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Design of Selective Hierarchical Cognitive Heart Wired Artificial Network

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Abstract

Artificial Intelligence Technology is playing an important role as the core engine of the future society. For building such a core engine, a highly efficient, structured and intelligent mechanism should be designed. As one of these directions, we proposed Hierarchical Cognitive Heart Wired Artificial Network which has Learning, Perception, Reasoning, Extraction and Selection function in a hierarchical frame. Especially in this system, emotional factors are designed to be combined with knowledge in the knowledge network. In the experiments, the proposed system was applied to event scheduling problem, the effects of emotional factors in the Emotion-Knowledge linkage structure were investigated. and the working phase of the functions is simulated. As a result, it shows that the effects of emotional factor on Decision making was traced.

keywords : Heart Wired Artificial Network, Reasoning Thread, Extraction depth, Emotion, Hierarchical cognitive structure

1. Introduction

It is expected that the driving force of the future to be unfolded will be the Artificial Intelligence technology modeling the human brain as the core, and it will be built in the form of various types of systems. The most comfortable environment for human beings to live will be created by building a new artificial ecosystem and developing conditions for intelligent communication with each other by integrating hyper-connected and super-intelligent functions with the system. Some scientists believe that artificial intelligence technology has the magical energy to turn dreams and imaginations into reality. Even more functions are not yet revealed so far, there are a number of effective features that are surprisingly effective, just known by research [1,2]. The direction of this study is not much different from the current AI research direction. Basically, modeling the human brain, we designed information

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connectivity, learning function, reasoning, information retrieval, extraction and selection function. The difference from other studies is that the knowledge processing consists of Learning phase and Reasoning phase in a hierarchical form. In Learning phase, after learning the trained network performs the perception process of discriminating what it be. It is a kind of an intuitive perception which can recognize instantaneously. In the other hand, the Reasoning phase processes Inference, extraction, Information retrieval and selection function. For realizing these functions, knowledge network is structured for the easy flow of Thought propagation. One knowledge is connected to the other knowledge by association link. Especially in the proposed system, Emotion-knowledge linkage structure was designed to combine the emotional factor to the knowledge network because the effect of emotional factor on the results is so high in the reasoning process and decision-making. We often experience that we have a same feeling to the memorized time when we recall some memory. It means that emotion can also be memorized with knowledge or events. For example, If you have a happy memory of going to the apple orchard with your mother as a child and picking apples and eating them, you will feel happy whenever you see an apple. This means that emotional factor is remembered together with knowledge and experience. In addition, the emotional factor will give an impact to the reasoning process and decision-making. In particular, when designing the Artificial Intelligence System such as a robot that should coexist with humans, these emotional factors should be considered. Therefore, the emotional factor needs to be carefully designed because there may be personal preference, tendency and individual experience. Even though Emotion and Knowledge are closely linked together, the studies about the link of emotion and knowledge have not been made yet. Therefore, in this work, we intend to design a more efficient intelligent system to have a hierarchical structure which consists of emotion-knowledge linked network and learning modules. We propose Hierarchical Cognitive Heart Wired Artificial Network (HCHWAN) which consists of Cognitive Network and Heart Wired Artificial Network. In this system the Learning part was implemented as Cognitive Network and the Reasoning part was implemented as Heart Wired Artificial Network. In Heart Wired Artificial Network, knowledge term and Emotional energy are combined in the structure of knowledge Network. Based on this knowledge emotion combined network, every knowledge extraction, reasoning and selection function are processed in this structure.

2. Related Works: Emotional Modeling

Oxford English Dictionary defines emotion as ‘any agitation or disturbance of mind, feeling, passion; any vehement or excited mental state’. And emotion is defined as ‘ biologically-based psychological state brought

on by neurophysiological changes, variously associated with thoughts, feelings, behavioral responses and a degree of pleasure or displeasure' in Wikipedia. Neurobiologists and psychologist have conceptualized an emotion as a concerted, generally adaptive, phasic change in multiple physiological systems in response to the stimulus[4-6]. Drawing upon two different theories, the first emotion theory acknowledges that emotion processing is domain-specific and relates to the value that stimulus has for an organism. Emotions derive from information that is of direct relevance to the organism's the homeostasis and survival, that is, the significance that situation has for the organisms both in terms of its immediate impact and in terms of organism's plans and goals in responding to the situation. Fear and Disgust are obvious examples of such emotions. The second concerns the cause-and-effect architecture of behavior, bodily states and central states. For example, we are afraid first and then run away. Emotion is regarded as a mental reaction directly related to survival and Amygdala, the innermost part of the limbic system in the brain structure, is responsible for emotional processing. In addition, emotion plays an important role in the perception of things, reasoning processes, decision-making and behavior. Emotional information processing depends on a complex collection of steps implemented in a large number of neural structures. Some components of this architecture can be made by implementing three processing steps : (1) perceptual representation of the stimuli. This step draws on higher order sensory cortex and some domain-specific processing: certain features of stimuli are processed by specialized sectors of cortex, permitting the brain to construct important information. (2) an association of perceptual representation with emotional response (3) a final sensory motor representation of representative models. There are Plutchick's Wheel of emotions [9] which arranges emotions around eight basic emotions , SentiWordNet which expresses emotions in an inverted triangle structure by determining the scale of positive and negative, Russell's emotion model[11] which classifies emotions in the axis of arousal-relaxation and pleasure-displeasure, and etc.. For Multi-dimensional analysis, psychologists have used methods such as factor analysis to map emotion-related value into a more limited number of dimensions. Emotions are boiled down to underlying dimensions that capture the similarities and differences between experience. The two dimensions are valence and arousal and can be depicted on a 2D coordinate map. Valence means how negative or positive and arousal represents how energized or enervated. The two dimensional map has been theorized to capture one important component of emotion called core effect [7-15].

In this study, Two dimensional emotion model by Russell as shown in Figure 1 was referred to.

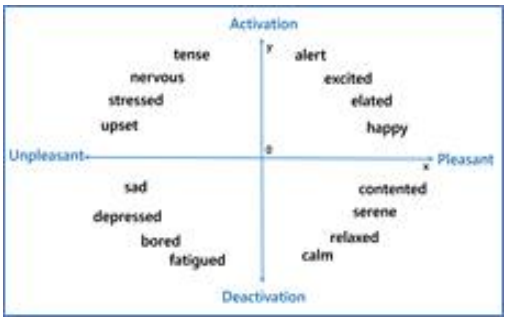

Fig. 1. Two dimensional Emotion model by Russell

3. The design of Hierarchical Cognitive Heart Wired Artificial Network(HCHWAN)

3.1 The structure of HCHWAN

3.1.1 The system overview

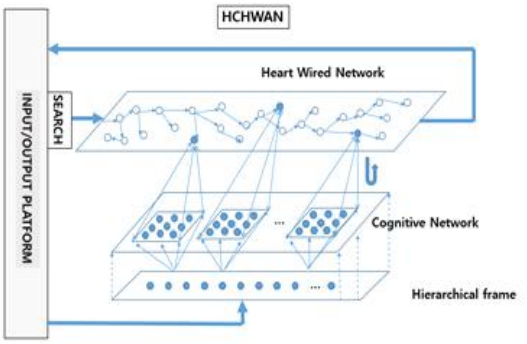

Fig. 2. The structure of HCHWAN

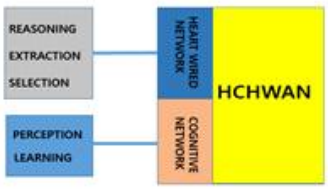

Fig. 3. HCHWAN functions

As shown in Figure 2, HCHWAN has a hierarchical structure which has two layers, Learning layer and Reasoning layer. Learning layer in the first floor takes part in Learning and Perception function. After the cognitive network finished learning with training data using LEARNING module, it prepares to perceive the things what it is. The structure of cognitive network is a form of fully connected network. If the corresponding input data come, this cognitive network perceives the things and produces the output results to the higher Reasoning layer of Heart Wired Artificial Network. In the Heart Wired Artificial Network, reasoning, information retrieval, data extraction and selection are processed. Heart Wired Artificial Network is composed of network which has knowledge nodes combined with emotional energy terms and associated links.

3.1.2 system workflow

HCHWAN system has two modes of [SET] and [USE] in operation. In [SET] mode, the learning process is performed in the cognitive layer with training data and Heart Wired Artificial Network is organized and adjusted. In [USE] mode, the actual functions of HCHWAN are processed. The work flow of HCHWAN in [USE] mode is as follows: It starts from input stream which consists of user's requests and the related data prepared for extracting and reasoning phase. Incoming input streams are analyzed through INPUT/OUTPUT PLATFORM. As a result of analysis, Input keywords and data are

produced. The produced Input keywords and data flows into layer according to the classification. There are two paths to flow. If it is for perception, data stream comes into the cognitive network. If it is for reasoning or extraction, data stream comes into Heart Wired Artificial Network. In the first case(Path1), data stream goes through perception step and arrives at the output node which connected to one node in the higher Heart Wired Artificial Network. Then Path1 continues to start reasoning process from the connected node by following the links. That is, Path1 is that starting from perception is connected to reasoning process, and return to INPUT/OUTPUTPLATFORM. In the second case(Path II), data stream starts from Heart Wired Artificial Network and perform reasoning process. If necessary, it meets the node connected to the cognitive layer below and extracts the conditional factors.

3.2 The basic frame of Hierarchical Heart wired Artificial Network

3.2.1 Cognitive Network : Learning & Perception Layer

Cognitive Network consists of artificial neural network which has learning function and has a fully connected structure. For perception, it must have been learned with training data in advance[3].

Learning phase is as following algorithm 1.

In Cognitive phase, only one forward pass occurs and the node with the largest value in the output layer is selected. From this node, the connected nodes are traced by following

Algorithm1 : Learning

Given : Training data $D = \{(x^d, y^d)\}_{d=1}^{N}$, learning rate=η

Procedure

While (error <= θ) :

Input-Hidden layer

$S_j = \sum_i W_{ji} x_i$

$f_j = \sigma(S_j) = \frac{1}{1+\exp(-S_j)}$

Hidden-output layer

$S_h = \sum_i W_{hj} x_j$

$f_k = \sigma(S_k) = \frac{1}{1+\exp(-S_k)}$

Calculate the error of output node

$\delta_k = (f_k - y_k) f_k (1 - f_k)$

Adjust the weight of hidden- output layer

$\Delta w_{kh} = -\eta \frac{\partial E_i}{\partial w_{kh}} = \eta \delta_i x_h$

Calculate the error of hidden node

$\delta_h = f_h(1 - f_h) \sum_k w_{kh} \delta_k$

Adjust the weight of input-hidden layer

$\Delta w_{hi} = -\eta \frac{\partial E_h}{\partial w_{hi}} = \eta \delta_h x_i$

the links in the upper Heart Wired Artificial Network.

In Cognitive phase of Cognitive network is as following algorithm 2.

Algorithm2 : Cognitive phase

Step1: Input Data Stream

Step2: [Input-Hidden layer]

$S_j = \sum_i W_{ji} x_i$

$f_j = \sigma(S_j) = \frac{1}{1+\exp(-S_j)}$

Step3: [Hidden-output layer]

$S_h = \sum_i W_{hj} x_j$

$f_k = \sigma(S_k) = \frac{1}{1+\exp(-S_k)}$

Step4: Select one node

$x_{k=\arg max_k f_k}$

Step5: Connect to $x_k.next$ in Heart Wired Artificial Network

Call Heart Wired Artificial Network reasoning module.

step6: Stop.

3.2.2 Heart Wired Artificial Network - Reasoning layer

Heart Wired Artificial Network located in the under layer as a reasoning layer has functions of reasoning, extraction and selection. This has the structure of knowledge network

with emotional energy factor. It has a great meaning that knowledge and emotion are combined together. That is, the emotional states are embedded in the knowledge during forming memory. Based on this structure, every calculations for reasoning, extraction and selection process are made. Knowledge Network consists of nodes and their links. The knowledge node (K_i) is connected to other nodes with links according to their relational strength, $< S_{ij} >$. (K_i) has attributes of $[ID, Value, SelfEnergy, EmotionalFactor]$. These attributes are abbreviated as $[ID_i, V_i, SE_i, (x_i, y_i)]$ where $-1.0 \leq V_i, SE_i, x_i, y_i \leq 1.0$. Therefore, the notation of knowledge network is represented as follows:

$[K_i : ID_i, V_i, SE_i, (x_i, y_i)] < S_{ij} >$
$[K_j : ID_j, V_j, SE_j, (x_j, y_j)]$

Association link, S_{ij}, which represents connection strength between knowledge nodes K_i and K_j, is calculated by equation (1).

$$S_{ij} = P(i|j) \tag{1}$$

3.2.3 Emotional Energy

In this work, we use two dimension model of Russell for Emotion design. In this model, 16 emotion states are specified in two dimensional space. For easy computation in this system, we converted these emotion terms to the form of the following coordinate. In this system, the coordinate value of emotion is converted to energy value by equation (2) and participates in the process of reasoning, extraction and selection process. Energy value, in the energy state is calculate by equation (2).

$$E_i^v = d^* \sqrt{x_i^2 + y_i^2} \tag{2}$$

$$d = \begin{cases} 1 & \text{if } x_i \geq 0.0 \text{ and } y_i \geq 0.0 \\ -1 & otherwise \end{cases}$$

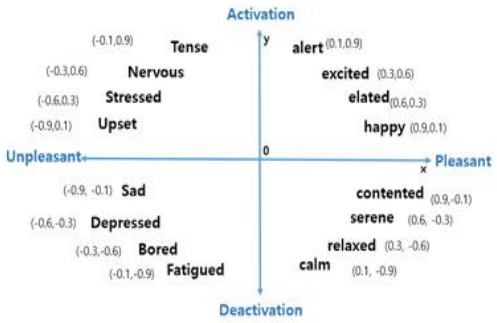

Fig. 4. (x,y) coordinate value of Russell's two dimensional emotion model

Also, Energy state of Emotion can be abbreviately represented as PU(Positive neUtral), PX(Positive eXcited), PI(Positive Inhibitory),NU(Negative neUtral), UU(neUtral neUtral), UX(neUtral eXcited), UI(neUtral Inhibitory), NI(Negative Inhibitory) and NX(Negative eXcited). These values are used for producing total energy value of extracted Reasoning Thread.

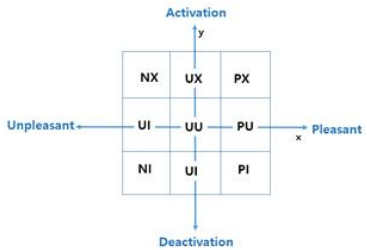

Fig. 5. (x,y) coordinate value of Russell's emotion model

The following Table 1 represents the coordinate values and energy states of 16

emotions. In the case of no emotion state, its coordinate value is (0.0, 0.0) and the energy state is UU.

Table 1. The coordinate value and Energy state of 16 Emotions

No.	Emotion	Coordinate value	Energy state
1	Happy	(0.9, 0.1)	PX
2	Elated	(0.6, 0.3)	PX
3	Excited	(0.3, 0.6)	PX
4	Alert	(0.1, 0.9)	PX
5	Contented	(0.9, -0.1)	PI
6	Serene	(0.6, -0.3)	PI
7	Relaxed	(0.3, -0.6)	PI
8	Calm	(0.1, -0.9)	PI
9	Tense	(-0.1, 0.9)	NX
10	Nervous	(-0.3, 0.6)	NX
11	Stressed	(-0.6, 0.3)	NX
12	Upset	(-0.9. 0.1)	NX
13	Sad	(-0.9, -0.1)	NI
14	Depressed	(-0.6, -0.3)	NI
15	Bored	(-0.3, -0.6)	NI
16	Fatigued	(-0.1, -0.9)	NI

3.3 Reasoning, Extraction and Selection mechanism based on Heart Wired Artificial Network

3.3.1 Reasoning Thread Extraction Mechanism by Switching

In the reasoning process, it starts from the keyword which come from INPUTOUTPUT /PLATFORM or the under Cognitive layer. Starting from this keyword, Reasoning Thread Extraction Mechanism processes. It extracts the connected knowledge nodes and links by following the connected line until the state of NILL, the end of network in the similar way to DFS(Depth First Search). If it meets branch, it follows the other paths. After extracting one path, it goes back to that branch and traces to the other path and extracts other path. This mechanism repeats this routine util it meets the end of complete condition. After execution of Reasoning thread extraction mechanism, the related threads are extracted. From the extracted reasoning threads, we can calculated the cumulated energy value which gives a criteria for selection.

3.3.2 The selection of extracted Reasoning threads and extraction depth

The system temporarily keeps extracted Reasoning threads produced by current cycle of Reasoning thread extraction mechanism. Supposed the extracted reasoning thread as shown in Figure 6, we can obtain the total self energy value, T_{SE_k}, and total emotional energy, $T_{E_i^v}$, by equation (3) and equation (4) respectively.

$$T_{SE_k} = \frac{1}{n}\sum_{k=1}^{n} SE_k \tag{3}$$

$$T_{E_i^v} = \frac{1}{n}\sum_{k=1}^{n} E_i^v \tag{4}$$

In reasoning thread extraction mechanism, the extracted depth of the reasoning thread can be set according to the extracting threshold. If the user wants to the strongly related information, system assigns a large value to the extracting threshold.

4. Experiments

In experiments, we applied the proposed

system to event scheduling problem and tested the function of extracting the event scheduling paths according to the user's choice. HCHWAN was simulated with Emotion embedded knowledge network which consists of 25 knowledge nodes as shown in the Figure 6. Table 2. shows self energy and the emotional coordinate value of each node. In this application, Self Energy represents the importance degree of the event. ID name Ki such as K1,K2… means the event name. For example, K1 is an event of 'K1: go to Market Place' , K2 is an event of 'K2: send a parcel at the post office.' and etc.. The proposed mechanism has two pathways for reasoning the event scheduling paths. One is a horizontal propagation and other is the reasoning connected to Cognitive network of the under layer. First, in the horizontal propagation, starting the keyword the related event scheduling paths are extracted by algorithm. Second, in the case of Cognitive network, for example, event 'K19: buy apples' is connected to the output node,'apple', of Cognitive Network vertically. This vertical link is bidirectional. Starting from Cognitive Network, it perceives 'apple' with input data representing the feature vector of 'apple' using the learned Cognitive Network. Then the node of 'apple' is activated, connected to K19 event in the upper layer and continue to extract the related event scheduling paths in a horizontal way. Figure 7-11 show the testing results of horizontal reasoning and Figure 12 shows the second case of Cognitive Network.

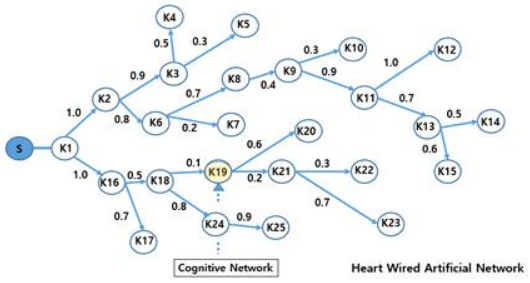

Fig. 6. Knowledge nodes and links in the Heart Wired Artificial network

Table 2. The attribute values of Knowledge nodes

Knowledge node no.	Self Energy	Emotional Value	Knowledge node no.	Self Energy	Emotional Value
K1	1.0	(0.0,0.0)	K14	1.0	(0.3,-0.6)
K2	0.9	(0.9,0.1)	K15	1.0	(0.0,0.0)
K3	0.8	(0.3,0.6)	K16	0.9	(-0.6,0.3)
K4	0.7	(0.6,-0.3)	K17	1.0	(-0.6,0.3)
K5	1.0	(0.0,0.0)	K18	0.8	(0.0,0.0)
K6	0.9	(0.3,-0.6)	K19	0.7	(-0.9,0.1)
K7	0.7	(0.1,-0.9)	K20	0.9	(-0.3,0.6)
K8	0.8	(0.1,-0.9)	K21	1.0	(0.0,0.0)
K9	0.9	(0.0,0.0)	K22	0.9	(-0.1,0.9)
K10	1.0	(0.9,-0.1)	K23	0.8	(-0.6,0.3)
K11	0.9	(0.9,0.1)	K24	0.8	(-0.9,-0.1)
K12	0.8	(0.0,0.0)	K25	0.7	(-0.6,-0.3)
K13	0.7	(0.1,-0.9)			

Figure 7 shows the simulation results for Reasoning Thread extraction mechanism and extraction depth by threshold. The connected knowledge nodes and links were extracted and 4 paths were retrieved. Because the extraction depth is 0.5. the links which have the condition of ' Strength is less than 0.5' were excluded in the extracting process. In the case of threshold, 0.5, 2 paths were extracted. The experimental tests for Selection of the extracted reasoning threads are shown in Figure 8-10. The

simulation results are different according to the user's choice. In Figure 8, It is the case of choice 1,that is, the system considers only self energy value of knowledge node. As a result, Path 1 which gained the highest score of Total self energy of extracted reasoning thread was selected. However in the case of choice 2 and choice 3, the selection results are quite different. Figure 9 and Figure 10 explain how different results are produced when emotional factors are taken into account. Figure 9 is the case that it consider only emotional factors and Figure 10 is the case that it consider both of them. In both cases, path 3 was selected. Figure 11 shows the comparison with Total Energy value of TS, TE and TSE. TS means the case of considering only Self Energy Value. TE considers only Emotional Value and TSE considers both Self Energy Value and Emotional Value. As shown in the graph, we can check that Event Scheduling path1 has highest Total Energy value in the case of TS. However, As Emotional factors are involving to the extracting process in the case of TSE, Event Scheduling path3 becomes to have the highest value and was selected for the extracted reasoning path. It means that emotional factors can effect on the reasoning process, selection, extraction and final decision making. Figure 12 shows extraction process starting from the activated node connected to output node of Cognitive Network. From the experiments, we could find the proposed HCHWAN system can retrieve the Event Scheduling paths in the second pathways of the proposed mechanism.

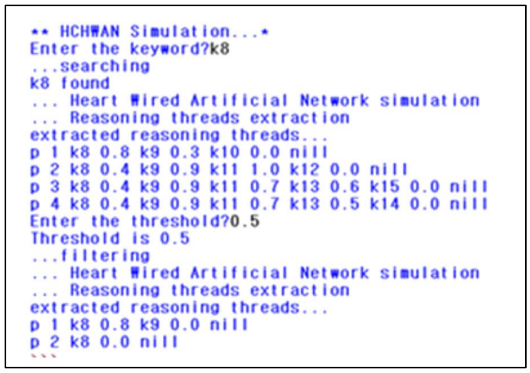

Fig. 7. Reasoning thread extraction for event scheduling paths and filtering by extraction depth.

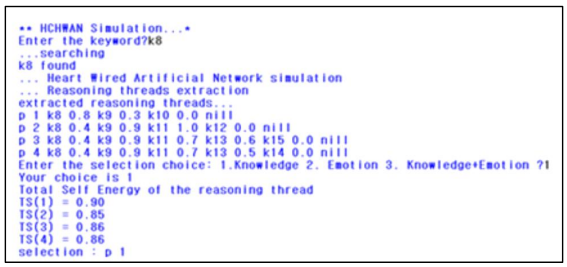

Fig. 8. Selection by total self energy (the importance of event schedule)

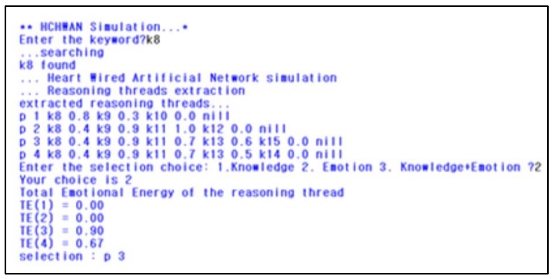

Fig. 9. Selection by Total Emotional energy(Preference)

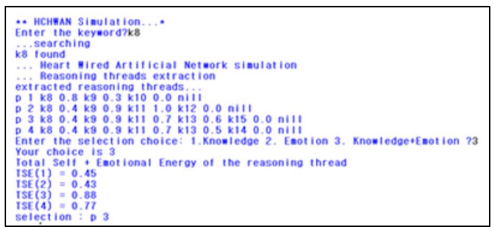

Fig. 10. Selection by Total Values(self energy+ total emotional enegy)

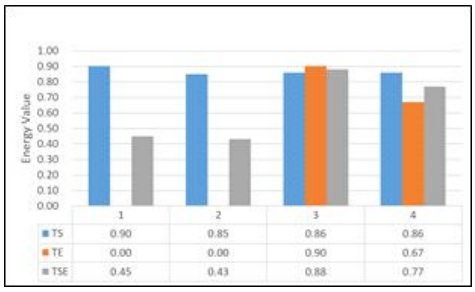

Fig. 11. The comparison with Total Energy Value of TS,TE and TSE

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** HCHWAN Simulation...*
from the Cognitive network...activated
k19
... Heart Wired Artificial Network simulation
... Reasoning threads extraction
extracted reasoning threads...
p 1 k19 0.6 k20 0.0 nill
p 2 k19 0.2 k21 0.3 k22 0.0 nill
p 3 k19 0.2 k21 0.7 k23 0.0 nill
```

Fig. 12. Reasoning thread extraction starting from the node connected to the Cognitive Network

5. Conclusions

In this work, adopting brain functions we proposed Hierarchical Cognitive Heart Wired Artificial Network (HCHWAN) which has Learning, Perception, Reasoning, Extraction and Selection function in a hierarchical frame. Especially in this system, emotional factors are designed to be combined with knowledge in the knowledge network. HCHWAN consists of Cognitive Network and Heart Wired Artificial Network. Cognitive Network takes part in learning function and the Heart Wired Artificial Network based on emotion-knowledge linked structure plays an important role of reasoning. In experiments, the effects of emotional factors were investigated. Emotion-knowledge linkage case was compared to the results of considering only knowledge term and only emotion term. As a result, the effects of emotional factor on Decision making was traced.

This approach has special significance in the first place in terms of: (a) Hierarchical structure which is efficient of the spatial intelligent processing and data storage (b) Both Learning&Cognition and Reasoning function : Sophisticate processing is possible because Cognitive Network and Heart Wired Network are connected vertically and horizontally. (c) Emotion-Knowledge linkage in the structure of Heart Wired Network: Emotional factor affects the reasoning process and Decision Making. This research work considering emotional factors in the decision-making process can be applied to make more sophisticate core engine for Intelligent system.

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