Samuel Neaman Institute
for National Policy Research

Science & Technology

Artificial Intelligence, Data Science, and Smart Robotics- First report summary

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Background

The Israeli government acknowledges the potential of the Artificial Intelligence, Data Science and Smart Robotics domains in fostering the Israeli economy, its security and societal welfare. The government is interested in promoting and augmenting the development of these fields, by supporting private and public investments.

The National Council for Research and Development (MOLMOP) at the Ministry of Science and Technology has issued a tender requesting a study and review of the activities in these technological domains in Israel. The Samuel Neaman Institute was commissioned to perform a comprehensive mapping of activities in the Israeli academy, industry and government sectors, and to explore the possibilities for promoting and developing these fields in Israel.

This interim report constitutes the first output in a series of three deliverables planned in the framework of this project. The report summarizes the first eight months of the project, in which extensive work was carried out to define the respective research domains and to review and map the activities in these domains in Israel. The report also includes an initial identification of the strengths and weaknesses of the Israeli ecosystem in the AI, Data Science and Smart Robotics domains and offers preliminary Insights towards the formulation of a national strategic plan in these fields.

The literature survey in the appendix of the report, reviews among other topics, global strategic programs in these areas. A part of the literature survey is devoted to human capital and examines various skill and education requirements of local labor markets in selected countries.

Research Goals

The research goals are as follows:

- To map the activities in the fields of Artificial Intelligence, Data Science and Smart Robotics in the academia and in the industry in Israel; To review selected activities in the defense and the government sectors;
- To examine Israel's strengths and weaknesses and to identify opportunities and threats in these fields;
- To review strategic plans in leading countries in these fields;
- To present preliminary insights towards the formulation of a national strategic plan in these fields.

Definitions

This report deals with three broad fields of research related to each other: Artificial Intelligence, Data Science, and Smart Robotics. There is no single definition in the literature for these terms. The lack of a common definition was also demonstrated in the interviews conducted by the research team, in which various respondents expressed different opinions with regards to the definitions and the boundaries between them. In light of this finding, we chose to look at both artificial intelligence and data sciences at their broadest form. For example, artificial intelligence is defined as:

"Method for programming computers to enable them to carry out tasks or behaviors that would require intelligence if performed by humans"

National Academy of Sciences, 2018

The definition of Data Science is also complex. The relevant technologies comprising this scientific field are:

- **Technologies for collecting information**: Technologies that collect information for various uses, such as the Internet of Things (IoT).
- **Technologies for Information processing and analysis**: data mining technologies, information visualization and predictive analytics.
- **Blockchain-based technologies**: Blockchain Technologies, autonomous algorithms and smart contracts.

However, domains such as Analytical Prediction can also fall under the broad definition of Artificial Intelligence. Indeed, some interviewees referred to Data Science as the base of Artificial Intelligence, while others referred to Data Science as a field that includes Artificial Intelligence.

The term 'Smart Robotics' indicates a link between robots or actuators in the physical world and artificial intelligence. The EU attributes the following to 'Smart Autonomous Robots' (Nevejans, 2017):

- Acquires autonomy through sensors and/or by exchanging data with its environment (inter-connectivity) and trades and analyses data;
- is self-learning (optional criterion);
- has a physical support;
- adapts its behaviors and actions to its environment

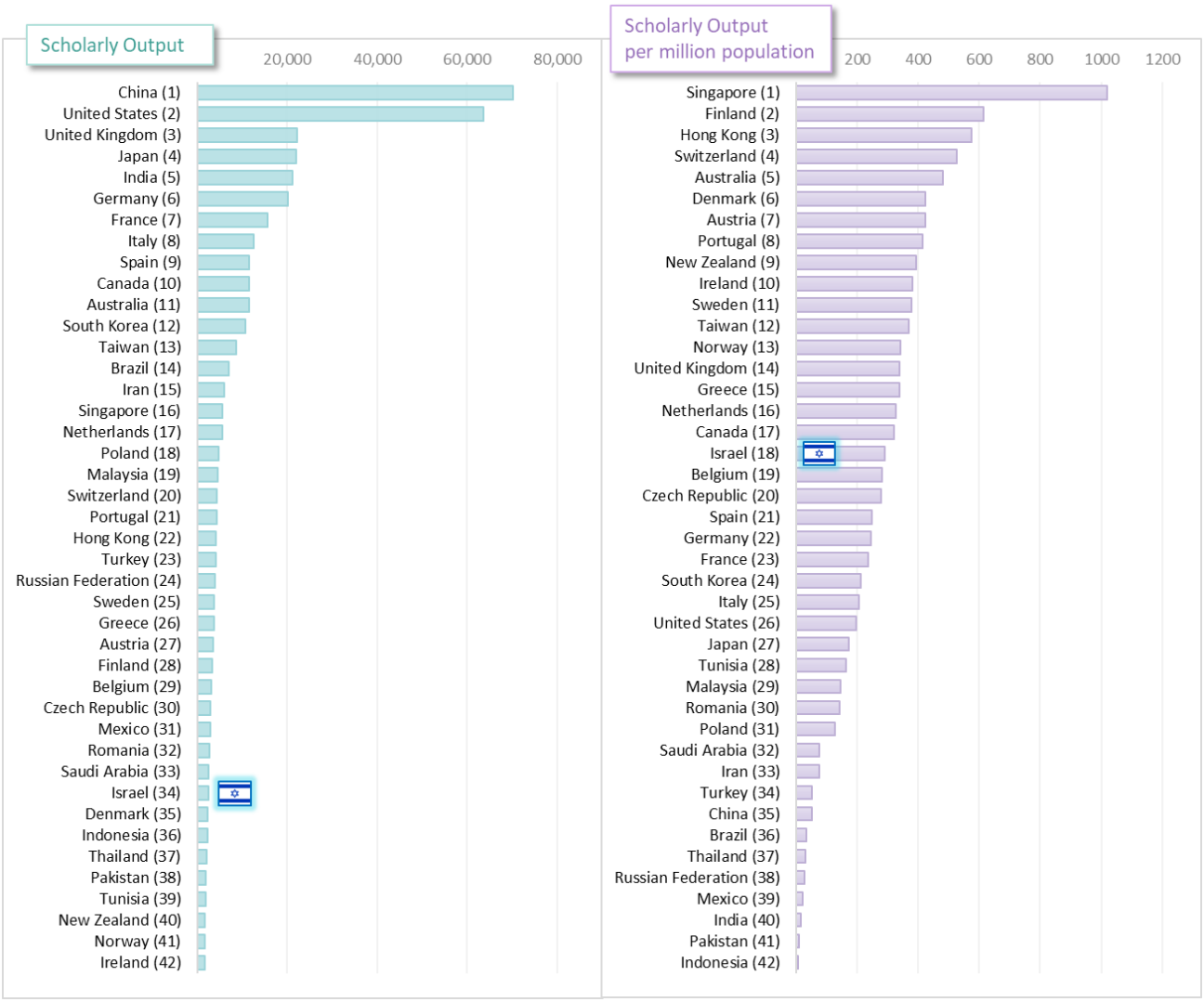
Research Outputs in Israel

► Scientific Publications

Preliminary findings show that China and the United States account for more than 36% of all world scientific publications in 2013-2017 in the categories defined as relevant to the research[1]. Israel is ranked 34th in total world scientific publications in these categories and 18th in publications per capita. (The leading countries in publications per capita are Singapore, Finland, Switzerland and Australia).

[1] The sub categories Artificial Intelligence, Human-Computer Interaction and Computer Vision and Pattern Recognition within the Computer Science category in the Elsevier's Scopus database.

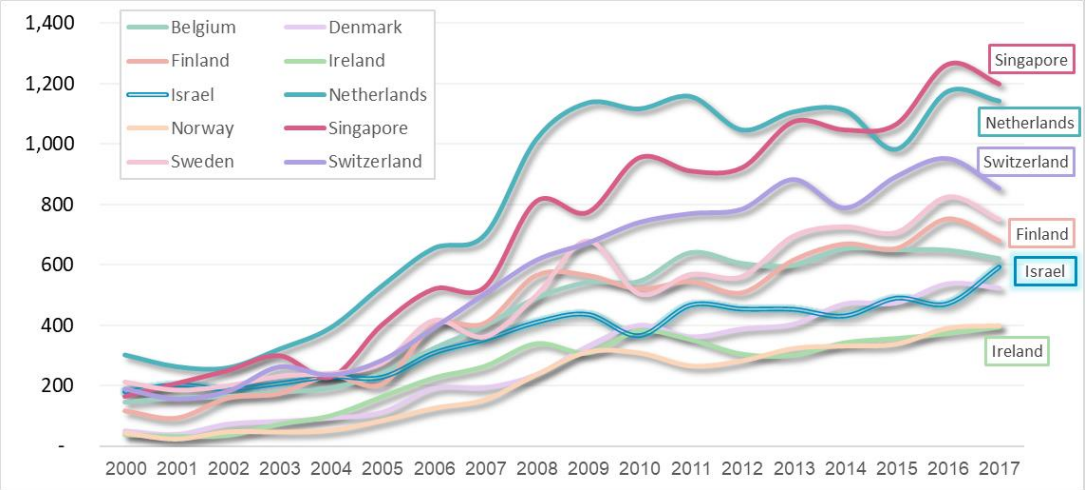
Figure 1: Total publications and publications-per-capita[2] by country, 2013-2017



Despite the increase in total Israeli publications between the years 2000-2017 (an increase of 229%), the rate of growth in countries such as Singapore, the Netherlands and Switzerland was higher (630%, 279% and 351%, respectively). The rate of growth in publications of the OECD countries was also larger than that of Israel in this period (409%).

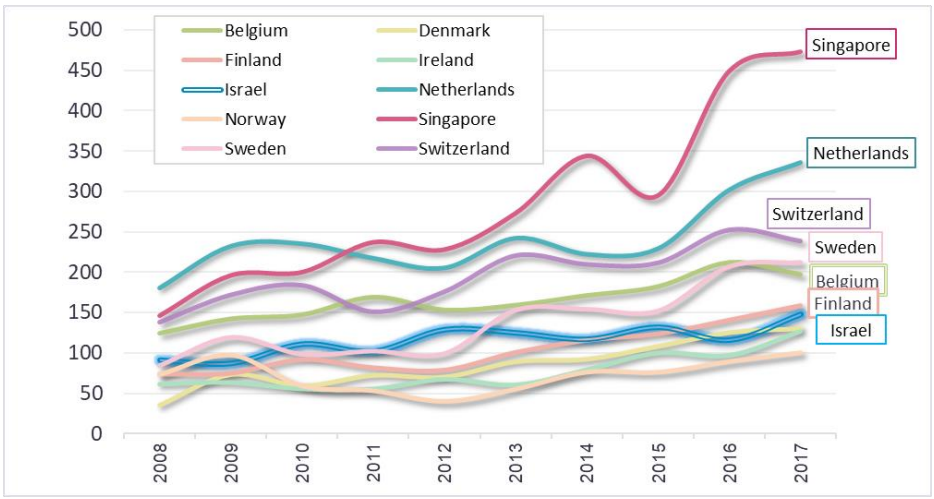
[2] In Artificial Intelligence (AI), Human-Computer Interaction (HC), Computer Vision and Pattern Recognition (CV)

Figure 2: Changes in the number of Israeli publications[2] compared with 'comparable countries'



High rate of growth in international cooperation between researchers contributes to the sharing of knowledge and the advancement of science. The number of Israeli joint publications has increased by 63% in years 2008-2017, but the growth rate was relatively low with respect to comparable-countries such as Singapore, which demonstrated a 224% increase in joint publications in this time period.

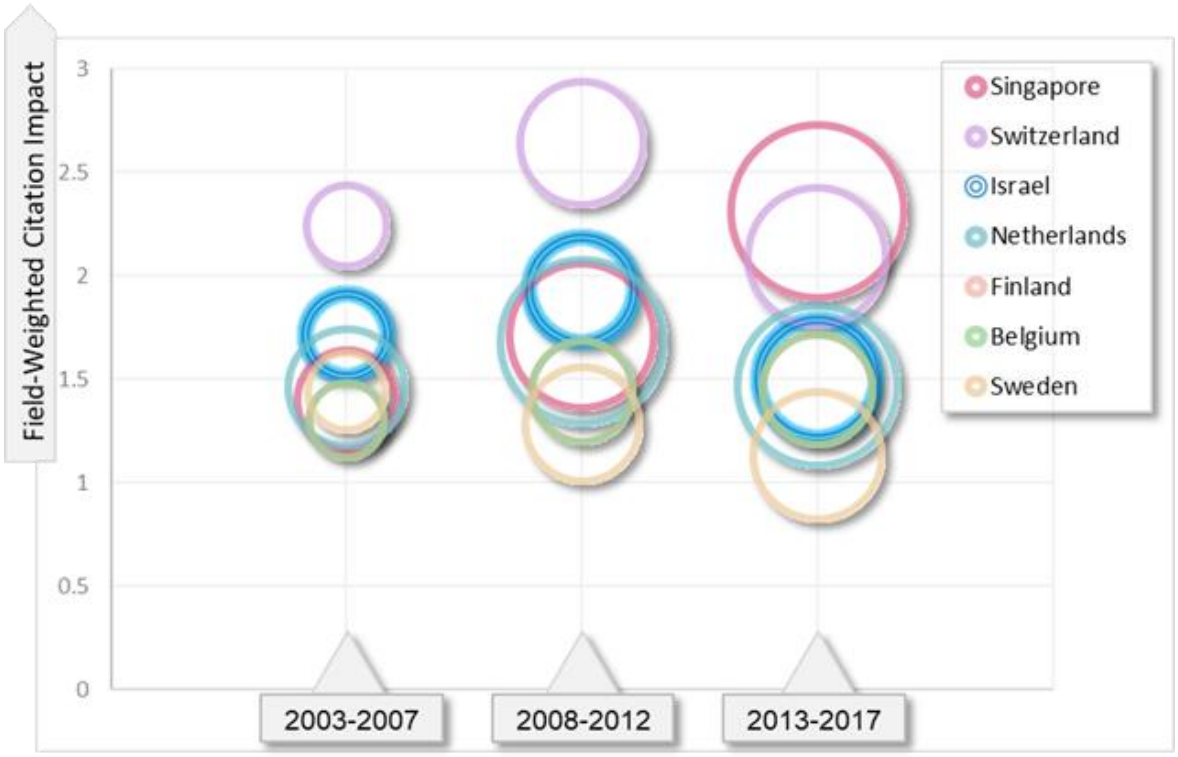
Figure 3: Number of internationally coauthored publications[3], 2008-2017



The number of citations per article constitutes a major indicator of the academic impact of the study. Singapore leads the growth rate in the number of publications in the group of the 10% most cited articles in the Artificial Intelligence category (252%). Israel demonstrated a moderate increase in this index in the relevant period.

[3] Artificial Intelligence category in Scopus/SciVal

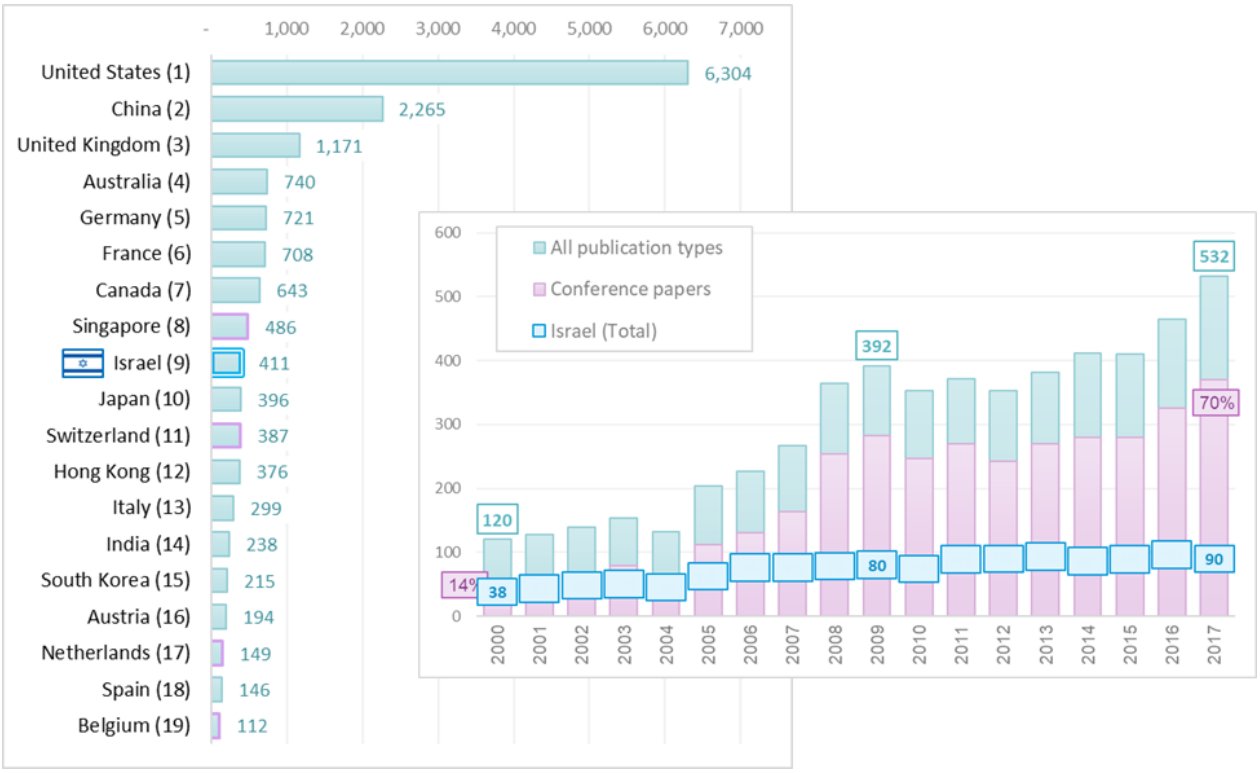
Figure 4: Number of publications[3] and normalized average citations in Israel and in 'comparable countries' [3], 2003-2017



It should be noted that the number of leading researchers who have published more than five articles in the last five years in the field of Artificial Intelligence in countries such as Singapore, the Netherlands and Belgium is significantly higher than the number of prominent researchers in this field in Israel. However, Israeli researchers do not fall short of researchers from these countries in terms of productivity (number of publications per researcher), and even surpass them in some cases.

Israel researchers published more scholarly output in 5 leading conferences (AAAI Conference on Artificial Intelligence, Computer Vision and Pattern Recognition, International Conference on Machine Learning, International Joint Conferences on Artificial Intelligence, Neural Information Processing Systems) in 2013-2017 than any other 'comparable country' except Singapore. Israel ranks 9 in the world in the number of publications in these conferences in the last 5 years.

Figure 5: Publications in 5 leading conferences by country, 2013-2017

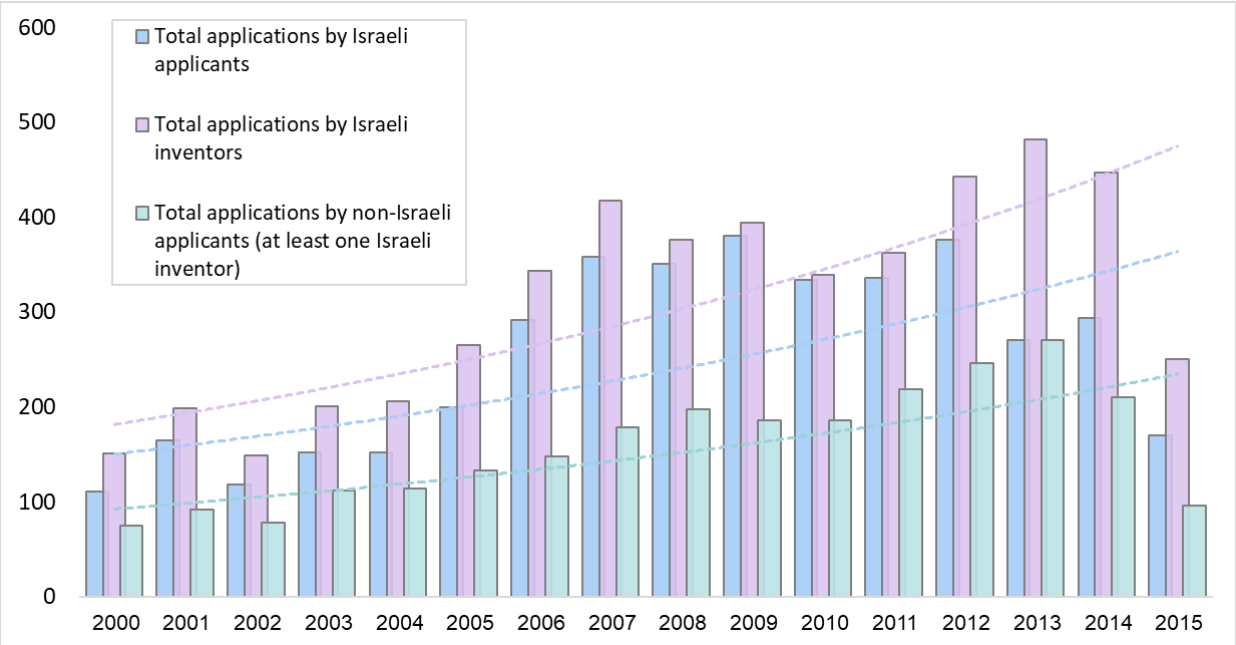


Israeli researchers have received 483 ERC grants, with only five of the EU member states and one associated state surpassing them in the number of grants. More than 5% (at least 26 grants) of the ERC grants received by researchers from Israeli universities were in fields related to Artificial Intelligence, Data Science and Smart Robotics.

► Patents

The total number of distinct applications for AI patents applied by Israeli applicants increased by an average of about 10% per year between the years 2000-2014. Applied Materials (Israel) leads the Israeli companies in the number of distinct patent applications, with IBM leading in number of patent applications by multinational companies with R&D centers in Israel.

Figure 6: Patent applications in AI for Israeli applicants, Israeli inventors and non-Israeli applicants (at least one Israeli inventor)



The leading patent technology classification (in terms of the number of distinct applications) is the 'Input arrangements for transferring data', which refers to input processing that can be manipulated by the computer (i.e. connected to a computer interface). This is also the leading technology for multinational companies with R&D centers in Israel, followed by a writing recognition technology.

Findings and Insights Based on In-Depth Interviews

The research team had conducted about sixty in-depth interviews, with several goals in mind:

- Understanding the current state of Artificial Intelligence, Data Science and Smart Robotics in Israel
- Qualitative analysis of the following research questions:
  - What are the main problems that practitioners in the relevant fields face? (e.g. manpower, training, research and infrastructure)
  - What are the fields of knowledge and business sectors in which Israel has an advantage within the broad fields of Artificial Intelligence, Data Science and Smart Robotics?
  - How can these fields be advanced in Israel?

Despite the relatively high number of interviewees, the findings in the next section should be regarded merely as tentative indicators. In the next part of the study, these indicators will be examined by surveying over 160 Israeli firms in the relevant fields.

► Infrastructures

» Data Infrastructures

Finding 1: Artificial Intelligence and Data Science are based on data. Shortage of data is one of the most significant barriers to progress in these fields.

Finding 2: There are two major sources for data: the industry (firms such as Google, Facebook, Amazon and others) and government agencies. Interviewees who addressed the issue of data shortage remarked that government intervention is required to ensure that government data is available for research purposes.

Insight 1: Opening governmental and public databases for research purposes is recommended, as well as building appropriate technological infrastructure, determining models for the use of databases, and addressing issues of information privacy and transparency.

Insight 2: Encouraging academic-industrial cooperation is recommended, especially for the transfer of data from industry to academia and/or start-up companies. Support for such endeavors can be achieved through the simplifying of intellectual property issues, prioritizing support requests in which the data is a significant component, and other means.

» Computing Infrastructure

Finding 1: There are two main models for hardware usage: local use of computers with Graphic Processing Unit (GPU's), and distributed use of servers in firms that offer cloud services, such as Amazon.

Finding 2: Some interviewees from the academic sector believe that there is sufficient computing power for research in universities. Others think that centralized management of cloud resources can streamline usage, mainly because of the fixed (monthly) payment model versus actual variable usage (pay per hour usage).

Finding 3: There is a growing shortage of computing power for university training.

Finding 4: The costs of computing power may be a barrier to start-ups and people who wish to enter the field independently.

Insight 1: A thorough examination of computing-power needs in university faculties which conduct research and training in Artificial Intelligence and Data Science is required to ensure computing infrastructures meet the required standards.

Insight 2: An examination of computing-power needs in Israeli industry, with an emphasis on small and medium-sized companies, is required to examine whether computing power is a barrier that should be lowered (the Companies Survey, which is part of the next stage of the research at the Neaman Institute, will address this issue).

» Smart Robotics Infrastructures

Finding 1: Israel has high-quality workforce in the field of Smart Robotics and several successful companies in certain niches of this field. However large investments are required to create the infrastructure needed for the development of Smart Robotics in industry and academia in Israel.

Finding 2: The technological infrastructure and expertise needed for the integration of mechanical engineering, software and robotic applications is lacking.

Insights: Until today the state of Israel has not yet officially recognized Smart Robotics as a field of national priority. Such a recognition will need to result in significant financial investments in infrastructure for research and development to bring Israel into line with other leading countries.

► Human Capital and Training

» Graduates of Non-Research Degrees

Finding 1: In the field of Data Science, there is an increasing demand for first-degree graduates with knowledge in the field. The demand is both from technological and non-technological firms. The demand for graduates is expected to grow significantly in the near future, especially among non-technological firms. The most significant increase in demand is expected for data engineering, data planning, data treatment and data control (optimization, labeling, etc.), data analysis and visualization.

It is important to note, however, that some of the literature suggests that areas such as analysis and visualization of data will undergo a process of automation and will require a smaller number of workers.

Finding 2: Some firms in the field of Artificial Intelligence and Machine Learning look for first-degree graduates with basic understanding in Artificial Intelligence and knowledge in AI tools for development (not research) roles.

» Graduates of Research Degrees

Finding 1: Graduates of research degrees in different areas of Artificial Intelligence are in great demand. Research in these areas (including industry) requires a broad scientific basis.

Finding 2: The number of students interested in pursuing research degrees is greater, in certain departments of some universities, than the ability of researchers to take in new students, especially in Artificial Intelligence .

Finding 3: An increase in industry demand for undergraduate students (see above) can possibly reduce the number of students interested in pursuing advanced degrees.

Finding 4: Large multinational firms are interested in employing leading researchers. In the US and elsewhere in the world, there is a strong competition between academia and industry, with the industry providing high wages and comfortable work conditions for senior researchers, with which the academia is incapable of competing.

Insights: Activities to promote the fields of Data Science and Artificial Intelligence should lead to an increase in the number of research students in order to meet the needs of the industry and to produce future generations of academic researchers. When considering the competition with industry and with universities abroad, several major coping strategies emerged:

a) Emphasizing the benefits of academia over the industry, including tenure and job security, the possibility of conducting meaningful research with academic freedom (for

faculty members), and the possibility of finding better positions in the job market (for students).

b) Significant improvement in access to data, including data that exists only in academia (see section on Data Infrastructure).

c) Scholarship-differentiation for students and salaries-differentiation for faculty members in fields of intense competition with industry and with universities abroad. Some suggestions were: post-doctoral fellowships for returning researchers and acceleration of tenure track for researchers.

d) Examining the desired model for university researchers work in industry. The models mentioned by the interviewees were:

   - Working in the industry one day a week (allows the researcher to be exposed to real life problems in industry);
   - Full-time job in academy and a full-time job in industry;
   - Unpaid leave for work in the industry for a specified period.

» Non-academic Training

Finding: There is room under existing market conditions for non-academic professional training. Such training can be useful for tool operators and for engineering or exact sciences graduates who aim for entry level positions.

Insight: An in-depth examination of the demand for graduates of non-academic professional training is required (the Companies Survey, which is part of the next stage of research at the Neaman Institute, will address this issue).

» Introduction Courses in Faculties of Engineering and Exact Sciences

Finding: Faculties of Engineering and Exact Sciences are considering giving students introduction courses to Artificial Intelligence and Data Science.

Insight: Market changes and the demand from students are leading the universities to prepare for the opening of these courses without external intervention. It is necessary to examine the possibility of expediting the granting of permits for such courses in order not to delay the universities

» Training in Faculties of Social Sciences and Humanities

Finding: Data Science is becoming a major research method in Social Sciences and Humanities. A basic understanding of the terminology and the possibilities of Big Data should be part of the digital/scientific literacy required from university graduates.

Insight: Graduates of Social Sciences and Humanities will need a certain type of training in Data Science in order to integrate into the future work and research world.

Israel's Strengths in Artificial intelligence, Data Science and Smart Robotics

Finding 1: The prominent AI areas mentioned as those in which Israel has an advantage in are medicine and cyber. Transportation and game theory were also mentioned.

Finding 2: Today Israel has no relative advantage in Smart Robotics. Creating an advantage in this field is possible with proper investments in infrastructure and training.

Finding 3: One of Israel's relative advantages is its unique ecosystem, academia-industrial-military-government ties, and the ability to respond relatively quickly to changes while taking advantage of "economy of (smaller) scale".

Insight: An in-depth examination of Israel's strengths is required (the Companies Survey, which is part of the next stage of the research at the Neaman Institute, will address this issue).

Next Phases of the Research

In the next phase of the project, a survey will be distributed among industry firms to reinforce and validate the findings and Insights that emerged from the in-depth interviews.

This will be followed by a review of topics that have not been addressed so far, such as ethics, privacy and transparency issues in Artificial Intelligence, Data Science and Smart Robotics

A final validation of the entire work will be done by round tables and/or brainstorming sessions, or other discussion methods.

Main Insights from Other National Strategic Plans

Between 2016 and 2017, seven national AI strategic plans have been launched in the United States, China, Japan, Canada, United Arab Emirates, Singapore and Britain. Some of those strategic plans dealt with smart robotics as well. The last two years, therefore, have been the crucial point in time in which nation states have realized the power of AI and the importance of R&D and readiness for its coming. By going over the seven plans from said countries, we have come up with several shared principles and guidelines.

► First Principle: Let the Industry Lead

All national programs relate to industry as a leading factor in the field of artificial intelligence. The industry leads in the realization, development and implementation of the principles discovered in academic research but is also capable of conducting high-level research on its own, by employing the most skilled researchers and attracting academic researchers. The industry is also able to change direction quickly - an important capability in an evolving field such as artificial intelligence, where existing perceptions can change dramatically overnight.

This acknowledgement has led to even highly-centralized China admitting that progress in the field of artificial intelligence must be made by relying on the industry as a leading factor and announced in its strategic plan that ‘the free market rules’.

In some of the national plans made by the United States, China, Singapore and the UK, the participation of the general public in the R&D process was also addressed, and the authors recommended urging the creation of maker spaces and joint platforms where inventors, developers and the general public could work alone and together to develop new applications in artificial intelligence. Suggestions were also made to open up access to databases - especially governmental ones, or information produced in government-funded academic studies - to the public. The data would be anonymized, of course, but could still help inventors and developers to train AI engines that could then be released to the market.

Through reliance on the industry and the public as leaders of innovation, the above countries intend to explore as many AI fields and possibilities as possible, at a low cost to governments .

► Second Principle: Governments Must Support Fields Left Neglected by the Industry

Industrial companies will advance many AI fields, but their interests are limited by necessity to services and products that can make a profit in a short time. A good example of this was when Google bought Boston Dynamics, the world's leading robot company, and got rid of it shortly after, realizing that the company's products were not yet ready to enter Market (Macfarlane, 2017).

In order to further promote certain aspects of artificial intelligence that are not profitable, governments will be required to support studies of several major types in academia:

a) **Basic-technological research:** Basic research is needed for developing AI theories that will ultimately bring about the next generation of technologies. History shows that basic research of this type, which was subsidized especially by the US government, yielded within decades the Internet and the technology and theories surrounding deep learning, which elevated artificial intelligence to new heights.

b) **Social research:** It is of critical to focus on the ethical and legal challenges posed by artificial intelligence to social institutions. Studies of this sort will hardly be carried out by the industry itself, and therefore requires governmental support.

c) **Research to promote an open market of innovation:** Research is needed to promote an open market of artificial intelligence by creating databases that all companies can enjoy free access to and development of open source software libraries and toolkits.

d) **Setting standards:** Governments must provide coordination and leadership in order to promote the creation of shared standards and encourage their widespread use in government, academia, and industry.

Additionally, governments must support the acquisition of exceptional talents in the field, bringing them to academia, and finding ways to keep them there, where they can train promising young researchers.

► Third Principle: Data is the New Oil

There is broad agreement that "data is the new oil". Without accessible and available databases, it will be difficult to open the market to innovation. As such, many national programs emphasize the release of as much information as possible to the general public through the creation of open databases. The data itself will come from academic studies supported by the government, and from government ministries (after anonymization).

► Fourth Principle: Coordination Among All Relevant Actors

The national plans call for coordination between all the relevant bodies in order to maximize the chances of success, and with the understanding that each sector - industrial, academic and governmental - can provide its own advantages. Such coordination can be realized in a number of ways, as follows –

- **Establishing an "AI Council"**: the AI Council will supervise the coordination between the different institutes and organizations and ensure that the national plan continues to progress at a sufficient pace and in the right direction.
- **Pushing towards coordination between organizations:** actively encouraging academic researchers to cooperate with industry. Government offices will assist the industry in assimilating artificial intelligence technologies in their activities and will help them in turn by providing firms with relevant public information.
- **Coordination between research centers**: It is vital that research centers work together, collaborate and share their computing power for artificial intelligence research.
- **Coordination in industry**: It is recommended that the largest companies coordinate the establishment of the infrastructure required to support start-ups and commercialization of products, and the establishment of open platforms to encourage and support innovation.
- **Setting shared standards** :The artificial intelligence community - users, industry, academia, and government - should take part in developing shared standards.
- **Coordination between the military and civilian sectors**: China especially emphasizes the coordination between the military and civilian sectors and means to further the integration between the two sectors in artificial intelligence, to establish mechanisms for normalizing communication and coordination between scientific research institutions, universities, factories and military units and to promote the military use of artificial intelligence to support military decision making and other military applications.

► Fifth Principle: Acknowledging the Soft Aspects of Artificial Intelligence

AI systems will necessarily operate according to the formal and informal norms prevalent in every human society. Therefore, in-depth research is needed on the rules of ethics, law, privacy, law, and society to which AI systems will be subject. This issue is so important that the United States and China have identified that it is one of the major challenges to be addressed.

In addressing the ethical, ethical, and legal aspects of artificial intelligence, one must understand how to improve the transparency of the algorithms that govern the lives of citizens, and how to incorporate the limitations of law and fairness into artificial intelligence. It is necessary to understand how to build ethical artificial intelligence, which adheres to existing laws, social norms and ethical principles, and to decide on a precise formal formulation of all such laws, norms and principles.

The answers to these questions will come from interdisciplinary studies that will advance the integration of AI with other fields such as neurology, cognitive science, psychology, mathematics, economics, sociology and others. As stated in China's strategic plan "the focus should be on finding answers to the legal questions raised by artificial intelligence, and where there is no consensus, scientists should be encouraged to explore freely, show daring and develop more original theories and discoveries."

► Sixth Principle: Understanding and Preparing for the Future of Work

There is a clear recognition that artificial intelligence technologies are capable of influencing the labor market by taking over human jobs on the one hand and creating new and desired professions on the other. Almost all the strategic plans require an examination of the future of work, to understand how to adapt the labor force in the country to the new needs of the market and technology. China will explore intensively how AI would change employment and the skills required for the new professions. The United States has made clear that there is a shortage of artificial intelligence experts compared to the demand they have. The UK recognized that there will be great demand for highly trained people in the field of artificial intelligence.

At the same time as research on the future of labor ensues, governments should support the development of a system of employee training and lifelong learning that will meet the needs of the new industry, in collaboration with universities and the industry. This support can be realized in a variety of ways, such as the development of online courses open to the public, the subsidization of high degrees in artificial intelligence and the development of a scholarship program for researchers and workers in the field of artificial intelligence.

Literature Review Findings Related to Scientific and Technological Workforce Requirements

Governmental agencies, as well as private sector bodies, are closely studying the unique workforce requirements in the fields of Artificial Intelligence, Data Science and smart Robotics. The current research describes changes in workforce demands and competencies relating to these fields. In addition, some of the actions undertaken by several countries to promote workforce capabilities in these areas are also described.

► Data Science

The reports studied in the current literature review predict a significant rise in demand for competent workforce in the various data science fields. These include business and financial analysts, managers with data analytics related capabilities and data scientists skilled in constructing sophisticated data models. According to the findings, a rise of 12% in demand for data science related workforce is expected in the US. The demand can cause, under certain circumstances, a shortage of approximately 250,000 workers by 2024 if certain data related actions (such as data preparation and cleaning) will not become automated. The demands are expected to rise from fields such as finance, insurance, professional services, manufacturing, healthcare, retail and more .

Additional countries such as Canada, Japan and Singapore are also expected to experience a significant rise in demand for skilled data science related employees in the coming years. In Israel a substantial demand increase of tens of percent has been noted in 2017.

Several reports show that the demand for data analysts with high analytical skills and sophisticated modelling capabilities is expected to be significantly lower in compare to other data related professions such as database administrators and managers (for example project or marketing managers) utilizing data for decision making.

The data science related skills vary between the different professions. Data science requires computing and programming capabilities, Business Intelligence (BI) skills and financial analysis. Additional proficiencies such as C++ and Python programming as well as machine learning and data storage abilities will be required for top-tier professionals (example data scientists). Data management and analysis skills will be an integral part of multiple professions.

Acquiring the relevant skills is done by various methods. Hundreds of US students have been involved in university data science related study programs. Employees in the industrial sector have undergone trainings performed in joint industry-academic collaborations, gaining basic data science knowledge. Students with mathematical and engineering background take part in bootcamps or Massive Open Online Courses (MOOCs). The graduates of such training programs gain skills in computer programming, statistics, machine learning, data mining, big data platforms and tools for performing data visualizations.

» Edison Project

The Edison Project[4], supported by the European Union, has comprehensively examined the needs for establishing the data science professions, and matching its relevant skills to the industrial needs. Four different aspects of the profession have been defined in this project: competencies[5], bodies of knowledge[6], learning programs[7] and professional profiles[8]. Since the Edison Project's reports are very detailed it is recommended to fully review them in the links provided herein. The reports provide a comprehensive picture of the profession components required and assist in establishing relevant educational and training programs.

► Artificial Intelligence

As mentioned, Artificial Intelligence (AI) is ambiguously defined as a separate discipline from data science on one hand and as complementary to it (for example, by using advanced data analytics tools for creating educated predictions) on the other.

A significant AI talent shortage currently exists and is also expected in the future. The supply versus demand ratio for this workforce has led to a substantial increase in professional workers' salaries. Due to the competition between the big technological companies, these can reach as high as $25-40 thousand USD a month in the US and 33 thousand NIS in Israel.

In the US, a 14-fold increase in the number of companies developing AI technology and a 6-fold increase in venture capital AI technology investments has been observed since the year 2000. The major increase was in the years 2010-2015. The demand for AI workers has risen 4.5 times in the US since 2013 and 10 times in Canada. In the UK, a 5-fold increase occurred with about 2.3 openings available for every worker. In Israel, according to several estimations, there is a shortage of at least 400 engineers for the core AI competencies (computer vision, deep learning and image processing).

An estimated number of 5000 professionals across the world are leading the AI field, participating in scientific conferences and publishing scientific papers relating to artificial intelligence. The number of people with significant knowledge in the field is estimated in the tens of thousands. Following the understanding of the potential embedded in this technology, governments are establishing AI R&D centers with billions of dollars investments.

There are multiple reasons for the AI talent shortage. Among these reasons is the fact that AI requires professional knowledge combining multiple disciplines such as data science, software engineering and expertise in mathematics and statistics, where workforce shortage may already exist .

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[4] The EDISON Data Science Framework [website]

[5] Data Science Competence Framework (CF-DS) [website]

[6] Data Science Body of Knowledge (DS-BoK) [website]

[7] Data Science Model Curriculum (MC-DS) [website]

[8] Data Science Professional profiles definition (DSP) [website]

The required competencies for AI relate to computer programming capabilities (such as C++, R, Java and Python programming languages), data analytics and problem solving, data management, mathematics and statistics. These capabilities are the basis for developing advanced AI skills.

Leading universities across the world offer undergraduate and graduate learning programs in AI, such as a B.Sc. diploma in computer science with specialty in AI as well as designated AI related M.Sc. and Ph.D. degrees.

► Smart Robotics

Following the introduction of robotic systems into production processes in many industrial sectors, many workers currently need robotic utilization skills in their everyday work. Examples for such workers are robotic programmers and robotic maintenance personnel. As the penetration of robotic technology into additional industrial and commercial fields accelerates, it is expected that more and more competent workers will be needed. A research conducted in recent years in the UK has revealed that there are difficulties in filling approximately 50% of the open positions requiring robotic engineering knowledge. In the US alone, there were approximately 130 thousand robotics engineers and this number is expected to grow by 5-9% in the next 10 years.

The Autonomous Vehicle field is a fast-paced developing field and is considered one of the leading and dominant fields of Autonomous Systems and Intelligent Robotics. It is important to emphasize that since this industry is in its early stages, most of the professions required today are related to R&D phases. Due to the shortage in autonomous vehicle engineers, high wages are offered to skilled workers. These may rise as high as $295,000 per year. Companies such as Google offer an average of $280,000 a year or even more, to engineers in the field of smart robotics.

The skills robotics engineers need are related to programming, engineering and design of automated robotic systems, signal processing, support, installation and calibration. The fields of knowledge required for this subject are mechanical engineering, computer engineering, electronics and mathematics.

Skilled personnel in smart robotics and autonomous systems need to have a multidisciplinary approach and is likely to be working with people from other fields, especially when working on robots designed to help people. For example, in healthcare and nursing, it is likely that other professionals such as psychologists, legal experts, ethics professionals and sociologists will also be required.

Several universities around the world offer courses in robotics and associated fields such as navigation and robotic vision, advanced courses in the use of computer networks and robotic communications and kinematics. Dedicated university centers focus on intelligent robotics applications that have autonomous abilities as well as the ability to interact with people.

» Talent Development for Artificial Intelligence, Data Science and Smart Robotics Skills in Selected Countries

A review of the steps taken by governments around the world, particularly in countries that are commonly referred to as "comparable countries" with the State of Israel, to promote

their skills in artificial intelligence, data science, robotics and cyber-security in a new “digital world” uncovers several insights:

- All the countries surveyed recognized the importance of digital skills. Even if countries did not have a clear strategy to advance skills in one or more of the above-mentioned areas, they took part in larger international consortiums (usually in European countries) to promote their labor force.
- There are great differences between the different countries regarding the governmental strategies, their implementation and their budget.
- Despite the government's role in education and training of the workforce, many initiatives come from the public (in the form of independent centers or not for profit organizations) or from the industry.
- Many countries make significant efforts to create high level academic infrastructure in order to prevent possible academic staff and student brain drain to other countries such as US and China.
- There is an overall understanding that a bi-directional approach is needed. On one hand support for the academy in order to increase the number of graduates in AI, data science and smart robotics. On the other hand, support for re-training programs for industrial workers in order to enable them to acquire practical profession in these fields.

Sector Mapping: Government, Academia, Defense and Industry in Israel

► Government Offices and Governmental Authorities

Many government ministries are working to promote issues related to Artificial Intelligence, Data Science and Smart Robotics. One of the most prominent projects is the “Digital Israel” Project. This is a government initiative that aims to harness and leverage the potential of the digital revolution and the progress in the information and communication technology to accelerate economic growth, reduce socio-economic gaps and turn the governance smarter, faster and citizen-friendlier, making Israel a global leader in the digital domain. The project is headed by the Ministry for Social Equality and operates in cooperation with government ministries, local authorities, business companies and non-profit sector organizations. Among the topics covered by the project: “Digital Health”, in cooperation with the Ministry of Health; “Digital Education” in cooperation with the Ministry of Education; “Digital Economy” in cooperation with the Ministry of Economy; and “Digital Welfare” in cooperation with the Ministry of Social Affairs and Social Services.

As part of a digital health project, with a budget of over NIS 900 million over five years, technologies such as artificial intelligence and data science will be employed to improve the health of the entire population of Israel and to promote digital health as the engine of growth in the Israeli economy. Among other, the Ministry of Health, together with various partners from the governmental agencies and academy, promotes the National Initiative for Personalized Health - a “Mosaic Project”, pursuing the vision of personalized medicine, encouraging entrepreneurship and promoting the creation of new jobs.

Another prominent project, co-sponsored by the Ministry of Transport and Road Safety, is the “National Plan for Smart Mobility”, is planned for the years 2017-2021 with a budget of approximately 200 million NIS. The aim of the project is to promote research, development, and entrepreneurship in the field of smart transportation in Israel, and to streamline the transportation system by encouraging the integration of advanced technologies .

The Ministry of Economy is promoting the national strategic plan for advanced industrial production at a cost of tens of millions of shekels. The program includes encouragement grants for small and medium-sized companies, the establishment of the Institute for Advanced Production and educational activities for exposing youth to advanced industry. Advanced production technologies include integration of information systems (Big Data), advanced robotics, 3D printing and the use of advanced materials. In 2018, no less than five consortiums competing for the funds, engage in fields related to artificial intelligence, data science or intelligent robotics.

The Ministry of Science and Technology established a research grants program to encourage and strengthen applied scientific research and engineering research, to create a critical mass of knowledge and manpower in the areas of artificial intelligence, robotics and big data. In addition, the Ministry of Science encourage cooperation in the field with parallel institutions in various countries such as India.

The Libertad Foundation of the Israeli National Intelligence agency focuses on technological research and development of start-up companies. The fund supports start-ups to create mutual benefits through cooperation and exchange of knowledge.

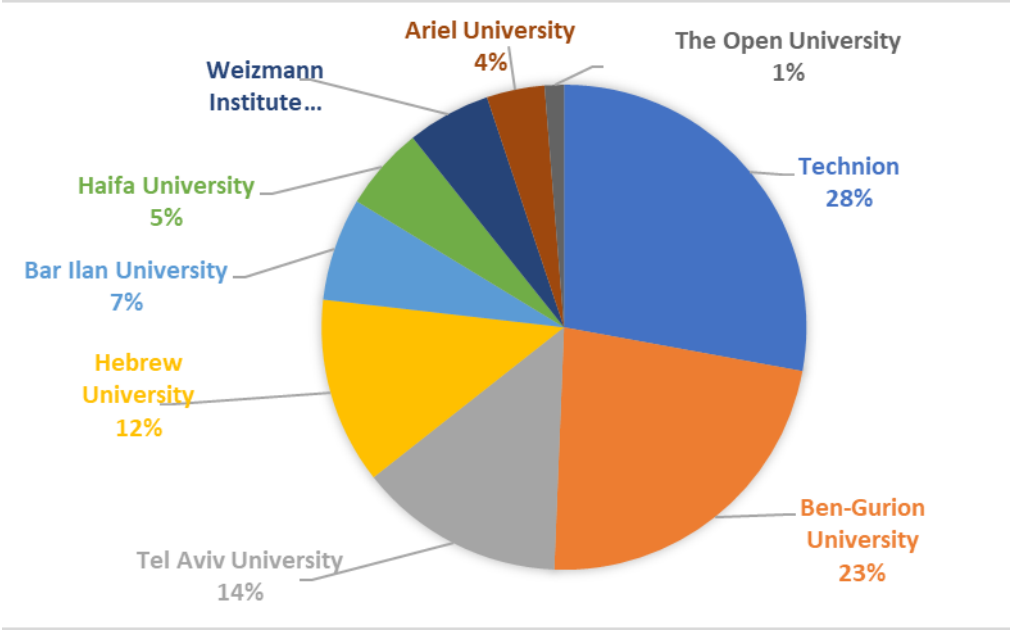
The Government ICT Authority, which serves as a center of knowledge and as professional consultant in the field of ICT to the government, works to improve the IT system and to promote technological innovation in government ministries and units, to improve government service and to reduce the bureaucratic burden by integration of advanced technologies in the field.

Additional various projects also exist in the Ministry of Education, the Ministry of Welfare and the Ministry of Defense.

» Researchers

A total of 270 researchers in the fields of Artificial Intelligence, Data Science and Smart Robotics, about 230 in universities and about 40 in colleges, were found in the mapping conducted by the research team. The mapping used keywords within the fields of interest in the personal websites of all researchers in the relevant faculties of all universities and colleges in Israel. The most prominent universities in number of researchers are the Technion and Ben Gurion University (about 50% in all university researchers are from these two institutions). The most prominent colleges in number of researchers are the Interdisciplinary Center Herzliya, the Holon Institute of Technology, and the Sami Shamoon College of Engineering University (about 50% of all colleges researchers are from these three institutions).

Figure 7: University researchers in Israel by institute



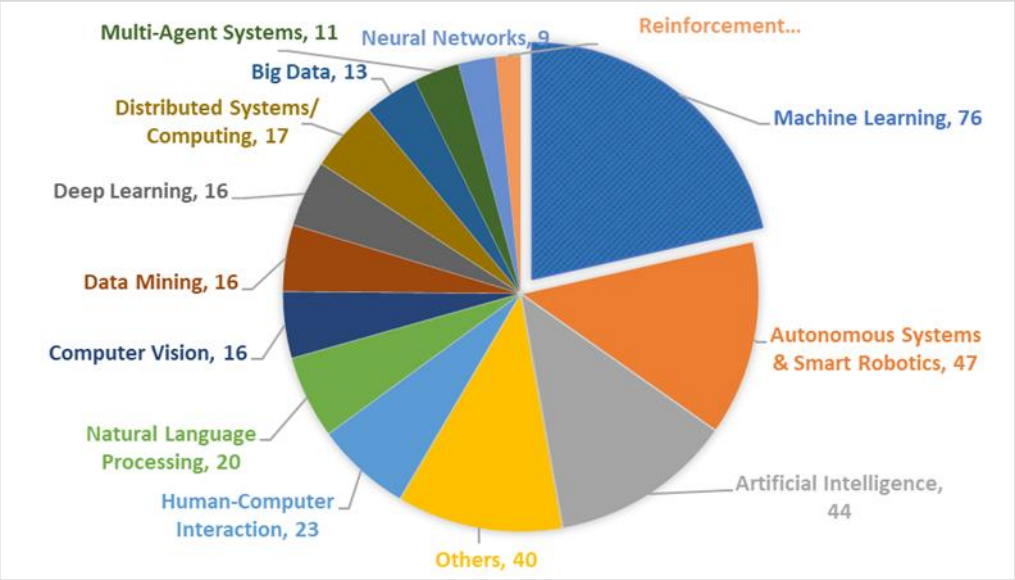
Most of the researchers at the leading universities are from the faculties/departments of computer science/software engineering, electrical engineering and industrial engineering/information systems. There are researchers in the relevant fields also in the faculties/departments of aeronautical and aerospace engineering, mechanical engineering, civil engineering and management. In other faculties like biology or social sciences and humanities there are few researchers.

The leading interests of the researchers in the mapping are:

- Machine Learning
- Artificial Intelligence
- Autonomous Systems & Smart Robotics

Other interests are: Human-Computer Interaction, Natural Language processing, Computer Vision, Data Mining, Distributed Systems/Computing, Big Data, Multi-Agent Systems, Neural Networks, Reinforcement Learning.

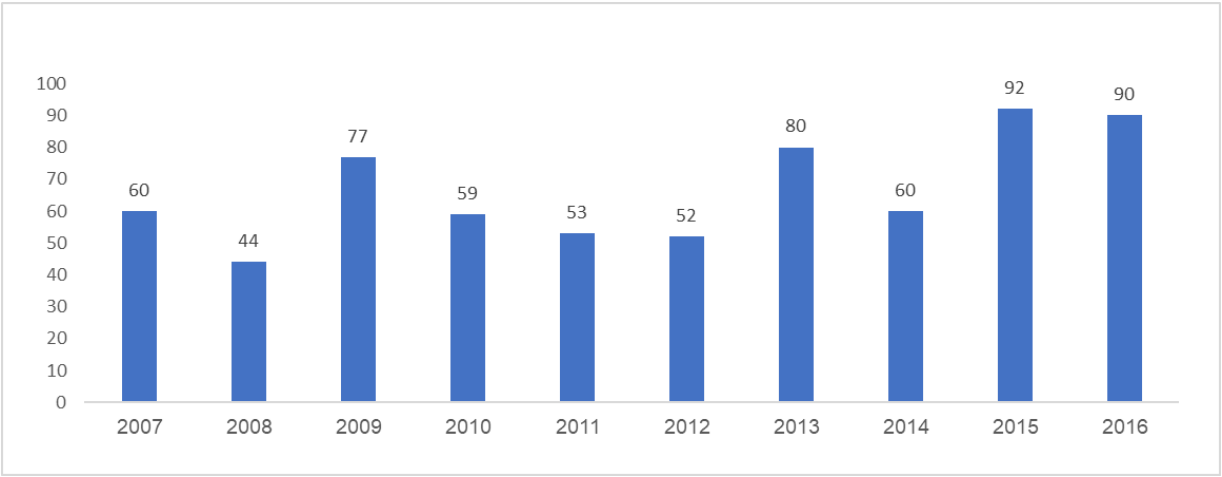
Figure 8: Research interests of Israeli researchers in the fields of artificial intelligence, data science and smart robotics



» Theses

There are 694 master's and master's degrees In the Israel Union List of libraries in Israel (ULI) in the areas relevant to Artificial Intelligence, Data Science and Smart Robotics (machine learning, computer vision, human-computer interaction, information mining, etc.) in 2007-2016. The average number of theses per year increased from 59 theses in the first five years of the decade to 75 theses during the last five years of the decade, with the major increase occurring in 2015 and 2016 (92 and 90 theses respectively).

Figure 9: Second- and third-degree theses, 2007-2016



Source: Based on data from ULI -Israel Union List

» Education programs

An examination of all the internet sites of Israeli universities and colleges revealed that there are dozens of tracks and courses for undergraduate and graduate students in subjects related to Artificial Intelligence, Data Science and Smart Robotics. These tracks can be divided into seven main areas:

- Information Systems / Data Science;
- Artificial Intelligence / Machine Learning / Intelugent Systems / Distributed Systems;
- Bio-Informatics / Cognition / Psychology with emphasis on information studies;
- Combined track of intelligence /Learning Systems and Information Science;
- Robotics / Autonomous Systems
- General tracks without specialization - a variety of courses
- General tracks - individual courses

» Defense Sector

The needs of the army and the defense sector in the fields of Artificial Intelligence, Data Science, Autonomic Systems and Smart Robotics are increasing rapidly, as is the need for suitable manpower. These areas are becoming part of both intelligence and operational activities, enabling management of various sources of information in ever-increasing numbers. As a result, the defense sector is dealing with an increasing need for gathering and storing data and turning it into knowledge by organizing, optimizing and processing it, and by drawing conclusions and making quick decisions in real time. The rapid development of the field of Artificial Intelligence and Data Science results not only in growing needs for systems and infrastructure, but also in need for organizational and cultural change in the defense sector. This change will require a change in personnel training, as well as in transparency and trust in the systems and in dealing with security clearance issues.

The combination of barriers inherent in the defense sector, and the rapid pace of development in the civilian world creates a situation in which civilian development and infrastructure lead the way, and civilian capabilities need to be harnessed for the needs of the defense sector. In addition, the defense sector, with its needs for security clearance and compartmentalization, will have to develop infrastructural and organizational capabilities, that will enable the production, maintenance, processing, and accessibility of data to all branches of the defense sector.

the army and other security organizations will need more data and information engineers and scientists in the near future, as well as researchers and engineers in the fields of robotics and other complementary fields. At the same time, technological manpower trained by the army is considered experienced and talented in various technological fields and serves as a leading human-infrastructure for civilian needs and for development of advanced technological industries in Israel. The cyber security industry is prominent in Israel and provides a vast wealth of information. Cyber and artificial intelligence nourish each other, and cyber is one of the growth engines of artificial intelligence. Additional

engines of growth are smart cities and the focused advertising industry, which is very similar in nature to military intelligence.

Data is also an essential infrastructure in the world of information science and artificial intelligence in general, and for the defense establishment in particular. The cellular and health industries are important players in the production of data as well as government ministries and other bodies at the state level.

The army and the intelligence agencies believe there should be a governmental investment in a national cloud in cooperation with one of the leading companies in the field. Such a cloud should have an open civilian section and a separate and closed security section. Such an infrastructure, if established in the Negev region, for example, will add jobs to the region and will be an essential and accessible computing resource even in times of emergency.

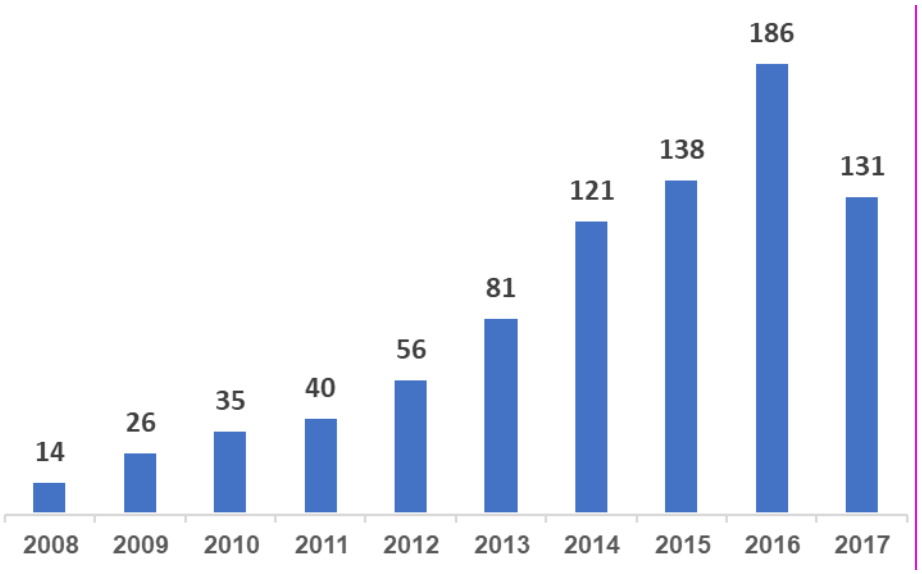
The army currently has several programs and tracks in the framework of the academic and technological training programs and is constantly working to adapt them to its changing needs.

» Industry

As of the beginning of June 2018, there were approximately 898 technology companies in the Startup Nation Central Finder database with at least one of the following tags: artificial-intelligence, machine-learning, big-data-analytics.

Over 65% of these companies have been established over the last five years (591 companies). about 186 companies were established in the peak year - 2016. Ten companies were founded in the 1990s. Most veteran companies employ more than 200 employees - NICE, RADCOM, Essence, G-STAT, Mobileye and more.

Figure 10: Israeli artificial intelligence companies by year of establishment



Source: Based on data from Startup Nation Central Finder[9]

[9] Start-Up Nation Finder [website]

Naturally, most companies are in the initial stages in terms of capital raising. Nearly 64% of the companies in the database are in the Pre-seed, Bootstrapped or Seed phase. About 25% of the companies are in financing rounds (16% in Round A, 5% in Round B and 4% in C + rounds), including leading companies in the Digital Health & Medical Technologies, such as EarlySense and Medasense Biometrics, Fintech & eCommerce, such as MySupermarket and Lemonade, Security & Safety Technologies like Cypereason, Software Applications like Cortica, and more.

According to the Startup Nation Central, there was an average increase of about 32% in the capital raised in artificial intelligence from the first half of 2015 to the first half of 2018. In the first half of 2016, $ 714M was raised in 78 rounds. This record was broken in the first half of 2018 with $ 773M raised in just 66 rounds. The surge in capital raising suggests that artificial intelligence is no longer a buzz word.

Science & Technology

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