Dynamic Sensory Gating Mechanism in Conditional Reactive Hierarchical Memory

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Abstract

Conditional Reactive Hierarchical Memory(CRHM) and its dynamic sensory gating system are proposed. CRHM has the hierarchical intelligent structure and has the efficient mechanisms of an acquisition stage, a retention stage and a retrieval stage for the memory process. The sensory gating system is designed for the adaptive perception in a retrieval stage. The sensory gate is tuned in to regulate the degree of reaction according to the stimulus frequency and the empirical knowledge. This system is applied to the area for estimating the purchasing degree from the type of customer's tastes, the pattern of commodities and the evaluation of a company.

1 Introduction

According to the study of brain, permanent memories are stored in the different cortical areas that process the different types of information. Permanent memories consist of a set of records that can be activated when their associated cues are in the environment or in the rehearsal systems. The unified associated consciousness can be elicited from the parallel distributed information processing in the memory. The brain as an equipment of acquiring the knowledge has the special functions to memorize the associative relations among the facts. The experiment of Pavlov shows the associative processing in the brain[1]. In his experiment, the dog was trained to eat the meat after bell sound. He found that the trained dog in this way showed the same reaction to the situation of presenting the meat even though the only bell sound was provided without providing meat. It means that these two facts, meat and bell sound, are not separated but connected each other.

The brain has also the function of using the empirical prior knowledge. The prior knowledge effects on the perception and decision making for a certain thing by producing a preconception. If he has a prior knowledge in his memory, he reacts very strongly on the input pattern related to this. The positive empirical prior knowledge has a positive effects on the perception and negative one has a negative effects. This empirical prior knowledge comes from the complex experience,namely, the environmental cause, teaching signal, the empirical memory from the award and punishment and etc.. This empirical prior knowledge can be a kind of a wisdom as well as conditional reaction by experience. For this reason, it can help to perform the effective precise perception and inference.

Many efforts have been made by the researchers in different various ways for applying this brain functions to the computer aided intelligent system[6]. The intelligent systems have many different types according to the structure, learning, memory and knowledge retrieval mechanism. To develop the well defined system, it is important to have a good structure and the efficient mechanisms for learning and knowledge retrieval.

Accordingly, in this paper, as one of method for implementing the brain function, Conditional Reactive Hierarchical Memory(CRHM) and its dynamic sensory gating system are proposed. The sensory gate system tunes in the reactive degree of the input data. Conditional Reactive Hierarchical Memory which has five layered hierarchical structure is controlled by mechanisms of memory called acquisition stage, retention stage and retrieval stage.

In a retrieval stage, the dynamic sensory gate effects on the reaction of a certain class. Its value of the sensory gate is dynamically controlled by the value of the node in the Associative layer. We apply this system to the area for estimating the purchasing degree from the type of customer's tastes, the pattern of commodities and the evaluation of a company.

2 Conditional Reactive Hierarchical Memory(CRHM)

Using the hierarchical structure described in the previous section, this system performs the mechanisms of knowledge acquisition, retention and retrieval stage.

The knowledge is obtained from the environment in the knowledge acquisition stage and retained in the memory during the knowledge retention stage. In these stages, Learning-Perception layer and As-

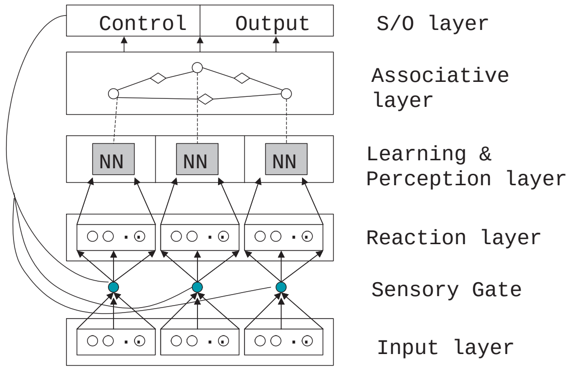


Figure 1: Conditional Reactive Hierarchical Memory

sociative layer are constructed by the learning algorithm. In the knowledge retrieval stage, the information can be extracted and inferred from the retained memory in a bottom-up or top-down way[5].

2.1 The structure

The brain concept is adopted for deciding the structural frame of the system. CRHM has three dimensional hierarchical structure as shown in Fig.1. It consists of five layers,namely, Input layer, Reaction layer, Learning-Perception layer, Associative layer and S/O layer. Through the hierarchical structure, this system is developed to perform the brain functions in the three types of memory as described in the previous section. In this system,the parallel distributed processing, which corresponds to the brain function of reactive memory, is performed by the mechanisms through the Input layer, Reaction layer and Learning-Perception layer. And the mechanism of Associative layer takes part in the associative processing ability to perform the brain functions of predicative memory and associative memory. Each layer has the different areas that belong to the different classes. These areas are connected to the corresponding areas in the other layers vertically.

The overview of the processing mechanism in CRHM is as follows. Input layer which corresponds to the sensory cell, takes part in the function of getting the data from the environment. The different classified cells in the Input layer get the data and pass them to Reaction layer. The data which belong to the different classes, can be mixed. If the mixed data come in to the Input layer, they go through the dynamic sensory gate and are reacted by the value of gate controlled by the control part in the Associative layer. The transformed values are propagated to the Reaction layer. In the Reaction layer, the mixed data are filtered by filtering function and activate the corresponding cells. Then the corresponding NN of the fired class is selected and performs its function in the Learning-Perception layer. It processes learning or perception mechanism in that step. The output values are passed to the nodes in the Associative layer. The Associative layer consists of knowledge cells that are connected by the associative relations and that contribute to process the unified associative functions. The activating state of the cells fired by the NN is propagated to the connected cells according to the associative relations horizontally. In this step, the related facts can be extracted as much as user wants. Each nodes has its empirical value, which is contained in the Control module and used for controlling the sensory gate in the low layer. Finally,the outputs from the Associative layer are passed to S/O layer in which produces the results. The functions of layers are as follows.

2.1.1 Input layer

Input layer has input cells that corresponds sensory cells and that are grouped by the different categories. The input cells get the real number data from the environment and check if input data are valid or not. Then they pass them to the Reaction layer.

2.1.2 Sensory gate

The Sensory gate is designed for controlling the reaction degree of a class by the control module in the central status. The gate for the class is opened as much as the permitted degrees by the control instruction. All the input data can be protected in the worst case that the gate is closed by the controlled instruction.

2.1.3 Reaction layer

Reaction layer performs the filtering mechanism by filtering the data from the Sensory gate. In the filtering mechanism, it calculates the filtering factor, F_i, which is the criteria for determining the state of firing.

$$F_i = P(C_i|e_1, e_2, \ldots, e_n) = \prod_{k=1}^{n} (C_i|e_k) \qquad (1)$$

where C_i is class i and e_i is the evidence i.

If filtering factor F_i is over the threshold, q_i, $(F_i \geq q_i)$, the corresponding class is fired. The corresponding NN of the fired class starts the learning or perception mechanism and produces the output. The values of the cells that don't belong to the activated class, are filtered and cleared. The outputs are propagated to the connected nodes in the Learning-Perception layer and activates NN of the fired class.

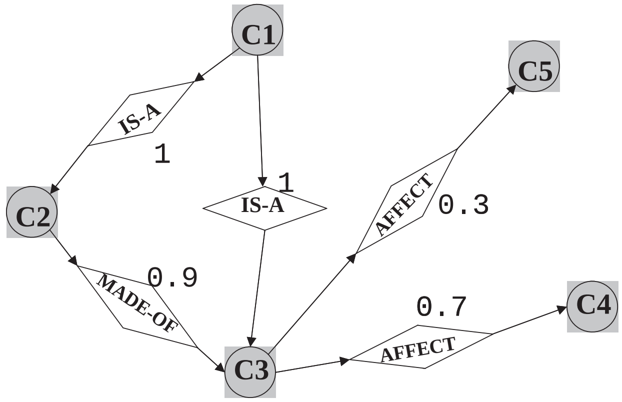


Figure 2: Relational graph

2.1.4 Learning-Perception layer

This layer contains multi Neural Network(NN) modules which perform the learning mechanism of the corresponding classes. In the knowledge acquisition stage, learning or perception mechanism is processed and the memory is retained. This retained memory has the reactive function similar to the Reactive memory in the brain. The retained memory is used for the perception mechanism. The structure of NN is three layered neural network trained by BP learning algorithm[3].

2.1.5 Associative layer

Associative layer consists of nodes and their relations. These nodes are connected to their neighbors according to their associative relations horizontally and connected to NN of the previous layer vertically. Their relations are represented by the relational graph as shown in Fig. 2.

Each node has two factors of P(Property) and EV(Empirical Value). P has the property of a class and EV retains the empirical value obtained by the mechanism. The empirical value represents the preference or the strength of activation. The relation between the two nodes is represented by both linguistic term and its associative strength.

TRANSFORM-TO : transform in time
AFFECT : partial transform
IS-A : generalization
MADE-OF :component

The linguistic terms are represented as TRANSFER-TO, AFFECT, IS-A, MADE-OF, NOT and SELF. Linguistic term denotes the degree of representing the associative relation. It can be transformed to the associative strength that has a real value of [-1,1] and that is used for extracting the related facts. The minus sign of the minus value means the opposite directional relation as -TRANSFORM-TO.

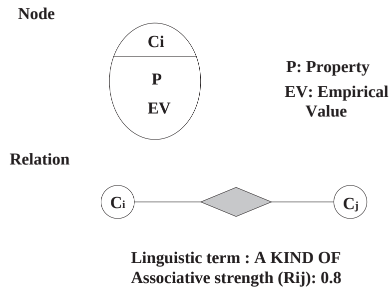


Figure 3: Node and Relation

The relational graph is transformed to the forms of AM(Associative Matrix) and vector B in order to process the knowledge retrieval mechanism. AM has the values of associative strengths in the matrix form and vector B denotes the EV of the nodes.

For example, the relational graph in Fig.2. can be transferred to the associative matrix A and vector B as follows.

The associative matrix,A, is :

$$A = \begin{bmatrix} 1.0 & 1.0 & 1.0 & 0.0 & 0.0 \\ -1.0 & 1.0 & 0.9 & 0.0 & 0.0 \\ -1.0 & -0.9 & 1.0 & 0.7 & 0.3 \\ 0.0 & 0.0 & -0.7 & 1.0 & 0.0 \\ 0.0 & 0.0 & -0.3 & 0.0 & 1.0 \end{bmatrix}$$

The matrix, A, has the form of $A = [R_{ij}]$. The associative strength,R_{ij}, between C_i and C_j is calculated by equation (2).

$$R_{ij} = P(a_i|a_j)D \tag{2}$$

where D is the direction arrow, $D = 1 or - 1$, $i = 1, \ldots, n$, $j = 1, \ldots, n$.

The vector B is :

$$B = \begin{bmatrix} -0.9 & 1.0 & 0.3 & 0.8 & 0.2 \end{bmatrix}$$

It consists of the empirical value,V_i.

Using this Associative Matrix,A, and vector B, this system can extract the related facts by following knowledge retrieval algorithm.

Algorithm 1 : knowledge retrieval algorithm

Step 1: Search the associated nodes in the row of the activated node in AM.

Step 2: IF((not found) AND (found the initial activated node))
Goto Step 3.
ELSE
Output the found fact.
Add the found fact to the list of inference path.
Goto Step 1

Step3: STOP

When the class,C_i, in the relational graph is assumed to be activated, from the node, C_i, the inferential paths can be extracted using the knowledge retrieval algorithm. The inferential path, I_i has the following form.

$$I_i = [\ C_i \quad (V_i) \quad (R_{ij}) \quad C_j \quad (V_j)\ ]$$

where C_i is i-th class node, V_i is its empirical value, R_{ij} is the associative strength between C_i and C_j. Empirical value,V_i, represents the prior knowledge of a node which is used to decide the Empirical values[-1.0,1.0] in the reactive layer. In this step, the empirical values of the classes are also extracted. The following example is the result from the matrix A and vector B using the knowledge retrieval mechanism.

I_1 = [$C_1(-0.9)$ IS-A(1.0) $C_2(1.0)$ TRANSFER-TO(0.9) $C_3(0.3)$ MADE-OF(0.7) $C_4(0.8)$]
I_2 = [$C_1(-0.9)$ IS-A (1.0) $C_2(1.0)$ TRANSFER-TO(0.9)]
I_3 =[$C_3(0.3)$ MADE-OF(0.7) $C_5(0.2)$]
I_4 =[$C_1(-0.9)$ IS-A(1.0) $C_3(0.3)$ MADE-OF(0.7) $C_4(0.8)$]
I_5 = [$C_1(-0.9)$ IS-A(1.0) $C_3(0.3)$MADE-OF(0.7)$C_5(0.2)$]

From the obtained inferential paths, this system can extract the related facts as much as user wants by masking with the threshold, θ. In this step, the connected facts that has the value of the associative strength over the threshold are extracted. In the case of I_1,when the threshold is 0.7, the extracted path is [$C_1(-0.9)$ IS-A(1.0) $C_2(1.0)$ TRANSFER-TO(0.9) $C_3(0.3)$].

The another function of the knowledge retrieval mechanism is to infer the new relations and is explained in the other paper[4].

2.1.6 S/O Interface

S/O Interface has Control module and Output Interface. Search Engine in the Control module finds the related facts from CRHM using the knowledge retrieval mechanism. Output Interface produces the results of the mechanism from the Associative layer.

3 Dynamic sensory gating mechanism by the Empirical Sensory factor

3.1 Empirical Sensory factor

Dynamic Sensory gate is designed for controlling the reaction degree of input data. It is dynamically controlled by the control value by calculating the Empirical sensory factor. we define the value that represents the empirical prior knowledge as Empirical Sensory factor. Empirical Sensory factor represents the empirical prior knowledge in the memory. This concept comes from the fact that human brain strongly reacts on the familiar facts which are experienced before in the perception process.

Empirical Sensory factor, E_i ,is calculated by the equation(4) from the Empirical Values of node i in Associative layer.

$$E_i = \frac{1 - exp^{-V_i}}{1 + exp^{-V_i}} \tag{3}$$

where E_i is Empirical Sensory factor and V_i is the Empirical Values.

Positive Empirical Sensory factor denotes the positive empirical prior knowledge and negative Empirical Sensory factor denotes the negative empirical prior knowledge. The value of Empirical Sensory factor is sent to the Control module. Reactive degree of the sensory gate which represents the degree of activation for the corresponding class, is calculated by Empirical Sensory factor and Historical Accessing factor, as shown in the equation(5)-(6).

Historical Accessing factor,H_i, represents the frequency of accessing to a certain class. If a class is not activated for a long time, the value of Historical factor decays.

$$H_i = \frac{1}{1 + e^{-A}}, A = \begin{cases} A + 1 & \text{if } accessed \\ A - 1 & \text{otherwise} \end{cases} \tag{4}$$

where H_i is Historical Accessing factor and A is the number of being accessed.

$$S_i = \frac{E_i + H_i}{2} \tag{5}$$

where S_i is Reaction degree of the sensory gate. This reaction degree is used for reacting the input data in the Sensory gate.

3.2 Knowledge retrieval mechanism using the Sensory Gate

We introduce one method of knowledge retrieval, bottom-up way, in this system. The top-down way is explained in the other paper[4].After calculating the reaction degree, it performs the knowledge retrieval step from the Input layer to S/O layer in a Bottom-up direction by the Conditional reactive algorithm as shown in Algorithm 2.

If the mixed data which belong to the different classes, come into the Input layer, they are reacted by the sensory gate which determines the reaction degree of a certain class. Their each value of the class filtered by filtering factor in the Reaction layer again. The filtered data are passed to the corresponding NN activated by the reaction degree.

The selected NN performing the perception step, propagates its output to the connected node in the

Associative layer. The extracting algorithm, retrieves the facts related to the activated nodes. Finally the retrieving facts and results are produced in the S/O interface.

The conditional reactive algorithm in a Bottom-up way for the knowledge retrieval is as following Algorithm.

Algorithm 2: Conditional reactive algorithm

Step 1: Get EV(Empirical Value) of the node in the Associative layer.

Step 2: Get the input data in the input layer.

Step 3: Perform the dynamic sensory mechanism through the sensory gate.

Step 4: Calculate the Firing factor,F_i, in the Reaction layer

$$F_i = P(C_i|e_1, e_2, \ldots, e_n) = \prod_{k=1}^{n}(C_i|e_k)$$

Step 5: Activate the corresponding NNi of a class i of if activation state is 1 and $F_i \geq q_i$.

Step 6: Propagate the output value to the connected node in the Associative layer.

$$O_i = Y_i * S_i$$

where O_i is the output value of a class NNi,Y_i is the actual output and S_i is the reaction degree.

Step 7: Extract the related fact in the Associative layer.

Step 8: Calculate the Empirical Sensory factor,E_i, in the Control module.

$$E_i = \frac{1 - exp^{-V_i}}{1 + exp^{-V_i}}$$

Step 9: Calculate the Historical accessing factor,H_i,

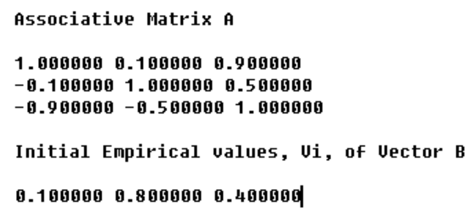
$$H_i = \frac{1}{1 + e^{-A}}, A = \begin{cases} A+1 & \text{if } accessed \\ A-1 & \text{otherwise} \end{cases}$$

Step 10: Calculate the Reaction degree,S_i,

$$S_i = \frac{E_i + H_i}{2}$$

Evaluate the activating state through reaction degree, S_i .
If

$$S_i \geq 0.5$$


Associative Matrix A

1.000000 0.100000 0.900000
-0.100000 1.000000 0.500000
-0.900000 -0.500000 1.000000

Initial Empirical values, Vi, of Vector B

0.100000 0.800000 0.400000

Figure 4: Associative Matrix A, vector B

activation state = 1
ELSE
activation state = 0

Step 11: Send the Reaction degree,S_i. to the sensory gate.

Step 12: Produce the output in S/O interface.

Step 13: Stop

4 Experiments

This system is applied to the area for estimating the purchasing degree from the type of customer's tastes, the pattern of commodities and the evaluation of a company. The purchasing estimation model is designed as shown in Fig.4. We tested with three classes. First class consists of ten customer's input term - four types of customer's tastes, second class consists of five input factors - three patterns of commodities and third class consists of eight evaluating terms - three evaluation degrees of company in the diagnostic area. Fig.5 and Fig.6 represent the results from the data extraction mechanism. Table 1. denotes the variation of output O_i according to the Empirical Value of the node in Associative layer where V_i is Empirical Value, E_i is Empirical Sensory factor, S_i is reaction degree, Historical Accessing factor H_i is 0.5000 and the output value of NNi is reacted by the reaction degree S_i. Fig.7 shows the variation of output by Empirical Sensory factor. As shown in these figures, this memory is reacted by the Empirical Sensory factor sensitively and produces the different output values according to the Empirical sensory factor. The input data of class, C_1,C_2 and C_3 are filtered and their output values are zero.

Table 1: The output by the reaction degree(Hi=0.5000

V_i	-1.0	-0.5	0.0	0.5	1.0
E_i	-0.8346	-0.4451	0.0000	0.8349	0.9146
H_i	0.5000	0.5000	0.5000	0.5000	0.5000
S_i	-0.1673	0.0274	0.2500	0.6674	0.7073
O_i	0.0000	0.0000	0.0000	0.6575	0.7298

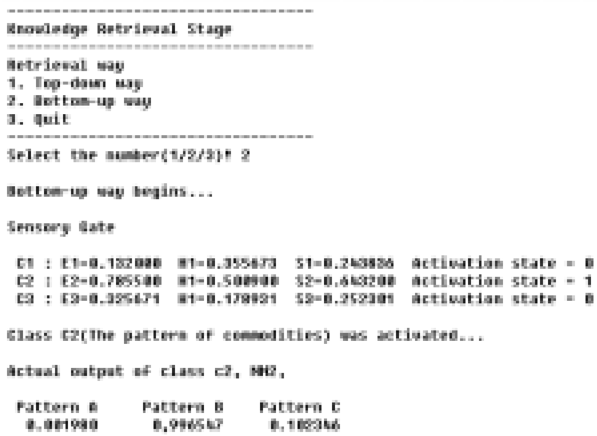


Figure 5: Knowledge retrieval step1 : output value from the mechanism

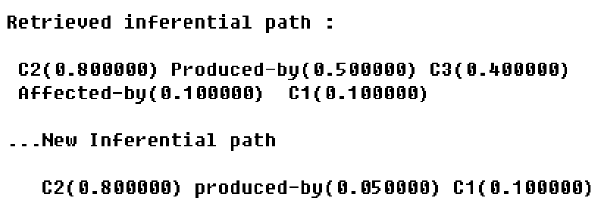


Figure 6: Knowledge retrieval step 2 : extracted inferential path

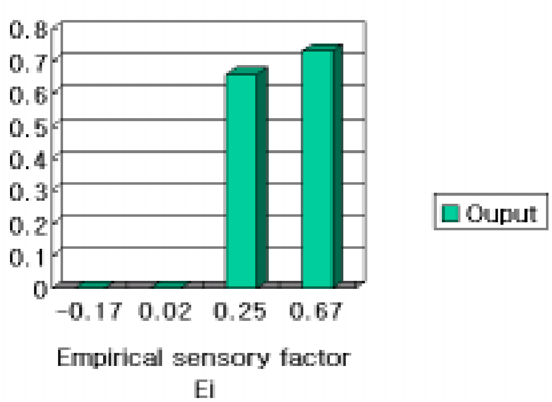


Figure 7: The output of class C_i according to the variation of Empirical sensory factor, E_i

5 Conclusion

We designed Conditional Reactive Hierarchical memory and the sensory gating mechanism. In a retrieval stage, the empirical sensory factor effects on the reaction of a certain class. This system is applied to the area for estimating the purchasing degree from the type of customer's tastes, the pattern of commodities and the evaluation of a company.

As a result of testing, we could find that it can extract the related data easily. This system is expected to be applicable to many areas as data mining, pattern recognition and circumspect decision making problem considering associative concepts and prior knowledge .

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