

NEUROBOTICS: ARTIFICIAL INTELLIGENCE IN NEUROSCIENCE

Abstract

Neurorobotics is the branch of neuroscience where robotics aligns with neuroscience. It is an interdisciplinary science which has enormous opportunity for exploration. Basically, neurorobotics involves the research in robotics and application of the same in *in silico* neuroscience. It involves artificial intelligence, robotics, neuroscience, machine learning and huge statistical analysis. It is based on the concept that our body is embedded in the environment and the brain is embodied. Neural computing is a powerful tool that has caused a revolution in the field of neuroscience research. Neurorobotics had begun with efforts to study adaptive behavior and attempts to understand the process involved in information processing by our brain in a parallel and distributed neural microarchitecture. Today modern neurorobotics stands at transforming computer vision, processing natural language and application of the science of robotics and artificial intelligence in addressing all range of issues of neuroscience. Now a days, neurorobotics has extensive utilization and application in medical science and research extending from diagnosis to understanding pathological conditions to deciding treatment patterns and interpreting the response to treatments in neuroscience.

Keywords: Neurorobotics, artificial intelligence, machine learning, neural computing

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I. INTRODUCTION

Neuroscience and artificial intelligence are having a time-long good symbiotic relationship [1]. In neuroscience, human intelligence is a higher intellectual function of the brain and its neuronal circuitry that provides a person with the ability to think, understand, learn, communicate, decide and solve problems [2]. Theoretically it is a cross link of cognitive, psychometric, developmental aspects critically called as IQ that can be quantified [3].

However human intelligence has certain limitations. Humans are more prone to errors where they may take decisions with emotional biases rather than logical approaches which may not thrive with gains. Human thinking is driven by external factors as they emerge from human experiences from the surrounding or from books or from listening or visualizing some events and from interactions with other persons that may again help the person to shape out a thought which may practically have unhealthy or less logical approaches [4]. Further human intellect is slow which may not compete with machine jobs for predicting a problem or framing a solution. Our intelligence is not progressive as it declines with age and problem solving of complicated matters may be blunted as a man ages [5].

Artificial intelligence is artificial modeling of a human neuronal circuitry of information processing and is focused on creating machines which can perform the tasks of human brain like learning, reading, reasoning surpassing human intelligence in in-depth problem solving of issues related to health and diseases for the wellness of mankind [6].

II. ARTIFICIAL INTELLIGENCE (AI) AND NEUROSCIENCE CONNECTION

In fact neuroscience has inspired men to design artificial intelligence by emulating human intelligence and framing neuronal networks that mimic brain structure [7]. Reciprocally, artificial intelligence has become an important tool for neuroscience research since 1950s. Although AI has leaped into replicating human-mimicking functions, they are quite far from creating man in bolts and nuts. This is because the creators need to have in depth knowledge about the entire working machinery of human brain and other sub-cortical neuronal network and has sub-cortical mind works.

AI models of application in neuroscience involve working memory, AI visual processing, AI analysis of neuroscience data, and computational psychiatry [8]. Human brain neurons and AI neurons have multiple neuronal networks that work in parallel. Indeed Rosenblatt had designed perceptron, i.e., a simple 'artificial neural network' (ANN) from the concept of Hebbian learning [9]. ANN are basically machine learning models that have been created being inspired by the brain functioning [9]. Later on scientists modified the perceptron network to form multilayer perceptron and back propagation theory, predictive coding, feedback alignment, equilibrium propagation and zero divergence interference learning for generation of expected results [10].

The concept of recurrent neural connection among the neurons of the cerebral cortex has a wide connection with the physiology of human working memory. This feature has helped scientists to develop an artificial recurrent neural network which uses previous output as input for the subsequent output for computing different types of cognitive activities. One such application of the concept of RNN in short term memory is to summarize texts

[11]. Similarly, incorporation of deep generator (DG) network to deep convoluted neural network (CNN) of the brain's ventral visual system have inspired scientists to construct AI computers i.e., Reinforcement Learning (RL) with improved visual reconstructions of perceived images with same CNN without DG to recognize the environmental condition for commanding the suitable action [12]. RL technology has also used extensive computing resources to recognize sounds, texts and images for computing the possible output responses [13]. Similarly analyzing behavioral responses is another target of neuroscience in the construction of AI. Again AI is an important tool to study the role of specific neuronal subsets amongst a complex neural circuit of the brain responsible for a typical animal behavior [15].

III. APPLICATIONS OF NEUROBOTICS

In simple words, AI and neuroscience when interact, they help each other in their progress. AI is the field of computer science that actually deals with simulation of human intelligence. This is achieved by using machines because of which machines gain the ability similar to human brain i.e, problem solving and decision making, etc. AI is widely applied in constructions of machines with intelligence which can perform tasks like speech recognition, game operation, auto driven cars, intelligent traffic management etc., AI is also utilized in addressing critical diagnostic issues like robotics assisted surgery, analysis of images and videos etc. Making decisions based on these analyses is also done by AI [15]. The main strength of AI is its ability to handle and analyze huge amount of complicated data at once and to extract the hidden pattern in it. Use of AI in handling and analyzing data of neuroscience is suitable for the fact that the signals from the brain are complex and complicated. Studies show that high performance AI is applied for models that drive hypothesis involving functions of the brain [16,17]. AI is now a day broadly utilized to identify, analyze and even to decide the treatments for certain brain problems. These neural issues primarily involve brain tumor, developmental disorders, degenerative disorders, seizures, headache, neurological infections and cerebrovascular disorders etc.[15]. Neurorobotic models specifically are reported for studying neurological disorders [18]. Neurorobotics is reported to be utilized in addressing certain specific neural disorders like Obsessive-Compulsive Disorder (OCD), Schizophrenia, Autism Spectrum Disorder (ASD), Unilateral Spatial Neglect, Parkinson's Disease (PD) and Huntington's Disease (HD) etc.[18] (Fig.1). These are some of the reported neurological disorders where neurorobotics is utilized.

- 1. Obsessive-Compulsive Disorder (OCD):** OCD is a neurological disorder that is expressed with symptom of repetitive tasks behind which runs some repetitive thoughts in the brain. In other words, unwanted thoughts culminate to repetitive behavior in a patient of OCD [19]. OCD is a decision making disorder and based on this a robot has been reported to be designed. This robot works based on cybernetics and signal attenuation model. The model was utilized to simulate OCD and it was used for studying OCD in details [18]. Neurocircuit models of OCD have also been designed for studying OCD [20].
- 2. Unilateral Spatial Neglect (USN):** USN is a pathological neurological condition that is described as a disorder of contralesional space awareness and generally follows brain injury. USN causes impairment of contralesional space or body awareness and also at times involve motor disorders [21]. Stroke or tumor on one side of the brain may also cause USN [22]. Studies report that limb activation through robotic therapy is capable to

improve midline perception. No promising improvement has been reported in functionality or daily activities or on tasks assessing visual scanning [23].

- 3. Autism Spectrum Disorder (ASD):** Autism spectral disorder is a developmental disorder in which the development of the neurological system is impaired. This affects the way an individual behaves and interacts with others, communicates and his learning ability. ASD can be diagnosed at any years of the life but the disorder gets easily detected at an early age within the first two years of age as because the symptoms start appearing in during the developmental milestones of the baby [24]. Neurorobotics Simulation of Autistic Behavior is reported to be induced by unusual sensory precision. This model helps to perform detailed study of the ASD [25]. The study used a humanoid robot controlled by a neural network and a precision-weighted prediction error minimization mechanism. The study suggests that both increased and decreased sensory precision could induce the behavioral rigidity in an individual which is characterized by resistance to change. And, this is the characteristic of autistic behavior[25]. The study using neurorobotic simulation of neurobiology provided system-level explanation of the mechanisms associated with various types of behavioral rigidity found in ASD and other types of psychiatric disorders [18, 25]. Further, neurorobotics and cognitive robotics study supports the hypothesis that the underlying mechanism excitation or inhibition imbalance in ASD is a local processing bias in ASD[26].
- 4. Schizophrenia:** Schizophrenia is recognized as a serious mental illness. In this neurological disorder the thoughts, feeling and behavior of a person is effected[27]. In schizophrenia, the patient suffers with hallucinations, depressions, speech disorder, delusions and lack of motivation etc.[28]. Humanoid robot models have been used in studying schizophrenia in human[18]. Nanometer-scale three-dimensional studies have been performed for brain networks of schizophrenia [29]. The study reveals that in microcircuits of schizophrenia cases, the connections between the distal neurons are suppressed [29]. This concept has been utilized for designing an artificial neural network with schizophrenia-mimicking properties and the same is used to simulate the observed connection alteration in the disorder [30]. The schizophrenia mimicking model is extensively used to study the underlying mechanism involved in the pathophysiology of Schizophrenia. The study suggests that the changes in connection observed in schizophrenia is actually not a load to the brain, rather, it has functional roles in regulating and impacting the performance of the brain.
- 5. Parkinson's Disease (PD):** PD is a neurodegenerative disorder in which uncontrolled and unintended movements occur in the patient. Balance and coordination are badly affected in PD [31]. One of the neurorobotics model of PD has been developed in which a well established computational PD model is embedded in a real robot [32]. Using the model, dynamics of PD is studied in details. The model is helpful to study the fact that different level of motor disturbance occurs in *healthy* and *parkinsonian* patient while both perform a simple behavioral task[32]. Another interesting report suggests that artificial intelligence mediated machine learning can be used to implant and regulate the PD condition in a patient. The technology involves surgical targeting of the brain pacemaker surgery and eventual optimization of the brain-pacemaker programming [32]. Neurorobotics in studying PD using integrated robotic technology helps to quantify the spectrum of motor symptoms of Parkinson's Disease (PD). Neurobotic model has the potential to help the objective assessment and this type of assessment is independent of the clinical ratings

[33]. New therapies for PD have also been tested in robots instead of using animal models and this is really a ground breaking event in science [34].

6. Huntington's Disease (HD): HD is a genetic neural disorder in which neurons in some parts of the brain gradually degenerate and die. People with HD develop abnormal unintentional movements and also exhibits abnormal postures. They also develop problems with communication, thinking, cognition, emotion and behavior [35]. Like other neurodegenerative studies, AI is used in developing models for HD and are used for understanding the pathophysiology of the disease [36]. HD based on a mouse musculoskeletal model has been utilized for neurobotic approach [37]. A combined neurobotic simulation model for studying PD, HD and other basal ganglia disorder has also been used and reported [38].

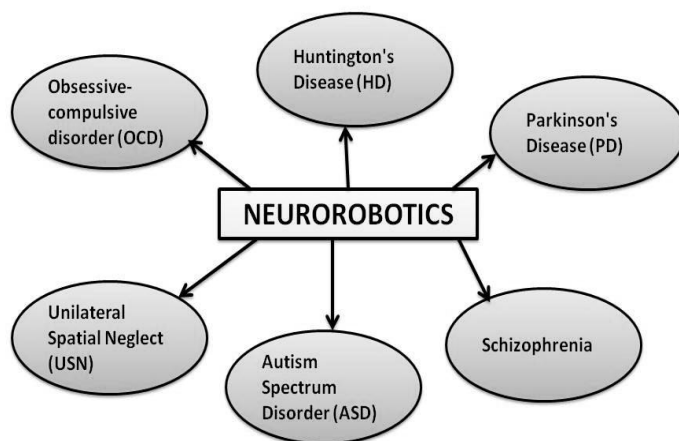


Figure 1: Application of Neurobotics in Evaluating Neural Disorders.

IV. FUTURE OF NEUROBOTICS

The recent trend of application of tools to investigate the underlying details of neurodegenerative disease has opened up various new possibilities in the neuroscience [36]. Neurobots are considered as powerful tools for understanding and studying the brain and nervous system in details [37]. This branch of interdisciplinary science is developing rapidly and the advancements in neurobotics is promising for finding out new diagnostic possibilities for the neural diseases. Different types of Neurobotic simulation models have been developed and are still developing using AI in neuroscience and applying Machine learning. Neurobotics not only involves understanding and designing of better robots using the concepts and understandings of the human brain “neural circuitry” but also involves advanced investigation and understanding of the neuroscience and human brain using robotics assisted tools and simulations robotic models of neuroscience. Some of them mimic the human brain and nervous system and some specific condition or disease state of the nervous system. The future science is actually going to be based on artificial intelligence and machine learning and robotics and information technology is going to have a wide application in expansion of all branches of science. The world is probably going to see a new

era research and inventions in the field of biological science with utilization of the science of AI, ML & robotics. Neurorobotics thus is going to be the future of diagnosis, treatment & the basis of advanced research in neuroscience. Neurorobotics is also beneficial as it reduces the use and requirement of experimental animal models for researches in neurobiology. Thus, neurorobotics is the future of neuroscience and they are going to grow and advance together in an interdependent manner.

V. CONCLUSION

The human brain is a mesh of billions of neurons and the processing of information as well as coordination of different paths of brain in intellectual actions are too difficult to study. In fact there are complex neural mechanisms that are yet not known fully. Here comes the interest of neuroscientists to study the complex neural network by the use of artificial intelligence. AI helps to unlock the secrets of brain neural networking by simulating models of virtual human brain to study higher order neural activity of the brain, human psychology and visual coordination related to learning and memory. AI assisted models enable us to address mechanisms of biological events at cellular, sub-cellular and molecular levels [40].

The interdependent and mutual beneficial relationship of AI with neuroscience helps to study brain health, counter diseases, and psychological issues by developing scientifically modeled AI technologies (neurorobotics) motivated by the ingenuity and depth of human intelligence. Neurorobots are the robots which have been designed based on the concepts and knowledge of the neuroscience and functioning of the brain. At the same time neurorobotics is being applied for understanding the functioning of the brain in detail and for testing various hypothesis of neuroscience. Neurorobotics is also used for making simulation models for understanding the underlying mechanism of various neurological disease and abnormal neurobiological conditions.

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