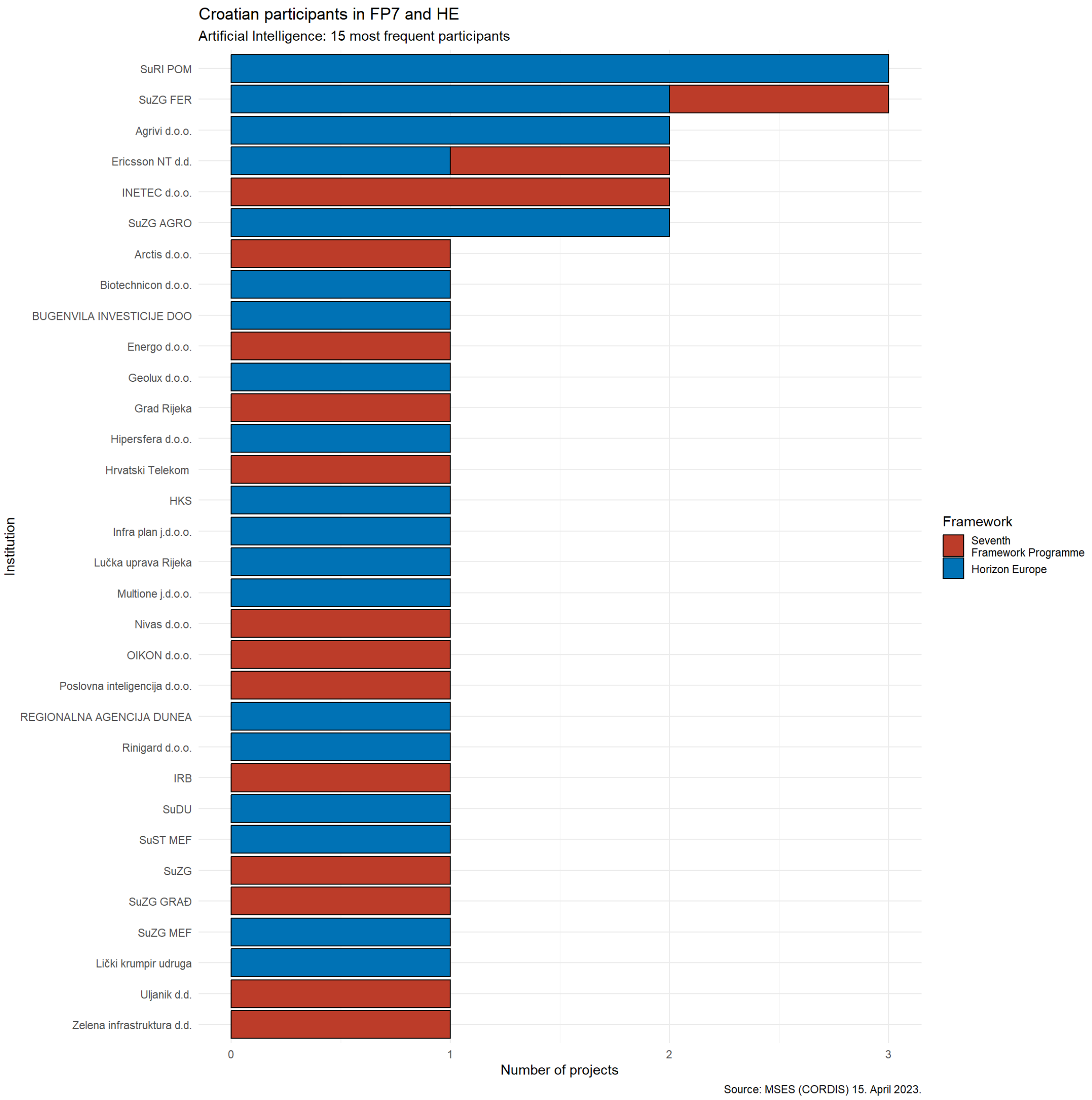


Figure 12 — Number of FP7 and Horizon Europe projects classified by institution. Horizon Europe projects are marked in blue and FP7 projects are marked in dark red.

Figure 13 shows the number of projects classified by specific objective. The contracted FP7 projects are marked in dark red and Horizon Europe projects are marked in blue. This chart provides information on which research topics are most common in this field. Under FP7, the most active objectives were Information and Communication Technologies (ICT) and Small and Medium-Sized Enterprises (SMEs), while Food, Bioeconomy, Natural Resources, Agriculture and the Environment was so far the most active objective under Horizon Europe.

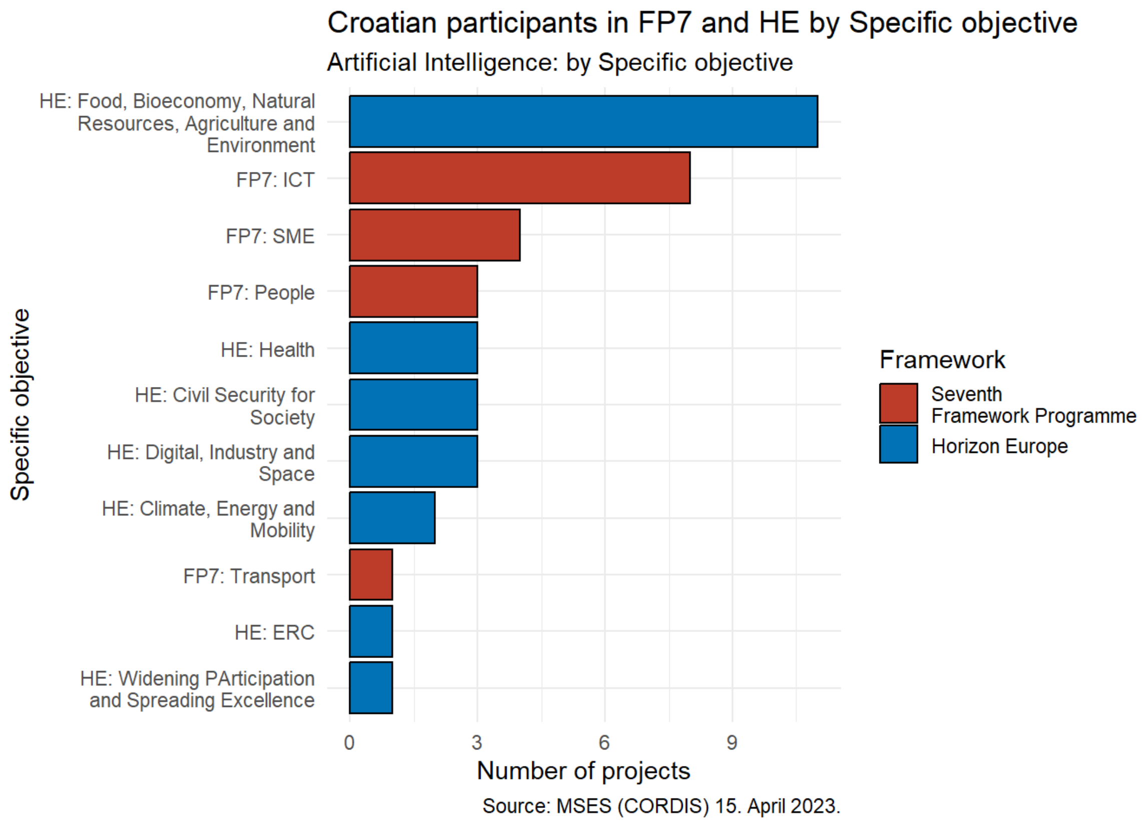


Figure 13 — Number of FP7 and Horizon Europe applications classified by specific objective. Horizon Europe projects are marked in blue and FP7 projects are marked in dark red.

2.3.3 Croatian Science Foundation (CSF)

The Croatian Science Foundation (CSF) is the central organisation for funding science in all scientific fields in the Republic of Croatia. The Croatian Science Foundation is an independent non-profit organisation that provides financial support for the implementation of scientific projects according to the criteria of scientific excellence. The Foundation was founded to promote science, higher education and technological development in the Republic of Croatia and to support scientific, higher education and technology programmes and projects, with the ultimate goal of ensuring sustainable social and economic development while encouraging employment based on the principles of social inclusion.

Since its founding, the Foundation has funded competitive scientific, development and innovation projects. Legal amendments from 2009 and 2012 (NN 78/2012) started a new chapter in the work of the Foundation because, in 2013, it took over the funding of national research projects from the Ministry of Science and Education, and in 2014, also the funding of career advancement for young researchers.

An important programme implemented by the CSF is the Research Projects programme (RP). This programme funds fundamental research that creates new and enhances existing knowledge in a specific field, but also applied research with clear technological, economic or societal objectives. The projects under this programme have so far always been contracted for a period of four years. Between 2013 and today, six calls for tenders have been published, funding more than 700 projects.

The CSF also implements the Establishing Research Projects programme (ERP) aimed at young scientists for the establishment of new research groups. The term *young scientist* means a researcher who has obtained a doctorate in science at least two years but not more than seven years prior to the deadline for applying to a call, and who wishes to set up or develop a new research group and become an independent researcher.

The research projects implemented the Programme for Stimulating Research and Development Activities in the Field of Climate Change and two thematic calls for tenders regarding the coronavirus pandemic.

The Career Advancement for Young Researchers programme aims to create a stable funding programme for young researchers at the doctoral and postdoctoral levels in all scientific fields. Under the Training of New Doctors of Science programme, six calls for tenders have been published between 2013 and today (in the figures, these projects are labelled simply as Doctoral Students) which gave more than 900 scientists the opportunity to recruit young researchers.

Under the International Cooperation programme, the goal of the CSF is to enable scientists to engage in mobility and international cooperation, and not necessarily just scientific cooperation, but also the development of the economic sector outside the borders of the Republic of Croatia.

For this mapping, the data available were the titles of the contracted projects, the summaries of the contracted projects, the researchers and the institutions from which these projects came from as well as which of the CSF programmes the projects belonged to. In the first round of the analysis of the secondary data, using the keywords defined above, the projects belonging to the field of artificial intelligence were filtered out. Subsequently, the results obtained were manually reviewed to see if the keywords signalled some projects outside the field. These projects unrelated to artificial intelligence were excluded from the analysis. Based on the charts obtained, the aim was, among other things, to get an insight into how active the scientists working in artificial intelligence at the national level of financing were, as well as the key institutions where there was activity in this field.

Figure 14 shows the number of projects in the field of artificial intelligence over the years (from 2013 to 2022 in line with the programme). Research projects and projects aimed at doctoral students were prevalent. Research projects were more prevalent between 2014 and 2020, followed by projects aimed at doctoral students in the period from 2018 until today. The reason for this is partly the pattern of publishing the calls for tenders by the CSF, since the projects for doctoral students chronologically followed the research projects. In 2022, a lower number of calls for tenders were published, so a lower number of projects were contracted in total.

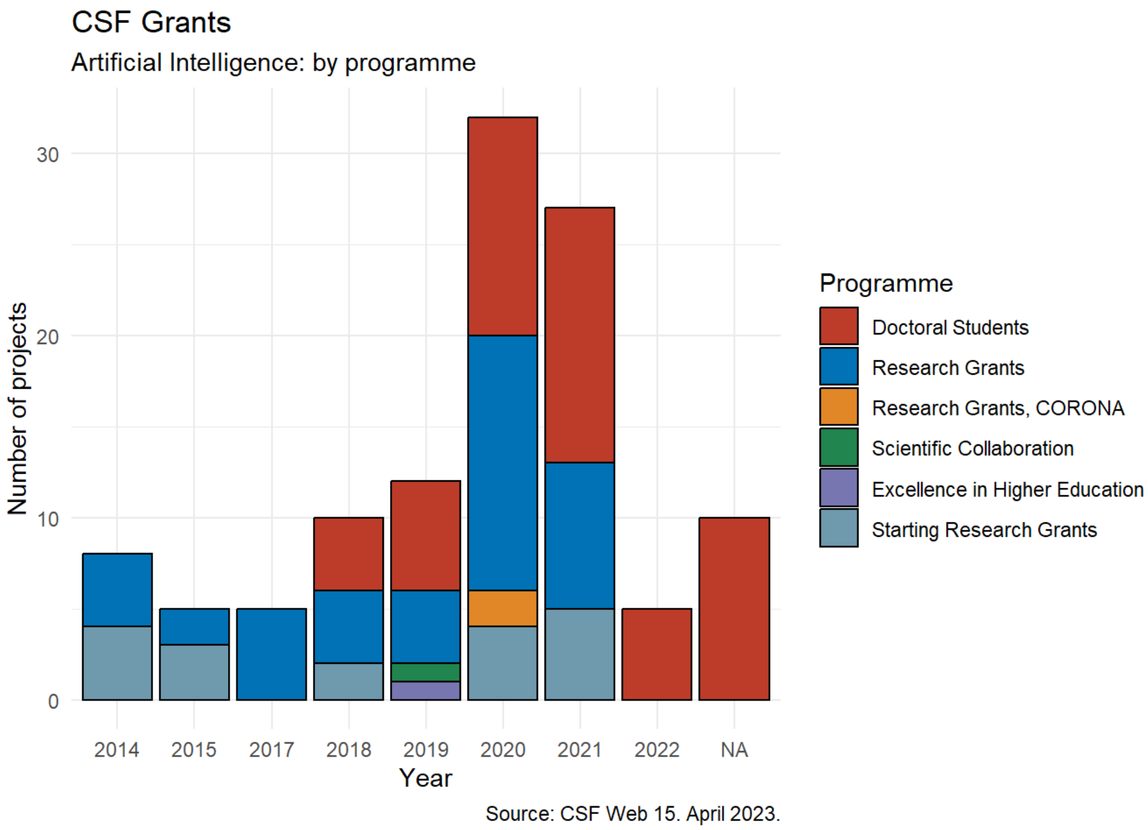


Figure 14 — Number of projects in the field of artificial intelligence under different CSF programmes over the years. Each project is listed only once in the year in which it was contracted. In the years not seen on the chart, there were no contracted projects related to artificial intelligence. NA refers to those contracted CSF projects for which the available data did not indicate the starting date of the contract.

Figure 15 shows the distribution of projects in the field of artificial intelligence by scientific field. The highest number of projects was in computer science, followed by electrical engineering and then information and communication sciences.

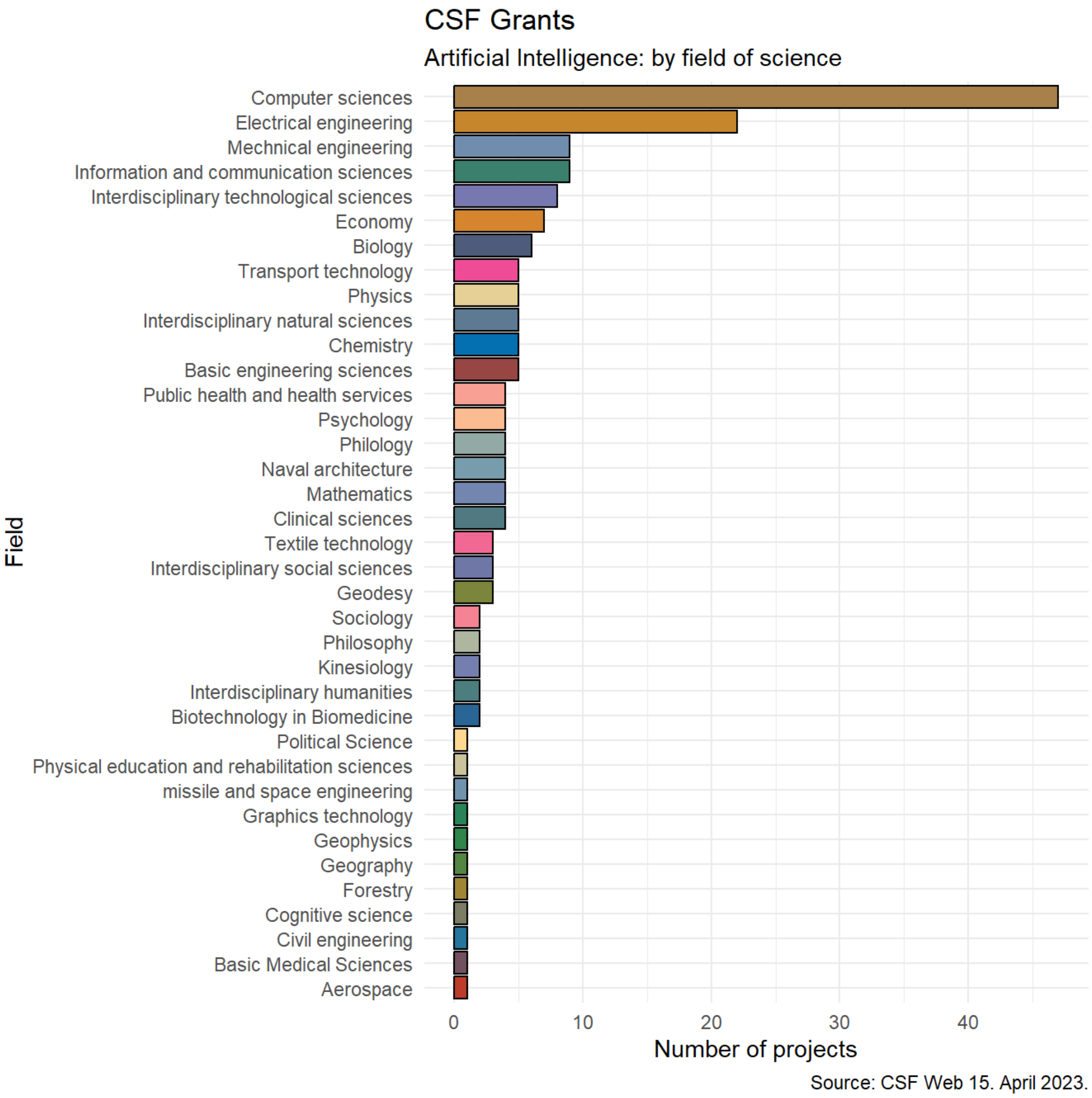


Figure 15 — Number of projects in the field of artificial intelligence divided by scientific field. The chart relates to all CSF projects in the field of artificial intelligence from 2013 to 2022. Some of the projects fall under two scientific fields and are listed under both.

Figure 16 shows the distribution of projects in the field of artificial intelligence by broader scientific field. The most prevalent were technical sciences, followed by social sciences and then natural sciences. Figure 17 shows the distribution of projects by scientific field over the years.

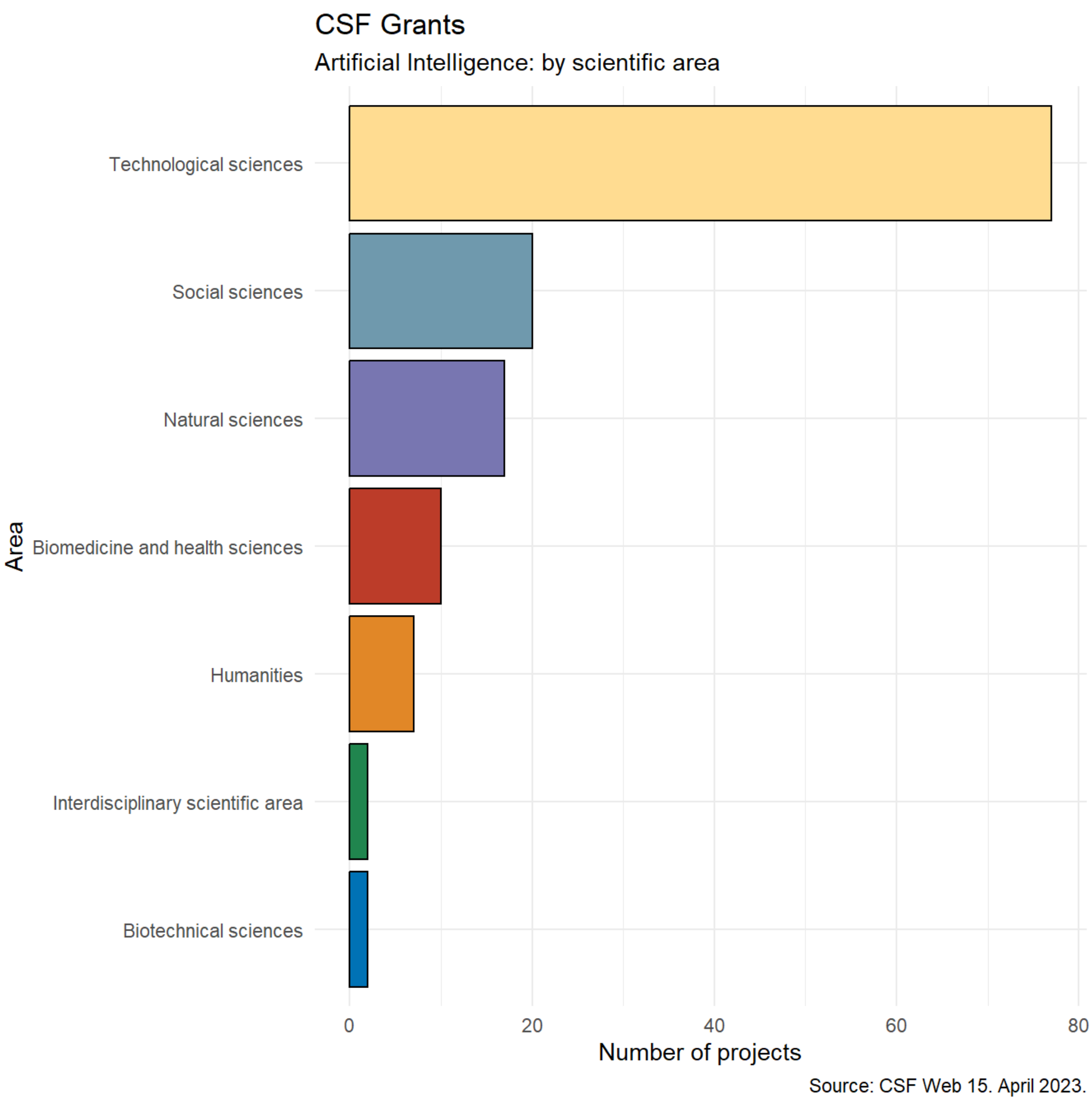


Figure 16 — Distribution of projects in the field of artificial intelligence by scientific field. The chart relates to all CSF projects in the field of artificial intelligence from 2013 to 2022.

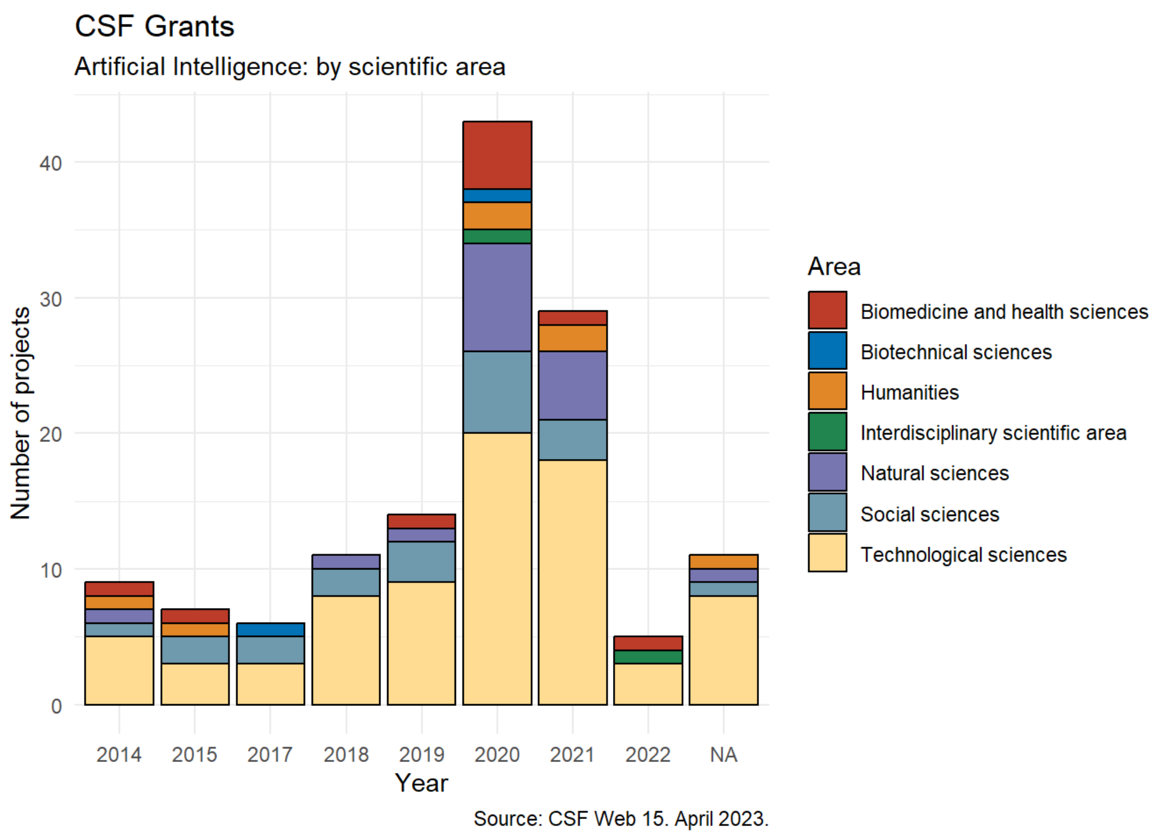


Figure 17 — Distribution of projects in the field of artificial intelligence by scientific field over the years. Each project is listed only once in the year in which it was contracted. In the years not seen on the chart, there were no contracted projects related to artificial intelligence. NA refers to those contracted CSF projects for which the available data did not indicate the starting date of the contract.

Finally, a very significant chart shows the distribution of CSF projects by institution (see Figure 18). In the field of artificial intelligence, the projects were predominantly implemented at the Faculty of Electrical Engineering and Computing of the University of Zagreb, the Ruđer Bošković Institute, the Faculty of Engineering of the University of Rijeka and the Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb, respectively. Among the top ten public institutions active in the field of artificial intelligence, the same institutions are found as in other secondary data databases, indicating the consistency of the data and the quality of the analysis. It is important to note that private institutions mostly did not participate in CSF projects unlike the EU funding instruments analysed in previous chapters, so they cannot be compared.

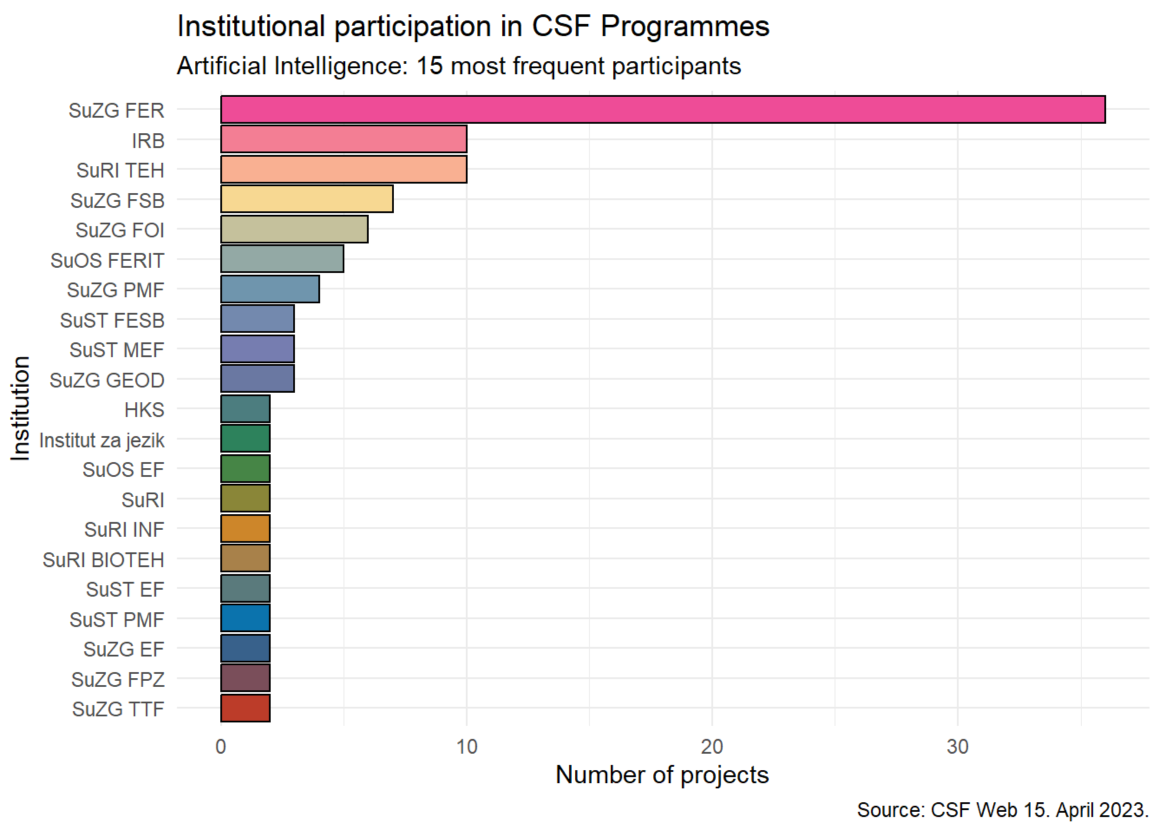


Figure 18 — Distribution of CSF projects by institution. The chart relates to all CSF projects in the field of artificial intelligence from 2013 to 2022.

2.3.4 Ministry of Economy and Sustainable Development (HAMAG-BICRO)

In this part of the mapping, calls for tenders were analysed that the Croatian Agency for SMEs, Innovation and Investments (HAMAG-BICRO) was in charge of implementing, which operates under the authority of the Ministry of Economy and Sustainable Development[3] (i).

The information on the prevalence of artificial intelligence in HAMAG-BICRO programmes can be obtained by detecting (by using the keywords) the projects concerning artificial intelligence out of the total number of projects for a given programme. Figure 19 shows the number of projects and the percentage of the total number of funded projects related to artificial intelligence for HAMAG-BICRO programmes listed in Chapter 1.3. The figure clearly shows that artificial intelligence projects were relatively significantly present (around 10% of projects on average). PoC-7 and RDI projects had the highest prevalence percentage in the programmes. The analysis of project applications, some of which were not funded, can be found below for those programmes for which data on applications was available.

[3] https://hamagbicro.hr/bespovratne-potpore/hamag-bicro-kao-korisnik-sredstava-tehnicke-pomoci/

HAMAG-BICRO programmes predominantly funded private sector legal entities. Public institutions were mainly present either as partners on some types of projects (RDI1 and RDI2) or as service providers in the innovation voucher programme.

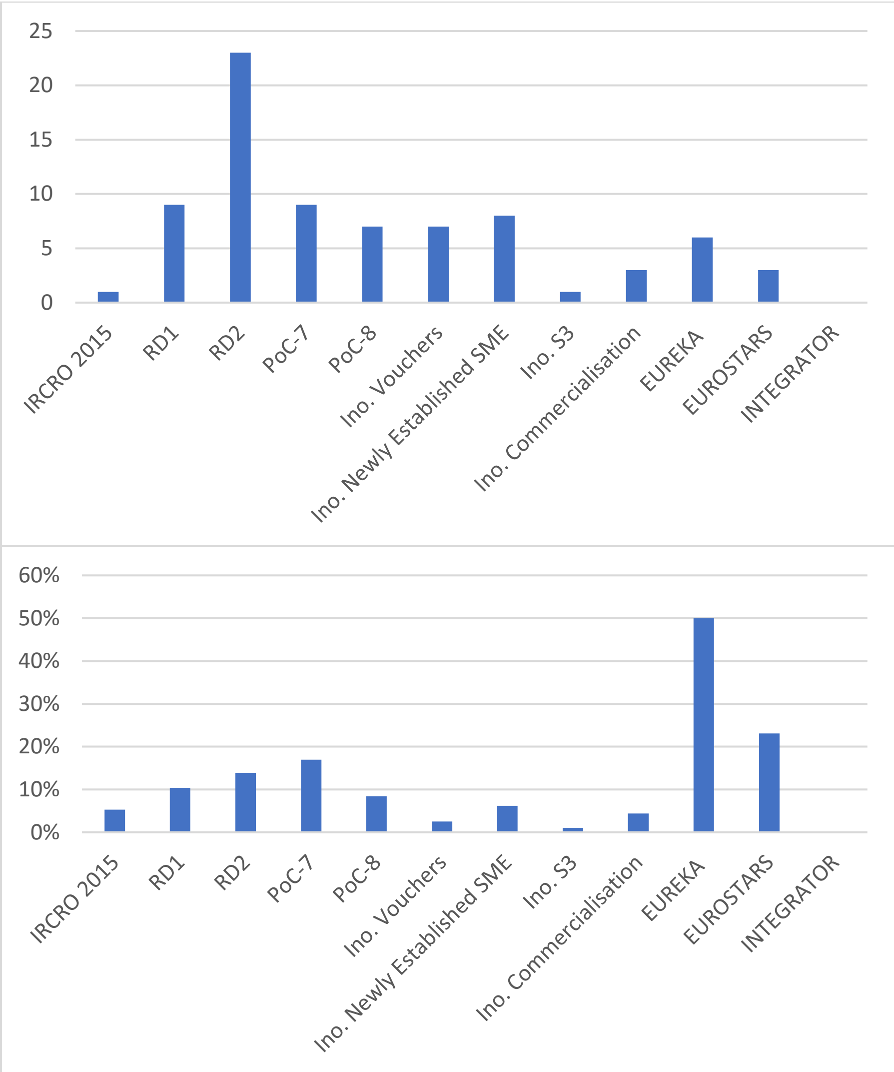


Figure 19 — Number of contracted HAMAG-BICRO projects in the field of artificial intelligence by programme (top) and percentage of contracted HAMAG-BICRO projects in the field of artificial intelligence by programme (bottom).

Below is a brief description of each programme and the number of projects related to artificial intelligence detected under any given programme.

2.3.4.1 Knowledge-Based Companies Development — the RAZUM programme in 2015

The aim of the programme was to provide initial funding for newly established companies, i.e. to provide initial funding for the development of a new product or service in existing SMEs. From 2005 to 2013, 24 projects worth HRK 117,423,760 were financed through the RAZUM programme, while the RAZUM programme from 2015 funded seven projects worth HRK 24,662,693.00.

In the call of the RAZUM programme from 2015, a total of 25 applications were received, none of which were related to the topic of artificial intelligence.

2.3.4.2 Research and Development Programme — the IRCRO programme in 2015

The Research and Development Programme (IRCRO) has been implemented since 2008 and is still current. It encourages SMEs to cooperate with research institutions in launching their own R&D activities. The objectives of the programme are:

- encouraging SMEs to increase their R&D activities;
- nurturing and strengthening the link between the economic and scientific sectors;
- making better use of existing infrastructure in research institutions;
- helping SMEs to shorten the time frame for implementing R&D projects; and
- encouraging public scientific institutions to cooperate with the economic sector.

The analysis of the 2015 IRCRO call for tenders found two project applications related to the field of artificial intelligence out of a total of 60 applications. A total of 19 projects were contracted, one of which was in the field of artificial intelligence. In total, an amount of HRK 13,226,614.58 was contracted, i.e. an average of HRK 696,137.61 per project.

2.3.4.3 Proof of Concept programme — PoC

The PoC programme has been implemented since 2010 and supports innovations at the earliest stage of research in order to provide pre-commercial capital for technical and commercial proofing of the innovative concept. Between 2010 and 2020, eight PoC calls for tenders were implemented. In total, 359 projects were financed with HRK 102 million in grants, and the total value of the projects was HRK 154 million.

For the purpose of mapping the potential of artificial intelligence, the titles and summaries of all the applications to the seventh and eighth Proof of Concept calls were analysed. The results were as follows.

Under the PoC-7 call, out of the total 135 project applications, 22 applications were in the field of artificial intelligence. A total of nine artificial intelligence projects were contracted out of a total of 53 contracted projects. Under the PoC-8 call, out of the total 154 project applications, 19 applications were in the field of artificial intelligence. A total of seven artificial intelligence projects were contracted out of a total of 83 contracted projects.

2.3.4.4 Increasing New Product Development and Services Arising from Research and Development Activities — RDI1 and RDI2

The RDI programme was launched in 2016 (RDI1 projects) and then again in 2019 (RDI2 projects). The call was open to applicants who were legal and natural persons as well as small, medium and large enterprises. The aim of the call was to increase private sector investment in R&D, to increase the number of entrepreneurs investing in R&D and to encourage the cooperation of entrepreneurs with research and knowledge dissemination organisations on R&D projects.

Under the RDI1 call, the lowest awarded project grant amounted to HRK 303,817.92, while the highest awarded grant amounted to HRK 52,226,456.66. In the second call, RDI2, the propositions of the call were such that the total amount of available grants under RDI2 was HRK 1,561,448,500.28, and the maximum permitted total grant value per project proposal was HRK 30,000,000.00.

Through an analysis of titles and summaries, out of a total of 87 contracted projects, nine artificial intelligence projects were identified under RDI1. Of these nine projects, four were related to transport (vehicles, bicycles and transport solutions) and two were related to agriculture.

Through an analysis of titles and summaries, out of a total of 166 contracted projects, 19 artificial intelligence projects were identified under RDI2.

2.3.4.5 Innovation in S3 Areas programme

The Innovation in S3 Areas programme was launched in 2019, and the eligible applicants were micro, small and medium-sized enterprises. This programme encouraged entrepreneurs to commercialise product/service innovation in accordance with the identified thematic priority areas and inter-sector topics of the Smart Specialisation Strategy (S3). Small and medium-sized enterprises (SMEs) focused on the production and marketing of innovative products/services in their business activities and thus contributing to the competitiveness of the Croatian economy were financially supported. Of the 99 contracted projects, one project was in the field of artificial intelligence.

2.3.4.6 Innovation Vouchers programme

The main objective of innovation vouchers is for research communities to transfer knowledge to micro, small and medium-sized enterprises (SMEs). By using vouchers, SMEs were able to obtain a service from the scientific community and thus transfer knowledge into their business. These were projects funded by lower amounts, specifically, the grant could not exceed HRK 75,000.00 per project proposal. Of the 279 vouchers awarded, 7 were in the field of artificial intelligence.

2.3.4.7 Innovation at Newly Established SMEs programme — Phase II

This call encouraged the development of newly established SMEs by introducing innovations, i.e. the successful launch of products and services with the potential for growth and export that are new to the market. Companies with radical innovations and significant improvements in the commercialisation of products and services had the advantage. Of the 130 projects funded, eight were in the field of artificial intelligence.

2.3.4.8 Innovation Commercialisation programme

The Ministry of Economy and Sustainable Development, under the National Recovery and Resilience Programme 2021 –2026, launched a call for project proposals related to the commercialisation of innovation that stimulates investments by micro, small and medium-sized enterprises (SMEs) aimed at producing advanced and innovative products and services of high added value. The call was published on 1 April 2022. The total amount of available funds was HRK 380,000,000.00, while the amounts of funding per project (i.e. the amount that can be awarded to any single applicant) were a minimum of HRK 760,000.00 and a maximum of HRK 5,320,000.00.

A total of 69 projects were contracted, three of which were in the field of artificial intelligence.

2.3.4.9 EUREKA

EUREKA is a programme designed to launch research and development activities aimed at encouraging small, medium and large enterprises to cooperate with international partners.

Between 2015 and today, out of a total of 36 applications, 15 were thematically related to the field of artificial intelligence. In the period between 2015 and 2020, 12 projects were contracted and as many as six included AI components.

2.3.4.10 EUROSTARS

EUROSTARS is a research and development programme created as a joint initiative of EUREKA and the European Commission. A minimum of two member states must participate in the consortium. The European Commission decided to contribute to SME development activities by participating with up to 25% of the total public co-funding under Horizon 2020 and Horizon Europe during their duration. The main partner in the consortium must be an SME engaged in R&D activities, while other project partners do not necessarily have to engage in R&D activities. There are no topic limitations, i.e. a project from any technological field may be submitted, provided that it has a social and civil purpose and includes the development of a new product, process or service.

Between 2015 and today, out of a total of 103 applications, 25 were thematically related to the field of artificial intelligence. From 2016 until today, 13 projects were contracted, three of which used artificial intelligence.

2.3.4.11 INTEGRATOR

This call encouraged the cooperation among small and medium-sized enterprises (SMEs) to establish supply relationships with integrator companies and become part of their value chain by creating new innovative products and services. The funding under this call was intended for co-financing innovation activities of a consortium of SMEs with the aim of establishing long-term supply relationships / value chains with other companies, the so-called integrators. No projects thematically related to the field of artificial intelligence were found in the Integrator programme.

2.3.5 Secondary Data from Intellectual Property Databases — Patents

The analysis of secondary data related to intellectual property was done in several steps. In the first step, a broad set of classification codes from the IPC was selected (the International Patent Classification is a hierarchical scheme for the classification of patents, see https://www.wipo.int/classifications/ipc/en/). In order to detect patents and patent applications specifically in the field of artificial intelligence, a wide set of patent class codes was selected in the first step (see Table 2 at the end of this section).

The patents search was done for a period of 20 years (from 2002 to 2022) in order to gain a better insight into the development of technology where the applicants were legal and natural persons from the Republic of Croatia, and the source of the data was the Espacenet online database, which includes data from a large number of sources (the State Intellectual Property Office, available data on domestic applicants' applications in the EPO and WIPO and all other available national databases). After the list of patents and patent applications with their titles and application summaries was obtained, they were analysed individually and the patents belonging to artificial intelligence were marked.

During the stated period, 60 patent applications in the field of artificial intelligence were found. Six patents mentioned neural networks as one of the methods of artificial intelligence. The syntagm *machine learning* was mentioned three times, and the syntagm *support vector* in one patent. In conclusion, the number of patents in the field of artificial intelligence from the Republic of Croatia is not negligible, although there is a possibility of significant growth if we compare the number of scientists who are active in the field and the great possibilities of applying artificial intelligence.

Table 2 — Selected patent classes relevant to the field of artificial intelligence according to the IPC classification.

A61B	*DIAGNOSIS; SURGERY; IDENTIFICATION*
B60W	*CONJOINT CONTROL OF VEHICLE SUB-UNITS OF DIFFERENT TYPE OR DIFFERENT FUNCTION; CONTROL SYSTEMS SPECIALLY ADAPTED FOR HYBRID VEHICLES; ROAD VEHICLE DRIVE CONTROL SYSTEMS FOR PURPOSES NOT RELATED TO THE CONTROL OF A PARTICULAR SUB-UNIT*
G01N	*INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES*
G01R	*MEASURING ELECTRIC VARIABLES; MEASURING MAGNETIC VARIABLES*
G01S	*RADIO DIRECTION-FINDING; RADIO NAVIGATION; DETERMINING DISTANCE OR VELOCITY BY USE OF RADIO WAVES; LOCATING OR PRESENCE-DETECTING BY USE OF THE REFLECTION OR RERADIATION OF RADIO WAVES; ANALOGOUS ARRANGEMENTS USING OTHER WAVES*
G05D	*SYSTEMS FOR CONTROLLING OR REGULATING NON-ELECTRIC VARIABLES*
G06N	*COMPUTING ARRANGEMENTS BASED ON SPECIFIC COMPUTATIONAL MODELS*
G06F	*ELECTRIC DIGITAL DATA PROCESSING*
G06T	*IMAGE DATA PROCESSING OR GENERATION, IN GENERAL*
G06V	*IMAGE OR VIDEO RECOGNITION OR UNDERSTANDING*
G16C	*COMPUTATIONAL CHEMISTRY; CHEMOINFORMATICS; COMPUTATIONAL MATERIALS SCIENCE*
G16B	*BIOINFORMATICS, i.e. INFORMATION AND COMMUNICATION TECHNOLOGY [ICT] SPECIALLY ADAPTED FOR GENETIC OR*

	PROTEIN-RELATED DATA PROCESSING IN COMPUTATIONAL MOLECULAR BIOLOGY
G06K	*GRAPHICAL DATA READING*
G06Q	*INFORMATION AND COMMUNICATION TECHNOLOGY [ICT] SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL OR SUPERVISORY PURPOSES; SYSTEMS OR METHODS SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL OR SUPERVISORY PURPOSES, NOT OTHERWISE PROVIDED FOR*
G10L	*SPEECH ANALYSIS OR SYNTHESIS; SPEECH RECOGNITION; SPEECH OR VOICE PROCESSING; SPEECH OR AUDIO CODING OR DECODING*
H01M	*PROCESSES OR MEANS, e.g. BATTERIES, FOR THE DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY*
H04L	*TRANSMISSION OF DIGITAL INFORMATION, e.g. TELEGRAPHIC COMMUNICATION*
H04N	*PICTORIAL COMMUNICATION, e.g. TELEVISION*

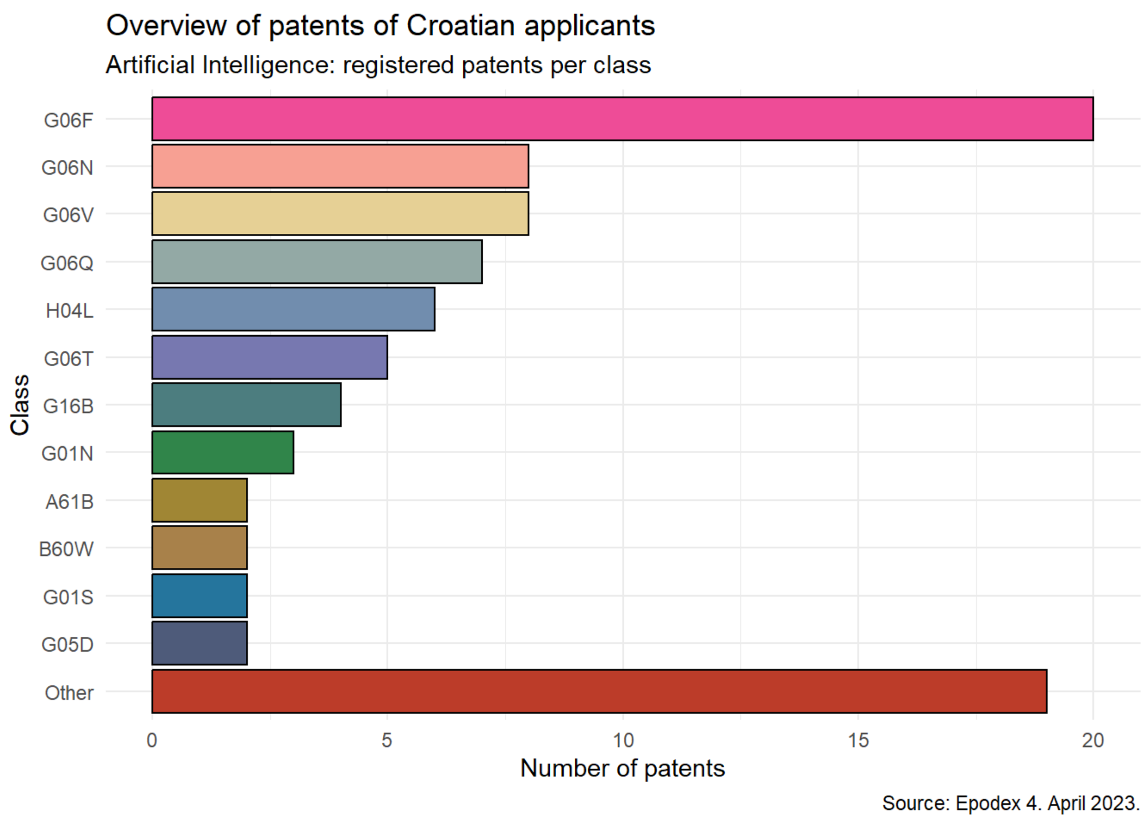


Figure 20 — Distribution of patents by IPC classification. Table 2 provides the classification key.

2.3.6 ESA Calls for Tenders in Croatia

In May 2020, the Implementing Arrangement on Technical and Professional Assistance entered into force. The purpose of the Implementing Arrangement was to determine the scope and modalities of the assistance to be provided by the ESA to the Republic of Croatia for the implementation of one or multiple calls for project proposals in the context of space-related activities. The Ministry of Science and Education, as part of the Implementing Arrangement, implemented a total of three national calls for project funding proposals from December 2020 to July 2022. Private and public institutions as well as the representatives of non-governmental organisations (NGOs) participated in the calls.

The areas covered by the call included:
a) Earth observation;
b) space technology;
c) space situational awareness; and
d) space astronomy and astrophysics as well as the exploration of the solar system.

Total amount allocated to Croatian applicants under the first call: EUR 1,104,000 (11 approved projects).
Total amount allocated to Croatian applicants under the second call: EUR 968,276 (9 approved projects).

Sixty-four project proposals were submitted and a total of thirty-four projects were approved for funding. Of the 34 approved project proposals, 16 were coordinated by the academic sector, while the remaining 18 project proposals were coordinated by the private sector. **During the writing of this report, the project summaries for only the first two rounds of the call were available, so this chapter presents an analysis of only those results (i.e. a total of 20 projects analysed).**

Of the 20 projects approved in the first two rounds of the call, four projects had the syntagm *machine learning* or *artificial intelligence* in their title or summary. The value of these four projects was EUR 510,000; three projects were from the private sector and one from the public sector. More specifically, the project from the public sector is being implemented at the Forest Research Institute, where artificial intelligence is used to observe forests and biomass.

Of the four projects mentioned above, three fall under this area, that is, this market. Within the context of Earth observation as part of space technologies, artificial intelligence, i.e. image processing, has a significant impact and these two areas overlap greatly.

3 Analysis of Primary Data Regarding the Research and Project Activities of Croatian Scientists and Entrepreneurs in **Artificial Intelligence Topics**

The methodology used to collect and analyse the primary data for mapping the potential of Croatian scientists in the field of artificial intelligence was designed in such a way that the results be complementary to the results of the processing of the secondary data in order to draw high-quality and accurate conclusions from all the data. The first step identified **44 public scientific institutions** (public higher education institutions and public scientific institutes) for which there was an indication that they had staff working in the development of AI methods or using it in their work. This information was obtained from the secondary data and took into account areas within the scope of research of individual institutions. Letters were sent to the addresses of these institutions, to the care of responsible persons (rectors, deans, directors and heads), asking them to provide a list of their employees who, according to their knowledge, carry out research in the field of artificial intelligence. The letter itself clarified and listed all that artificial intelligence included in order to make identification precise.

From the administrations of the public institutions, a list of **139 scientists** working in the field of artificial intelligence was obtained. **This number is interpreted as the lower limit of researchers working in this field.** Specifically, the administrations sent a list of research heads, i.e. prominent scientists, and not of the entire research group. A survey was sent to the addresses of the identified scientists and it was completed by **96 scientists or 69%** of the total list of researchers. A description of the survey, the collected data and its analysis is given below in this chapter. The interpretation of the numbers from the secondary and primary data is given in the conclusion.

When asked *How many **years of work experience** do you have in the academic and research sector in research related to the topic of artificial intelligence*, **the median response of the scientists was seven years and the mean value was 11.2 years.**

When asked *Assess the percentage of time you devoted on average MONTHLY to scientific research in the field of artificial intelligence as a percentage (%)*, the **median reported was 25% and the mean value was 32.8%**.

In addition to the primary data obtained from public scientific institutions, the primary data from companies working in the field of artificial intelligence was also collected. In the first step, **259 companies** were identified for which there were clear indications that they were working in artificial intelligence. These were companies that applied for EU and HAMAG-BICRO projects, i.e. companies identified by CroAI (the Croatian Artificial Intelligence Association, established in 2019). Using publicly available information, the list of companies was supplemented by contact details of researchers or responsible persons and a survey that was modified through pilot testing was sent to their addresses. We obtained **24 completed surveys** from the companies analysed in this chapter.

Chapters 3.2.–3.5. relate to surveys conducted at public scientific institutions. Chapter 3.6. refers to surveys conducted at private companies.

3.1 On the Survey

The survey was set up so as to enable research into the following parameters:

(i) the specific field, i.e. methods within the field of artificial intelligence, that the scientist or company dealt with (the possibility of marking multiple fields was given);
(ii) the application of artificial intelligence, i.e. the markets targeted by these applications;
(iii) the project activity of the scientists, i.e. of the institution they work at (the number of projects and sources of funding for completed projects and ongoing projects, i.e. projects that were in the process of being reviewed were all analysed separately in order to obtain information on the dynamics of research development);
(iv) collaboration with other scientists and institutions or economic entities to obtain information on the networking of public institutions and companies;
(v) the activity of scientists and companies in the protection of intellectual property (e.g. patents, number of patents applied for and granted, trademarks, number of licences or licensing agreements, etc.);
(vi) portfolio of scientific research results (whether the main results are scientific papers or some kind of commercialisation of the results); and
(vii) information on the capital infrastructure being used (the survey examined what the infrastructure was, who owned it, where it was located and whether it had been included in the Šestar database).

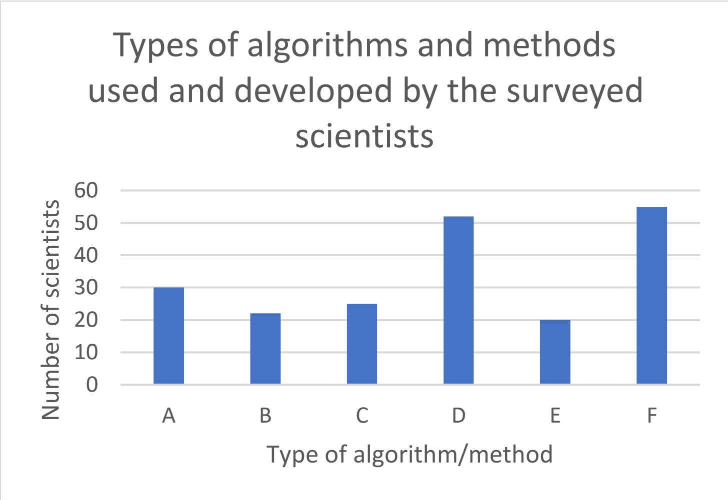
The survey for companies was somewhat modified compared to the survey for public scientific institutions. In addition to the above parameters, the survey for companies also contained questions about:

(viii) own resources that companies invested in the development of artificial intelligence;
(ix) the number of employees working in this field and any recruitment plans; and
(x) future investment plans (including potential new areas in which they plan to work).

The above parameters summarise the essence of the questions contained in the surveys. For this report to be complete, the surveys sent to the scientific institutions or companies themselves are included herein.

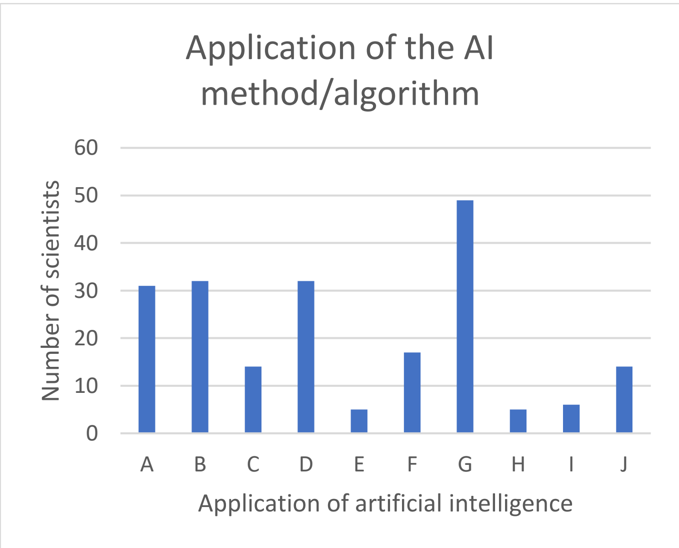
3.2 Main Directions of Research at Public Scientific Institutions

One of the aims of the survey was to gain an insight into the artificial intelligence methods that our researchers worked with. This information allowed, among other things, to assess how they followed global trends in the development of AI. The list of methods is given in chapter 1.3. The distribution of the activities of the scientists by the artificial intelligence methods they use is illustrated in Figure 21. The most common answer was that they did not develop their own methods but used methods developed by others. This is an expected response because the development of own algorithms is time-consuming and expensive, while a range of ready-made solutions is available in the open source domain, solutions that can very quickly and easily be adapted to specific needs. The second most prevalent response was neural networks and deep neural networks, from which it is easy to conclude that our scientists in fact are keeping up with trends, since, globally, these methods have been developed extensively and used in various applications in recent years.



A. k-nearest neighbours method
B. support vector machines
C. decision trees and random forests
D. neural networks and deep neural networks
E. other
F. we do not develop artificial intelligence methods but use existing algorithms and methods

Figure 21 — Distribution of scientists by the artificial intelligence methods they use and develop in their research.



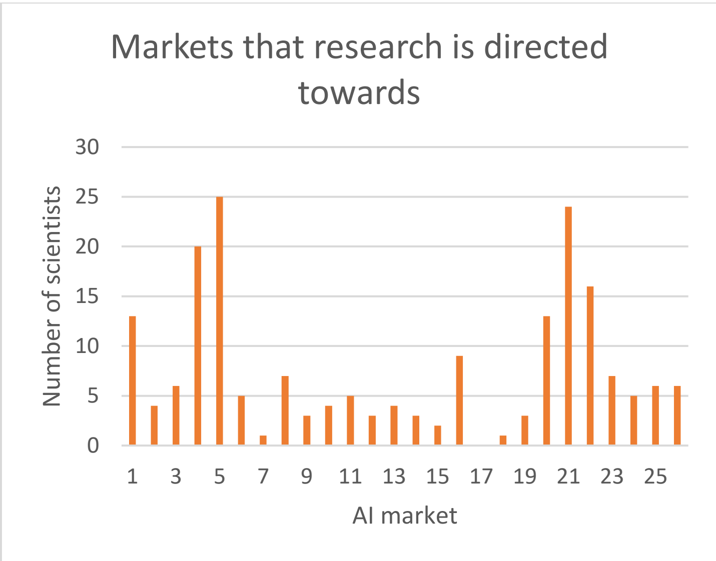
A. big data collection systems (image, voice or text)
B. planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources)
C. text recognition and processing systems (digitalisation and processing of archives)
D. image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth)
E. search systems (contextual search engines)
F. automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines)
G. expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.
H. game development systems (logical games such as chess or the development of virtual or augmented reality environments)
I. the development of legal or ethical norms and principles for the operation of artificial intelligence

J. other

Figure 22 — Distribution of scientists according to the application of their scientific research.

The distribution of scientists according to the application of artificial intelligence is illustrated in Figure 22. It can be seen that the most common applications are in the development of expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology and philosophy, followed by the development of big data collection systems (image, voice or text) and planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning and management of key national resources).

The distribution of the scientists, i.e. of their research by the end market, is shown in Figure 23. It can be seen that applications in medicine and biomedicine as well as transport and logistics stand out.



1. automotive industry
2. banking and financial services
3. electrics and electronics
4. ICT and telecommunications
5. medicine and biomedicine, medical devices
6. energy
7. construction
8. geospace and space
9. food and drink
10. innovation and design
11. mechanical engineering and naval architecture
12. quality and improvement of business
13. marketing, advertising, customer relations
14. measurement and metrology
15. waste and recycling
16. agriculture
17. legal affairs
18. risk and insurance
19. mining and materials
20. security (including cybersecurity) and defence
21. transport and logistics
22. information management
23. environmental management and sustainability
24. virtual reality
25. data protection
26. entertainment

Figure 23 — Distribution of scientists according to the application of their scientific research.

Although the survey questionnaire was completed by 96 scientists, and given that they were sent to as many as 44 institutions, it can be assumed that the distributions would not change significantly by increasing the number of scientists sampled.

3.3 Analysis of Project Activities and the Cooperation among Scientists, Institutions and Companies

In one part of the survey, the scope of the project activity of scientists was investigated. When asked *Were you involved in projects (completed, ongoing or proposed) in the field of artificial intelligence,* *whether they be competitive scientific projects or collaborations with the business community*, 71 respondents replied affirmatively (74%), while 25 claimed that they did not participate in such projects, as illustrated in Figure 24.

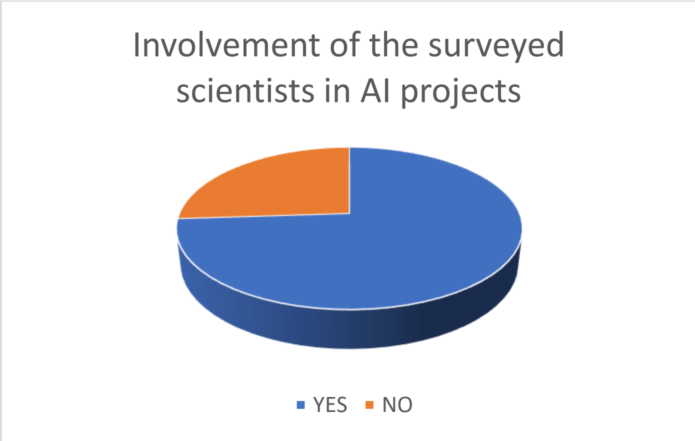


Figure 24 — Proportion of scientists who participated in projects in the field of artificial intelligence.

Whether the scientist was a project leader or associate, and whether the institution at which they worked was the holder (coordinator) of such a project, was relevant for the assessment of potential. The answers to these questions in the survey were as follows. The number of projects in the field of AI where:

- the scientist was the principal researcher was 82
- the scientist was a research associate was 191
- the institution was the lead partner (coordinator) was 106.

The narrow speciality of the surveyed scientists was investigated by asking *Please provide keywords describing your scientific activity in the field of AI* and was found to be in the following research topics (the responses were grouped to omit repetitions):

- computer vision, object tracking and detection, image classification, activity recognition, image analysis in medicine, traffic scene analysis, image enhancement methods and robot vision;
- use of machine learning algorithms to analyse big data, time series, data classification, anomaly detection, object counting, etc.;
- logistics, traffic safety, traffic and transport;
- experiential quality modelling for advanced multimedia services;
- natural language processing (NLP) and computational linguistics;
- automation of synthesis processes and broader applications to other industrial processes;
- use of artificial and convolutional neural networks in the field of the interpretation of data obtained by geophysical measurements (electrical tomography, magnetometry and lithology, i.e. well data);

- microwave and optical communication systems, antenna systems and sensor systems;
- applications of AI in digital ecosystem protection (or attacks) and digital forensics using AI;
- automation and robotics;
- Higgs boson physics and applications of AI in physics;
- immunology and virology, development and optimisation of predictive models based on machine learning algorithms for applications in biomedicine and drug discovery and medical diagnostics based on image classification;
- monitoring and inventory of forest ecosystems;
- defining user requirements and system architecture;
- quantitative finance;
- modelling, finding data by using artificial intelligence;
- development of innovative tools for the assessments of environmental impacts and risks on human health, personality psychology and well-being; and
- ethical issues related to the wider use of artificial intelligence.

The following three tables show the distribution of completed, ongoing and proposed projects. These are projects involving the surveyed scientists.

Table 3 — Artificial intelligence: number of COMPLETED competitive research projects (between 2016 and May 2023) under the programmes.

HORIZON 2020, Horizon Europe	31
Structural funds (RDI, SIIF, etc.)	24
UKF (Unity through Knowledge Fund)	0
PoC (Proof of Concept programme)	6
IRCRO, RAZUM, EUREKA, Eurostars	5
CSF (Croatian Science Foundation) programmes	51
Other scientific projects	14

Table 4 — Artificial intelligence: number of ONGOING competitive research projects under the programmes.

HORIZON 2020, Horizon Europe	22
Structural funds (RDI, SIIF, etc.)	20
UKF (Unity through Knowledge Fund)	0
PoC (Proof of Concept programme)	0
IRCRO, RAZUM, EUREKA, Eurostars	0
CSF (Croatian Science Foundation) programmes	39
Other scientific projects	18

Table 5 — Artificial intelligence: number of PROPOSED competitive research projects.

HORIZON 2020, Horizon Europe	15
Structural funds (RDI, SIIF, etc.)	11
UKF (Unity through Knowledge Fund)	1
PoC (Proof of Concept programme)	2
IRCRO, RAZUM, EUREKA, Eurostars	0
CSF (Croatian Science Foundation) programmes	0
Other scientific projects	0

Table 3 shows that our scientists prevalently used the funds from the CSF, Horizon 2020 and Horizon Europe and the structural funds. Project activity under the HAMAG-BICRO programme is significantly smaller, but still exists. This tells us that, in this field, there is cooperation between scientific institutions and economic entities on HAMAG-BICRO projects. Table 5 shows that researchers are now focused on Horizon Europe and Structural Funds projects, which is understandable given that the frequency of calls by national agencies has decreased, while at the same time, scientists have gained the experience and contacts needed to apply for European Structural Funds.

The surveyed scientists carried out their projects and research in cooperation with scientific institutions in the Republic of Croatia and abroad and in cooperation with the business sector. Of the Croatian institutions and companies, the following were mentioned in the survey responses:

the Faculty of Electrical Engineering and Computing in Zagreb, the Faculty of Economics and Business in Zagreb, the Faculty of Organisation and Informatics in Varaždin, the Faculty of Education and Rehabilitation Sciences in Zagreb, the Faculty of Agriculture in Zagreb, the Faculty of Civil Engineering in Zagreb, the Faculty of Mechanical Engineering and Naval Architecture in Zagreb, the Faculty of Veterinary Medicine in Zagreb, the Ruđer Bošković Institute, the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture in Split, the Faculty of Transport and Traffic Sciences in Zagreb, the Croatian Meteorological and Hydrological Service, the Institute for Medical Research, the Faculty of Kinesiology in Split, the Faculty of Science in Split, the Faculty of Humanities and Social Sciences in Rijeka, the Institute of Croatian Language and Linguistics, the Faculty of Food Technology and Biotechnology in Zagreb, Aduro idea d. o. o., the Croatian Bureau of Statistics, the Central State Office for Digital Society Development, Osijek State Archives, the Faculty of Civil Engineering and Architecture in Osijek, the Faculty of Food Technology in Osijek, the Faculty of Geodesy in Zagreb, the Faculty of Civil Engineering in Split, the University of Zadar, the Faculty of Informatics and Digital Technologies in Rijeka, the Academy of Dramatic Arts, the Academy of Fine Arts, the Faculty of Engineering of the University of Rijeka, the Faculty of Maritime Studies of the University of Rijeka, Virovitica University of Applied Sciences, Peharec Polyclinic in Pula, the Faculty of Kinesiology in Zagreb and the Institute of Oceanography and Fisheries.

The institutions and companies from abroad mentioned in the survey responses were: Animal Eye Consultants of Iowa (USA), Johannes Kepler University Linz, the Polytechnic University of Madrid, Technische Universität Braunschweig (Zürich) University of Applied Sciences, the University of Seville

(Spain), Virginia Tech in Blacksburg (USA), the University of Texas in Arlington (USA), Tampere University (Finland), Medical University Graz (Austria), Philips (the Netherlands), Siemens (Austria), Huawei (Finland), the European Investment Bank, the Finnish Meteorological Institute, the Computer Vision Centre, Universitat Autònoma de Barcelona (Spain), the Faculty of Electrical Engineering, University of Ljubljana (Slovenia), Hochschule Bonn-Rhein-Sieg (Germany), the International Hellenic University (Greece), the Academy of Science (Bulgaria), the Faculty of Electrical Engineering in Podgorica (Montenegro), Johannes Kepler Universität (Austria), Technische Universität Braunschweig (Germany), Universidad Politécnica de Madrid (Spain), Zürich University of Applied Sciences (Switzerland), Skyguide Swiss Air Navigation Services Ltd. (Switzerland), Institut de Robotica i Informatica Industrial, Barcelona (Spain), the Jožef Stefan Institute (Slovenia), Institute for Research in Biomedicine (Spain), INESC-TEC (Portugal), Universidad Politecnica de Valencia, Escola Superior de Tecnologia de Setúbal, Collegio Carlo Alberto, the University of South Florida, the Automation and Control Institute (ACIN), the Faculty of Electrical Engineering and Information Technology, TU Wien, Insights2Techinfo (India), EAI — European Alliance of Innovation, the Science Fund of the Republic of Serbia, Centre for AI and Cyber Security Research and Innovations, Asia University, Taiwan, EPFL Lausanne, Universitat Oberta de Catalunya, University College London, EXUS Ltd., My Documenta Creaciones Multimedia Avanzadas S.L, Education4sight, Diginext, Institut de Robòtica i Informàtica Industrial, Barcelona, the Faculty of Theology / Institute for Philosophy and Ethics, Ljubljana, the Faculty of Technical Sciences, University of Prishtina (Serbia), State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Nanjing Hydraulic Research Institute, Nanjing (China), the Faculty of Science, Agronomy Department, Hydraulics Division, Laboratory of Research in Biodiversity Interaction Ecosystem and Biotechnology (Algeria), the Faculty of Civil Engineering in Sarajevo, University of Sarajevo, Sarajevo (Bosnia and Herzegovina), Islamic Azad University, Ahvaz (Iran), GMV aerospace and defence, UNESCO, University of British Columbia (Canada), INESC (Portugal), Delft University of Technology, University of the Aegean, Trinity College Dublin, Dublin, University of Applied Sciences Western Switzerland (HES-SO) Valais, Valais, the Faculty of Technical Sciences, Novi Sad, the University of Boston, Ecole Polytechnique Paris, the University of Latvia, John Hopkins University (Baltimore), Riga Technical University, CVC Barcelona, Technical University of Valencia, Università degli Studi dell'Aquila, the University of Belgrade, Žilinská univerzita v Žiline, Universitat Politècnica de Catalunya, Faculty of Computer and Information Sciences, Beihang University (PR China), the University of Ruse (Bulgaria), Gdynia Maritime University (Poland), University of Wisconsin-Madison (USA), INRIA Grenoble (France), TU Dresden (Germany), Shenzhen Institute of Advanced Technology (China), the University of Toulouse (France), Fraunhofer Institute for Computer Graphics Research, Darmstadt (Germany), the University of Girona (Spain), CNRS France, INRIA Grenoble, TU Graz, IRISA Rennes, the University of Wuppertal, TU Dresden, TU Berlin, Nankai University (China), Trinity College Dublin (Ireland), the Faculty of Technical Sciences Bitola (North Macedonia), Trinity College Dublin (Ireland), Leibnitz Institute of Technology (Germany), UPM (Spain), ZHAW (Switzerland), Technische Universität Braunschweig (Germany) and Universitat Linz (Austria).

The answers of the surveyed scientists when asked *Please indicate the number of projects in cooperation with the business sector (private companies, research centres, etc.) in which the business sector was the contracting authority in the field of AI* were as follows:

- number of companies from abroad 36
- number of companies from Croatia 52,

i.e. a total of 88 such projects were carried out.

The surveyed scientists were asked to evaluate the quality of collaboration in the field of AI so far with ratings from 1 (very poor) to 5 (very good). The ratings of the cooperation with stakeholders are as follows:

- cooperation with the research community 4.4
- cooperation with the business community 3.2
- cooperation with the government/public sector 2.5
- cooperation with the non-governmental sector 2.4.

It is evident that cooperation within the scientific community is rated very highly, while the cooperation between the scientific and business communities is rated somewhat lower. The cooperation between the scientific community and the state/public sector and NGOs has significant room for improvement in this field.

In order to assess the motivation, i.e. the reasons, for cooperation from the perspective of Croatian scientists, they were asked to assess the importance of the following reasons for cooperation with partners (business sector and scientific institutions) on projects / scientific papers in the period from 2016 to 2022. The results are given in Table 6. The reasons for cooperation were mainly joint R&D projects and the transfer of knowledge between partners, while the less important reasons included intellectual property and the licensing/registration of patents.

Table 6 — Assessment of the importance of the reasons for cooperation with partners (business sector and scientific institutions) on projects / scientific papers related to AI from 2016 to 2022. The responses were on a scale of 1 (not important) to 5 (very important). The table shows the average rating for each question.

Joint R&D project	4.5
Transfer of knowledge between partners	4.3
Procurement of R&D services	3.0
Technological consultation / preparation of technical documentation	3.1
Testing/creating a new prototype	3.5
Commercialisation of research	3.0
Licensing/registration of patents	2.5
Intellectual property	2.7
Joint publication of research in journals	4.1
Some other reason	1.5

In order to understand what needs to be done to increase the number of collaborations and strengthen it, the reasons why this number is not higher were assessed using the questionnaires. The results are given in Table 7. The main reasons for the lack of cooperation were the lack of time (scientists are too busy with daily work) and the lack of resources (e.g. human or financial resources or research infrastructure).

Table 7 — Assessment of the importance of the reasons for there not being a higher number of collaborations. The responses were on a scale of 1 (not important) to 5 (very important). The table shows the average rating for each question.

There is insufficient information about the needs of companies/institutions.	3.3
There are not enough incentives to collaborate with companies/institutions.	3.4
It is difficult to work with companies/institutions.	2.6
The disclosure of business secrets in research is a concern.	2.2
We don‘t have enough time because we’re too busy with daily work.	3.8
We do not have enough resources (e.g. human or financial resources or research infrastructure).	4.1
There is no need for projects in the field of innovation and technology.	1.6
Some other reason	1.4

3.4 Patents and Research Commercialisation

This part of the report analyses the primary data related to intellectual property and the commercialisation of research. When asked *Have you used some forms of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research in the period from 2016 to 2022*, 18% of the surveyed scientists replied YES and 82% replied NO (Figure 25). The results show that one in five scientists use intellectual property protection, an unusually high number of patents when compared to those analysed from the secondary data.

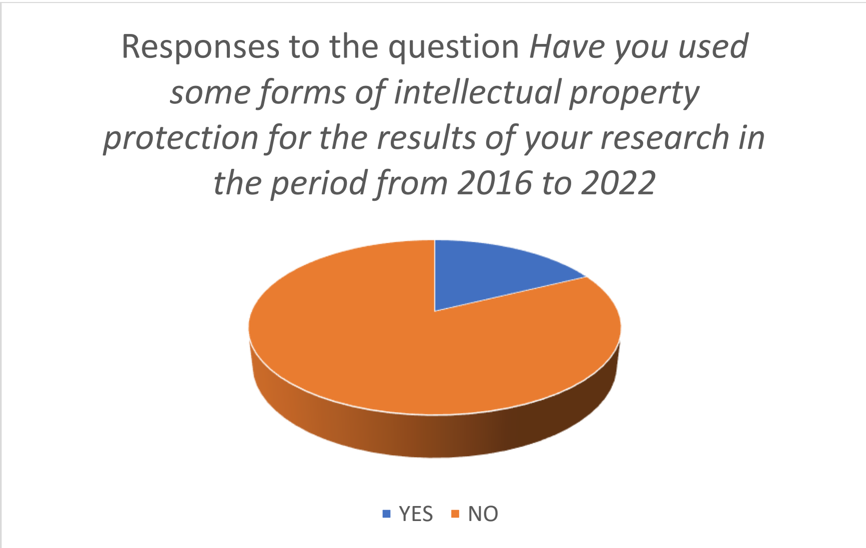


Figure 25 — Proportion of the use of intellectual property protection by the surveyed scientists.

An insight into the form of intellectual property protection is given in Table 8, which clearly shows that these are mainly patents and copyright. The number of national or international patents applied for and granted is given in Table 9. None of the scientists surveyed had any income from patent licenses. Three scientists of all the scientists surveyed started spin-off companies that are still active, with a total of five employees and a turnover of EUR 23,000 per year. In the field of artificial intelligence, there have been **11 commercialisations of scientific research**. The reasons for the lack of commercialisation in scientists who did not commercialise any research results were investigated using a survey question, and the answers are given in

Table 11. No answer is significantly prevalent, and under *Some other reason*, the scientists gave different reasons; however, none stands out as the predominant reason for the lack of commercialisation.

Table 8 — Number of different forms of intellectual property protection used by the surveyed scientists from 2016 to 2022.

Patent	8
Trademark	2
Industrial design	1
Copyright	8
Some other right (please specify):	0

Table 9 — Number of national or international patents applied for by the surveyed scientists and granted.

Number of national patents applied for	1
Number of national patents granted	1
Number of international patents applied for	8
Number of international patents granted	2

In order to determine the reasons why some of the surveyed scientists did not patent their results, the motives behind the scientists not choosing to protect intellectual property were examined. The results are given in Table 10. It is clear that the main motive behind the lack of protection were the overly expensive patent application and maintenance.

Table 10 — The answers of scientists who have not used intellectual property protection to the question about the reasons for not doing so. If you have not used any form of intellectual property protection from 2016 to 2022, please provide a reason. (Multiple answers may be selected.)

The application process is too expensive.	26.3%
Maintaining protection is too expensive.	26.3%
The protection of intellectual property does not provide protection in our industry.	22.2%
Some other reason	25.3%

Table 11 — Answers of the surveyed scientists to the question regarding the commercialisation of results. If you have not commercialised the results of your research in the field of artificial intelligence in the period between 2016 and 2022, please indicate the reasons. Rate your answer on a scale from 1 (low importance) to 5 (high importance).

Lack of means for commercialisation	2.9
Lack of expertise and experience needed for commercialisation	2.9
Difficulties in finding a partner for commercialisation	3.1
Strong competition in the market	2.5
Insufficient market demand	2.6
Lack of support from the institution at which the scientist is employed	2.4
Commercialisation of research results was not planned/expected	3.4
Some other reason	1.5

The results produced by scientists working in artificial intelligence are primarily scientific papers, followed by improved processes. It is clear that the main motivation of scientists to work is the publication of scientific papers. This is linked to the fact that scientific publications are the primary criterion for career advancement, while the patenting and commercialisation of research are not crucial, i.e. they are not considered in the context of advancement.

Table 12 — Answers of the surveyed scientists to the question Please state the results of your research in the Artificial Intelligence thematic area*.*

Manufactured or improved prototype of a product	14.0%
New service developed	10.5%
A new or significantly improved process	20.5%
Scientific papers	51.5%
Other	3.5%

3.5 Research Infrastructure

Of the total number of the scientists surveyed, 23% used capital research infrastructure which, for the purposes of this study, was defined as equipment costing more than EUR 50,000. The scientists listed a total of 38 pieces of capital equipment falling under this definition, including:

the BURA supercomputer and other supercomputers, GPU servers for machine learning, the Worldwide LHC Computing Grid (WLCG), data storage systems of over 50 TB, the InfoCoV workstation and other workstations, the CERN Grid computer system, a Supermicro server with A100 technology, Srce equipment and seismographs.

The percentage of equipment use is given in Table 13. The table was summarised based on the question *What is the percentage of your use of this equipment for research purposes during the year*.

It is obvious that the equipment is used to a reasonable degree. **74% of the equipment was owned by the scientific institutions** that used it, and **26% was either rented or** used in other ways. Of the equipment owned by the institutions, **32% was included in the Šestar database, 32% of the equipment was not included,** and for the remaining part, the scientists who used it did not know the answer.

Table 13 — Percentage of use of capital equipment. Only 21.1% of the scientists used the equipment for research purposes during less than 25% of the year.

< 25%	21.1%
25%–50%	23.7%
50%–75%	18.4%
75%–100%	36.8%

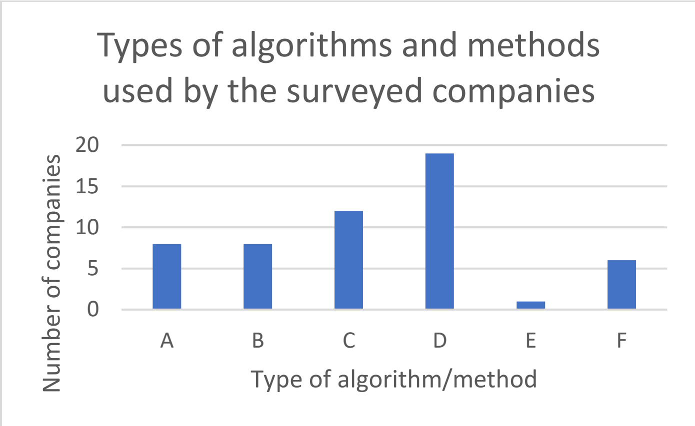
It can be concluded that equipment invested in research resources was used. Furthermore, since only 23% of the scientists used capital equipment, it is evident that there are human capacities to use a larger portion of research equipment.

3.6 Mapping the Potential of Croatian Companies in the Field of Artificial Intelligence

A number of Croatian companies actively use artificial intelligence in their work, i.e. their products and/or services are related to artificial intelligence. Some of them are actively developing new algorithms and methods, while some only use existing ones in their work. The secondary data shows that Croatian companies are also participating in RDI funding programmes that touch on artificial intelligence. **This part of the analytical report, based on the processed primary data (questionnaires), provides an insight into their current business activities and future plans, as well as an overview of answers to questions related to methods and algorithms, target markets, cooperation with scientific institutions and other companies in the Republic of Croatia, project activities, intellectual property protection, plans for further development as well as increasing human potential and placing products and services on new markets.**

Surveys were prepared to obtain precise information on the above topics, and the questionnaire itself is attached to this report. The questionnaires were sent to the addresses of 259 companies, 24 of which completed the survey.

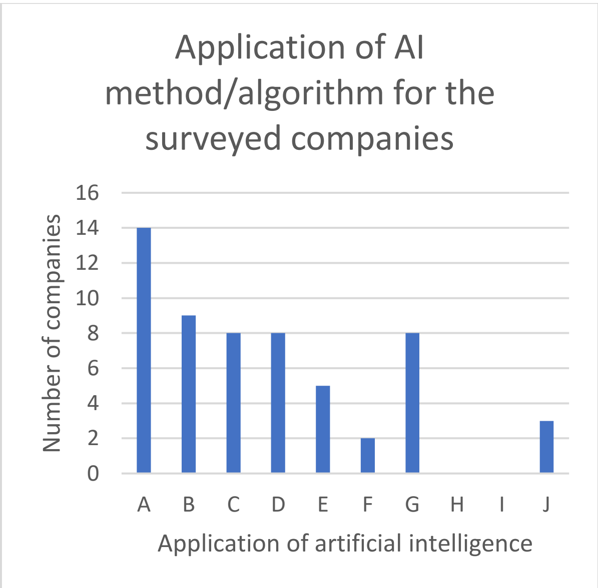
In the first part of the survey, the methods or algorithms used by the respondents were investigated, i.e. whether they were developing their own methods, using already existing ones or both. Figure 26 contains answers from which it is evident that the surveyed companies used the advanced methods of neural networks and deep learning the most. Each company could choose from six possible responses, and marking more than one response was allowed. The figure shows that most companies develop their own methods while also using, on a smaller scale, ready-made methods and algorithms (some companies develop their own algorithms and methods, but within their business activities, they use ready-made algorithms and methods alongside development).



A. k-nearest neighbours method
B. support vector machines
C. decision trees and random forests
D. neural networks and deep neural networks
E. other
F. we do not develop artificial intelligence methods but use existing algorithms and methods

Figure 26 — Distribution of the use of the different types of artificial intelligence algorithms and methods used by the surveyed companies.

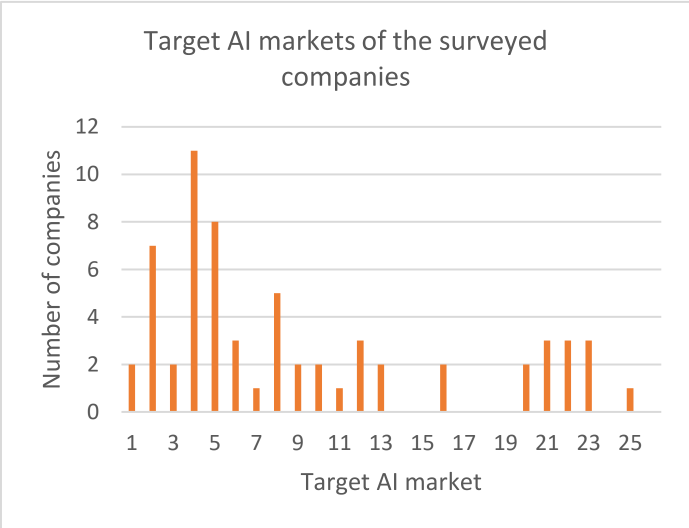
In addition to specifying the methods, one question asked was also related to their application in the development of an innovative product or process. There were ten possible responses, and companies could choose up to three answers that best illustrated their area of activity. The histogram of the answers to the questions is shown in Figure 27. Big data collection systems (image, voice or text) and planning and process management systems were the prevalent application areas.



A. big data collection systems (image, voice or text)
B. planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources)
C. text recognition and processing systems (digitalisation and processing of archives)
D. image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth)
E. search systems (contextual search engines)
F. automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines)
G. expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.
H. game development systems (logical games such as chess or the development of virtual or augmented reality environments)
I. the development of legal or ethical norms and principles for the operation of artificial intelligence
J. other

Figure 27 — Distribution of the use of the different types of artificial intelligence algorithms and methods used by the surveyed companies.

An important piece of information is on which markets our companies place their products and services. The answer to this question is illustrated in Figure 28. The survey offered 26 possible responses, i.e. 26 markets, and companies could choose up to three most important ones. The leading markets were ICT and telecommunications, medicine and biomedicine, i.e. medical devices, and banking and financial services.



1. automotive industry
2. banking and financial services
3. electrics and electronics
4. ICT and telecommunications
5. medicine and biomedicine, medical devices
6. energy
7. construction
8. geospace and space
9. food and drink
10. innovation and design
11. mechanical engineering and naval architecture
12. quality and improvement of business
13. marketing, advertising, customer relations
14. measurement and metrology
15. waste and recycling
16. agriculture
17. legal affairs
18. risk and insurance
19. mining and materials
20. security (including cybersecurity) and defence
21. transport and logistics
22. information management
23. environmental management and sustainability
24. virtual reality
25. data protection
26. entertainment

Figure 28 — Distribution of target markets in the field of artificial intelligence used by the surveyed companies.

The above three illustrations provide basic information on the characteristics of products and services, i.e. markets. The potential of these companies in a given field also depends on the total number of employees (i.e. the number of hours worked) working in artificial intelligence (FTE — Full-Time Equivalent), the number of years of experience in this field, plans to recruit new personnel and the number of projects previously implemented. This information can be found in Table 14.

Table 14 — Summary of answers to survey questions intended for companies working in artificial intelligence.

Total FTE	283.2
Average FTE per company	11.8
Average years of experience	9.4
Total number of projects implemented (2016 –2022)	267
Average number of projects implemented per company	11.1
Projects where the company was the coordinator	168
Average number of projects where the company was the coordinator	7.0
Average annual value (2016 –2022) of the R&D investment (in thousands of EUR)	210
Expected number of new employees in the next three years	215
Average number of new employees in the next three years per company	9.0
Planned development investments within the next three years (in thousands of EUR)	850

Table 15 provides an insight into the sources of funding of the surveyed companies for their previous and planned research and development projects. For previous projects, own resources accounted for 56% of funding sources, while EU funds accounted for around 32%. For planned projects, the situation was reversed, in the sense that the companies planned to source 50% of the funds used for development from EU funds.

Table 15 — Sources of financing for previous and planned projects for the surveyed companies.

	Previous projects	Planned future projects
a) Own resources:	56%	39%
b) EU programmes and grants:	32%	52%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks):	0%	0%
d) Commercial loan from a commercial bank:	0%	0%
e) Other sources (please specify):	12%	9%

The current rate of cooperation of the surveyed companies with public scientific and higher education institutions shows that **two-thirds of the companies cooperate with scientific institutions in the Republic of Croatia** on problems related to the field of artificial intelligence, while **83% of them plan to do so in the future**. The institutions mentioned in the survey responses were: the Faculty of Electrical Engineering and Computing, University of Zagreb, the Faculty of Geodesy, University of Zagreb, the Faculty of Science, University of Zagreb, the Faculty of Science, University of Split, the Faculty of Organisation and Informatics in Varaždin, the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, the University of Rijeka (FIDIT), the Faculty of Economics, Business and Tourism, University of Split, the Department of Mathematics of the University of Osijek, the Faculty of Food Technology and Biotechnology, University of Zagreb, the Ruđer Bošković Institute, the Institute of Oceanography and Fisheries from Split, the Croatian Geological Survey, Algebra University College, St Catherine Specialty Hospital in Zabok, Dubrava University Hospital in Zagreb, Thalassotherapia Special Hospital in Opatija, Acibadem Sistina Clinical Hospital, Innovation Centre Nikola Tesla (ICENT), Zagreb School of Economics and Management (ZŠEM), Fraunhofer Institute for Industrial Mathematics, Leiden University Medical Centre, University of Edinburgh Medical School, Macquarie University, Genome Institute of Singapore, King's College London and the University of Amsterdam — AI. With these institutions, the companies surveyed carried out **70 joint projects between 2016 and 2022.**

About 50% of the surveyed companies did not cooperate with other companies on research related to artificial intelligence. The surveyed companies **carried out 178 joint artificial intelligence projects with other business entities between 2016 and 2022**.

Capital infrastructure, which, for the purposes of this survey, was defined as equipment worth over EUR 50,000, **was used by 50% of the companies**. Of the companies that used capital infrastructure, 83% owned their own infrastructure, while 67% also used external capital infrastructure (Figure 29). Some companies used both their own and external infrastructure.

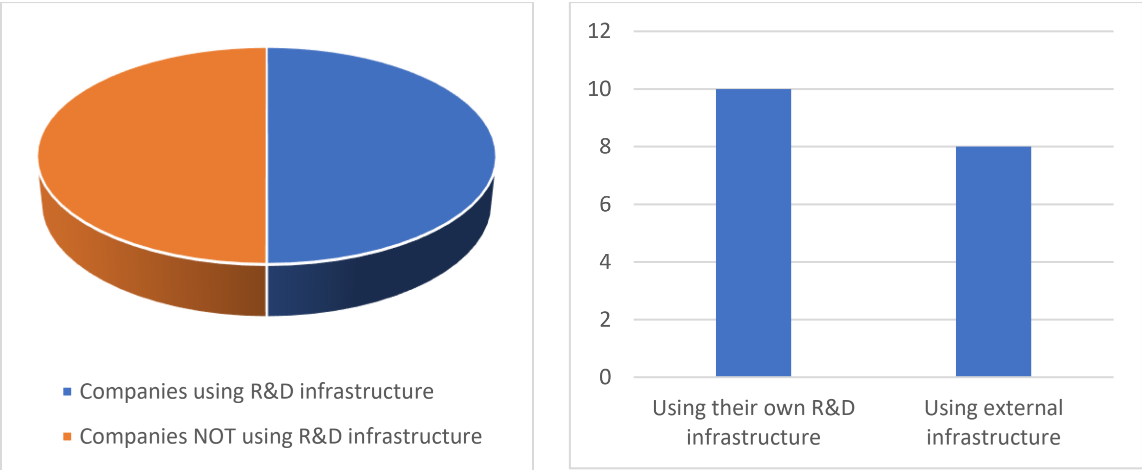


Figure 29 — Use of research and development (R&D) infrastructure by the surveyed companies. The left chart shows the percentage of companies that use or do not use R&D infrastructure. The right chart shows the number of companies that use their own or external infrastructure. The right chart applies only to companies that use capital infrastructure.

The percentage of equipment use for the purposes of development or projects in the field of artificial intelligence was 65%. The listed own equipment included one internal data and processing centre at company premises, a data centre, a small server farm, application systems for archiving and data processing, HPC (High Performance Computing) computers, GPU-based AI training servers (GPU — graphics processing unit), GPU-based decision-making servers, CPU-based servers (CPU — central processing unit) for other types of processing (machine learning, data science, etc.). The external equipment used included cloud services such as Google, Amazon, AWS, Azure, Oracle, Hetzner and VPS infrastructure. The companies were not interested in sharing their capital infrastructure with other legal entities (two of the surveyed companies would allow the use of its equipment to other scientific institutions, and only one to other companies).

Of the companies surveyed, slightly less than 50% used intellectual property (IP) protection, and protection was mainly used on trademarks followed by copyright and finally patents (Figure 30). A total of three companies stated that they have licensed their IP with a total of seven contracts per licence.

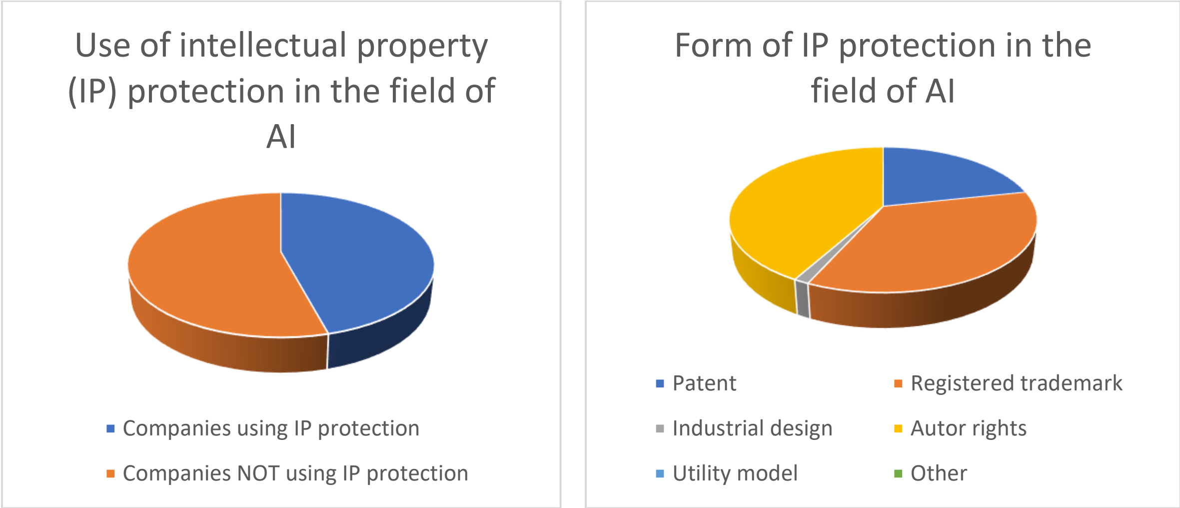


Figure 30 — Distribution of the use of intellectual property (IP) protection for surveyed companies (left) and distribution by type of IP in the field of AI (right).

All the companies stated they planned to expand their business into new markets and use new methods and algorithms. It is worth pointing out that the companies that took the survey and are active in the field of artificial intelligence currently employ 283 experts in that field, while also planning to hire another 215 experts in the next three years, which is an increase of 76%.

4 SWOT Analysis

Based on the primary and secondary data collected for the target area, a SWOT analysis was carried out which shows the strengths (S), weaknesses (W), opportunities (O) and threats (T) within the target area of artificial intelligence. SWOT analysis is a tool that helps analyse an organisation or technological field, identify internal strengths and weaknesses as well as external opportunities and threats, and help design a successful strategy for the future. A summary of the SWOT analysis is given in Table 16.

Table 16 — SWOT analysis. The table shows the strengths (S), weaknesses (W), opportunities (O) and threats (T) within the target area of artificial intelligence.

STRENGTHS	**WEAKNESSES**
• An active technological community of professionals in the public and private sectors oriented towards basic research (development) and the application of AI technologies in a wide range of target markets, from ICT to medicine and space to automotive industry • The great potential of the research sector within this field for advanced research, development and innovation, evident from the published primary scientific literature and project applications for national and international calls for tenders • The field of artificial intelligence has seen significant growth in Croatia, and there is an increasing interest and support for this field in national and supranational strategic documents (the Croatian National Development Strategy 2030, the Smart Specialisation Strategy and European Commission Regulations) • Existing expertise at several scientific institutions cooperating with the economic sector, resulting in innovative projects • Applicability of AI-based solutions in almost all areas and sectors (smart cities, transport, tourism, health, cybersecurity, justice system, etc.)	• Despite their talent, there is a lack of AI professionals, which can slow down the development and application of this technology • Lack of use of AI in improving services in the public sector • Low use of intellectual property protection to protect innovative solutions • Lack of sectoral incentives for developing or exporting AI-based software solutions • Insufficient availability of AI-based solutions for smaller companies
OPPORTUNITIES	**THREATS**

• Increased education and awareness of AI to encourage the uptake of this technology in different sectors and by a wider range of users • The development of start-up ecosystems for artificial intelligence with incubators and investors, which provides an opportunity to develop innovative solutions and entrepreneurship • Artificial intelligence can be crucial for the digital transformation of different sectors in Croatia, which opens new opportunities for process optimisation and the creation of new values • Additional development and supply, as well as systematic investment in maintaining advanced computing resources and resources for high performance storage and network connectivity needed for modern and multidisciplinary science • Developing a platform for dialogue and merging the public and business sectors to facilitate the flow of information, knowledge and needs in both sectors, which yields a multiplicative effect • Development of centres of excellence and competitiveness in the field of artificial intelligence • Strengthening cooperation between the scientific and business sectors through support for R&D cooperation • Public procurement of innovative solutions can be a driver for the development of advanced tools and solutions for the digitalisation of public services	• The lack of financial instruments for AI research and development, primarily at the national level and in particular those instruments that foster cross-sectoral cooperation and IP management, may limit the potential growth of this sector • Croatia faces strong global competition, which requires continuous innovation and keeping up with the latest trends • AI entails ethical and legal challenges, such as data privacy, security and accountability, which requires adequate regulation and standards • The use of AI can lead to changes in the labour market, so the retraining and adaptation of the workforce needs to be ensured in order to reap the benefits of technology

5 Conclusions and Recommendations

5.1 Main Findings of the Mapping

One of the main objectives of the mapping was to estimate the number of **researchers** developing or using AI methods in their activities to develop innovative products or services in the area of their activities or research. The aim was also to identify those stakeholders who possess the knowledge and resources for innovative development and research in the field of artificial intelligence and who possess the capacity to implement research and industrial projects in this field.

Based on the secondary data from the SCOPUS database that indexes scientific publications, the **upper limit** of human potential in the Republic of Croatia was estimated **at 1,474 researchers** in the public and private sectors. This figure was obtained by the following procedure: the first step filtered out all the authors who, within a period of eleven years (2012 –2022), published, in the SCOPUS database, scientific or other types of papers indexed by the said database and containing at least two of the keywords listed in Table 1 in their title, summary or list of keywords. In the second step, this list of authors was reduced to those with at least two keywords related to their name, i.e. 1,474 researchers. This figure of 1,474 individuals includes authors, i.e. researchers from public and private institutions. It is important to note that this figure also includes authors who may have published one paper in the period between 2012 and 2022, and then no longer worked with artificial intelligence.

The lower limit of **139 scientists** was obtained by directly contacting the administrations of **44 public scientific institutions** which were concluded on the basis of the secondary data to have potential in this area. It should be noted that the figure of 139 researchers only includes researchers from public scientific institutions. **In conclusion, based on the mapping, it is estimated that there are between 139 and 1,474 researchers in the public and private sectors of the Republic of Croatia who develop or use artificial intelligence methods in their work.**

Based on the primary data, the conclusion is that the **aforementioned 139 researchers have worked in AI-related technologies for an average of 11 years and that, on average, this field accounts for one-third of their working hours**. Around one-third of the researchers use existing AI algorithms and methods in their work, with supervised access to machine learning and the use of neural networks being the most prevalent among the methods that scientists are developing and using. The highest number of researchers cited, as their field of work, the development of expert systems to assist all types of activities, from medicine to linguistics, as well as the development of systems for planning and managing processes with the help of machine learning, followed by the development of a system for collecting and analysing big data (data science) and processing images, text or sound. Of the other applications, the automotive industry is one that stands out. The development of search systems or computer games was the least prevalent activity of the surveyed researchers. It is also worth pointing out an aspect of human potential, although represented by a relatively low number, which deals with the development of legal or ethical standards related to the field of artificial intelligence (two researchers indicated working on this topic).

Of the 26 target market sectors that AI R&D is directed towards, seven stand out, with medicine and biomedicine taking point, followed by telecommunications and ICT (with a particular focus on cybersecurity and information management) and then transport and the automotive industry. It is also important to highlight the notable presence of AI applications in climatology, agriculture and environmental management.

The secondary data shows that there are capable engineering groups in the field of the development of distributed decision-making systems and unsupervised methods of classification and prediction, which can further bolster the development and application of AI methods.

On the basis of the secondary and primary data, the following public scientific institutions active in the field of artificial intelligence were highlighted: from the University of Zagreb, these were the Faculty of Electrical Engineering and Computing, the School of Medicine, the Faculty of Geodesy, the Faculty of Humanities and Social Sciences, the Faculty of Agriculture, the Faculty of Science, the Faculty of Transport and Traffic Sciences, the Faculty of Food Technology and Biotechnology, the Faculty of Mechanical Engineering and Naval Architecture and the Faculty of Economics and Business; Josip Juraj Strossmayer University of Osijek; from the University of Rijeka, these were the Faculty of Engineering, the Faculty of Informatics and Digital Technologies and the Faculty of Medicine; from the University of Split, these were the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, the Faculty of Science, the School of Medicine and the Faculty of Civil Engineering; University North and the University of Applied Sciences in Zagreb; of the various institutes, these were the Ruđer Bošković Institute and the Institute of Oceanography and Fisheries, Split, and the Croatian Meteorological and Hydrological Service. Several university hospitals in Zagreb (KBC Zagreb, KB Dubrava, KB Sestre Milosrdnice), Split (KBC Split) and Rijeka (KBC Rijeka) also stood out.

The assessment of the quality/excellence of Croatian researchers working with artificial intelligence was made on the basis of published papers and their citations, as well as on the basis of submitted and implemented projects. Under the European Union's Seventh Framework Programme, a total of ten projects that can be classified under artificial intelligence were contracted. A total of 406 project applications in the field of artificial intelligence were identified under Horizon 2020, out of which 42 projects were contracted (a success rate of 10.3%, below the national average of 13.5%, according to Horizon Dashboard data), three of which were coordinated by Croatian partners. In these contracted projects, there were 27 partners from public institutions, while 24 contracted projects had partners that were entrepreneurs from Croatia. Under Horizon Europe, a total of 18 projects that can be classified in the field of artificial intelligence were contracted, two of which were coordinated by Croatian partners. In the national system of project funding, the field of artificial intelligence was funded, through the programmes of the Croatian Science Foundation, in 115 projects, of which a roughly equal number, approximately 40, entailed the funding of doctoral students and research projects.

The citation rate of scientific papers was the highest for review papers (about seven to eight citations per year per paper), while other articles were cited mainly three to five times a year. Although the rate of average annual citation per paper is still relatively modest, there has been a trend of rising citation between 2018 and today, which is a very good sign for increasing the international visibility of scientific research in the field of artificial intelligence. From the above-mentioned estimated numbers of scientists and entrepreneurs and the number of contracted projects under EU and CSF calls, we conclude that the level of quality, i.e. excellence of researchers, as well as their success in obtaining research funds (especially in the European context) is very good (considering the success of applications for projects from the available data, as well as the average citation rate of papers), but that there is room for additional improvement, primarily in attracting competitive research projects.

The bulk of the secondary data on the application of artificial intelligence in the private sector comes from information on submitted and contracted EU projects, the second-level implementing body, HAMAG-BICRO, as well as from the call for tenders of the European Space Agency (ESA). Additionally, a valuable source of innovation potential in the field of application and development of artificial intelligence is the register of companies maintained by CroAI, the Croatian Artificial Intelligence Association, which has since 2019 been bringing together private companies and (which is extremely important) start-ups working with artificial intelligence, and this register contains over 340 organisations directly or indirectly related to the development and application of artificial intelligence in Croatia. Based on these sources, it is estimated that there are about **250 companies active in the development or application of artificial intelligence and machine learning methods in the Republic of** Croatia. In the above-mentioned calls for tenders, the companies were active or even more active (FP7 or calls conducted by HAMAG-BICRO) than public scientific institutions. Among the most active companies, in terms of successfully securing research funds, the companies Agrivi d. o. o., Ericsson Nikola Tesla d. d., INETEC d. o. o., Infra-plan j. d. o. o., Energo d. o. o., Hipersfera d. o. o., OIKON d. o. o., Poslovna inteligencija d. o. o., Geolux d. o. o., Arctis d. o. o., Biotechnicon d. o. o. and Hrvatski Telekom d. d. stood out from the rest. On the basis of the primary data, it was clear that the dominant markets were related to ICT, medicine, space and banking services, and that companies mostly used copyright protection and trademark registration as a model of management of intellectual property more than patent protection. When interpreting the results of the primary research related to companies, it should be noted that 24 of the 259 companies completed the survey.

From the surveyed researchers in the public and private sectors, it was evident that the level of cross-sectoral cooperation was high — as many as two-thirds of the companies surveyed cooperated with public research institutions, with a planned increase to 85%. From the perspective of the public sector, cooperation is somewhat poorer (partly due to the larger sample covered), but still boasts a good rate. Of the approximately 250 projects implemented or ongoing at the surveyed public scientific institutes and higher education institutions, 88 had a contracting authority from the private sector (of which 36 were from abroad). The lack of time (scientists are too busy with daily responsibilities), lack of resources (e.g. human or financial resources or research infrastructure) for collaboration and the lack of information on the needs of companies were cited as the reasons preventing or reducing the rate of cooperation. It is also evident, from the survey conducted at public scientific institutions, that the protection of intellectual property and the commercialisation of research were not high-ranking motivation factors, which further reduces the potential for collaboration with companies.

5.2 Recommendations

5.2.1 Support for Scientific and Applied Research

Recommendation: develop support instruments in fundamental and applied AI research. The field of artificial intelligence is highly prevalent in the public and private sectors of the Republic of Croatia. The field of artificial intelligence is showing a trend of growth, be it developing new or improving existing algorithms and tools for the use of AI methods or applying already existing methods in a wide range of sectors, from medicine, communication and agriculture to security and banking. Therefore, it is extremely important to support this growth right away in the short term by developing and investing in financial support instruments, both in fundamental and applied research. The existing national support system for fundamental and applied research (CSF, HAMAG-BICRO, etc.) needs to be further bolstered financially in order to increase the available funding for AI research, but also to increase the frequency of project calls, which would ensure timely funding for research ideas and further enable an increase in RDI in this field.

Recommendation: foster the development of artificial intelligence in the fields of health, environmental conservation and food product development, smart transport and security. The Republic of Croatia has already recognised the importance of the development and application of artificial intelligence methods through subscribing to the proposed thematic priority areas according to the draft proposal of the Smart Specialisation Strategy by 2029. In addition to digital products and solutions that strongly promote AI, another priority area of the Smart Specialisation Strategy is personalised health care. Given that this mapping identified the significant application of artificial intelligence in medicine, it is very important to emphasise that the merging of these two sectors, through the encouragement of cross-sectoral and interdisciplinary cooperation among private companies, health care institutions and research institutions, represents great potential for the Republic of Croatia. Therefore, it is recommended to bolster existing instruments and develop new ones that encourage such cooperation (especially by encouraging private companies to cooperate with the public health care sector). An analogous approach is also preferred in the priority areas of environmental conservation and food product development, smart transport and security, both digital and physical.

Recommendation: develop the national IT infrastructure. In cases where the development or application of some of the AI methods requires a greater computing capacity (either because of the complexity of the approach or the amount of target data), it is preferable to further develop national IT infrastructures, ideally by providing long-term financial and organisational support to the recently established Croatian Scientific and Educational Cloud (HR-ZOO). The availability and capacity of such infrastructure can be further bolstered by encouraging a partnership between the public and private sectors that allows the private sector to use the infrastructure based on a commercial or privileged model.

5.2.2 Competence and Skill Development

Recommendation: invest in the education of staff with competence in the field of artificial intelligence. Given that the field of AI is highly competitive and rapidly growing globally, there is a high risk of loss of human potential, primarily in the public sector and especially in higher education institutions. This would result in a slowdown in the education of new generations and a possible slowdown of the upward trend in working in this field. Therefore, it is of utmost importance to establish a high-quality meritocratic support system for top-tier competitive scientific research, primarily through facilitating access to human potential by creating conditions for more competitive income that would be more appealing on the international level, and then by simplifying the recruitment process, introducing a model of cumulative and part-time employment, as well as further reducing barriers to the recruiting of international scientists and professionals in the public and private sectors.

Recommendation: attract top-tier human potential to the field of artificial intelligence. Closely linked to the previous recommendation is encouraging top-tier scientists to seek employment at higher education institutions, which should multiplicatively increase the return on investment through high-quality education of scientists and experts of the next generation, who will be able to use the acquired knowledge in the scientific and economic sectors, through competitive science and the development of cutting-edge products and services in the field of artificial intelligence. In this context, it is essential to establish a system of additional financial support for recruitment, where professionals would be attracted not only by the position itself but also through competitive funding packages for the establishment of research laboratories with the aim of acquiring the necessary equipment, personnel and miscellanea, as is established in developed scientific environments.

Recommendation: develop new educational programmes that include a comprehensive approach to AI-related topics. Attracting top experts should also aim to develop new curricula focused on data sciences, quantitative disciplines and machine learning, combined with the educational content of targeted application technologies such as natural sciences, biomedicine, transport, security and social sciences. Such a combination of acquired knowledge and skills results in developed professionals who are much more willing and more prepared to apply AI methods in a wide range of areas.

5.2.3 Development of Innovation and Commercialisation Systems

Recommendation: foster the influx of high-risk capital into the ecosystem of AI companies. Because AI methods are increasingly present (primarily as a tool and way of dealing with problems) in a number of technological sectors, and because there is no major barrier to market entry for the application of a wide range of these methods, the ecosystem of companies that focus their activities on AI applications is seeing a huge increase in the number and diversity of target sectors and technologies. This is especially the case with start-ups. Access to risk and high-risk capital is of utmost importance for such an ecosystem, as it has proven, in the global innovation field, to be one of the key factors for the success of many start-ups (and is also taken into account in the ranking of the innovation potential of countries, e.g. via the European Innovation Scoreboard). The availability of high-risk capital should be ensured by increasing the international visibility of Croatian companies and researchers, for example by encouraging participation in international conferences, fairs or presentations. Also, it is necessary to systematically act in order to better present the good examples of successful Croatian companies in the field of artificial intelligence at the international level and among global high-risk finance operators in order to incite them to include the entire ecosystem of Croatian companies in their activities. In addition, the development and improvement of the private sector tax relief system should be used to make it easier for large and medium-sized companies to invest their profits in the establishment and support of national funds that would deal in high-risk capital and thus further strengthen the innovation potential of small and start-up companies.

Recommendation: foster further cooperation between the public and private sectors in the field of artificial intelligence. Cooperation between the public and private sectors is crucial for the further development of the application of artificial intelligence in the Republic of Croatia. It is thus essential to encourage such cooperation in addition to the previous recommendations on human potential development and targeted financial instruments linking the two sectors. In addition to financial instruments, it is necessary to provide the representatives of the private and public sectors with numerous opportunities for dialogue, through the organisation of joint seminars and scientific business meetings, in order for the representatives of both sectors to be able to find the widest possible common ground for future cooperation. Additionally, providing scientists from the public sector more flexible working conditions and adequate valuation should be used to further encourage them to devote part of their time to working in a commercial environment.

Recommendation: strengthen instruments for encouraging the protection of intellectual property resulting from projects implemented in the public and private sectors. In order to strengthen the cooperation between the public and private sectors, it is important to eliminate the protection of intellectual property and the commercialisation of research not being important motivators of scientists in their work, as this mapping has shown. It is necessary to provide financial instruments for the stable financing of intellectual property protection at public scientific institutions and use adequate valuation in the system of scientific advancement to encourage scientists in the public sector to focus more attention on the management of intellectual property generated by research.

Recommendation: encourage the commercialisation of research. It is necessary to ensure, through developing public policy in the scientific and economic sectors, that there is motivation for scientists to found start-ups or spin-offs. This includes raising awareness of the process of going from a scientific discovery at a public scientific institution and the protection of intellectual property to the establishment of start-ups or spin-offs, and ultimately to the institutional and national assistance in attracting investors or project funds for the initial operation of the company.

5.2.4 Society Development

Recommendation: develop ethical and legislative standards in the field of artificial intelligence. Given the extremely high potential and applicability of AI in a wide range of human activity, as well as the high risk of AI methods being applied in sectors of particular vulnerability (health, security, decision-making support or even decision-making itself), it is essential to focus society's activities towards developing a comprehensive set of ethical standards for the application of AI, as well as a wide range of legislative acts that allow for effective but also flexible regulation of AI application in all target areas. Such acts should regulate the rules, warrantability and prudence of applying AI methods in all aspects of society.

Recommendation: encourage the development of associations bringing together stakeholders involved in the field of AI. The field of AI is very well-represented through the representative association, CroAI, which brings together a wide range of companies, public institutions and researchers. CroAI periodically publishes a publication that presents the Croatian national landscape of companies, public institutions and individual stakeholders in the field of artificial intelligence (either as creators and providers of new technologies or as their users). This is an example of good practice in bringing all interested parties together around a topic of common interest, and also provides an already structured platform for dialogue between state authorities and all the stakeholders in the field. Therefore, it is necessary to further encourage the activities of this association through its involvement in the preparation of national legislative and strategic documents, but also as an advisory entity in the participation of the Republic of Croatia in strategic planning at the EU level.

Recommendation: strengthen the social responsibility of research in AI by bringing together all of the stakeholders. Artificial intelligence, due to its potential applicability in a wide range of technologies, is a digital discipline with a saliently high degree of expansion onto all spheres of society. Therefore, in addition to its commercial aspect, in the use of AI methods in response to existing and emerging global challenges, it is important to make all stakeholders aware of the societal importance of this digital transformation, which should be in line with the phrase *in society and for society*. It is therefore necessary to ensure the effective transfer of knowledge, skills and good practices, as well as to enable open access (open science and open data) communication among the private sector, scientific sector and public authorities. A good example is the involvement of all stakeholders in the European Digital Innovation Hubs (EDIHs), which are part of the Digital Europe Programme of the European Commission.

6 References and Appendices

6.1 List of Useful Links and References

- [Institute of Economics] https://mzo.gov.hr/UserDocsImages/dokumenti/EUfondovi/OPKK_2014-2020/ZTP/Analiticko-izvjesce-o-provedenom-znanstvenom-i-tehnologijskom-mapiranju-KK-01-1-1-03-0001.pdf
- [SCOPUS] https://www.scopus.com/search/form.uri?display=basic#basic
- Smart Specialisation Strategy https://mzo.gov.hr/vijesti/savjetovanje-o-prijedlogu-nacrta-strategije-pametne-specijalizacije-do-2029-s3/5203
- [ASJC] https://service.elsevier.com/app/answers/detail/a_id/15181/supporthub/scopus/
- [CSF — RP] https://hrzz.hr/programi/istrazivacki-programi/
- [CSF — YR] https://hrzz.hr/programi/razvoj-karijera/
- [CSF — International Cooperation] https://hrzz.hr/programi/medunarodna-suradnja%e2%80%8b/
- [HB — EUREKA] https://hamagbicro.hr/bespovratne-potpore/eureka/
- [HB — EUROSTARS] https://hamagbicro.hr/bespovratne-potpore/eurostars/
- [MINGOR — S3] https://hamagbicro.hr/otvoren-javni-poziv-inovacije-u-s3-podrucjima/
- [MINGOR — Voucher] https://hamagbicro.hr/javni-poziv-inovacijski-vauceri/
- [MINGOR — Innovation at Newly Established SMEs] https://hamagbicro.hr/javni-poziv-inovacije-novoosnovanih-msp-ova-ii-faza/
- [MINGOR — Innovation Commercialisation] https://hamagbicro.hr/objavljen-poziv-za-dostavu-projektnih-prijedloga-komercijalizacija-inovacija/
- [HB — IRCRO] https://hamagbicro.hr/bespovratne-potpore/programi-podrske-inovacijskom-procesu/ircro/
- [HB — RAZUM] https://hamagbicro.hr/bespovratne-potpore/programi-podrske-inovacijskom-procesu/razum/
- [MINGOR — RDI2] https://strukturnifondovi.hr/en/natjecaji/povecanje-razvoja-novih-proizvoda-i-usluga-koji-proizlaze-iz-aktivnosti-istrazivanja-i-razvoja-faza-ii/
- [Šestar] https://sestar.irb.hr/redirect.php
- [OECD publication on the commercialisation of research results] https://www.oecd-ilibrary.org/industry-and-services/supporting-entrepreneurship-and-innovation-in-higher-education-in-austria_1c45127b-en

6.2 Appendices

6.2.1 List of Tables

6.2.2 List of Figures

6.2.3 Glossary

Table 17 — Glossary.

Term or Acronym	Explanation
SCOPUS	SCOPUS is a comprehensive, expertly selected database of summaries and citations with enriched data and related scientific literature from various disciplines. It quickly finds relevant and authoritative research, identifies experts and provides access to reliable data, metrics and analytical tools.
Primary data	In order to collect the primary data that would give an insight into the two target areas, a survey questionnaire was created which included questions about basic information on the scientists, research and development projects, sources of funding, projects with the economic sector and other scientific institutions, infrastructure used, etc.

Secondary data	This data represents the data collected from available databases and secondary data sources of individual ministries, agencies and/or institutions related to different programmes in which researchers and engineers from the two target areas participate.
Research projects	For data related to contracted national competitive scientific projects, the projects taken into account were: — projects of the Croatian Science Foundation; — UKF projects; and — scientific projects from the European Structural and Investment Funds (excluding infrastructure projects). For data related to contracted international competitive scientific projects, the projects taken into account were: — projects of the EU Framework Programme for Research and Innovation (FP, H2020); — projects of the European Science Foundation (ESF); — projects of the Euroatom programme; — projects of the science foundations of EU countries; — projects of the National Institute of Health (NIH); — projects from Global Development Network donations; and — other projects for which public scientific institutes guarantee scientific significance and purpose (IPA as well as bilateral and multilateral projects are not included in this category).
Scientific organisations	The term *scientific organisation* refers to scientific institutes and higher education institutions which, in addition to higher education, carry out scientific activities, as well as scientific associations, state administration organisations and other public institutions carrying out scientific activities.

6.2.4 Survey Questionnaires

Survey Questionnaire for Researchers at Scientific Institutions

1. First and last name:
2. Name of scientific institution:
3. Email address of the researcher:
4. Telephone number of the contact person:
5. How many years of work experience do you have in the academic and research sector in research related to the topics Artificial Intelligence and Space Technologies? AI: ____, ST: ___
6. Please estimate the time you spent on average MONTHLY for scientific research in the fields of Artificial Intelligence (AI) and Space Technologies (ST) as a percentage (%): AI: ______% ST: ________%

7. Select the field where your R&D activities are most prevalent.

a) Artificial Intelligence (complete 7.1.) b) Space Technologies (complete 7.2.)

If you are active in both fields, please complete both parts of the questionnaire.

7.1. ARTIFICIAL INTELLIGENCE

Does your field of work relate to the development of AI methods and/or to the application of existing methods in one of the technological fields?

7.1.1. Development of artificial intelligence algorithms and methods (classification, regression, supervised, semi-supervised and unsupervised methods)

Please specify the algorithms and/or methods you are developing (e.g. neural networks, support vector methods, random forests and others), note that multiple answers are allowed:

A. k-nearest neighbours method;
B. support vector machines;
C. decision trees and random forests;
D. neural networks and deep neural networks; or
E. other, please specify: ______________________________
F. We do not develop artificial intelligence methods but use existing algorithms and methods.

7.1.2. Application of methods in the development of an innovative product or process to (choose up to three answers):

A. big data collection systems (image, voice or text);
B. planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources);
C. text recognition and processing systems (digitalisation and processing of archives);
D. image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth);
E. search systems (contextual search engines);
F. automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines);
G. expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.;
H. game development systems (logical games such as chess or the development of virtual or augmented reality environments);
I. the development of legal or ethical norms and principles for the operation of artificial intelligence; or
J. other, please specify: ____

7.1.3. Please select the applications, i.e. target markets, of the technologies listed in question 7.1.2. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. automotive industry;
2. banking and financial services;
3. electrics and electronics;
4. ICT and telecommunications;
5. medicine and biomedicine, medical devices;
6. energy;
7. construction;
8. geospace and space;
9. food and drink;
10. innovation and design;
11. mechanical engineering and naval architecture;
12. quality and improvement of business;
13. marketing, advertising, customer relations;
14. measurement and metrology;
15. waste and recycling;
16. agriculture;
17. legal affairs;
18. risk and insurance;
19. mining and materials;
20. security (including cybersecurity) and defence;
21. transport and logistics;
22. information management;
23. environmental management and sustainability;
24. virtual reality;
25. data protection; or
26. entertainment.

<u>7.2. SPACE TECHNOLOGIES</u>

Does your field of work within space technologies relate to one of the following technological fields?

7.2.1. Please mark up to 3 of the 15 listed fields that are primary in your work (if you are active in more than 3 fields, mark the 3 primary areas of your work):

upstream technologies for the development, construction, launch and maintenance of space systems (1–9);
midstream technologies that serve to establish connections between space systems (e.g. functional satellites) and end users (10–11);
downstream technologies for the exploitation of space data as well as the development and production of equipment for end users and for (12–15);

1. structures (launch systems, satellite systems, tanks or thermal control);
2. propulsion systems (solid, liquid, hybrid or electric propulsion);
3. load (optical and infra-red (IR) instruments, radars, telecommunications and navigation, automation and robotics or adaptive systems);
4. power supply systems (solar panels, batteries or electricity distribution);
5. mechanisms (satellite mechanisms or launcher mechanisms);
6. space subsystem control (Attitude and Orbit Control (AOCS) sensors and actuators);
7. on-board data subsystems (on-board computers, microelectronics, machine learning and artificial intelligence for on-board data);
8. communication systems (RF technology, antennas or telemetry, tracking and command systems (TT&C));
9. optoelectronics (optical communication, photonics, quantum technology, detector technologies or laser technologies);
10. terrestrial stations and operations (terrestrial stations, missions or terminals);
11. support systems (terrestrial support equipment, data processing, data archiving or data systems);
12. Earth observation (EO);
13. GNSS (Global Navigation Satellite System), i.e. for global positioning and navigation;
14. satellite communication; or
15. sustainability of space use and security in space, SSA (Space Situational Awareness), which includes modelling and risk analysis, collision avoidance systems, laser satellite tracking and space debris and asteroids monitoring.
16. If you work with space technologies that are not listed in the 15 items above, specify your field of work here: ______________________________.
17. We do not develop space technologies but are implementing existing solutions.

7.2.2. Please select the applications, i.e. target markets, of the technologies listed in question 7.2.1. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. Earth observation with applications in meteorology and climate observation, climate change monitoring, sea and water observation, forests and agriculture observation, etc., the Copernicus programme, led by the European Commission and the ESA, etc.;
2. GNSS applications, including applications in air transport, maritime transport, vehicle control, time measurement and synchronisation as well as search and rescue applications, or general applications in the industry sector using global positioning, Galileo or European GNSS, etc.;
3. services relying on satellite communications (SatCom services), broadband services, broadcasting services, telemedicine, secure communication, etc.;
4. terrestrial context — Earth stations, telemetry, monitoring, management and control;
5. flight operations — launch centres or launch vehicles;
6. research missions — life science, microgravity and the International Space Station (ISS); or
7. security in space — SSA, the application of collision and space debris avoidance technology or space climate monitoring.
8. If you apply space technologies in a market sector not listed in the 7 items above, specify that sector here: ______________________________.

II. Main Areas of Scientific Activity

2.1. Please specify the keywords that describe your scientific activity in the fields of artificial intelligence and/or space technologies.

Artificial intelligence: ____

Space technologies: ____

III. Competitive Research Projects

3.1. Have you been involved in competitive research projects (completed, ongoing or proposed) in the fields of artificial intelligence and/or space technologies, be it competitive scientific projects or collaborations with the business community?

Artificial intelligence: a) YES b) NO

Space technologies: a) YES b) NO

3.2. If yes, please indicate the number of competitive research projects in artificial intelligence that you have worked on as:

a) Project leader: ______
b) Project associate _____
c) In how many projects listed under a) and b) did your institution participate as the lead partner /coordinator? ____

3.3. If yes, please specify the number of competitive research projects in space technologies you have worked on as:

a) Project leader: ______
b) Project associate _____
c) In how many projects listed under e) and f) did your institution participate as the lead partner /coordinator? ____

3.4. The completed and ongoing competitive research projects (in the period from 2016 until today) in which you participated or currently participate in the field of artificial intelligence / space technologies are funded from the following sources:

Programme	Number of completed projects	Number of ongoing projects
HORIZON 2020, Horizon Europe		
Structural funds (RDI, SIIF, etc.)		
UKF (Unity through Knowledge Fund)		
PoC (Proof of Concept programme)		
IRCRO, RAZUM, EUREKA, Eurostars		
CSF (Croatian Science Foundation) programmes		
Other scientific projects, please specify:_____________________________________		

3.5. Do you have any PROPOSED international competitive research projects (waiting for evaluation, verification and not in the implementation phase) related to the AI/ST thematic area?

a) Yes b) No

3.6. If yes, please indicate to which programme(s) you have submitted AI/ST competitive research projects.

Programme	Number of projects submitted
HORIZON 2020, Horizon Europe	
Structural funds (RDI, SIIF, etc.)	
UKF (Unity through Knowledge Fund)	
PoC (Proof of Concept programme)	
IRCRO, RAZUM, EUREKA, Eurostars	

CSF (Croatian Science Foundation) programmes	
Other scientific projects, please specify: ___________________________________	

3.7. Please indicate the number of projects in cooperation with the business sector (private companies, research centres, etc.) where the business sector was the contracting authority from the field of AI/ST.

AI: Number of projects: ____; of which the number of companies from Croatia was:____, of which the number of companies from abroad was:___

ST: Number of projects: ____; of which the number of companies from Croatia was:____, of which the number of companies from abroad was:___

3.8. In the listed projects, which areas are your speciality; where do you have the most knowledge and experience?
____
____

3.9. Please specify a few scientific institutions you have collaborated with as part of your AI/ST projects / scientific papers.

<u>AI</u>
Croatian institutions: __________________________
Institutions from abroad (name of institution/country): ___________________________________

<u>ST</u>
Croatian institutions: ____
Institutions from abroad (name of institution/country): ___________________________________

3.10. Please rate the importance of the listed reasons for cooperating with partners (business sector and scientific institutions) on competitive research projects / scientific papers related to AI and ST in the period from 2016 to 2022 on a scale of 1 (Not important) to 5 (Very important).

Joint R&D project	1	2	3	4	5
Transfer of knowledge between partners	1	2	3	4	5

Procurement of services for research and development (R&D)	1	2	3	4	5
Technological consultation / preparation of technical documentation	1	2	3	4	5
Testing/creating a new prototype	1	2	3	4	5
Commercialisation of research	1	2	3	4	5
Licensing/registration of patents	1	2	3	4	5
Intellectual property	1	2	3	4	5
Joint publishing of research in journals in the WoS or SCOPUS databases	1	2	3	4	5
Other, please specify:_______________	1	2	3	4	5

3.11. Please rate the quality of your cooperation in the field of AI/ST so far using ratings ranging from 1 (Very poor) to 5 (Very good).

Cooperation with the research community	1	2	3	4	5
Cooperation with the business community	1	2	3	4	5
Cooperation with the government/public sector	1	2	3	4	5
Cooperation with the non-governmental sector	1	2	3	4	5

3.12. Please rate the importance of reasons why there is not a higher rate of cooperation. Rate your answer on a scale from 1 (low importance) to 5 (high importance).

We do not have enough information on the needs of the companies/institutions	1	2	3	4	5
We do not have enough incentives to work with companies/institutions	1	2	3	4	5
It is difficult to work with companies/institutions	1	2	3	4	5
The disclosure of business secrets in research is a concern	1	2	3	4	5

We don't have enough time because we're too busy with daily work	1	2	3	4	5
We do not have enough resources (e.g. human or financial resources or research infrastructure)	1	2	3	4	5
There is no need for innovation and technology projects	1	2	3	4	5
Other, please specify: ______________________________	1	2	3	4	5

IV. Intellectual Property and Commercial Potential

1. Have you used some forms of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research in the period from 2016 to 2022?

a) Yes b) No

2. If yes, which forms of intellectual property protection have you used to protect the results of your research between 2016 and 2022?

a) patent;
b) trademark;
c) industrial design;
d) copyright; or
e) some other right (please specify): _________

3. If you have applied for a patent, indicate how many patent applications you submitted from 2016 to 2022 in the AI/ST thematic area.

a) National patents (Croatia):
Number of patents applied for:__________
Number of patents granted: __________

b) International patents (WIPO, EPO or the national patent offices of other countries):
Number of patents applied for:__________
Number of patents granted: __________

4. If you have not used any form of intellectual property protection from 2016 to 2022, please provide a reason. (Multiple answers may be selected.)

a) The application process is too expensive.
b) Maintaining protection is too expensive.
c) The protection of intellectual property does not provide protection in our industry.
d) Other, please specify: ____

5. Have you licensed (or had income from licensing) your patent between 2016 and 2022?

b) Yes b) No

6. Have you established spin-off and/or spin-out companies from 2016 to 2022 in the Artificial Intelligence and/or Space Technologies area?

a) Yes b) No

7. If you have established spin-off and/or spin-out companies from 2016 to 2022 in the AI/ST area, please answer the following questions.

a) How many such companies were established? ____________________
b) How many are still active? _____________________
c) How many employees do these companies have on average (data from the last relevant year):______________
d) How much revenue do these companies have on average (data from the last relevant year in EUR):______________

8. Please state the results of your research in the AI/ST thematic area.

a) Manufactured or improved prototype of a product;
b) new service developed;
c) a new or significantly improved process;
d) scientific papers; or
e) other, please specify: _________________________

9. Have you commercialised the results of your competitive research projects between 2016 and 2022?

Note: commercialisation involves the use of knowledge from the scientific sector in the business sector to produce products and services for the market.

a) Yes b) No

10. If yes, please indicate the number of commercialisations in the period between 2016 and 2022.

_____

11. If you have not commercialised the results of your research in the field of AI/ST in the period between 2016 and 2022, please indicate the reasons.

Lack of means for commercialisation	1	2	3	4	5
Lack of expertise and experience needed for commercialisation	1	2	3	4	5
Difficulties in finding a partner for commercialisation	1	2	3	4	5
Strong competition in the market	1	2	3	4	5
Insufficient market demand	1	2	3	4	5
Lack of support from the institution at which the scientist is employed	1	2	3	4	5
Commercialisation of research results was not planned/expected	1	2	3	4	5
Other, please specify: ______________________________	1	2	3	4	5

12. Please list the portfolio of professional services you offer on the market for R&D activities (contracted research, studies, testing or training) in the fields of AI/ST.

AI: _____________

ST: _______________

V. Research Infrastructure

In this section, please indicate whether you use R&D infrastructure worth more than EUR 50,000.

Artificial intelligence
5.1. Do you use capital research infrastructure and equipment (supercomputers, computer equipment, data collection equipment, etc.)?
a) YES b) NO

5.1.1. If yes, answer the following questions for up to three pieces of equipment that you most frequently use:

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year?

a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO
- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ____________________________ (name of institution/company, city and country)

- Name of instrument/equipment ______________________________________
What is the percentage of your use of this equipment for research purposes during the year?
a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO
- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ____________________________ (name of institution/company, city and country)

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year? a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO
- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. ____________________________ (name of institution/company, city and country)

<u>Space technologies</u>

5.2. Do you use capital research infrastructure and equipment (telescopes, satellites, supercomputers, data collection equipment, etc.)?
b) YES b) NO

5.2.1. If yes, answer the following questions for up to three pieces of equipment that you most frequently use:

- Name of instrument/equipment ______________________________________
- What is the percentage of your use of this equipment for research purposes during the year?
a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%
- Is the equipment included in the Šestar database?
a) YES b) NO c) I don't know
- Do you own this equipment?
a) YES b) NO

- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. __________________________ (name of institution/company, city and country)

- Name of instrument/equipment ____
- What is the percentage of your use of this equipment for research purposes during the year?

a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%

- Is the equipment included in the Šestar database?

a) YES b) NO c) I don't know

- Do you own this equipment?

a) YES b) NO

- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. __________________________ (name of institution/company, city and country)

- Name of instrument/equipment ____
- What is the percentage of your use of this equipment for research purposes during the year?

a) < 25% b) 25%–50% c) 50%–75% d) 75%–100%

- Is the equipment included in the Šestar database?

a) YES b) NO c) I don't know

- Do you own this equipment?

a) YES b) NO

- If your answer to the previous question was NO, please indicate the owner of the equipment and where you use it. __________________________ (name of institution/company, city and country)

Please specify what you are missing in terms of research infrastructure to be able to generate new knowledge in research as well as innovation and ensure the transfer of new knowledge and technology in the AI/ST thematic area to a greater extent.

____

Thank you for your participation!

<u>Survey questionnaire for Companies</u>

1. First and last name:
2. Company name:
3. Email address of the contact person:
4. Telephone number of the contact person:
5. Company size: a) micro b) small c) medium d) large
6. Total number of employees at the company (FTE): ______

7. Select the field where your R&D activities are most prevalent.

a) Artificial Intelligence (complete 7.1.) b) Space Technologies (complete 7.2.)

If you are active in both fields, please complete both parts of the questionnaire.

7.1. ARTIFICIAL INTELLIGENCE

In the questions below, please indicate whether your field of work relates to the development of artificial intelligence methods and/or to the application of existing methods in one of the technological fields.

7.1.1. Development of artificial intelligence algorithms and methods (classification, regression, supervised, semi-supervised and unsupervised methods)

Please specify the algorithms and/or methods you are developing (e.g. neural networks, support vector methods, random forests and others), note that multiple answers are allowed:

A. k-nearest neighbours method;
B. support vector machines;
C. decision trees and random forests;
D. neural networks and deep neural networks; or
E. other, please specify: ______________________________
F. We do not develop artificial intelligence methods but use existing algorithms and methods.

7.1.2. Application of methods in the development of an innovative product or process to (choose up to three answers):

A. big data collection systems (image, voice or text);
B. planning and process management systems (e.g. traffic, manufacturing and industry processes, health capacity planning, urban planning or management of key national resources);
C. text recognition and processing systems (digitalisation and processing of archives);
D. image recognition and processing systems (archived or in real time, detection of objects in video surveillance or remote surveillance and reconnaissance from space, atmosphere and on Earth);
E. search systems (contextual search engines);
F. automotive systems (systems for autonomous or semi-autonomous driving, monitoring and movement of robots and machines);
G. expert systems to assist experts in medicine, natural sciences, transport, linguistics, psychology, philosophy, etc.;
H. game development systems (logical games such as chess or the development of virtual or augmented reality environments);
I. the development of legal or ethical norms and principles for the operation of artificial intelligence; or
J. other, please specify: ____

7.1.3. Please select the relevant applications, i.e. target markets, according to the answers given in question 7.1.2. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. automotive industry;
2. banking and financial services;
3. electrics and electronics;
4. ICT and telecommunications;
5. medicine and biomedicine, medical devices;
6. energy;
7. construction;
8. geospace and space;
9. food and drink;
10. innovation and design;
11. mechanical engineering and naval architecture;
12. quality and improvement of business;
13. marketing, advertising, customer relations;
14. measurement and metrology;
15. waste and recycling;
16. agriculture;
17. legal affairs;
18. risk and insurance;
19. mining and materials;
20. security (including cybersecurity) and defence;
21. transport and logistics;
22. information management;
23. environmental management and sustainability;
24. virtual reality;
25. data protection; or
26. entertainment.

7.2. SPACE TECHNOLOGIES

Does your field of work within space technologies relate to one of the following technological fields?

7.2.1. Please mark up to 3 of the 15 listed fields that are primary in your work (if you are active in more than 3 fields, mark the 3 primary fields of your business activities):

upstream technologies for the development, construction, launch and maintenance of space systems (1–9);

midstream technologies that serve to establish connections between space systems (e.g. functional satellites) and end users (10–11);

downstream technologies for the exploitation of space data as well as the development and production of equipment for end users and for (12–15);

1. structures (launch systems, satellite systems, tanks or thermal control);

2. propulsion systems (solid, liquid, hybrid or electric propulsion);
3. load (optical and infra-red (IR) instruments, radars, telecommunications and navigation, automation and robotics or adaptive systems);
4. power supply systems (solar panels, batteries or electricity distribution);
5. mechanisms (satellite mechanisms or launcher mechanisms);
6. space subsystem control (Attitude and Orbit Control (AOCS) sensors and actuators);
7. on-board data subsystems (on-board computers, microelectronics, machine learning and artificial intelligence for on-board data);
8. communication systems (RF technology, antennas or telemetry, tracking and command systems (TT&C));
9. optoelectronics (optical communication, photonics, quantum technology, detector technologies or laser technologies);
10. terrestrial stations and operations (terrestrial stations, missions or terminals);
11. support systems (terrestrial support equipment, data processing, data archiving or data systems);
12. Earth observation (EO);
13. GNSS (Global Navigation Satellite System), i.e. for global positioning and navigation;
14. satellite communication; or
15. sustainability of space use and security in space, SSA (Space Situational Awareness), which includes modelling and risk analysis, collision avoidance systems, laser satellite tracking and space debris and asteroids monitoring.
16. If you work with space technologies that are not listed in the 15 items above, specify your field of work here: ______________________________.
17. We do not develop space technologies but are implementing existing solutions.

7.2.2. Please select the relevant applications, i.e. target markets, according to the answers given in question 7.2.1. Please cite up to three market sectors (if you are present in more than three, please specify the 3 most important ones):

1. Earth observation with applications in meteorology and climate observation, climate change monitoring, sea and water observation, forests and agriculture observation, etc., the Copernicus programme, led by the European Commission and the ESA, etc.;
2. GNSS applications, including applications in air transport, maritime transport, vehicle control, time measurement and synchronisation as well as search and rescue applications, or general applications in the industry sector using global positioning, Galileo or European GNSS, etc.;
3. services relying on satellite communications (SatCom services), broadband services, broadcasting services, telemedicine, secure communication, etc.;
4. terrestrial context — Earth stations, telemetry, monitoring, management and control;
5. flight operations — launch centres or launch vehicles;
6. research missions — life science, microgravity and the International Space Station (ISS); or
7. security in space — SSA, the application of collision and space debris avoidance technology or space climate monitoring.
8. If you apply space technologies in a market sector not listed in the 7 items above, specify that sector here: ______________________________.

The following questions allow answers for activities/work in both of the fields; if you are active in neither of the fields, please reply with 0.

8. Please indicate the number of employed engineers/researchers/experts working in the Artificial Intelligence and Space Technologies areas; please enter the number referencing FTE (Full-Time Equivalent). If your company does not work in one of the fields, please reply with 0.

8.1. Artificial intelligence: ___________ (FTE),

8.2. Space technologies: __________ (FTE),

9. How many years of work experience do you have (as a company or research group) in research related to the Artificial Intelligence and Space Technologies thematic areas? If your company has experience in both areas, please enter the number of years of work experience for both.

9.1. Artificial intelligence: ____ year(s).
9.2. Space technologies:____ year(s).

10. Number of R&D projects you have worked on under the thematic areas from 2016 until today and roles held on those projects (an R&D project implies planned research with the aim of acquiring new knowledge or developing new products/services/processes):

10.1.1. Artificial intelligence: A total of ___________ projects, of which projects where you participated as the coordinator of the whole project: ___________

10.2.1. Space technologies: A total of ___________ projects, of which projects where you participated as the coordinator of the whole project: ___________

11. Please provide an indicative average annual value (for the period between 2016 and 2022) of R&D investment in the thematic areas (human resources, equipment or other). We suggest rounding the amounts to the nearest thousand, in EUR. For example, if you invested EUR 100,025, round down to EUR 100,000. If your company does not work in one of the fields, please reply with 0.

Artificial intelligence: EUR ___________

Space technologies: EUR ___________

12. Sources of funding for research and development projects under the thematic areas If your company does not work in one of the fields, please reply with 0.

12.1. We funded R&D projects under the **Artificial Intelligence** thematic area from the following sources (express as percentages so that the sum of the percentages is 100%):

a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): _______________________ (source), ____%

12.2. We funded R&D projects under the **Space Technologies** thematic area from the following sources (express as percentages so that the sum of the percentages is 100%):

a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): ___________________________ (source), ___%

13. Intellectual Property Rights Protection

13.1. Have you used some forms of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research in the period from 2016 to 2022?

a) YES b) NO (If NO, skip the questions about commercialisation and move on to question 14.)

13.2. Which forms of protection did you use for the results of your research from 2016 to 2022? For the selected replies, please also indicate the number of applications for protection if there were more than one.

<u>13.2.1. Artificial intelligence:</u>

a) Patent: _______
b) Trademark: __________
c) Industrial design: ___________
d) Copyright: ______________
e) Utility model: _____________
f) Some other form of protection (please specify): ______________, please specify the number:__________

<u>13.2.2. Space technologies:</u>

a) Patent: _______

b) Trademark: __________
c) Industrial design: __________________
d) Copyright: ____________
e) Utility model: _____________
f) Some other form of protection (please specify): ______________, please specify the number:__________

13.3. Have you licensed any of the elements of intellectual property protection?

13.3.1. Artificial intelligence: a) Yes, please specify the number of licenses _______ b) No

13.3.2. Space technologies: a) Yes, please specify the number of licenses _______ b) No

14. Cooperation with Scientific Institutions

Have you collaborated with scientific institutions under the two thematic areas between 2016 and 2022?

14.1. Artificial intelligence:
a) Yes
b) No

If yes, please indicate the number of projects collaborated on with scientific institutions during this period and list the institutions you have worked with under the thematic area.

14.1.1. Number of projects collaborated on with scientific institutions in the Artificial Intelligence area: ________

14.1.2. List of scientific institutions you have collaborated with in the Artificial Intelligence area: ____
____
______

14.2. Space technologies:
a) Yes
b) No

If yes, please indicate the number of projects collaborated on with scientific institutions during this period and list the institutions you have worked with under the thematic area.

14.2.1. Number of projects collaborated on with scientific institutions in the Space Technologies area: ________

14.2.2. List of scientific institutions you have collaborated with in the Space Technologies area: ____
____
______

15. Cooperation with Other Companies under the Thematic Areas

Have you collaborated with other companies under the two target thematic areas between 2016 and 2022?

15.1. Artificial intelligence:
a) Yes
b) No

If yes, please indicate the number of projects collaborated on with companies in the specified period.

15.1.1. Number of projects collaborated on with companies in the Artificial Intelligence area: ________

15.2. Space technologies:
a) Yes
b) No

If yes, please indicate the number of projects collaborated on with companies in the specified period.

15.2.1. Number of projects collaborated on with companies in the Space Technologies area: ________

16. Infrastructure

In this section, please indicate whether you use R&D infrastructure worth more than EUR 50,000.

16.1. Artificial intelligence
Do you use R&D infrastructure (supercomputers, computer equipment, data collection equipment, etc.) worth more than EUR 50,000?
a) YES b) NO

16.1.1. If yes, do you own your own R&D infrastructure or use infrastructure that is not owned by you (e.g. the infrastructure is owned by a scientific institution or by a commercial service provider)? Multiple answers may be selected.

a) We have our own R&D infrastructure for work on AI solutions. (Please specify the type and location.) ________________________________
b) We use external R&D infrastructure for work on AI solutions. (Please specify the type and location.) ______________ (name of institution/company, city and country)

16.1.2. Please indicate a percentage for the time of use of the said own equipment for developing solutions (the development of algorithms and methods as well as the application of methods) in the field of AI. _______%.

16.2. Space technologies
Do you use R&D infrastructure worth more than EUR 50,000?
a) YES b) NO

16.2.1. If yes, do you own your own R&D infrastructure or use infrastructure that is not owned by you (e.g. the infrastructure is owned by a scientific institution)? Multiple answers may be selected.

a) We have our own R&D infrastructure for work on solutions in the field of space technologies. (Please specify the type and location.) _________
b) We use external R&D infrastructure for work on solutions in the field of space technologies. (Please specify the type and location.) ______________ (name of institution/company, city and country)

16.2.3. Please indicate a percentage for the time of use of the said own equipment for developing solutions in the field of space technologies. _______%

16.3. If you own your own equipment and infrastructure, is there any possibility that you would rent it to other companies or scientific institutions, with the aim of achieving cooperation between scientific institutions and the private sector?

a) YES
b) YES — only to companies
c) YES — only to scientific institutions
d) NO

16.3.1. If you replied A, B or C, please specify the equipment you would be willing to rent to scientific institutions:
Artificial intelligence:
____

Space technologies:
____

17. Do you plan to recruit personnel to work in the Artificial Intelligence / Space Technologies areas in the next 3 years?

17.1. Artificial intelligence:
a) Yes (If yes, please specify the number of personnel you are planning to recruit.) __________
b) No

17.2. Space technologies:
a) Yes (If yes, please specify the number of personnel you are planning to recruit.) __________
b) No

18. How much do you plan to invest in development in the Artificial Intelligence / Space Technologies areas in the next 3 years? Round the amounts to the nearest thousand, in EUR. For example, if you invested EUR 100,050, round down to EUR 100,000. If you do not plan to invest, please reply with 0.

18.1. Artificial intelligence: EUR ____________

18.2. Space technologies: EUR ____________

19. Do you plan to collaborate with scientific institutions in the next 3 years?

19.1. Artificial intelligence:
a) Yes (If yes, please specify the institution with which you plan to collaborate.) ______________________
b) No

19.2. Space technologies:
a) Yes (If yes, please specify the institution with which you plan to collaborate.) ______________________
b) No

20. Do you plan to start working in new artificial intelligence / space technologies fields in the next 3 years (in which you have not worked so far)?

20.1. Artificial intelligence:
c) Yes (If yes, please specify these fields.) ______________________
d) No

20.2. Space technologies:
c) Yes (If yes, please specify these fields.) ______________________
d) No

21. How do you plan to fund future R&D activities?

21.1. Artificial intelligence:
a) Own resources: ____%
b) EU programmes and grants: _____%
c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): ___________________________ (source), ___%

21.2. Space technologies:
a) Own resources: ____%
b) EU programmes and grants: _____%

c) EU financial instruments (loans with low interest rates, guarantees on loans from commercial banks): _____%
d) Commercial loan from a commercial bank: ______%
e) Other sources (please specify): ___________________________ (source), ___%

22. Do you plan to expand to new markets? If yes, please specify which ones.

22.1. Artificial intelligence:
a) Yes (If yes, please specify which ones.) ______________________
b) No

22.2. Space technologies:
a) Yes (If yes, please specify which ones.) ______________________
b) No

6.2.5 List of Acronyms and Abbreviated Names of Institutions Used in this Report

Table 18 — List of acronyms and abbreviated names of scientific institutions.

Acronym or Abbreviated Name	Institution
Algebra	Algebra University College
DHMZ	Croatian Meteorological and Hydrological Service
Ericsson NT d. d.	Ericsson Nikola Tesla d. d.
HEP	Hrvatska elektroprivreda, Croatian national energy company
HKS	Catholic University of Croatia
HZJZ	Croatian Institute of Public Health
IFS	Institute of Physics
INANTRO	Institute for Anthropological Research
IOR Split	Institute of Oceanography and Fisheries
IRB	Ruđer Bošković Institute
Institute of Language	Institute of Croatian Language and Linguistics
KB Dubrava	Dubrava University Hospital
KB Fran Mihaljević	Fran Mihaljević University Hospital for Infectious Diseases
KB Merkur	Merkur University Hospital
KB Sveti Duh	Sveti Duh University Hospital
KBC Rijeka	Clinical Hospital Centre Rijeka
KBC SM	Sestre Milosrdnice University Hospital Centre
KBC Split	Split University Hospital
KBC Zagreb	University Hospital Centre Zagreb
MUP	Ministry of the Interior
NP Telaščica	Telaščica National Park
SSJEV	University North
SuDU	University of Dubrovnik
SuOS	Josip Juraj Strossmayer University of Osijek
SuOS EF	Josip Juraj Strossmayer University, Faculty of Economics
SuOS FERIT	Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology
SuRI	University of Rijeka
SuRI BIOTEH	University of Rijeka, Department of Biotechnology
SuRI FF	University of Rijeka, Faculty of Humanities and Social Sciences
SuRI FIZ	University of Rijeka, Faculty of Physics
SuRI INF	University of Rijeka, Faculty of Informatics and Digital Technologies
SuRI MEF	University of Rijeka, Faculty of Medicine
SuRI POM	University of Rijeka, Faculty of Maritime Studies
SuRI RITEH	University of Rijeka, Faculty of Engineering

SuST	University of Split
SuST EF	University of Split, Faculty of Economics, Business and Tourism
SuST FESB	University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture
SuST GRAĐ	University of Split, Faculty of Civil Engineering
SuST KIN	University of Split, Faculty of Kinesiology
SuST MEF	University of Split, School of Medicine
SuST PMF	University of Split, Faculty of Science
SuST POM	University of Split, Faculty of Maritime Studies
SuZD	University of Zadar
SuZG	University of Zagreb
SuZG AGRO	University of Zagreb, Faculty of Agriculture
SuZG EF	University of Zagreb, Faculty of Economics and Business
SuZG FER	University of Zagreb, Faculty of Electrical Engineering and Computing
SuZG FF	University of Zagreb, Faculty of Humanities and Social Sciences
SuZG FKIT	University of Zagreb, Faculty of Chemical Engineering and Technology
SuZG FOI	University of Zagreb, Faculty of Organisation and Informatics
SuZG FPZ	University of Zagreb, Faculty of Transport and Traffic Sciences
SuZG FSB	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
SuZG GEO	University of Zagreb, Faculty of Geodesy
SuZG GRAĐ	University of Zagreb, Faculty of Civil Engineering
SuZG KIN	University of Zagreb, Faculty of Kinesiology
SuZG MEF	University of Zagreb, School of Medicine
SuZG PBF	University of Zagreb, Faculty of Food Technology and Biotechnology
SuZG PMF	University of Zagreb, Faculty of Science
SuZG PROMET	University of Zagreb, Faculty of Transport and Traffic Sciences
SuZG RGN	University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
SuZG STOM	University of Zagreb, School of Dental Medicine
SuZG TTF	University of Zagreb, Faculty of Textile Technology
SuZG ŠUMFAK	University of Zagreb, Faculty of Forestry and Wood Technology
TVU Zagreb	Zagreb University of Applied Sciences
VU Krapina	Krapina University of Applied Sciences