Connectionism

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Connectionism is one of the prevalent and widely accepted solutions to the mind-body problem in recent years. Connectionism may be categorised into localised and distributed. I will be addressing mainly distributed connectionism which may be defined as a network model that uses neuron-like structures to perform cognitive computations. It extends the idea that in the brain, neurons are connected serially and in parallel, creating small neural networks.

Why It Came About

The roots of the connectionist theory of the mind date way back to the Turing thesis, which posited that if cognition were truly rational and algorithmically calculable, then they could be understood through formal systems and could be computed using Turing machines.

McCulloch and Pitts elaborated on the Turing thesis with the logical neuron hypothesis, the essence of which was that neurons were made of simple logic gates and that a brain could be made using connections of logical neurons. The logical neuron was a homuncular functionalistic model that used an oversimplified model of a neuron to attempt to explain cognition. It was the first theoretical foundation for neural networks and computation in the brain.

Interest died down in neural networks and got transferred towards the computational functionalism-rooted GOFAI that entailed a rule-governed manipulation of formal symbols. GOFAI was rooted in logical reasoning and language use as paradigm cases of mental activity, treating them in a somewhat idealised manner that abstracted away from the concrete details of how cognitive systems are implemented.

John Searle's criticism of GOFAI in light of the Chinese Room thought experiment called the functionalistic model into question. Searle argued that a system merely manipulating symbols does not actually understand a language, thus, the brain must be doing more than the 'mere shuffling of formal symbols' and that any artificial thinking machine would have to duplicate the specific neurophysical processes

responsible for thought in the human case'. Thus, Searle set the stage for a resurgence in interest in the neural-network-centric model of cognition.

This was followed by Rumelhart et al., publishing their landmark paper regarding parallel distributed processing as a potential model for cognition in the brain, wherein hey tackled the concern of the serial-processing model of cognition being too slow to be plausible. They created a network model that had neuron-like structures to perform computation. The distributed connectionist model was better than GOFAI at capturing softer aspects of human cognition since they workwith representations that are more like statistical averages and continua than the hard-and-fast localist rules and representations of GOFAI. Connectionism is still one of the prevalent models in understanding human cognition.

Implications of Connectionism

Connectionism started off with a simple input->processing->output model of computation, implementing a single input layer, hidden layer(s) and an output layer. To achieve a better model, the initeal idea was to keep increasing the number of hidden layers and the depth of the neural network. However, this potentially faces the same fate as the CYC project. Following this was supervised learning, where the creators of the model manually adjusted the weights of each node. This method denies scalability by nature. This led to the advent of backpropagation - the recursive model where nodes start with random weights and the error difference between the actual output and predicted output is sent back as a parameter to each neuron of the hidden layer till the gradient error is minimised. Connectionism has many implications, including intelligence and emergent properties-

1. Intelligence - Intelligence may be defined as good adaptive behaviour in a particular context. Rumelhart's work on parallel distributed processing suggests that cognitive processes arise from the interaction of a large number of simple units. He believed that intelligence could be modelled by connectionist networks, because distributed networks learn from experience and can generalise knowledge across tasks.

2. Emergent Properties - Fault tolerance and pattern completion emerge as a sort of collective intelligence that is exhibited by individual neuron-like units

Advantages of the Connectionist Model

1. Multiply Realisable - Just like functionalism, the representational theory of the mind and GOFAI, connectionism supports multiply realisability as neural networks can be made of biological neurons but also be artificially synthesised by software

2. Biological Plausibility - Connectionism, through neural networks, mimics the brain's parallel distributed processing mechanism. Neurons work in large interconnected networks that adjust themselves based on weights and biases.

3. Damage Resistance and Graceful Degradation - Due to the distributed representation of neurons, the connectionist model can cope with missing or noisy data. As opposed to GOFAI's model of each input providing independent, important information to the algorithm, connectionism is robust in that the break down of one cell simply results in readjustment of weights, causing no significant damage to the model. Damage to a single neuron results in a negligible amount of noise / uncertainty in the system. The performance of the network gradually deteriorates with damage incurred - this is known as *graceful degradation*.

4. Memory Retrieval v/s Processing - The connectionist model retrieves stored information using its contents as a cue for accessing the rest of it. "Remembering" and "inferring" are analogous and performed by the same mechanism of readjusting weights of a previous state. GOFAI relied on knowing the location of a piece of information before accessing its contents, making it location-addressable. GOFAI's model is the conventionally thought of memory-retrieval whereas the connectionist model can be thought of as **memory processing**.

Flaws of the Connectionist Model

Though it is the predominant theory today, connectionism is not perfect. It faces the following criticism:

1. Jerry Fodor and the Train-of-thought Argument - Fodor argued that humans' train-of-thought was argument-like in that mental states are syntactically structured and syntactic structure determines causal will in mental processes. and that thought is a syntactic operation on mental sentences. He argued that human thought follows a rational, logical, rule-governed format that connectionism fails to provide for. Additionally, the truth-preserving character of though could be made compatible with the representational theory of the mind because state transitions of mental states are such that they led from informational truths to true beliefs when a series of computational steps is followed. Fodor claimed that there was no such rule-governance in the connectionist model.
   Connectionism might be an acceptable model for perception or pattern recognition but not higher order cognition that involve abstract reasoning and language. In response to Fodor, connectionism posits that higher level cognitive functions emerge as a product of low-level processes.

2. Brain-centricism - A prevalent argument against connectionism is that it is another model that it is highly brain-centric and physicalist in that it denies the irreducibility of mental states. It relies, to a large extent, on information received by the central nervous system, whereas the human body receives input from the peripheral nervous system and our physical surrounding environment as well. This dimension of information is neglected by connectionism.

3. Simplistic Neuronal Model - Connectionism uses a somewhat reductionist model of a neuron and doesn't permit the autonomy possessed by neurons in humans. Daniel Dennett mentions how neurons are autonomous to the point of needing rewards to continue functioning. They make judgements and decisions about which signals to let pass and which to withhold that cannot be completely modelled computationally. Connectionism does not account for this and assumes that if the weight received by a certain neuron exceeds a threshold limit, it propagates the signal, else it doesn't. While neural networks do not need to be identical to the way human neurons function, they need to apply to human

cognition, which are governed by our neurons. Thus this discrepancy could cause variation in the decision made by a neural network based model of cognition and the decision made by an actual human.

Contemporary Ideas

Yet to fill

Conclusion

Yet to fill