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An Instantaneous Memory Simulation Model Based on Information Fusion

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Abstract. In order to explore the process of the information processing for memory, we put forward an energy fusion model of neuron from functional view, that is, the neuron executes a fusion process before accepting the task. With the fusion computation and modeling processes of waiting and activation, initial selection, and network growth, an instantaneous memory model formed with tree structure and neural network structure. The modeling demonstrates the processing of memory function from encoding to storage, and the retrieve function in line with the extraction of memory. The model structures showed good network performance consistent with other memory network model. The theoretical model provides a new understanding for memory functions and applications.

Keywords. Memory model, instantaneous memory, fusion model, information process, neural network

1. Introduction

Memory model has a sea of types from different view. The traditional research on memory comes from psychology, which is a reverse validation study of clinical memory from a cognitive or clinical perspective. It can't vividly and intuitively understand the cognitive and functional characteristics of memory, nor can it be quantified through numerical calculations. Memory modeling can simulate the brain memory function through deterministic methods, which can vividly and intuitively symbolize abstract and disordered memory representations into an orderly and scientific understanding. The establishment of memory models and the exploration of their mechanisms have a direct driving effect on revealing and scientifically understanding the internal connections between brain structure, function, and dynamics.

Modeling provides a direct view for understanding the research in the field of subjective cognition. Research on brain memory models had from psychology to neuroscience, from initial single mode structures to dual mode structures, and even to three-level memory storage models, including multimodal structures, cyclic structures, and unified common models [1]. As we all known, the study of memory models ranges from macroscopic view to mesoscopic view, and then to microscopic. Mathematical model or cognitive model, the more microscopic the model, the more in-depth it can

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indicate the clinical function of organs. But the difficulty lies in the vast number of neurons to simulate the memory function and connection.

Early research mainly focused on psychological or clinical perspectives. In 1960, Sperling put forward a three-level memory model from information process view [2]. Willshaw introduced the information topic into memory [3]. Shiffrin explored a multiple-step memory model to impress the memory [4]. Ratcliff also set up an information memory model to describe how the memory processed the information [5]. Renart set up the modular memory model from neuron and brain region view [6]. In recent years, with the integration of disciplines such as mathematics, computer science, statistics, and control science, memory models shift more from qualitative descriptions to quantitative calculations. Hasson put forward an integral memory model [7]. Wang regarded memory as the convert rapid action [8]. Spiegler put forward a connectivity memory model [9]. Shehzad set up a neural network from complex network [10]. Ritter define a dependent state to demonstrate neuronal processing [11]. More and more they focused the point to neural network and information process. Tresp presented a unified computational method for perception and memory [12]. Arab used EEG to describe a dynamic auditory verbal learning model from information process by acquiring, retaining, and retrieving [13]. Yang presented a brain-inspired episodic memory model by memory assistance [14]. Nicoletti proposed a chemical model with energy consumption, information storage, and negative feedback and lead to the emergence of dynamical memory [15].

The memory model not only describes itself, but can also borrow the process and features of memory for more advanced algorithm design and intelligent applications [16]. One famous is long short-term memory which has been applied in deep learning within different fields for intelligent classification, recognition and prediction [17-19].

In order to explore the role of neuron in memory process, we discussed the information communication and storage in neuron with an energy fusion model based on neural computation basis. The modeling process was described by four steps with selected neurons. At last, we obtained the instantaneous memory model with two types of structure to finish the memory processes.

2. Methods

2.1. Neuron Functional Fusion

Neuron is the most basic structural and functional unit of the nervous system, divided into two parts: cell bodies and protrusions. Cell bodies have the function of connecting and integrating input information and transmitting information. There are two types of protrusions: dendrites and axons. The function of dendrites is to receive impulses from other neuronal axons and transmit them to the cell body. The function of axons is to receive external stimuli, which are then transmitted from the cell body.

From the structural of the neuron, we can infer the function of cell bodies and protrusions. In order to describe the functions of them, we can classify the neurons to different functions, sensory neurons, motor neurons, and communication neurons so that we can map the structure to the function of neuron [20]. Although the neuron structure has a long confirmation from the organism, the issue concerning of neuron function quantization has hardly been uncovered.

About memory, all kinds of neruocomputational models have been put forward to simulate the function of memory and organism [1]. From a purely functional perspective, memory is also a form of information transmission from input to output by energy consumption, but we can't quantize the information and the energy [15].

It's well known that there are many types of memory from different views. Memory is divided into instantaneous memory, short-term memory, and long-term memory classified by time. Instantaneous memory, also known as sensory memory, is a type of memory system that stimulates the short-term memory caused by sensory organs. It usually refers to a time of about one second, which is the time it takes to first feel the information being noticed.

In order to simulate the process of memory from input to output, we put forward a method from functional of neuron based on meta-memory [21]. From the information view, all the process formed in the beginning of the memory generation which is corresponding to the step of instantaneous memory, so the model is more to describe for instantaneous memory. Another, in the information process of neurons, the neuron can accommodate a certain amount of information capacity. All the information will be fusion when they come into the same neuron.

2.2. Energy Fusion Model

As we all know, artificial neural networks simulate the parallel and distributed information processing structure where the neuron provides an artificial neuron model with multi-input and single-output [22]. It supposed that the neurons need energy when they process the information. We put forward an energy fusion model to simulate the work of neuron as Fig.1.

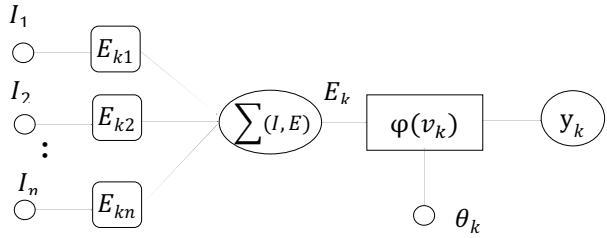


Figure 1. Neuron energy fusion model.

In the model, $E_k = \sum_{j=1}^{n} E_{kj} I_j$, $v_k = E_k - \theta_k$, $y_k = \varphi(v_k)$. I is the input of neuron with energy. The output will be determined how many neurons store the information after the fusion function.

2.3. Modeling Process

Memory models are mostly modeled from a clinical perspective. In order to better measure memory, information is applied as a feasible means, but most models are theoretical models. How to measure the size of memory and incorporate the amount of memory into the model through modeling is a challenge. In order to better explain and study the measurement of memory, this paper proposes an energy based fusion model based on the results of theoretical models [2-7].

It is well known that there are three types of memory divided by the duration of memory retention, instantaneous memory, short-term memory, and long-term memory.

This model is responding to the instantaneous memory by four steps, waiting and activation, initial selection, network growth, and network fusion [21].

(1) Waiting and activation: All the neurons wait for the tasks to active self in the beginning, and the neurons will be selected to active when the tasks come.

(2) Initial selection: Different input requirements with different energy come to the neurons after they were activated, and all the neurons come into the initial states regardless of whether the same task has occurred before.

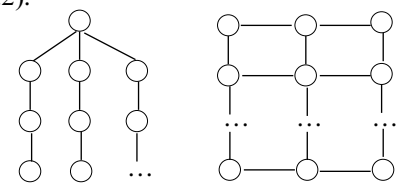
(3) Network growth: Every selected neuron receives certain mass of inputs with deterministic energy taking part in the process of memory generating after the fusion model. The information was stored in the neuron for outputting, retrieving and communicating for the instantaneous memory. Different tasks lead to different memory processes. The model enters the step of generation and growth when the new task comes. All memory neurons will connect with each other to form a path based on the order of arrival, thereby forming a tree. When multiple tasks arrive, they will eventually form a complex neural network that is interrelated. All the selected neurons formed a neural network corresponding to the specific tasks that is the memory model.

(4) Network fusion: When the same task or task unit arrives, the model enters the retrieval process which is the fusion of the model. If energy permits, old or identical tasks will merge into the same neural unit, resulting in shorter paths, that is retrieving process.

The process happens in the beginning of the memory. It is temporary and changeable. After the modeling, the architecture should have an optimization process for the model, and it will be change if new tasks come or the old tasks appears, that is, the retrieve function.

3. Results

Based on the energy fusion model, the storage structure can be formed by modeling process as follows (Fig.2).



(a) (b)

Figure 2. Storage structures of memory model.

From the storage structures, we can get the memory model described to two types of data structure, one is a tree or the forest where more than one tree exist corresponding to a mount of tasks, another is a neural network.

From the view of information storage and realization, we can select the MFset as the data structure [23]. In the Fig.2(a), the process of fusion is similar to the function of fix_mfset() where the architecture is the same, we can conclude the high search efficiency with polynomial time complexity. In the Fig.2(b), the network is close to the fully connected network which has higher search efficiency, and is similar to artificial neural network which has powerful information processing capabilities.

4. Discusison

From the results of memory models and retrieve efficiency, the memory models describe the information process and memory process from input to output corresponding to the encoding, storage, and extraction, that is, the functions of recognizing, maintaining, recalling, and forgetting.

In Fig.1, different inputs have different energy and the inputs may be individual or complex, for example, a character or a word. The fusion includes $\sum$ and φ where $\sum$ is the sum up all the energy of the inputs, and φ can be an operation to energy in the inner of neuron.

About the energy fusion model, the active neurons undertake the energy computation and fusion processing. The computation of energy sums up all the input energy by a certain strategy, that is E_k, and the fusion processing induces the fusion computation by the function of $\varphi(v_k)$ within a certain capacity range. The role of θ_k is to ensure the stability and capacity of neuronal fusion within limits [22]. After the fusion, the y_k is capable of working normally under normal conditions, and another neuron is needed to assist in special circumstances.

For an active neuron, it is first to receive the tasks and then to determine how many tasks to store based on its energy retain. After the fusion process, the neuron connects others to grow the network together to finish the tasks. At last, the network structure corresponding to specific tasks formed to express the memory process.

In Fig.2, the tree or the network were organized by nodes and edges. The nodes are the selected neurons which are active with certain energy, and the edges are the connectivity of the nodes which finish the specific tasks. In the tree structure, one node may be a unit for memory, for example, a word or a character, and the path can express a word, a phrase or a sentence. In the neural network, a line or a sub-network may be a word, a phrase or a sentence for memory.

The structures of fusion memory model have some characters of memory functions. For the tree model, it is hierarchical and independent in a path from root to leaf and a tree can be regarded as a module, so this structure is modular and hierarchical which is consistent with many memory models. For the neural network model, it is a mesh like structure and has the strong connectivity.

Once the memory model is built, search efficiency is crucial, that is, memory recalling or recognizing which can be measured by retrieve times. The retrieve times not only indicates the verification of memory success, but also expresses the efficiency of memory storage, indicating how much time it takes to remember problems, and how much energy is consumed. The number of searches can also express the search time, with the more times, the more time, and the fewer times, the shorter the time. By the tree and modular structure with MFset and fix_mfset(), the cost of the retrieve is polynomial [23]. For the neural network structure with graph storage, the model has the strong connected sub-graph which has smaller average search length than tree.

Our memory model is first and foremost in line with the reality of people's memory, and its efficiency is very high in terms of storage and retrieval. Compared to other network models, its structure is hierarchical and modular, and its retrieval efficiency is also very high.

Comparing our previous work [21], the model is closer to clinical significance from the neurobiology view. They are all have the structure of tree, hierarchical and modular characters, and polynomial search length. This model provides a new view for simulating the memory information process, and it will be stronger and more applicable

if it is verified through experiments. Although they used similar structures and processes, compared to previous work, in clinical practice, this model not only better explains energy activation, corresponds to clinical indicators, but also obtains consistent results with other models, verifying the feasibility of the model. Compared with previous work in terms of structure, the model not only has a tree structure, but also a neural network, which is more in line with the characteristics of memory networks.

With our model, the phenomenon of memory can be explained from an informational and clinical perspective. It provided a new method for describing memory from qualitative to quantitative aspects, especially for quantitative research on memory. In clinical practice, functional memory problems can be explained for diseases related to memory.

This theoretical model describes the instantaneous process of memory. If all three processes of memory are modeled, it should be a process of continuous retrieval, optimization, and fusion. At the same time, from the perspective of long-term memory, the forgetting process should also be considered, and in the entire memory model, energy calculation should be combined to demonstrate retrieval, fusion, and forgetting for more accurate results. From the perspective of implementation, this model needs to express energy at the micro level through clinical indicators in clinical or experimental settings, which is a challenge in both experimental and clinical settings.

5. Conclusions

In this paper, we put forward a theoretical model to simulate the memory information process. The model describes the process of instantaneous memory from building to storing. With the fusion model, the neuron executes the deterministic work in line with the neurobiology results and implements the function of information processing. The characters of model structure are more in line with other memory models, such as the small-world characters, the hierarchical and the modular features.

About the energy model, the challenges are how to define and calculate the energy of neurons, how to define and plan the ability of a memory task, and all energy calculations and fusion should have certain formulas. However, this is a microcosmic problem and the biggest difficulty in implementing this model. Although it is a theoretical model, it provides a bridge between theory and experiment starting from the most basic clinical phenomena. Through our model, researchers can be inspired to define and calculate qualitative problems, thereby achieving quantitative calculations. If experimental designs can verify this calculation, it will provide important value for the theory and practical application of memory.

Meanwhile, it is a theoretical model suitable for the instantaneous memory and it has several issues under unknown. How much energy of an input is, how to compute energy, and how to compute fusion are all no definite calculation methods yet. Meanwhile, the selection mechanism is unclear because some neurons are inactive state beyond the certain energy requirements. Moreover, this model does not consider the situation when the same task occurs. All the solutions of the issues will refine and strengthen the model and application to the memory research.

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