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Applications of Artificial Intelligence in Neuroscience Research: an Overview

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Abstract: *This article presents a review of how artificial intelligence (AI) supports neuroscience investigations and explores a case study where it is applied. AI has an important role to play in research, because it focuses on the mechanisms that generate intelligence and cognition. Neuroscience benefits from AI techniques and increased computing power to improve the interpretation of brain behaviors, having focused on the reciprocal importance that both areas have on research & development. In the future, it is expected that both neuroscience and AI will increase their results of research and empirical advances, accelerating the knowledge of these areas of research and science.*

Keywords: *Artificial Intelligence, Neuroscience Research, Applied AI.*

1. Introduction

Since classical antiquity, Science has been dedicated to the study of the various dimensions of intelligence. In the last 60 years, as a result of the evolution of technology and the needs of the industry, there has been a great growth in the study of Artificial Intelligence. By allowing to overcome the limitations raised by the analysis of large amounts of data, it makes it possible to explore new horizons in various sciences, such as medicine, engineering, and economics.

This paper presents an overview of applications of Artificial Intelligence in Neurosciences.

2. Artificial Intelligence and Medicine

Artificial Intelligence was coined in 1955 by John McCarthy and Marvin L. Minsky [1]. This new field of research is aimed to the development of machines mimic human typical actions and decisions. The first studies on the human brain and related reasoning processes date back to the beginnings of the Ancient Greek civilization. Artificial Intelligence has assumed a very important role in medicine due to the impact that has been observed in the development of various diagnostic techniques. In all sciences, but with a particular focus on health, incorrect diagnoses and medical errors can have serious consequences on future treatments and, consequently, on the quality of life of individuals, accounting for 10% of all deaths in the United States in 2015 [2]. PathAI, is one of the world leading providers of technology that uses artificial intelligence for pathology, focuses on reducing errors in cancer diagnosis. Buoy Health, on the other hand, uses complex algorithms to diagnose and treat diseases, using a chatbot that interacts with the patient, listening to their symptoms and health concerns, guiding them to a treatment according to their diagnosis.
In hematology, the evolution of AI has also been observed. The American company Beth Israel

Deaconess Medical Center uses microscopes to help clinical microbiologists diagnose potentially fatal blood infections and improve patients' chances of survival. Since the importance of AI for medical diagnosis is evident, it will also be important to understand its role in the development of the science that studies the functioning of the structures associated with the nervous system, neuroscience.

3. Neuroscience

The nervous system is known today to be one of the most important systems of the human body, related to understanding, perception and responses to internal stimuli and the environment that surrounds us. Neuroscience is the area that seeks to know its functioning, structure, and development. The first known studies on the brain originate from the Greek philosophers, through simple observations. The understanding of its structure and functioning changed with Charles Darwin's theory of evolution, but it would be the invention of X-rays and computed tomography that would create the foundations for the birth of the term Neuroscience in 1970. Lobotomy, a technique invented by the Portuguese physician Egas Moniz, which allowed us to discover that we could disconnect prefrontal areas in our brain and still continue to live and interact with the world around us, and attention to the importance of emotions in learning and decision making, field of study by António Damásio, the greatest Portuguese neuroscientist, were excellent examples of this evolution. The importance of linking this science to information and communication technologies (ICT) was the focus for the European Union to fund the Human Brain Project. This project aims to implement a state-of-the-art research infrastructure that will allow advances in scientific knowledge in the areas of neuroscience, computing and medicine related to the brain [3]. This project was named “EBrains”.

EBRAINS aims to make a major contribution to developing Europe's digital leadership by supporting the development of brain-inspired Artificial Intelligence (AI) and other related technologies, including neurorobotics (robots controlled by functional neural models) and neuromorphic computing systems (with architectures that emulate that of the brain) [4]. In this project, The Virtual Brain (TVB) was used as a simulation platform and Adaptive Exponential (AdEx) Integrate and Fire neural network models were incorporated, i.e., mathematical models that describe neuronal activity. Its use led to the conclusion that this TVB-AdEx model replicates some of the synchrony and responsiveness properties observed in the human brain and is a promising tool to study brain dynamics in various clinical states [5]. These models can capture key intrinsic firing properties of central neurons, such as adaptation, and include typical kinetics of postsynaptic conductance.

Never until today have so many doors been opened for the development of neuroscience, with the help given by the rapid progress in digital technology, big data, computing and artificial intelligence.

4. Neuroscience and AI

Neuroscience research is divided into specific fields that explore different areas of the nervous system. Neurophysiology investigates the physiological tasks that fit the different areas of the nervous system, while neuroanatomy is aimed to understanding the structure of the nervous system, and neuropsychology studies the interaction between the actions of the nerves and the functions linked to the psychic area. Behavioral neuroscience studies the contact of the organism, and its internal factors. Cognitive neuroscience focuses on the study of the cognitive capacity, as well as the knowledge of the self. It is also important to mention the interdisciplinarity of neuroscience in the aforementioned Human Brain Project, from the European Union, where neurorobotics is applied, allowing researchers in neuroscience and industry to experiment with the brain models developed in the project in virtual robots; neuroinformatic that will provide data from scientific research around the world, brain simulation that will integrate information into unified computer models for carrying out tests that are not possible to be performed on people; neuroinformatic computing that will transform brain models into a new class of hardware

devices, testing their applications and, finally, high-performance computing that will provide the interactive supercomputing technology that neuroscientists need for data modeling and simulation.

5. Large-scale simulations

In Figure 1 it is possible to see an example of a hon "An Evening with BerferdIn Which a Cracker is Lured, Endured, and Studied" (PDF). cheswick.com. Retrieved 3 Feb 2021.eypot graphical interface.

An important development in the collaboration between AI and neuroscience is the possibility of performing large-scale simulations of neural processes that generate intelligence. The cortex of a mouse brain has approximately 8×10^6 neurons and 8000 synapses (structure that transmit an electrical or chemical signal between neurons) per neuron. A group of IBM researchers managed to represent 8×10^6 neurons and 6400 synapses per neuron on the IBM Blue Gene processor and ran 10 times faster than real time [6]. With this processing capacity and its expected increase in the coming years, it is expected that large sections of the human cortex (which is about 1000 times larger than the mouse brain cortex [6]) can be modeled in substantial detail in a near future. The Blue Brain project [7] is another case study that applies AI in neuroscience and aims to establish simulation neuroscience as a complementary approach alongside experimental, theoretical, and clinical neuroscience for understanding the brain by generating digital reconstructions and simulations. biologically detailed mouse brain. These large-scale simulations will provide a virtual research tool through the characteristics of the human brain, and their relationship to cognitive function can be investigated at a scale and level of detail that is not hampered by the practical and ethical limitations of brain research. Large-scale simulations can also be used to study in detail the interaction between thousands of neurons, or to investigate the effect of specific lesions on these interactions, or to investigate the role of specific neurotransmitters in neuronal interactions. In this way, the limitations of experimental methods can be increased [8].

6. Influence of Neuroscience on Artificial Intelligence

The evolution of the benefits of using AI in the study of neuroscience is evident. However, is it possible for AI to be influenced by neuroscience? Considering that AI refers to systems that simulate human-like intelligence, given the long relationship between these two areas of knowledge, it would be expected that the study of the nervous system would play an important role in the development of new techniques for the evolution of AI. In fact, neuroscience provides a rich source of inspiration for new types of algorithms and architectures, independent and complementary to mathematical methods and ideas. Furthermore, neuroscience can provide validation of AI techniques that already exist [9]. Genetic algorithms evolve and become more efficient, contributing to the creation of more robust solutions. Considering that there is still a huge gap between the machine and human intelligence, it seems inevitable to expect that neuroscience ideas will become increasingly indispensable for the growth of AI. A very different way in which neuroscience can serve AI is by providing new analytical tools for understanding computation in AI systems [10]. The use of machine learning techniques seems to play a very relevant role in the development of these systems, as it is based on computational algorithms that benefit from the knowledge acquired in the different processes of studying the nervous system [9]. This learning is based on the use of Deep Learning, which is a machine learning technique that trains computers to perform tasks like humans, including speech recognition, image identification and predictions [11].

7. Neuroethics and Artificial Intelligence

Using AI to recreate a human-like brain opens space for ethical dilemmas. To prevent Neuroscience from becoming an instrument for shaping society, by allowing behavioral control in pathological cases, rigorous ethical scrutiny is important. Therefore, an ethical framework for AI is essential, with expert committees that ethically

evaluate projects and research teams. The complexity of this area of study imposes that AI must incorporate codes and algorithms of ethical responsibility, verifiable by others, not only the inventors themselves [12].

At the international level, there is already a set of bodies that coordinate this matter. Indeed, after approval by the European Parliament, in 2020, of a package of new legislative initiatives aimed at greater regulation of AI, the European Commission created for this purpose a European ethics group composed of a team of experts [13]. Based on the three legislative own-initiative reports presented to the European Parliament, "Code of ethics for AI", "Liability for harm caused by AI" and "Intellectual property rights", a legislative proposal is expected to be ready in 2021. In this way, what João Lobo Antunes defends as a neurosurgeon and president of the National Council of Ethics for Life Sciences will be put into practice, "good science generates good ethics, even when this entails moral risks" [14].

8. Conclusion

This paper presents the relationship between Neuroscience and AI, having focused on the reciprocal importance that both areas have on research & development. Large-scale simulations are fundamental for the knowledge and development of neuroscience, while it has also contributed to the growth of AI, especially machine learning, and more recently, deep learning, with the increasing use of neural networks. In the future, it is expected that the collaboration between researchers in neuroscience and AI, the identification of a common language between the two fields of study and the sharing of results and empirical advances, will allow accelerating the knowledge of these areas of study and science.

9. References

[1] McCarthy, J. & Minsky, M., (2006). *A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence.* AI Magazine. 27(4), 12-14.

[2] Built In. (2021) *32 Examples of AI in healthcare that will make you feel Better About the Future,* https://builtin.com/artificial-intelligence/artificial-intelligence-healthcare

[3] Human Brain Project. (2020) *Discover EBRAINS A key enabler to advance brain science,* https://www.humanbrainproject.eu/en/

[4] J. Frye, R. Ananthanarayanan, and D. S. Modha. (2007) *Towards real-time, mouse-scale cortical simulations,* IBM Research Report RJ10404

[5] Goldman, J.S., Kusch, L., Yalcinkaya, B.H., Depannemaecker, D., Nghiem, T-A., Jirsa, V. and Destexhe, A., (2020). *Brain-scale emergence of slow-wave synchrony and highly responsive asynchronous states based on biologically realistic population models simulated in The Virtual Brain.* bioRxiv. https://doi.org/10.1101/2020.12.28.424574

[6] V. Braitenberg and A. Schuz. (1991) *Anatomy of the Cortex: Statistics and Geometry.* Springer.

[7] H. Markram. (2006) *The blue brain project.* Nature Reviews Neuroscience, 7 (2), 153–160.

[8] Gonzalez, R.T., Riascos, J.A., Barone, D.A.C. (2017) *How Artificial Intelligence is Supporting Neuroscience Research: A Discussion About Foundations, Methods and Applications.* In: Barone D., Teles E., Brackmann C. (eds) Computational Neuroscience. LAWCN 2017. Communications in Computer and Information Science, vol 720. Springer.

[9] SAS Institute Inc. (2021) Deep Learning https://doi.org/10.1_007/978-3-319-71011-2_6

[10] Hassabis D, Kumaran D, Summerfield C, Botvinick M. (2017) *Neuroscience-Inspired Artificial Intelligence*, Neuron, 95(2). https://doi.org/10.1016/j.neuron.2017.06.011

[11] Marblestone H, Wayne G, Kording KP. (2016). *Toward an integration of deep learning and neuroscience.* Front. Comput. Neurosci., 10, p. 94

[12] Ribeiro, J. (2021) Neuroética e Inteligência Artificial, Jornal Público, (in Portuguese). https://www.publico.pt/2021/02/11/opiniao/noticia/neuroetica-inteligencia-artificial-1950013 consulted on May 7, 2022.

[13] Parlamento Europeu (2020) Parlamento na vanguarda das normas europeias sobre inteligência artificial, (in Portuguese) https://www.europarl.europa.eu/news/pt/press-room/20201016IPR89544/parlamento-na-vanguarda-das-normas-europeias-sobre-inteligencia-artificial consulted on May 7, 2022.

[14] Antunes, J. (2010, Janeiro, 18) Neurociências, os Avanços e os Desafios que se Colocam, VI Conferência da Indústria Farmacêutica, Lisboa. (in Portuguese)

https://www.medicina.ulisboa.pt/newsfmul-artigo/11/vi-conferencia-da-industria-farmaceutica consulted on May 7, 2022.