Artificial intelligence and advanced technologies - some case studies from European research space

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Abstract.
Being advanced technology under development itself, Artificial Intelligence may help for further development of many other advanced technologies in key areas of human activity. In the article, several case studies from European research space are considered illustrating the symbiosis between Artificial Intelligence and Advanced Technologies.

Key words: artificial intelligence, advanced technologies

Introduction

On 19 of April 2018, a conference named "HPC or Extreme Scale Scientific and Industrial Applications" took place at the National Palace of Culture in Sofia, Bulgaria. The event was a part of the Bulgarian Presidency of EU events and was organized in close cooperation with the European Commission. The event demonstrated the huge interest in the advanced technologies, including future and emerging technologies. Most often, these new technologies come together with Artificial Intelligence intended to monitor and manage the technological systems.

Artificial Intelligence (AI)

Artificial intelligence (AI) is a research field that studies how to realize the intelligent human behaviours on a computer. The ultimate goal of AI is to make a computer that can learn, plan, and solve problems autonomously. Although AI has been studied for more than half a century, we still cannot make a computer that is as intelligent as a human in all aspects. However, we do have many successful applications. In some cases, the computer equipped with AI technology can be even more intelligent than us. The Deep Blue system which defeated the world chess champion is a well-know example.

The main research topics in AI include: problem solving, reasoning, planning, natural language understanding, computer vision, automatic programming, machine learning, and so on. Of course, these topics are closely related with each other. For example, the knowledge acquired through learning can be used both for problem solving and for reasoning. In fact, the skill for problem solving itself should be acquired through learning. Also, methods for problem solving are useful both for reasoning and planning. Further, both natural language understanding and computer vision can be solved using methods developed in the field of pattern recognition.

Advanced Technologies (AT)

We may divide the advanced technologies into two groups – Advanced Information Technologies and Advanced Technologies of the Material World.

Among the Advanced Information Technologies today we may consider Supercomputing (High Performance Computing), Artificial Neural Networks and Quantum computing.

Among the Advanced Technologies of the Material World today we may consider Advanced Materials, New Energies, Automation and Robotics, Micro- and Nanotechnologies, Photonics, Industrial Biotechnologies, Military technologies, Aero and Space technologies, Cutting Edge Health Care technologies etc.

Below we will mention only some of the advanced technologies.

Supercomputing (High Performance Computing). Computing is increasingly integrated into all aspects of societies, economies and everyday life.

Nowdays, supercomputers are an essential tool for scientists and engineers. However, if the software used to solve complex scientific questions or engineering problems is not appropriately programmed or optimized, even powerful supercomputers can not generate quick results. To make efficient and sustainable use of High Performance Computing (HPC), sound programming by well-trained and highly qualified staff is just as important as having state-of-the-art hardware.

Artificial Neural Networks. Neuromorphic computing platforms are brain-inspired computing devices which enable high-speed, low-energy simulations of spiking neural networks with synaptic plasticity.

Quantum computing. Quantum processors have a great potential for increasing the performance of computers. They are however still in its development phase. Quantum annealing should be mastered first, then quantum computing.

The first half of 2017 saw considerable news about the imminent impact of quantum computing (QC) on science, math and data analysis (Palmer, 2017). Diverse viewpoints predict from years to decades for initial impact, and debate what type of problems will first be affected.

The conceptual appeal of QC systems is the use of their computational power, which grows exponentially with the number of quantum bits (or qbits), to reduce the time spent executing combinatorial algorithms, which on classical computers grows exponentially with the number of variables.

The most advanced commercially available quantum computers are currently delivered by D-Wave Systems. The number of qbits in these systems has doubled every other year for the past six years, a trend that is expected to continue.

Contemporary quantum computers implement one of two computational models: the gate of circuit model (Feynman, 1986) or the quantum annealing model (Kadowaki and Nishimori, 1998).

A quantum annealing processor is a special-purpose device that natively solves the quadratic unconstrained binary oprtimization (QUBO) problem. The goal of QUBO is to find the $x_i \in \{0,1\}$ that minimize $x^T Qx$ for upper-triangular matrix Q with $Q_{ij} \in R.$ The QUBO form is equivalent to the unconstrained binary quadratic programming (UBQP) problem and the Ising model.

One can think of a quantum annealer as a hardware implementation of simulated annealing that uses quantum effects – superpositioning, entanglement, and quantum tunneling – to reduce the likelihood of getting stuck in a local minimum. In both quantum and simulated annealers, finding the x_i that truly minimizes $x^T Qx$ is not guaranteed. Instead, the goal is normally to find good solution quickly. A D-Wave quantum computer can propose a solution of $x^T Qx$ in only 5µs even for $N > 2000$ (where the search space is greater than 2^{2000}) as supported by a D-Wave 2000Q system.

Mapping computational problems into QUBO form is a key challenge that all subsequently-described applications face.

Applications of quantum computing are as follows:

- Graph Partitioning. Computational optimizations as graph-theoretic problems is ubiquitous throughout mathematics, computer science, physics, chemistry, bioscience, machine learning, and complex systems. Many of these problems are NP-hard and therefore rely on heuristic solutions (Mniszewski, Ushijima-Mwesigwa, Negre, 2017).
- Traffic Flow Optimization. Certain parts of the real-world problem of optimizing traffic flow can be mapped into a form suitable for QA (Neukart et al., 2017).
- Finance. Here specific applications include multi-period mean-variance portfolio optimization, hierarchical risk parity feature selection for credit scoring, and tax loss harvesting.
- Programming. Only in the last year or two have interfaces emerged that are higher level than the system-dependent quantum machine intrusion exposed by D-Wave's low-level system interface

Automation and robotics. Robotic machines play an ever larger role in industrial production and elsewhere. Automation is the key for creating complex and precise machines, as well as machines capable to work autonomously at conditions where humans can't survive.

Artificial Intelligence and Advanced Technologies

Being advanced technology under development itself, Artificial Intelligence may help for further development of many other advanced technologies in key areas of human activity.

Artificial Intelligence can successfully be used in Information Technologies, for example for analysis of Big Data, for development of Cyber-security, for 3D visualization and Virtual Reality.

Virtual and Augmented Reality technologies are booming in Europe. They are expected to create 480 000 jobs, with the industry increasing in value to upwards of 34 billion euro by 2020. Virtual Reality can be applied across a wide array of sectors.

In manufacturing and mechanical engineering, an example of application of Virtual Reality is the product Oculus Medium – 3D modeling tool for creating virtual “sculptures” through Virtual Reality headsets and controllers.

In health care, examples of Virtual Reality are Fearless – application utilizing procedures based on exposure therapy for overcoming phobias – and Medical Realities – educational platform combining 360 degree videos with 3D animations.

In finance, Cisco Spark VR is an application for business collaboration and interaction.

In creative industries, Tilt brush is VR painting tool of Google, and Quill VR is VR painting tool of Facebook.

In construction, ScanARchitect is architectural and construction visualization tool.

Examples of using Virtual Reality technologies in tourism are Iceland and Hotel Abruzzi Rome.

In retail, example of Virtual reality application is Virtuosa VR – 360 degree video with VR catalogue of Virtuosa, a jewellery shop.

Artificial Intelligence also can successfully be used to develop Advanced Technologies of the Material World, for example Industrial Biotechnologies and Health Care technologies.

Below we will consider several case studies from European research space illustrating the symbiosis between Artificial Intelligence and Advanced Technologies.

Whatify. Whatify is awareness-raising campaign that stimulates the modernization of European industry. The campaign focuses on the technological transformation of traditional SMEs, promotion of regional digitization and uptake of advanced technologies – notably Key Enabling Technologies. Whatify seeks to boost the rate of European industrial modernization through increased productivity and efficiency, resulting in improved competitiveness and job creation. Watify promotes the technological transformation of a wide range of sectors, across a wide range of technologies.

The key enabling technologies are: advanced materials, micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced manufacturing technologies and photonics.

The sectors transformed are: manufacturing, health care, finance, creative industries, mechanical engineering, construction, tourism, retail, agro-food.

Digitisation technologies are: automation and robotics, internet of things, big data, 3D visualization, artificial intelligence, high-performance computing – HPC, cybersecurity.

Watify presents 100 Success Stories identifying and documenting a pool of challenges and benefits that individual companies have faced in their technological transformation process. We consider here three of them: VR Express, Printivo and Redborder.

Printivo Ltd. Is a bioprinting company combining cutting-edge bioengineering technology and up-to-date scientific approach. Printivo presents Eve – desktop 3D bioprinter, which has been specialized for the creation of 3D human tissue grafts in any size and conformation.

VR Express is a virtual reality service provider, creating custom VR content ranging from 360 degree videos and VR animation to interactive experiences.

Redborder is an open source solution for traffic visibility, Big Data analytics, and dynamic Cybersecurity. It enables the creation of customizable dashboards and reports for corporate networks and Managed Service Providers. They implement Collect-Analyse-Act motto for cyberatacks, detection, the definition of KPIs to support Security Operational Centers.

PRACE. Partnership for Advanced Computing in Europe (PRACE) is an international non-profit organization with its seat in Brussels. The PRACE research Infrastructure provides a persistent world-class high performance computing service for scientists and researchers from academia and industry in Europe. The computer systems and their operations accessible through PRACE are provided and funded by five PRACE members (BSC representing Spain, CINECA representing Italy, CSCS representing Switzerland, GCS representing Germany and GENCI representing France).

Since 2008, PRACE has offered a diverse training program in HPC, including seasonal schools, workshops and industrial seminars. Additionally, the PRACE Training Portal (2018) provides access to video tutorial and an extensive range of training materials. Early in 2017, PRACE introduced two new educational opportunities: Massive Open Online Courses (MOOCs) and the CodeVault (2018), a core repository for training codes open to everyone worldwide.

Currently, two MOOCs are available: Supercomputing: Discover how supercomputers are powering scientific breakthroughs (2018) and Managing Big Data with R and Hadoop (2018)

The PRACE Advanced Training Centers (PATCs) have been in operation since 2012: The Barcelona Supercomputing Center (Spain), CINECA – Consorzio Interuniversitario (Italy), CSC – IT Center for Science Ltd. (Finland), EPCC – the Edinburgh Parallel Computing Center at the University of Edinburgh (UK), The Gaus Center for Supercomputing (Germany), La Maison de la Simulation (France).

Different research projects have been awarded research time on the supercomputers of PRACE: Modelling olfactory system (2018), Photo protection in plants (2018), Planetesimal formation in protoplanetary disks (2018), Modelling the epoch of reionization - Ross, Dixon, Iliev, Mellema (2017) and Sullivan, Iliev, Dixon (2018), Visualising tornadoes (2018), Investigating the optical properties of grapheme nanoribbons (2018) – Avisati, Lisi, Gargiani, Della Pia, De Luca, Pacile, Cardoso, Varsano, Prezzi, Ferretti and Beti (2017) and Della Pia, Avvisati, Ourjini, Cardoso, Versano, Prezzi, Ferretti, Mariani, Betti (2016), Paradoxical activation in cancer treatment (2018) – Papaleo, Saladino, Lambrughi, Lindorff-Larsen, Gervasio, Nussinov (2016) and Kuzmanic, Sutto, Saladino, Gervasio, Nebreda, Orozco, (2017), Mixed convection in channel flows (2018) – Pirozzoli, Bernardini, Verzicco, Orlandi (2017) and Pirozzoli, Bernardini, Orlandi (2016), Corner vortex shedding in solid rocket motors (2018) – Lacassagne, Bridel-Bertolomeu, Riber, Cuenot, Casalis, Nicoud (2017) and Lacassagne, Riber, Cuenot, Nicoud (2017), Multiscale modeling of ionic conductors (2018) – Zguns, Ruban, Skorodumova (2017) and Nilsson, Vekilova, Hellman, Klarbring, Simak, Skorodumova (2016).

Human Brain Project (HBP). The Human Brain Project (HBP) is one of the Future and Emerging Technology Flagship initiatives funded by the European Commission. It is a ten-year initiative in medicine, neuroscience, and computing which brings together scientists and institutions from 20 nations across Europe, and has a strong element of international cooperation.

The HBP is following a unique, multi-disciplinary approach to accelerate brain research, brain medicine and brain-inspired technology. The infrastructure makes available a growing range of data, models, software tools and hardware capabilities to scientists and industry.

The HBP is creating an advanced ICT platform to support researchers studying the brain and its diseases, empower brain-inspired computing and drive technological development. It includes cloud-based collaborative virtual experiments, data analytics and compute services and databases that enable meta-data handling and provenance tracking. Leading-edge supercomputers, brain-inspired neuromorphic computers, and neurorobotic systems combining simulated brains with robotic bodies, are being provided to scientists. The HBP is developing advanced software for big data analytics, modeling and simulation at all levels of brain organization – from the level of single molecules to the whole brain – to understand how the different levels of brain organization interact and generate complex behavior. Researchers can access all these from their own laboratories and collaborate with other labs.

Whole brain is in cm scale, neuron is in μm to mm scale, synapse is in nm to μm scale. The biggest challenge in understanding the brain is the bridging of different scales in space and time. This means identifying how genetic, molecular and cellular organization is translated into brain functions such as cognition and intelligence. It also means deciphering how behavior, disease and environment may influence what happens at the molecular, genetic or cellular levels – and all of this over time, from millisecond responses to the whole lifespan. The databases generated at these levels of description are so large that neuroscience needs high-performance computing to connect the scales into a comprehensive picture. The ability to combine simulation and Big Data analytics with experiments is key to making brain complexity scientifically tractable.

The HBP's quest to understand the human brain is advancing well. Detailed online brain atlases and models are being created. New insights are emerging from a broad spectrum of experiments, supercomputing-based analysis of large, complex data sets and simulations of molecules, cells and networks of cells. Progress is being made in the area of neurorobotics, where brain models are tested by connecting them to physical or virtual robots.

The worldwide scientific community can now start exploring the initial versions of the HBP six ICT Platforms – HBP-ICT (2018).

The Platforms reflect the HBP's key objectives: to gather and disseminate data describing the brain, to simulate and build models of the brain, to develop brain-inspired computing and robotics, and to create a global scientific community around the developing research infrastructure.

The Platforms consist of prototype hardware, software tools, databases, programming interfaces, and initial datasets, which will be refined and expanded on an on-going basis in close collaboration with end users.

The Platforms are the result of an extensive multidisciplinary effort, involving more than 750 scientists and engineers from over 100 institutions.

The HBP Collaboratory collects tools from the HBP Platforms in one place and organizes them into collaborative workspaces. Users can create a workspace, build a team, describe a project, collect and organize tools, share data, use Jupyter notebooks to share ideas, code and workflows.

Similar projects are developed outside EU. Below is a short list of currently active similar projects. EU: The Human Brain Project, 2013; USA: The brain initiative, 2014; Australia: The Australian Brain Alliance, 2016; China: The China Brain Project, 2016; Japan: Brain/MINDS project, 2016; Canada: Government/Brain Canada joint funding, 2017.

The Neuroinformatics Platform – HBP-NIP (2018) serves as the Human Brain Project's search engine for distributed data, data repositories, brain atlases and knowledge about the brain. The Platform consists of APIs for querying and a web-based platform and application programming interface (APIs), i. e. a set of standards, protocols and tools for building software applications. Data can be examined by species, contributing laboratory, methodology, brain region and data type, thereby allowing functionality not currently available elsewhere. The data are predominantly organized into atlases (HBP Strategic Rodent Brain Atlases and HBP Hyman Brain Atlasses) and linked to the KnowledgeSpace – a collaborative community-based encyclopedia.

The Neurorobotics Platform – HBP-NRP (2018) – is an Internet-accessible simulation system that allows the simulation of robots and environments controlled by spiking neural network. The Platform enables simple virtual closed-up experiments in cognitive neuroscience to be performed using brain models developed within the HBP, with the capability to customize several variables, such as the environmental and physical parameters, using a Robot Designer, Environment Builder and a Closed Loop Engine.

Released in April 2016, the Human Brain Project's Brain Simulation Platform (BSP) – HBP-BSP (2018) - is one of the six internet-accessible ICT Platforms for collaborative brain research. The goal is to offer scientists user-friendly tools to reconstruct and simulate data-driven models of neurons and whole brain tissue. A key driver was the Blue Brain Project's work to reconstruct and simulate neocortical microcircuitry in somatosensory cortex, and the application of Blue Brain techniques and workflows to other brain regions, notably cerebellum, hippocampus and the basal ganglia.

The Platform provides reconstruction and simulation pipelines, packaged into web-accessible workflows or showcased as use cases.

Medical Informatics Platform of HBP – HBP-MIP (2018) is to provide researchers with the ability to access and analyze large amount of anonymised clinical data from hospital, research, and pharmaceutical clinical trial databases through an innovative data management system.

The system integrates heterogeneous data formats seamlessly and federates data sources into a harmonized virtual database with a customized interface for navigation and data mining. The patterns discovered in the data ("biological signatures" which uniquely identify diseases) generate new hypotheses about brain disease classifications based on biological, physiological and anatomical features, in addition to the classical patterns of phenomenology expressed in symptoms, signs and syndromes. In the long run, the MIP will unlock the wealth of information stored in medical and research databases will provide a credible and rapid path to precision (or personalized) medical care.

High Performance Analytics and Computing (HPAC) Platform of Human Brain Project – HBP-HPAC (2018) provides high performance computing, storage and data processing capabilities to run simulations of sophisticated, detailed brain models and to analyze large, complex datasets. The execution of some of the tools, for example for visualization and data management, does not necessarily require a supercomputer, but they can be used on standard computers and notebooks. Other software, like parallel programming frameworks, can be used on both types of architectures. Scientists who would like to use a supercomputer need experience in programming with languages like C, C++, Python or Fortran.

In the frames of Human Brain Project – HBP-NCP (2018), two complementary Large-scale Neuromorphic Computing Systems (NCS) are set-up in Heidelberg (the BrainScaleS system) and Manchester (the SpiNNaker system).

The BrainScaleS system is based on physical (analogue or mixed-signal) emulations of neurons, synapse and plasticity models with digital connectivity, running up to ten thousand times faster than real time.

The SpiNNaker system is based on numerical models running in real time on custom digital multicore chips using ARM architecture. Models and simulation experiments are described in a Pyton script using the PyNN API. Experiments can be submitted via browser through a web API (Python client available).

Red Border - Cybersecurity and Artificial Intelligence

Red Border offers the ultimate real-time Network Traffic Analysis (NTA) and Cybersecurity Platform based on Big Data and Open source.

Red Border characteristics include: Collecting Machine Data, Scaling Out Big Data, Active Cybersecurity, Analyses, Open Source, Wireless Extensions.

Red Border ecosystem includes: redborder Probes and redborderApps. The probes are related to SNORT Red Border Edition. Applications are related to Traffic, Mobility, Intrusion, Vault, Social.

Red Border Intrusion offers IDS/IPS functionalities, allowing to detect or prevent intrusions. To do this, redborder NG Firewall/IPS probes or probes from third parties compatible with Snort are deployed, which are responsible for collecting data. The probes also perform the traffic analysis and the application of the specific security policies of each implementation, in order to generate alarms (IDS) or block traffic (IPS) in an active Cybersecurity action. The platform and the redborder IPS probes holds several configuration modes: Red Border appliances, bare metal, virtual on-premise, virtual on-cloud.

Vault: SIEM (Security Information and Event Management). The redborder Vault probes can be any network equipment that provides a historic of its logs (Syslog) in order to monitor the behavior of the network and these devices. These logs are sent to a correlation engine, where they are analyzed (Deep Log Analysis) by machine learning algorithms and AI, being able to model the usual network traffic and generating alarms when possible deviations or outliers in the behavior are detected. It has the following capabilities:

1. Timestamping: all logs that arrive in the system are given a time mark which validates the exact moment in which the reception of the log occurred.

2. Hashing: In order to avoid the alteration and/or modification of the stored logs, all of the entries are signed with a light algorithm with the server's own digital certificate.

3. Complete data: logs are stored in two different ways – a reduced version in the OLAP database (for the later visualization of the data), and the original version in a distributed file system.

Conclusion

Artificial Intelligence will be integral part of the technological transformation of our society. In this sense, it will help to further development of society.

In European Union, some potential benefits of technological transformation are: 30% increase of productivity, growth 15% more if using advanced technologies, 22% higher revenues, 2 times more jobs, 1,5 million additional jobs for EU economy.

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