Chapter 2
Visualizing Neuroscience Through AI:
A Systematic Review

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ABSTRACT

The field of neuroscience explains how the neural networks in the brain work together to perform a variety of tasks, including pattern recognition, relative memory, object recognition, and more. The mental activity that makes different jobs possible is difficult to understand. Understanding the various patterns present in natural neural networks requires a combination of artificial intelligence and neuroscience, which requires less computation. As a result, it is possible to understand a large number of brain reactions in relation to the activity that each person is engaged in. Human brain neurons need to be trained by experience in order to perform activities like moving the hands, arms, and legs while also considering how to respond to each activity. In the past 10 years, artificial intelligence (AI), with its potential to uncover patterns in vast, complex data sets, has made amazing strides, in part by emulating how the brain does particular computations. This chapter reviews the replication of neuroscience via AI in a real-time scenario.

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INTRODUCTION

Intelligence is described in terms of how an object responds to a circumstance or action. Human intelligence is characterized by abilities in data manipulation and accurate pattern identification. Humans can learn to match patterns by retraining their neural networks in the brain. We call this human intellect. The human brain is made up of one million neurons connected in various ways. Since trained neurons are required for learning, seeing, and analyzing, these skills make up intelligence. In order to infuse systems with human intelligence and teach them to observe, learn from, and respond in accordance with that intelligence, artificial intelligence (AI) tries to imbue them with human cognition. For scientists, mathematicians, and researchers working on AI, the mechanical, anatomical, and functional properties of the brain have served as an inspiration. AI has shown promise in the field of neurology. Artificial intelligence (AI) has led to unexpected learning and perception outcomes when it comes to the data carried by brain neurons due to how challenging it is to comprehend brain neurons. Using this information, abilities like pattern matching, inference, object detection, etc. are developed. Artificially intelligent systems (AIS) would be able to reason, learn on its own, reason, and match patterns, and other cognitive functions if neuroscientists succeed in replicating the human brain in AIS. Pandarinath collaborated with David Sussillo, a computational neuroscientist at the Google Brain Team in San Francisco, California, on his study on latent variables. Sussillo asserts that an artificial neural network is merely a crude analogy of how the brain works. For example, it represents synapses as numbers in a matrix while, in reality, they are intricate bits of biological machinery that interact with their neighbors in dynamic ways and use both chemical and electrical activity to send or terminate impulses. Sussillo claims that “a single integer in a matrix is as far from the truth of what a synapse actually is as you could possibly get” (Quan, 2022).

The artificial intelligence system has developed to the point where it can mimic human thought processes and display what those people are thinking. As a result, AIS are utilized not only in the fields of marketing and data analysis but also in the diagnosis and detection of medical conditions. As a result of these devices’ accuracy, operating rooms now use them. A large number of robots are educated to do various surgical procedures. These systems have been trained for great levels of precision, making this conceivable. Artificial intelligence, artificial neural networks, machine learning, and deep learning are just a few of the technologies that the writers focus on in this chapter that have their roots in neuroscience. Understanding the development of these methods, which draw inspiration from the human brain, as well as the various fields in which they are used and have achieved state-of-the-art status, is the main goal.

This chapter focusses on the relationships between neuroscience and AI. It also discusses the AI systems that have been developed to achieve various goals such as visualizing objects, pattern matching, mimicking human knowledge and prediction capabilities. It also analyses the various AI systems to understand the parameters linked to the human brain and the activities performed by them.

The chapter is organized as follows: section (ii) discuss about the background of AI and neuroscience (iii) discusses about the literature survey (iv) discuss about the future scope and conclusion.

Background

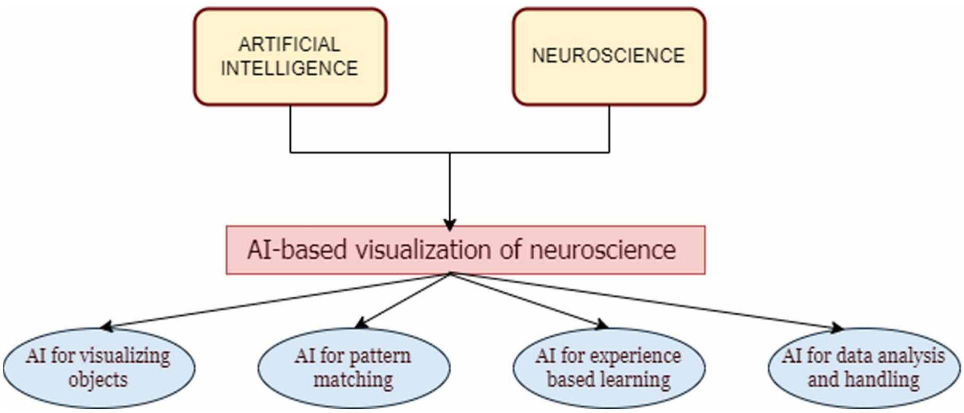
The relationship between AI and neuroscience goes both ways, and when it comes to interdependence, AI and neuroscience are dependent on one another in a way that both contribute to a deeper knowledge of the human brain and improve the accuracy of AI systems. The tasks associated with neuroscience include pattern matching, learning, and thinking formation, as well as tasks related to visualization and analysis. AI helps in understanding the human brain with respect to the parameters through which human brain has the capability to perform multiple operations. The fields of neuroscience and artificial intelligence have made remarkable advancements in recent years (AI). AI can be developed in two ways with the support of intensive biological intelligence research. First off, neuroscience can supplement the traditional mathematical and logical methodologies that have mostly dominated Artificial Intelligence, in addition to generating inspiration for new kinds of algorithms and structures. The second benefit of neuroscience is that it can verify current AI methods. It is clear from this that the presence of a recognized algorithm in the brain indicates that it is most likely a crucial component of general intelligence.

LITERATURE REVIEW

As a field of technical psychology and computational neuroscience, there is a distinction between theory-based models (e.g., reinforcement learning, etc.) versus techniques that are data-driven (e.g., deep learning). It should be noted that while the former model contains a great deal of information about biological mechanisms, the probability of success is higher for the latter. Methods with high performance are typically the least explicable, and methods that are easily explained are generally not the most accurate. This area is currently the focus of several efforts: (i) Evaluate the application of neurostimulation-relevant explainable learning solutions to neuroscience and neuropsychiatry datasets, (ii) encourage the formation of an explainable learning community among scholars, and (iii) encourage researchers to share data and theories freely (Jean-Marc et al., 2019).

This essay provides a concise overview of the various applications of artificial intelligence and neuroscience in our daily lives, including managing data and visualizing objects—tasks connected to brain functions—as well as matching patterns, learning from experience, and learning based on experience. Deep examination of neuroscience with regard to learning, visualizing, analysing, and predicting led to the development of the AI approach. Systems with embedded AI function in every way like humans do.

Figure 1. Breakdown of how neuroscience can be visualized through AI in different life scenarios



AI for Visualizing Objects

Artificial intelligence also makes use of deep neural networks to decode human thought. With the use of this device, they want to scan deep into the brain to decode and reconstruct images. In order to scan the brain's interior instead of only the surface, scientists develop fMRI (Functional MRI), which is different from regular MRI and exclusively tracks brain activity. Tracking brainwaves and blood flow to the brain is one of fMRI's peculiar behaviours.

The technology decodes the scan's data to determine the subject's state of mind at the time of the scan. Using a sophisticated neural network, data is transformed into picture format. Humans are required to turn on the system in order for it to function. When the machine is trained on how the brain functions, it learns how the human brain thinks and develops a solution. It gathers information from blood flow by monitoring the path, velocity, and direction of the blood toward the brain.

The device generates visuals by monitoring blood flow and using the data it gathers. This approach requires the use of multilayer deep neural networks. DNN includes elements of image processing. The data is then sent to Deep Generator Network (DGN) Algorithm, which uses it to build the image with a high degree of precision and accuracy. Obtaining clean or high-resolution photos is not possible without DGN. DGN can capture faces, eyes, and textual patterns, resulting in the production of high-quality visual cues. Highly similar decoded images are produced by a DGN algorithm when its efficiency is greater than 99% (M UMER Mirza, 2020).

Scientists from Stanford and UCLA have created a computer system that recognises and learns about items in the real world using the same visual learning strategy that people do.

With the aid of this "computer vision" technology, a computer can interpret and recognise visual images. The development of general artificial intelligence systems—computers that can think, learn on their own, and behave more like people—begins with the help of this technology. Although contemporary AI computer vision systems are becoming more powerful and capable, their capacity to recognise what they see is constrained by the amount of training and programming they have received. The method is broken down into three main steps. It starts by dividing each image into discrete units known as "viewlets." The machine then learns how to match each viewlet together after that. Last but not least, the system looks at neighbouring items to see whether they may be used to describe and identify the principal object.

In order to assist the new system "learn" like humans, researchers created a framework based on findings from cognitive psychology and neuroscience. About 9,000 photos, each depicting people and things, were used by the researchers during their testing. The software was able to create a thorough model of the human anatomy without assistance or labelling from other sources. Automobiles, motorbikes, and planes were used for engineering testing. Their system consistently outperformed conventionally taught computer vision systems, or at least came close to it (New AI system mimics how humans visualize and identify objects, 2018).

According to researchers at MIT's Computer Science and Artificial Intelligence Laboratory, robots can also learn to see by touch. Based solely on tactile information, an AI model predicts how the environment will interact based on the movement of the hand. The integration of senses could make the robot more powerful and reduce the amount of data needed to conduct tasks like manipulating things and grasping them. Using Generative adversarial networks (GANs), the team pieced together visual images based on tactile data. There are two parts to GANs: generators that produce samples and discriminators that try to distinguish them from actual data (Wiggers, 2019).

AI for Pattern Matching

The relationship between brain functions and cognitive function is a topic of interest for scientists (such as perception, memory, intelligence, reasoning, and consciousness.) (Kaku 2014)(Kaku, 2014). The neocortex in particular, in the brain, is continually attempting to comprehend the data. If it can't fully comprehend a pattern, the neocortex descends to a lower level. Patterns that are unfamiliar to all levels are referred to as novel patterns.

There are numerous studies being done on the human neocortex. While HBP (Markram, 2012)(Markram, 2012) intends to model the human brain, BRAIN (National Institutes of Health 2016) seeks to create a comprehensive picture of brain activity. In "On Intelligence" (Hawkins and Blakeslee 2007), (Hawkins & Blakeslee, 2004)one of the complementary theories regarding brain functioning, systematic descriptions of the neocortex's role in pattern matching are given. The neocortex is responsible for high level cognitive functions. These ideas suggest that in order to match patterns, the neocortex functions through modules of pattern matching.

The pattern matching problem has been discussed from a variety of angles in the literature. Another strategy comparable to ours is wavelet theory, which employs a series of filters to extract characteristics from an original image at particular spatial frequencies and sizes (Taubman and Marcellin, 2012)(Taubman & Marcellin, 2012). Our model analyses more generic features that are broken down recursively rather than the extraction of intrinsic features in a pattern, in contrast to the wavelet theory, which is used to apply recognition (edges recognition, texture classification, etc.).

Today's machine learning research is seeing the emergence of the field of deep learning. Through deep learning, computers are able to create complex notions from simpler ones. Convolutional neural networks (CNNs) are among the Deep Learning pattern matching methods that have been developed in recent years (LeCun, Bengio, and Hinton 2015)(LeCun et al., 2015), recursive patterns matching model, where the recursive solutions provide a succinct, understandable, and elegant solution (recursivity), but they call for enormous trees, where it is feasible to accelerate execution time through parallelism (Puerto et al., 2018).

First, researchers ask healthy volunteers to spend 20 minutes watching a 10-second YouTube video as part of their investigation. The five video categories—waterfalls, people, faces, forms, moving objects, and motorsports—were chosen at random from a larger pool of movies. The final round of videos includes motorcycle, vehicle racing, water scooter, and snowmobile videos. By examining and comparing the brain waves each movie produced, the researchers were able to use EEG to pinpoint unique brain reactions to different video categories.

They chose three at random from the five categories mentioned above. Recently, neurobiologists created two artificial neural networks.

The first phase is the creation of specific images from noise, and the second is the creation of noise identical to that produced by the EEG. Both systems interacted to produce an actual image. The experiment was then performed for unused videos belonging to the same categories. In this technique, it was possible to generate identical images with an estimated 90% accuracy (M UMER Mirza, 2020).

AI for Experience-Based Learning

A framework for artificial intelligence is being created that will instruct computers how to learn from experience, much like people do. Children, for example, start off by learning to identify things like faces and toys before moving on to learning about communication. They can develop their thinking in this way as they get older. They want AI bots to be able to recognize hazards on their own. As a result, the AI agent may dynamically learn about typical behavior and network traffic patterns, enabling it to recognize and stop assaults before they cause serious harm. Which approach is ideal in this situation? Possibly by learning?

Utilizing a reinforcement learning method, machines examine their surroundings and pick up new information through positive and negative reinforcement. They are able to accomplish a goal by keeping an eye on the future. The use of this kind of algorithm necessitates voluminous and reliable historical data that precisely captures all conceivable configurations and traits for every particular scenario.

There are actions the agent takes, rewards or punishments it receives, and a certain state it is in [St] while it strives to accomplish its goal. The agent chooses an action [At] at this stage of the process based on his observations of the surroundings and his desire to advance to the next state. The agent is first unsure of what the subsequent state will be like. If you advance to the next state, neither you nor your activities can tell you whether the benefits will be greater or worse. Only the current state of their current state and their potential actions depending on the current state are taken into consideration by agents at each phase. In this way, with repeated execution, the agent will learn how the value of his actions changes over time and which ones will yield the largest rewards. As a result, instead of learning how to maximize the goal itself, the agent learns how to come up with the best plan of action to accomplish it.

Exploitation and exploration are crucial components of reinforced learning. Exploration involves choosing random acts. However, employing exploitative methods relies on figuring out whether a particular action is worthwhile at the time in question. Depending on how we want to learn and grow, there will be a range of levels of exploration and exploitation. Every action has a null value in the initial state. It is impossible to forecast the general environment in advance because to the possibility that a state's share availability may differ from state to state. Stocks only increase in value over time. Therefore, investigation is crucial (Online, 2022).

In industry reinforcement, a range of jobs are performed by robots with learning capabilities. These machines are not only safer than people for the duties they carry out, but they are also more productive.

In order to keep Google Data Centers cool, for instance, Deepmind employs AI agents. A 40% decrease in energy use was the effect of this. Without human input, artificial intelligence manages the centers. Experts are still watching over the data center. It operates as follows:

- Deep neural networks are fed data snapshots from data centers every five minutes.
- Then, depending on various combinations, an estimate of future energy use is made.
- A set level of safety must be maintained while identifying the operations that will use the least amount of power possible, and then implementing those actions in the data center (Mwiti, 2022).

AI for Enormous Data Handling and Analysis

Software that is powered by data automatically analyses data from any source and offers insightful information. Data from client interactions can be instructive, influencing product development, enhancing team effectiveness, and identifying what functions well and poorly. Your data analysis can be automatically cleansed, processed, explained, and in the end visualized with artificial intelligence-guided systems.

Asymmetries in data management are the outcome of two things: I public information patterns that some negotiation parties fail to observe, and (ii) difficult to understand acts by an economic actor. The system learns by computations that are automatically improved. These three components—the data to be processed, the connectivity with the cloud and BD, and the computation models—are essential to the machine learning process. These three objectives must all be accomplished using ML, AI, and data science (Serey et al., 2021).

Artificial intelligence-powered data processing systems are distinct from those that use conventional techniques. Artificial intelligence software only initially needs human input; it does not require it continuously. We are working with training data in this situation. AI may analyze data in a variety of ways, such as:

- A bot can produce speedy responses for data analysis using Natural Language Processing (NLP). AI bots are recognized to outperform humans because they work with accumulated stored data, which enables them to respond with pertinent information more quickly.

- Text analysis, a branch of AI/ML, allows machines to comprehend human language and communication. Natural language processing (NLP) is used in text analysis to examine texts and extract information from the data they contain.
- Businesses can diagnose, prescribe, and predict by utilizing AI to analyze qualitative data. Businesses can forecast outcomes by employing numerous strategies at once with the use of machine learning (ML) (Ramakrishnan, 2021).

Another team's research on "Neural Encoding and Decoding with Deep Learning for Dynamic Natural Vision" was published in the journal Cerebral Cortex. Deep learning algorithms were created in order to decode the data stored in the brain.

Over the course of many hours, the researchers observed three women while they watched a range of video clips and recorded their brain activity. Videos regarding avian life, aircraft, and other relevant topics were screened. They received the photos from the cerebral cortex researchers' published studies. Using a functional MRI equipment, researchers monitored signals associated with visual brain activity. Deep learning algorithms predicted brain activity after seeing numerous clips, and it was remarkably comparable to what the women actually performed with their brains. Artificial systems imitate the workings of the brain and, by reacting to particular thoughts, provide tangible outcomes.

Researchers were able to identify the cortical region that governs thought processing thanks to their work. The acquired images were then processed and visually represented using a neural network that had been trained to do so. After the test, the network decoded the brainwaves and provided data with an accuracy rate of more than 50%. In addition, even without scanning a person's brainwaves, the network can create a visual depiction of their thoughts. The experiment's accuracy rate is 25% (M UMER Mirza, 2020).

Based on our research on different life scenarios, three quite used models or algorithm, with their advantage and the year of their introduction are mentioned below.

FUTURE SCOPE IN ARTIFICIAL INTELLIGENCE

Recent AI research has advanced at a remarkable rate. In difficult object identification tests, it has been demonstrated that artificial systems are capable of matching human performance. AI can translate between languages (Wu et al., 2016)(Wu et al., 2016), replicate human speech and, in some cases, natural visuals (Lake et al., 2015)(Lake et al., 2015), and produce neural artwork (Gatys et al., 2015) (Gatys et al., 2015) that is nearly identical to that produced by their human counterparts. AI may also

Table 1. Summary of literature survey

Model/Algorithm/Method	Advantage	Year Introduced
Convolutional neural networks (CNNs)	The fundamental benefit of CNN over its forerunners is that it uses the unique characteristics for every category on its own during pattern matching and automatically determines the significant aspects without human supervision.	1990s
Generative adversarial networks (GANs)	Generative models, which use an unsupervised learning approach, produce data that resembles real data.	June 2014
Deep generator network (DGN) Algorithm	DGNs are able to generate a wide variety of distinctive samples that are fairly convincing, and which helps in better visualization and enlargement of datasets.	2016

be used to learn from the past and forecast the future, which will assist AI systems improve the calibre of their output as they develop.

There is still a lot of work to be done before artificial intelligence reaches human levels, though. The use of neuroscience concepts will be crucial as we seek to close this gap. As a result of their ability to characterise neural circuit computations in great detail, a new generation of techniques for brain imaging and genetic bioengineering are altering our understanding of how mammalian brains work (Deisseroth and Schnitzer, 2013)(Deisseroth & Schnitzer, 2013). With continued research, it is feasible to learn more about the deep-seated brain neurons that react to sensory visions.

CONCLUSION

Brain research has been a major source of inspiration for artificial intelligence research since the turn of the 20th century. Artificial intelligence may be viewed in this sense as an enticing design template given that the brain is capable of sensing, planning, and decision-making. High-dimensional deep neural networks, which can combine memory and visual object identification tasks, frequently include hierarchical brain-inspired architecture. Neuroscience has benefited from the advancement of AI as well (Macpherson et al., 2021).

The importance of the field has been highlighted by our examination of the different ways that neuroscience has assisted AI development. It is vital to remember that when we prepare for future cooperation between the two disciplines, neuroscience's contributions to artificial intelligence have rarely resulted in comprehensive solutions that could be instantaneously put into machines. Instead, by offering insights into the learning and thought processes of animals, neuroscience has traditionally offered a more subtle benefit to researchers researching artificial intelligence. Insights from neuroscience will, in our opinion, help AI research move more swiftly. The most effective method to accomplish this is for AI researchers to actively collaborate with neuroscientists to determine the most crucial challenges that require experimental investigation.

Researchers in these two fields need to work closely together in order to successfully apply the learnings from neuroscience to the development of artificial intelligence algorithms. The researchers in these two domains regularly exchange ideas, which is where these breakthroughs frequently originate. If we can better comprehend the mind by boiling down intelligence to an algorithmic design and contrasting it with the human brain, we may be able to decipher the meaning of creativity, dreams, and even consciousness (Hassabis et al., 2017).

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KEY TERMS AND DEFINITIONS

Convolutional Neural Networks (CNNs): It is a Deep Learning algorithm that is capable of receiving image input, weighing the components and elements of the image, and determining which is significant among them.

Electroencephalography (EEG): A device that captures and measures the electrical activity in the brain.

Functional MRI: A functionality of using magnetic resonance imaging for estimating and mapping brain activity based on the measures of circulation and oxygenation.

Natural Language Processing: It is a subfield of computer science (in particular, artificial intelligence) that enables computers to interpret verbal and written information much like humans.

Neocortex: A significant portion of the higher brain functions are concentrated in the layered, complex tissue that comprises the cerebral cortex.

Neural Network: They are a component of deep learning algorithms modeled after brain activity, emulating how neurons communicate with one another.

UCLA: It stands for University of California, Los Angeles.