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THE STRUCTURE OF A SEMANTIC NEURAL NETWORK EXTRACTING THE MEANING FROM A TEXT

D. E. Shuklin

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A clocked linear tree is considered as the structure of connections between neurons of a semantic neural network that can extract the meaning from a text on a real-time basis. The process of extracting the meaning from a text in a natural language is represented by the propagation of waves of neuron activity through the semantic neural network, and the meaning itself is represented by the state of the network.

Keywords: *semantic neural network, extracting the meaning from a text, clocked linear tree, real-time operation.*

A semantic neural network [1] can be considered as an algebra of logic [2]. In such a network, the operations of algebra of logic are represented by individual neurons performing the logical operations of disjunction, conjunction, and negation, the values of object variables are represented by gradient values processed by the neural network, and the sequence of application of operations is specified by the structure of connections between neurons. In the network, individual neurons denote elementary notions of the meaning (predicates) being processed, and connections between neurons denote elementary relations between notions.

When a semantic neural network is implemented on a sequential digital computer, the problem of clocking a great number (about several million) of simultaneously running processes of processing data arises. To solve this problem, we introduce the notions of clocked and unclocked neurons. Unclocked neurons process input data and continuously output the results obtained, and clocked neurons also continuously output the results obtained but process input data only during definite quanta of time. The moment of activation is determined by a special clock input [1].

A text in a natural language is an ordered stream of symbols. An understanding of the meaning of such a text is a process evolving in real time. Symbols are processed sequentially, one by one, in the order of their position in the text. As new information arrives, the meaning of the data processed is simply refined, and the data that arrived previously are usually not processed repeatedly [1]. The neural network does not directly perceive and process symbols, and, hence, methods of formal representation of symbolic information in neural networks, transformation of input symbolic sequences into formal representation, and processing of symbolic information in a formalized form are required. A method of output of results obtained in a form useful to the addressee of these results, for example, in the form of a text consisting of an ordered stream of symbols is also needed.

The transformation of an input stream of symbols into a state of the neural network can be performed by receptors. Receptors transform an input action into a signal arriving at dendrites of neurons. The receptors recognizing one-type external actions, such as symbols of a text, are organized as specialized layers of receptors. The input stream of symbols arrives at the receptor layer of neurons; each receptor of this layer recognizes only one alphabet symbol in the input sequence and ignores all the other symbols. If a symbol is recognized, then the gradient value corresponding to the level of successful recognition of the symbol, for example, the value “logical truth,” is assigned to the output of the corresponding receptor. Individual symbols are recognized as the text arrives from the input stream. If the receptors obtain one symbol for

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Kharkov State Technical University of Radioelectronics, Ministry of Education of Ukraine, Kharkov, Ukraine.
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recognition in unit time, then only one neuron has the logical value "true" and the other neurons have the logical value "false" in this case. Hence, only one symbol from the text is recognized by receptors during one step (clock cycle). When the occasion requires, some different symbols can simultaneously be applied to the layer, and several different receptors will simultaneously be activated in this case.

The results of processing of a text are outputted from the neural network by effectors. Effectors transform signals of axons into actions on the external environment. The effectors realizing one-type actions on the environment are organized as specialized effector layers. For example, an effector layer in which one symbol of the output alphabet corresponds to each neuron can output a text as a symbolic sequence. In unit time, only one effector is activated by some gradient level that corresponds to one symbol printed on a dump terminal. At the same time, several notions can be combined into one effector. For example, if an adjective is outputted, then the effector corresponding to adjectives is in the active state and that corresponding to nouns is in the passive state. In this case, several effectors corresponding to different notions can be simultaneously activated.

We note that if two neural subnetworks are connected in series, then the same neurons can operate as receptors in one subnetwork and as effectors in the other subnetwork. Owing to this, the process of extracting the meaning from a text can be subdivided into some relatively simple stages. Each stage is realized by an individual subnetwork implemented in the form of a layer of neurons. The result of operation of a subnetwork is some input information for another subnetwork.

In a subnetwork that extracts the meaning from a text, an individual neuron denotes an elementary notion corresponding to the stage of processing to which belongs a given sublayer of the neural network. An elementary notion is understood to be any notion (of a natural language) having a complete meaning such as a symbol, a syllable, a word, a word-group, a sentence, a paragraph, or a text. To different stages of processing correspond different levels of aggregation of elementary notions, for example, a symbol, a syllable, a word, and a word-group. If such a notion is in the text being analyzed, then the corresponding neuron assumes the value "true," and if it is absent, then this neuron assumes the value "false." Since the process of analysis of a text is progressing in time as new data arrive at the neural network, waves of activity emerge in it and travel from receptors to effectors. We can postulate that to one wave front corresponds the meaning of the text fragment accepted by the network immediately before the start of this front. Then the termination of processing of the text can be understood to be the moment of arrival of the wave front generated by the last symbol of the text being processed at the effector layer. Thus, the result of extracting the meaning from the text is obtained on the effector layer in the form of effector states.

After analyzing a text in the processing layer, the result of processing is dynamically formed in the effector layer as an aggregate state of all the neurons of the effector layer. Each neuron of the effector layer represents an elementary notion of the meaning being extracted. For example, the neuron representing the notion "a noun of feminine gender" is activated after attaining of the effector layer by the wave front corresponding to the end of inputting words such as "мама," "маме," "машина," and "машине" in the network.

The layer of extracting meaning can be constructed by different methods. Let us consider a linear tree as a method of construction of a neural network extracting the meaning from a text. To facilitate the synchronization of parallel processes and to implement the network on the existing hardware, we will use clocked and unclocked neurons. The processing layer constructed on the principle of a clocked linear tree contains clocked neurons performing the operations of conjunction and unclocked neurons performing the operations of disjunction and negation. These neurons are connected in the form of a set of intersecting trees whose roots are pointed toward receptors and whose nodes are pointed toward effectors. The processing layer is subdivided into sublayers. To each sublayer corresponds one wave front of processing.

In a simplified synchronized linear tree extracting individual words from the input stream of symbols, all neurons perform the clocked operation of conjunction. The linear tree consists of sublayers. To each sublayer corresponds a wave front of processing. The neurons of the first sublayer correspond to the first letter of a word, those of the second sublayer correspond to the second letter, etc. The total number of sublayers is equal to the maximum number of letters in a word. The first sublayer consists of the neurons recognizing the first letter, the second sublayer consists of the neurons recognizing the first two letters, and the third one recognizes the first three letters. Each neuron has one input connection with a neuron that belongs to the preceding sublayer and corresponds to the preceding letters of the word and one input connection with a neuron that belongs to the receptor layer and corresponds to the current letter. Each neuron can have output connections with an unlimited number of neurons from the next processing sublayer. A fragment of a simple clocked linear tree recognizing the words "мама," "маме," "машина," and "машине" is presented in Fig. 1.

The same signal "new symbol," which is not shown in the figure, acts on the clock inputs of all neurons. This clock signal is generated by the receptor layer after successful recognition of a new symbol by receptors. At the moment of arrival

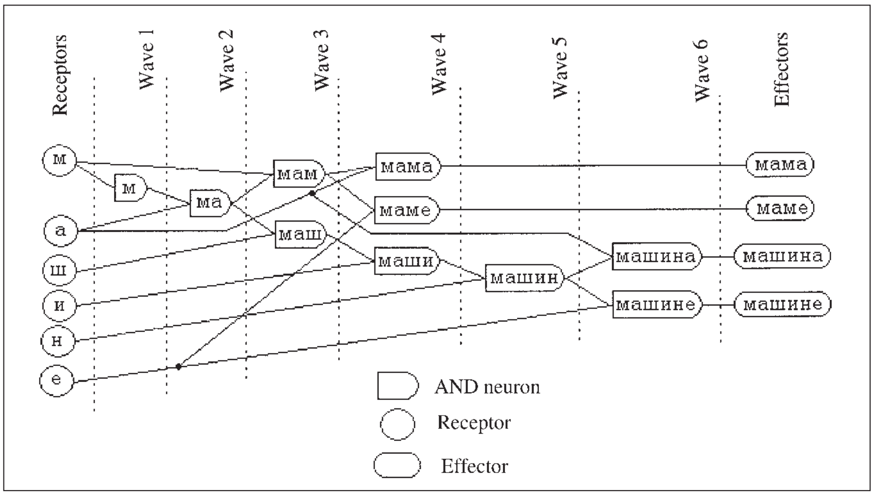

Fig. 1

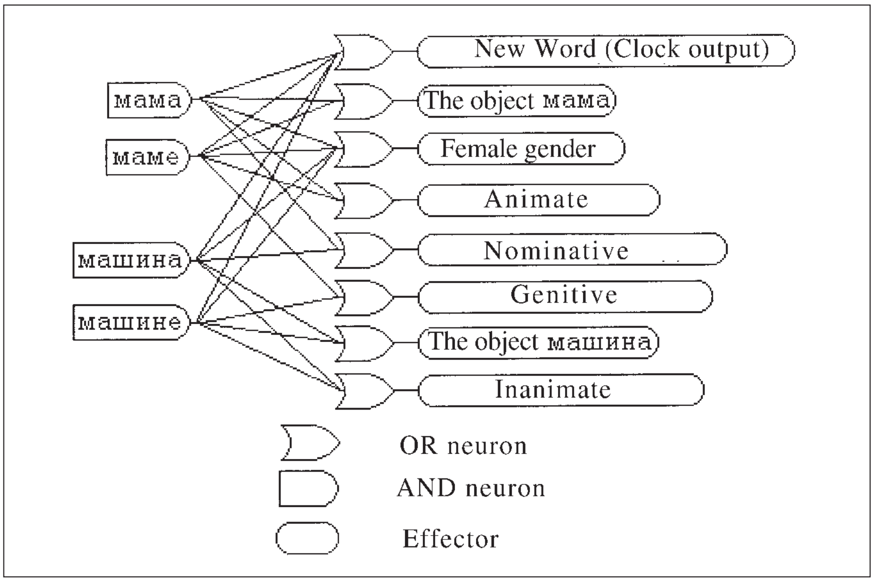

Fig. 2

of a clock pulse, all the neurons of the simple linear tree process their input signals. Since these input signals are computed from the results of the preceding clock cycle and are obtained by other clocked neurons, the effect of a processing wave is produced in the tree. We note that only ten neurons performing the conjunction function, six receptors, and four effectors are required to recognize four words consisting of $4+4+6+6=20$ symbols.

In the network presented, the functions of definition of types or classes of objects such as "a noun," "male gender," "feminine gender," etc. are absent. The functions of definition of object types are easily realized by means of an aggregation sublayer consisting of unclocked OR neurons and also inversion ones, if required (Fig. 2).

All the outputs of the neurons representing complete notions are combined by means of an unclocked OR neuron. When needed, the clock signal generated at its output can be used; this signal assumes the value "true" after obtaining the next recognized notion at the output of the linear tree. All the outputs of the neurons of the same type are combined by means of an unclocked OR neuron and are responsible for recognition of this type.

Sublayers of unclocked OR neurons are allocated between sublayers of clocked AND neurons (Fig. 3). As a result, a multi-layer structure is obtained in which an aggregation sublayer follows after each wave-front sublayer. In aggregation sublayers, unclocked inversion neurons are allocated, if required.

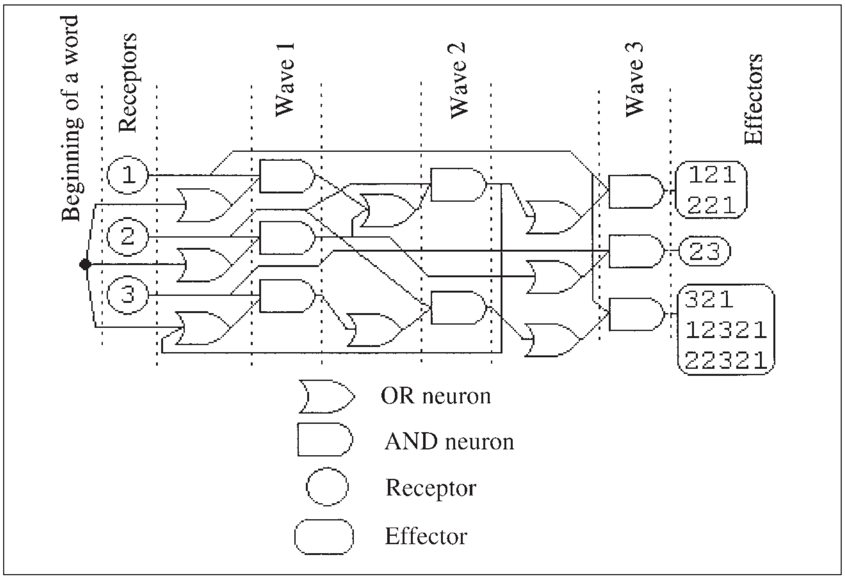

Fig. 3

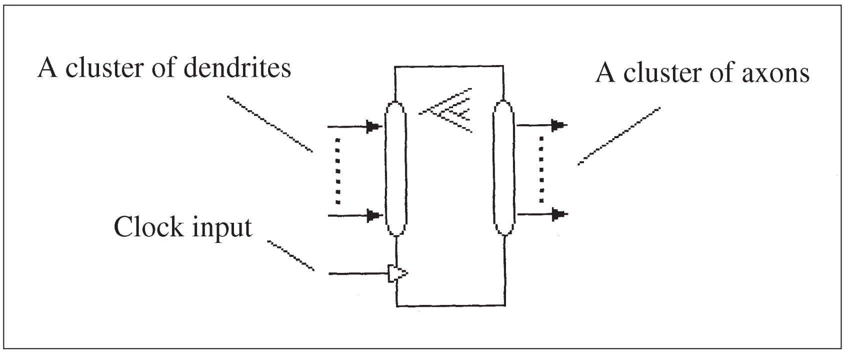

Fig. 4

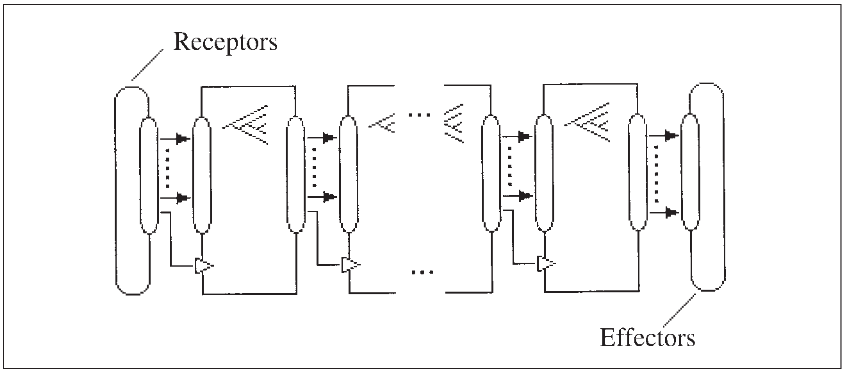

Fig. 5

For convenience, we combine sequential sublayers, which are presented in Fig. 3 and have a common clock input, into a group of neurons. We call this group a clocked linear tree and denote it as shown in Fig. 4. A group has a clock input, an input cluster of dendrites, and an output cluster of axons. The analysis of more complicated constructions such as word-groups or sentences consists of several stages and is realized by including linear trees one after another (Fig. 5).

The clock input of each clocked linear tree is connected with the clock output of the preceding linear tree. For the current linear tree, each preceding network is a receptor layer, and each succeeding layer is an effector layer. We note that the types of objects formed by the layer of type recognition are processed by the next tree as ordinary words. Linear trees process stable combinations of types as stable combinations of words, for example, “adjective-noun” or “harsh-truth.” The presence of unclocked layers of OR neurons allows for obtaining several solutions at the same time. Such a distinctive feature is an advantage of the proposed structure of neural networks since it makes it possible to simultaneously obtain all possible versions of extracting the meaning from the input stream of symbols. This provides the sequential processing of notions whose level of abstraction is increased after passing through each linear tree. The first, second, third, fourth, etc. trees processes, respectively, symbols, morphemes, words, word-groups, etc.

In the neural network considered, to different states of the input stream of symbols correspond different collections of states of this network. The meaning extracted from a text fragment processed during one quantum of time is the momentary state of all linear trees. The momentary state includes a snapshot of the set of neurons, the set of connections between neurons, and the set of internal states of neurons.

The considered structure of a semantic neural network makes it possible to process input streams of symbols in real time owing to a high degree of parallelism of computations. The lag time of the result of processing depends on the number of sequentially connected layers of processing input data, rather than on the number of neurons belonging to this neural network.

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