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Study on word clustering by recurrent neural networks

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How do children acquire language? There are many reports of research, which try to solve this question from various academic fields, such as linguistics, psychology, cognitive science, brain science, and computer science. One important approach among them is the connectionist's method for elucidation of language acquisition process. SRN(simple recurrent neural network) proposed by Elman is one of the most fundamental connectionism models. Whenever a word is input, the SRN predicts the next word of the given word(the sentence-prediction task). The SRN is considered to learn grammatical structure of simple sentences of 2 or 3 words[Elman,1990]. SRN can learn the grammatical structure of the complicated sentences containing relative clauses[Elman,1991,1993]. Tamamori has reported that SRN can also learn interrogative sentences[Tamamori, 1999] . In addition, Elman shows the hierarchical clustering in the SRN[Elman,1990]. Elman indicates that this word cluster represents the concept of grammar(syntactic category like a noun or a verb) and meanings(semantic category like "people" or "animal"), and SRN acquires grammar and the meanings without innate knowledge. However, there is a question whether the word cluster expressed there reflects the grammar and the meanings which are acquired by SRN. This is because we cannot deny the possibility

that the cluster represents just the information of sequential order of the given words.

Therefore, the purpose of this research is to verify whether the word cluster of SRN is due to learning or not. Although the cluster of the word reflects the nearness of syntactic and semantic categories, we show indirectly using a RAAM(recursive auto-associative memory) model that SRN may not learn the categories. Furthermore, in order to show that the word cluster obtained by SRN is only reflecting the syntax-structure as the time series of input words, the layer independent of the context is added between the input layer and the hidden layer of SRN. Then we show that a hierarchical word cluster isn't obtained from the activation pattern in the layer even if the layer is independent of the context.

The methods and results of the experiments are shown as follows.

(1) Word clustering by a hidden layer of RAAM

As input sentences, we generate simple 2 or 3-word sentences according to the sentence-prediction task of Elman. We assume that each word is mutually orthogonal and the distance between the words are equal. Any 1 bit does not overlap with others for every word such as 00100000 or 00000100, for example(local encoding). The sample words are input without updating synaptic weights of the encoder part (input layer, hidden layer and context layer) of RAAM. Random values($-1 < weight < 1$) are given as the synaptic weights initially. Whenever words are input, the activation pattern in the hidden layer is recorded, and an average of the activation pattern for each word is calculated. The degree of similarity can be measured by the Euclidean distance between the word's mean activation patterns. And we form a hierarchical clustering tree, placing similar words closer and lower on the tree. The word cluster has the hierarchical structure, which can be referred to as a syntactic category (like "noun" or "verb"). We should note that this result is acquired from the non-learned RAAM. In the next experiment, we examine the word cluster of the hidden layer of a SRN without learning. Input sentences are the same as those in the previous experiment. The cluster shows the structure reflecting the syntactic category which is similar to the result of the non-learned RAAM. Even if the

word cluster looks like reflecting the syntactic category, the word cluster should actually reflect the sequence of the words. Therefore, we cannot conclude easily that the SRN acquires the syntactic category by learning.

(2) Word clustering without context-sensitivity

In this model, a layer(layerB) is added between the input layer and the hidden layer(layerA) of SRN. There is no connection between layerB and the context layer. Input data are the same as the data in (1). BP(back propagation) is used for learning of Elman's sentence-predication task. In layerB, the word cluster is analyzed as shown in (1) after learning. However, the word cluster reflecting the syntactic category is not observed. On the other hand, the word cluster reflecting the syntactic category can be built by layerA which is combined with the context layer. If each word is given to the network separately in order to cut the influence of the context, the word cluster which reflects the syntactic category cannot be built in layerA. When there is no context information, even if it is after learning, the syntactic category or the meanings of words are not reflected in the word cluster.

Using the Elman's method of clustering words, we observe that the syntactic category-expression corresponds to the sequential information of words which can be expressed as context in the hidden layer of a SRN. Thus we cannot declare that the SRN acquires syntactic category-expression by learning.