Storage and Associated Retrieval of Experiential Knowledge In a Machine Based Environment

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Abstract

How can we store experiential knowledge in a machine in such a manner that when a similar situation or need arises, the information can be associated and retrieved?

The human brain is an immense neural network and all experiences form a series of patterns. A popular theory explains that we keep things close to the agent that first learned them, and organize them about a Knowledge-line.

Artificial neural networks are programs that attempt to model brain pattern recognition in a procedure oriented sequential Von Newman architecture computing machine. The configuration and the weights define a unique pattern. This can be represented and stored as a matrix. The largest magnitude weight can define the K-line that can assist in orderly storage and retrieval. The other significant weights can connect to related concepts.

Introduction

Memory is a specific past experience that can be remembered. It is measured by recall, reproduction, recognition, and relearning. Retention is the persistence of an experience during a period without stimulus. [Chaplin]

Artificial neural networks, or ANN's, are programs that run on a conventional procedural oriented computer. They attempt to simulate animal brains that parallel process. They are very adept at pattern recognition and storing experiential knowledge. This knowledge is acquired in a learning process. Similar to the brain, this knowledge is stored in the connecting weights. [Haykin]

Pattern recognition or pattern matching is a process where a specific data structure is compared and matched to a given general pattern. [Smith] Its power is in its ability to generalize, that is to produce an output for an input that it has not seen before. [Haykin]

There are two basic classifications of memory. Procedural memory is the set of skills for daily tasks, such as driving a car, swimming, writing, etc. One does this without deliberate conscious retrieval and it is believed to be housed in the cerebellum and basal ganglia. [Time Life]

Declarative memory encompasses the storage of information. It is further split into two types of information and two time periods. Semantic memories are the rules, facts, and principles independent of one's existence. Episodic memories are events or experiences peculiar to a specific individual. Short-term memory is typically about seven (7) numbers and is stored for about two (2) minutes, but can

be retained for as much as 30 minutes. It can be transferred into long term memory which some say can last a lifetime. [Greenfield] [Tulving in Yazdani]

Long term memory utilizes the hippocampus and medial thalamus to place the information into the cerebral cortex. [Greenfield] [Allport] This information is distributed throughout the cortex. Depending upon what is remembered, associations trigger circuits connecting areas all over the cortex. [Greenfield] Wilder Penfield tried (and failed) to prove that memory was retained forever and that certain types were located in specific areas. [Allport]

Experiential knowledge results from actual experience and consists of specific facts and surface knowledge heuristics. [Smith] The brain makes its own rule base from what we commonly call experience. [Haykin]

Knowledge is a combination of facts and relationships. [Smith] It can be stored as data, process, or a combination of both. [Simon]

Numerous approaches to memory representation have been described. Marvin Minsky presents frames as electronic file folders. They can summarize questions & answers or one's expectations. [Minsky]

Memory plays a limited role in puzzle like problem solving, but is important in semantically rich domains. A large part of this latter type work occurs in long-term memory as it is guided by information found there. [Simon] Experience can assist in the improvement and fine-tuning of the reasoning process. It can also reinforce known rules or previous hypotheses. Case based reasoning and analogy works by comparing to previous experiences, increasing the desirability of episodic memory. [Kolodner & Simpson in Kolodner & Riesbeck]

Memory should also be dynamic, it should change with each new experience. New experience can modify or correct any mistakes or changes due to variations over time. Different experiences could cause different solutions. [Kolodner & Simpson in Kolodner & Reisbeck]

The capability of retrieving information relevant to a new situation is necessary for learning by experience. Analyzing a new episode based upon a previous one is called analogy. Similarities from both episodes combine into generalized knowledge of memory schema. [Kolodner & Simpson in Kolodner & Reisbeck]

With this limited understanding of memory storage and allocation, an attempt to create a rudimentary imitation of these processes in a computer is presented. As in a living creature, a neural network will capture the episodic experience and store the associated weights as the knowledge contained in the network. Matrices can represent this knowledge, containing both the weights and the network geometry.

Knowledge lines are represented by matrices, it being addressed by the particular experience and connecting to other associated memories. The largest magnitude weight defines the K-line, and the other matrix cells point to associated or assumed memories.

Human Memory

Learning is adding a new experience to memory. One theory of memory suggests that each learned item is located close to the agent that learned it. Each item in memory is associated with a Knowledge line, or K-line. This K-line is a list of all the activities involved with the action or particular memory. [Minsky] Karl Lashley called this phenomenon an Engram, a hypothetical trace in the nervous system. This concept was employed to explain retention. [Allport] [Chaplin]

The stronger the tie to a concept, the stronger the connection to the K-line. The connection strengths can vary widely. According to the level band theory, these weights can be separated into ranges, indicating intensity of association. The weakly activated memories are assumptions by default. [Minsky]

These assumptions stay aroused unless something conflicts with it. If someone were to mention an automobile, one would think of a gasoline powered vehicle with four (4) wheels. That would be assumed, unless one was also told that it was an electric vehicle. This commonsense knowledge is merely what is usual or typical. [Minsky]

Societies of memories are formed when a new experience occurs and one develops a new K-line, connecting related K-lines of the recent experience. This way of creating a memory is efficient and organized. Trying to connect each and every piece of information together could require hundreds of thousands of connections. Because of this type of connection, one would tend to remember only what was recognized at the moment of the experience, as unrecognized chunks would not trigger any K-lines. The information contained is from both senses and recognition. [Minsky]

The origin of associative memory was Aristotle, who in his *Classical Laws of Association*, explained four (4) ways that memories could connect:

1) Experiences occurring simultaneously or 'spatial contact'
2) Occurrence in close succession or 'temporal contact'
3) Similar experiences
4) Contrary or opposing experiences

This concept is to address memory on the basis of content, rather than location. [Narayanan in Yazdani]

Humans store an enormous quantity of facts, procedures, and associations in memory. Cues can affect speed and/or success of retrieval. Obviously, better cues provide faster and easier retrieval of target memory. The environment and preceding thoughts do affect performance. [Dosher & Rosedale]

Cues are contextual information and can be either specific or general. Specific cues link to target memory by newly learned episodic or consistent and longstanding semantic associations. [Dosher & Rosedale]

Experiential Representation in an Artificial Neural Network

A neural network is comprised of a network of input and output neurons and any number of hidden layers. Once it has been trained, by whichever method, it has corresponding weights for the connections. Once specified, the configuration and associated weights define a unique experience or relationship.

Traditionally, the trained artificial neural network, or ANN, has been used for prediction and forecasting, much like regression analysis. Only recently have researchers been looking at the trained ANN for the knowledge that it contains. Programs have been written and research has been done in an attempt to extract this knowledge. The initial programs looked at only the data and tried to extract a set of rules. The more recent research has used both the trained ANN and the data. [Morantz and Nemati]

The largest weight defines the knowledge line, and the other substantial weights connect to the other main attributes. To apply this to our earlier example of the ball, the main line might be the ball, while the other connections could be the physical characteristics. “Might” and “could be” are used because each person has his or her own set of associations. Someone else might think of a sporting game first, and a different set of relationships.

As in human memory, the strongest weight defines the K-line, and the other significant weights, within range, form the level band of associated and assumed connections. Each memory experience is related as a K-line connecting to other K-

lines, directed by the strongest weight and the level bands. In a machine, this can be accomplished by storing a matrix, pointing to the other matrices representing other knowledge lines. This in turn will point to matrices of weights and network designs, describing each individual chunk of information.

Experiences could be sorted by the single heaviest weight in the matrix of weights, and lists maintained by which cell had the heaviest weight, creating lists of all experiences that had the same strong force affecting it. When a new experience occurred, it should be sorted by the strongest weights, to lead one to other experiences that have this same strong affecting force. This is much like Minsky's Knowledge line.

The matrix of weights from a trained neural network, representing an experience, supplies this information. The heavy weights indicate the strong influences, the heaviest leading to the K-line. The K-line is another matrix, listing other relationships, and the magnitude of the respective influences. The level band

theory can be used to determine which are significant, and which are associated or assumed.

When conflicts arise, as they often do, there are two methods to settle the dispute. If one has a much greater weight, then it obviously should be the winner. If they are both comparable in this respect, then recency should determine the outcome. An influence in the more distant past might be obsolete or have been replaced by new data.

Future Directions

The next step is to design algorithms and program a machine to have these capabilities. One must also consider the neural network integrated circuits that are currently under design, as they might offer advantages over the current procedure oriented architecture machines.

After this concept is perfected for episodic memory, it can be applied to semantic and then procedural memory. Machine based problem solving can become a reality, replacing the stories of wise King Solomon.

Summary

Artificial intelligence has been discussed and researched for over fifty (50) years, and despite all of the work, memory storage has been arranged to be friendly to the existing computer designs.

The human brain functions in a different way, storing information in neurons and synaptic connections. The knowledge is not organized in databases as a computer would, but along knowledge lines, connecting multiple experiences together. The knowledge is dynamic, updating with each new experience.

Typical computer programs store information in numerical form in data structures. Language is actually numerical data that is converted to alphabetic by table look-up. The brain stores its knowledge in the connection weights in the neurons, and therefore in attempting to imitate the brain, knowledge should be stored as the weights of an experience trained neural network.

The connections between various chunks of knowledge and other experiences need to be connected along a knowledge line, just as in the brain. The present computer technology allows this to be done utilizing a matrix for each K-line. Connections can be made using the highest magnitude weights in the matrix of weights. This allows for a dynamic organization that can continually accept or retrieve required episodic memories and allow updating on a real time basis.

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