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MODELLING THOUGHT PROCESSES ON A NEURAL NETWORK

L. P. Ranatunga
Department of Mathematics
University of Brunei Darussalam
Tel: 673-2-249001
Fax: 673-2-249502
email: lpr@ubd.edu.bn

ABSTRACT

The analysis and classification of consciousness and the details of human thought processes can be found in the Theravada Buddhist theory of mind. A thought process consists of several thought moments and each thought moment has some sort of function in the process. The constituents of thought moments, known as mental states, can be computed. Based on such a computation, we construct a neural network to model thought processes.

Keywords: ***Buddhist psychology, Thought process, Neural networks***

1.0 INTRODUCTION

A considerable amount of details about the operating system of the human brain can be found in Buddhist psychology. The details about thought processes are good example of the above claim.

There are two types of thought processes; five sense door thought process and mind door thought process. The first type receives input information from the sensory system while the latter receives input information from the mind itself. A thought process consists of several thought moments or consciousness. When one thought moment perishes, it transmits at the same time all its potentialities to its successor. Thus, there is a continuous flow of consciousness. In Section 2, we present thought processes in details.

Every consciousness is accompanied by a set of mental qualities which are called mental factors or states. No consciousness exists without its mental states. Coexisting consciousness and mental states are related to one another by association rules. The computation of mental states associated with thought moments has been presented before [1]. The results of such computation relevant to thought process are presented in Section 3.

The information about constituents of consciousness can be used to model thought processes on a neural network. The idea behind this is to use populations of neurons to model mental states. Coexisting mental states of a thought moment can then be represented using a layer of those populations which in turn represents the thought moment. Since we know coexisting mental states at each stage of thought process, network structure for the whole thought process may be specified. This will be the subject of Section 4. Section 5 is devoted to the conclusion and suggestions for further work.

Computer modelling of thought processes has already been studied [2]. Their analysis concerns with the effect of determining consciousness on thought process. Considering three mental states, namely, attachment, aversion and equanimity, Karunananda [2] calculates probabilities in future stages of the three mental states. We have presented a stochastic model of impulsive thought moments before [1].

It should be pointed out that there are many technical terms in Buddhist psychology which cannot be rendered into English so as to convey their exact meaning. For the exact meaning of the technical terms used here, the publications [4, 6, 7, 8] may be consulted.

Finally, it is worth pointing out that the network structure will apply only to ordinary human beings and not to Buddhas and Arahants.

2.0 THOUGHT PROCESSES

According to the Buddhist theory of mind normally there is no moment when we do not experience a particular kind of consciousness, hanging on to some object-either physical or mental. The time-limit of such a consciousness is termed one thought moment. A thought process consists of several thought moments. As we mentioned earlier, there are two types of thought processes. In this section, we shall present them in detail.

2.1 Sense-Door Thought Process

In a thought process, there is a sequence of steps called thought moments or consciousness. Each step has some sort of function in the process. There are 17 thought moments in sense-door-thought process which is summarised in Fig. 1. The initial state of thought process is the life-continuum consciousness. Its function is to keep the stream flowing.

The flow of life-continuum is interrupted when objects enter the mind. Owing to the rapidity of the flow of life-continuum an external object does not immediately give rise to a thought process. There is a possibility that the transition from life-continuum to next state, sense-door consciousness, will not take place at all in respect of the given object. In such a case, the object is termed very slight object.

If a transition is made to the state of sense-door-consciousness then the mind is turned towards the object. Depending on the nature of the object (form, sound, etc.) transition is made to respective state of sense consciousness (i.e. eye-consciousness, ear-consciousness, etc.). The next state is the receiving consciousness which accepts or receives an object. Next comes a momentary examination of the object so received. This state is termed as investigating consciousness. After this comes the state of representative cognition termed the determining consciousness. Discrimination is exercised at this stage. Freewill plays its part here. This is the gateway to a moral or immoral thought process. If a transition is not made to the next state, i.e., impulsion, then the thought process will cease and loop back to life-continuum. In such a case the object is termed slight object.

Psychologically most important stage is the impulsion. It is at this stage that an action is judged as moral or immoral. There are normally seven impulsive thought moments. Again, the thought process may cease here looping back to life-continuum. In such a case the object is termed great object.

If the thought process reaches the next state, the registering consciousness, then it will last for two thought moments. Registering consciousness performs the function of retention. Starting from life-continuum there are 17 thought moments in the complete process. As a rule, for a complete perception of a physical object through one of the sense-doors precisely 17 thought moments must pass. Such an object is termed very great object. Finally, the thought process loops back to life-continuum. Therefore, thinking mechanism is cyclic. The information run cycle time is infinitesimal.

2.2 Mind-Door Thought Process

As in sense-door thought process, mind-door thought process starts with the phase of life-continuum. There are three moments of this phase. In this cognitive series, mind door consciousness turns mind towards a mental object. The other states of consciousness shown in Fig. 2 are explained in Section 2.1. After the phase of registering consciousness there are four thought moments of life-continuum consciousness completing 17 thought moments in the thought process.

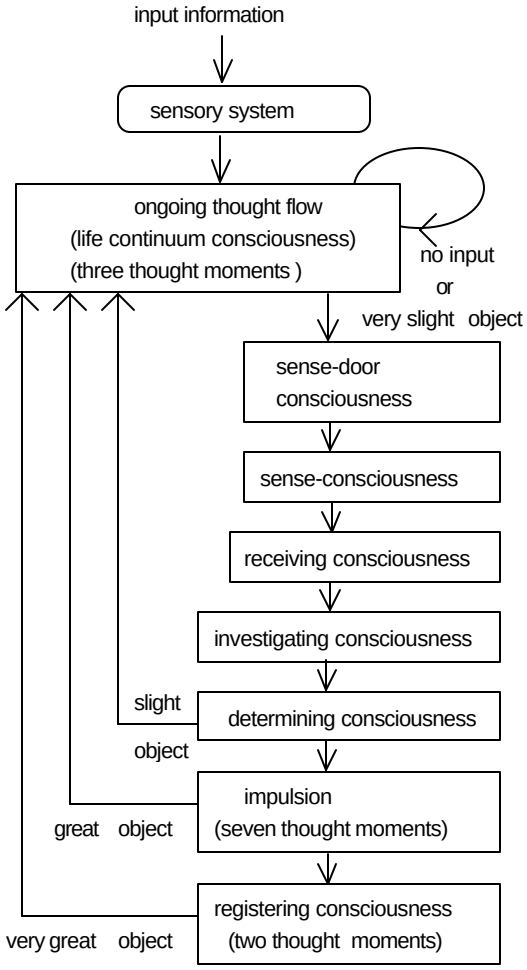

Fig. 1: Sense-door thought process

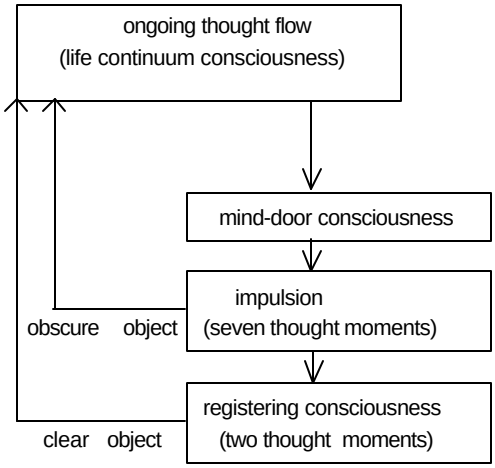

Fig. 2: Mind-door thought process

When a thought process, arising through the mind-door, ceases at the phase of impulsion, the object is termed obscure. If it extends up to the phase of registering consciousness then the object is regarded as clear.

When an object is presented to our minds through our sensory system after the sense-door thought process there arises a mind-door thought process perceiving the object mentally. Again the stream of consciousness subsides into life-continuum and two more similar thought processes arise before object is actually known.

2.3 Handling Redundant Information

It was mentioned in Section 2.1 that the five sense door thought process consists of 17 thought moments. For a given object the thought process may not run for 17 moments and it was mentioned that in the case of very slight object the thought process may not arise. This feature of the thought process contributes to the protection of our mind against redundant information, information input must fit its limited capacity of the brain. In the case of slight objects, sense-door thought process ends before reaching the stage of impulsion. In the case of such objects the perception has not been complete.

It is clear that slight and very slight objects are processed faster than great and very great objects. In this manner our minds handle redundant information.

3.0 MENTAL STATES ASSOCIATED WITH THE THOUGHT MOMENTS

In the previous section, we learnt that five sense door thought process and the mind-door thought process consists of several thought moments. A thought moment is a time duration of consciousness which performs the respective function in the cognitive series. There are, collectively, 45 types of consciousness which are experienced by ordinary people.

According to the Buddhist theory of mind, every consciousness is accompanied by a set of mental qualities which are called mental factors or states. No consciousness exists without its mental states. Collectively, there are 52 mental states. Coexisting consciousness and mental states are related to one another by association rules and therefore it is possible to compute coexisting mental states for a given type of consciousness. The computation of mental states associated with thought moments has been presented before [1].

Each function in the thought process is performed by at least one type of consciousness. Certain functions are performed by more than one type of consciousness and therefore we would get more than one combination of coexisting mental states for such functions. The combinations of coexisting mental states for each function are presented in the Table 1.

It is worth pointing out that each combination includes a common set of seven mental states, namely, contact, feeling, perception, volition, one pointedness, faculty of life, attention.

Table 1: Combinations of coexisting mental states

Type of consciousness	Combinations	Number of states for a combination
Life-continuum	5	10,31, 32(2 times), 33
Sense-door consciousness	1	10
Mind-door consciousness	1	11
Sense consciousness	1	7
Receiving	1	10
Investigating	2	10, 11
Determining	1	11
Impulsion	42	15(2), 17(2), 18(10), 19(6), 20(2), 31, 32(5), 33(9), 34(5)
Retention	6	10, 11, 31, 32, 32, 33

4.0 MODELLING THOUGHT PROCESSES USING A NEURAL NETWORK

In the previous section, we have presented mental states associated with thought moments. A state of consciousness lasts as long as the combination of its mental factors. The simultaneity of these factors has to be conceived as something fluid and not static [5]. We may make use of this information about constituents of consciousness to model thought processes on a neural network.

Populations of neurons could be used to model mental states. Coexisting mental states of a thought moment can then be represented using a layer of those populations. Since we know coexisting mental states at each stage of thought process, network structure for the whole thought process may be specified.

We shall construct a neural network representing sense-door thought processes. The network diagram presented in Fig. 3 is of its simplest kind where a single neuron is used to represent a mental state and a layer of neurons is used to represent coexisting mental states in the cognitive series. For simplicity, we concentrate only on very great objects.

The first three layers of the network represent three thought moments of life-continuum consciousness. Recall that there are five possible combinations for life-continuum consciousness. The most important feature of this life-continuum is that it determines the inherent qualities of a person in a particular life-time and this is some type of permanent behaviour during that particular life-time [9]. As such, for the first three layers of the network, we may choose only one combination with a fixed number of neurons (say, 33) selected from the first row of Table 1.

Layers 4, 5, 6, 7 and 8 represent sense-door consciousness, sense consciousness, receiving consciousness, investigating consciousness and determining consciousness, and have 10, 7, 10, 11 and 11 neurons, respectively. For this network, we have selected only one combination of neurons to represent investigating consciousness.

Layer 8 is the gateway to a moral or immoral thought process. Layer 9, represents the first moment of the seven impulsive thought moments. There, we have 42 combinations (see Table 1). We represent these by 42 branches. For example, we have two branches with 15 neurons each, 2 branches with 17 neurons each, etc.

According to the Buddhist psychology, the mental states occurring in seven impulsive thought moments are similar, but their intensity differs. Thus, there are no connections between branch i in layer 9 to branch j in layer 10 when $i \neq j$. On the other hand, the number of neurons for each layer in layers 9 to 15 must be a constant for any branch.

These branches represent moral or immoral impulsion. If viewed rightly, at the determining stage, the impulsion becomes moral; if viewed wrongly it becomes immoral.

To decide which branch receives the current information in layer 9, we use self-organising feature-mapping (SOFM)[3]. The total number of neurons of the layer 9 is 1056. Let $\mathbf{w}_j$ denote the normalised synaptic weight vector of neuron j, j = 1, 2,…, 1056, of layer 9. To find the best match of the output vector $\mathbf{x}$ of layer 8 with the synaptic weight vector $\mathbf{w}_j$, we compute minimum Euclidean distance between vectors. Let $i(\mathbf{x})$ denote the neuron that best matches the input vector $\mathbf{x}$. We may then determine $i(\mathbf{x})$ by

$$i(\mathbf{x}) = \arg_j \min \| \mathbf{x} - \mathbf{w}_j \|, \qquad j = 1, 2, \ldots 1056$$

where $\|.\|$ denote the Euclidean norm of the argument vector. Let $B_{i(\mathbf{x})}$ denote the branch which contains the winning neuron $i(\mathbf{x})$. We then select the branch $B_{i(\mathbf{x})}$ and modify weights of the each neuron j in the same branch by the rule

$$\mathbf{w}_j(n+1) = \mathbf{w}_j(n) + \eta(n)[\mathbf{x} - \mathbf{w}_j(n)]$$

where $\eta(n)$ is the learning rate parameter at time n. The output of the branch $B_{i(\mathbf{x})}$ in layer 9 is now taken as the input vector to branch $B_{i(\mathbf{x})}$ in layer 10 and modify the weights in the same branch using the above rule. This process will continue up to (and including) layer 15 for the branch in hand.

Layers 16 and 17 represent the phase of retention. There, we have 6 branches corresponding to the combinations presented in Table 1. The network connections from layer 15 to layer 16 have to be considered with some additional details which we shall present below.

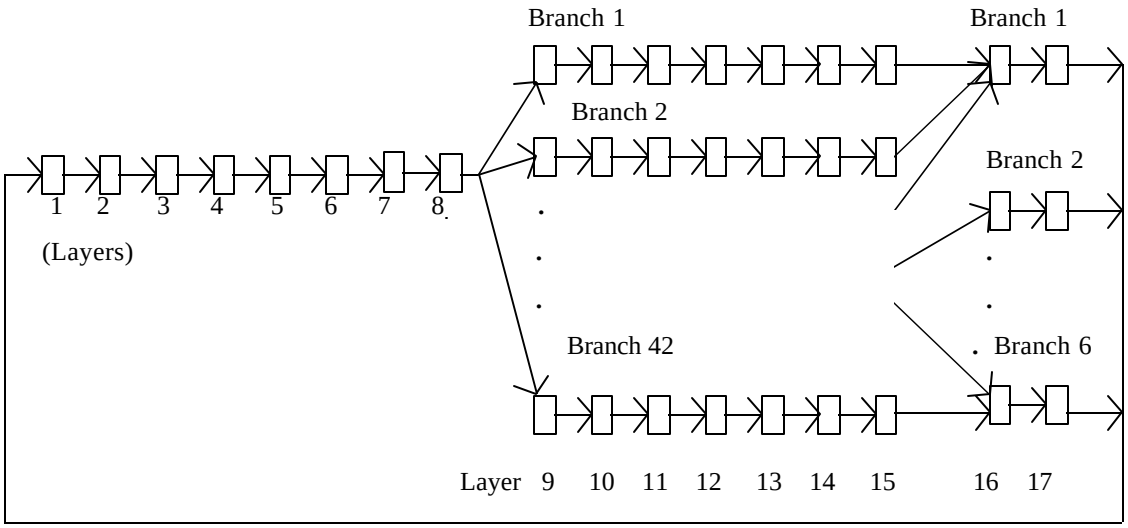

Fig. 3: A neural network representing sense-door thought processes

A feeling is a mental state common to all types of consciousness. Feeling is five fold, namely, happiness, pain, pleasure displeasure, and indifference. Impulsive thought moments are, however, accompanied by only pleasure, displeasure or indifference feeling. According to table 1, we have 42 sets of coexisting mental states for the phase of impulsion. From these sets, there are 17 sets accompanied by indifference feeling, 6 sets accompanied by displeasure feeling and 19 sets accompanied by pleasure feeling. Table 2 summarises this information.

Table 2: Impulsive thought moments according to type of feelings

	Indifference	Displeas-ure	Pleasure
Number of mental states	15(2), 17, 18(4), 19(2), 31, 32(4), 33(3)	17, 18(5)	18, 19(4), 20(2), 32, 33(6), 34(5)
Total	17	6	19

From Table 1, we have 6 sets of mental states associated with retention. From these, three are accompanied by indifference, three are accompanied by pleasure and none is accompanied by displeasure feeling. Table 3 summarises this information.

Table 3: Retentive consciousness according to different type of feeling

	Indifference	Pleasure
Number of mental states	10, 31, 32	11, 32, 33

As a rule, the proceeding impulsive thought moments and the subsequent retention possess a similar feeling. For example, if the impulsion is accompanied by pleasure, then the subsequent retention is accompanied by pleasure. The impulsive thought moments accompanied by displeasure feeling, are, however, followed by retentive thought moments accompanied by indifference feeling. Other than this, we have no information how to connect branches in layer 15 to layer 16. We propose a network structure inspired by Table 4.

In Table 4, row 2 contains 31 mental states for each type of consciousness. These mental states are identical for both types. The same is true for row 5. So, we connect the branch with 31 (respectively, 32) neurons in layer 15 to the branch with 31 (respectively, 32) neurons in layer 16. Given any row, the branches that would represent mental states corresponding to the first column of Table 4 are connected to the branch that would represent mental states corresponding to the second column.

Table 4: Information for connecting layer 15 to layer 16

	Impulsion (number of mental states per thought moment)	Retention (number of mental states per thought moment)
Indifference or displeasure	15(2), 17(2), 18(9), 19(2)	10
	31	31
	32(4), 33(3)	32
Pleasure	18, 19(4), 20(2)	11
	32	32
	33(6), 34(5)	33

Finally, after the retentive thought moments, the thought process loops back to life continuum consciousness, thus we connect these six branches to the first layer. Because of the recurrent nature of the network it exhibits short-term memory while the weights of the network exhibits long-term memory.

The size of the network is large and that restricts us from implementing it on a PC. A simple model with seven layers has been implemented using C++ language.

5.0 CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

The details of the thought processes as given in Theravada Buddhist theory of mind have been presented. A neural network has been constructed to model thought processes. The network will model sense door thought processes of ordinary human beings.

Mind door thought process could be easily modelled from the information given here. To do this, one would need only to add additional layers representing thought moments of life-continuum consciousness, mind-door consciousness and remove layers 4, 5, 6, 7 and 8.

Volition is the most significant mental state which is common to all types of consciousness. According to the theory, volition is that which co-ordinate the mental states associates with itself on the object of consciousness. It determines the activities of the mental states associated with it. Additional details like this could be incorporated to the network by connecting other neurons within the layer to the one representing volition.

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BIOGRAPHY

L. P. Ranatunga obtained his Ph.D. in Computer Science from University of Kent at Canterbury in 1989. Currently, he is working as a lecturer at the Faculty of Science, University of Brunei Darussalam. His research areas include concurrency theory and Artificial Intelligence.