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Dynamic Switching Belief Network based on IoT Knowledge Capsule

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Abstract

Objectives: IoT based technology is getting more importance in the internet connected world. To implement IoT system, an efficient intelligent system which can perform the functions better in the communication line should be designed. **Methods/Statistical Analysis:** In this paper Dynamic Switching Belief Network based on IoT Knowledge Capsule is proposed. IoT based knowledge capsule is defined as a basic structure and Dynamic Switching Belief network system is designed to have functions of dynamic switching, selection, flexible structural reconfiguration and data extraction. **Findings:** In the experiments, the test of switching mechanism and reconfiguration focusing on switching function was made. The change of network structure is according to the incoming data and Type. As a result of test, we could find that this proposed system works well in the dynamic information environment. **Improvements:** It can be usefully applied to IoT based information system as an intelligent information system for implementing Smart Home.

Keywords: Belief Network, IoT, Knowledge Capsule, Switching, Type Matching

1. Introduction

As Internet world is coming to human society, the feature of information processing was dramatically changed. The network based concept of Internet changed symbol oriented human thinking way to connection oriented way. In the previous time before Internet connection, the amount of data was relatively small and the data was represented by symbolic form with fixed data structure[1]. The refined data in a fixed data structure was processed sequentially in a logical way. But after Internet the data circumstance was totally changed to big data era. Huge amount of data makes the previous symbolic processing way difficult to deal with. Not only data uncertainty but also quickly changing feature of data makes more difficult to process. Because of huge amount of data, uncertainty and changing nature it is necessary to design a new information technology[2]. Furthermore as every device, data or systems are starting to be connected each other by the Internet of Things technology, the information circumstance is getting more complex and flexible. To solve this problem and deal with flexible big data in the IoT based connection, we should design more intelligent system adopting human brain functions[3–7].

So, in this paper Dynamic Switching Belief Network System which can be worked intelligently is proposed. As a basic structure IoT based Knowledge capsule is defined and Dynamic Switching Belief Network system is designed to have functions of Dynamic Switching, Selection, flexible structural reconfiguration and data extraction.

2. IoT Knowledge Capsule based Belief Network Design

2.1 The structure of Belief Network

For implementing an intelligent system, we should consider two important factors. One is a structure as a basic frame and the other is its mechanism inspired to the designed structure. The systematic efficiency depends on these two factors how intelligently it is correlated. On the perspective of intelligent design which can be processed for IoT frame, Belief Network based on Knowledge cap-

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sule is designed in this work. Belief Network consists of nodes which are represented as Knowledge capsule. Inside Belief Network, Knowledge capsule nodes are connected to each other with associated relation who has a Belief value.

2.1.1 Knowledge Capsule Design

First of all, describing knowledge capsule, the structure of Knowledge capsule has a form of the following Figure 1. Knowledge capsule has a describing factor of ID, ATTR, T and E. ID represents the identification of knowledge capsule node and ATTR means an attribute of Knowledge capsule. T is defined as Type which represents characteristics or category of class. Type can be differently designed according to the application area or problem domain. E is a self-energy of Knowledge capsule. The value of self-energy E contributes to calculate the criteria value for Activation, Filtering, Selection or Switching.

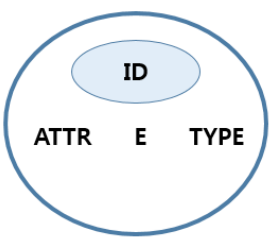


Figure 1. The structure of knowledge capsule.

2.1.2 Belief Network Structure

The specified above Knowledge capsule nodes make the structure of Belief Network as Figure 2. Each Knowledge capsule is connected to other Knowledge capsules with associative relations who are represented as a value of 'Belief'. The concept of 'Belief' plays an important role to consolidate the structure of network. The Belief link has two factors of Belief Type and Belief value.

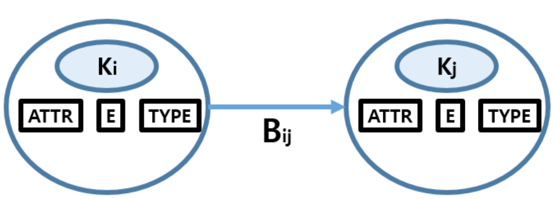


Figure 2. The structure of belief network.

Belief Type is defined as a binding type between two Knowledge capsules. It is classified into four types of M, C, F and U as following Table 1. Four type of Belief is used for network dynamics of links. Belief value representing the associative relation between two Knowledge capsules has a form of Bayesian probability as Equation (1).

$B_{ij} = P(j|i)$ (|)Σ_▒□()□D_Dd________□□□□_ (1)

Table 1. Belief type

Belief Type	Description of Relation
M	Mutual Exclusive : A node has an only link to the other one node and can not share with extra other nodes. It is a bi- relation.
C	Correlated : A node has multiple closely correlated relations.
F	Fixed : A node has relations with other nodes as a state of naturally fixed. For example, the relation between parent and children.
U	Multiple : A node has multiple relations which can have dynamics.

2.1.3 Dynamics

This proposed system has a dynamics in the structural configuration according to the data change. The adaptive characteristics are inspired to the Belief Network structure. The characteristic of dynamics is summarized in the Figure 3. Dynamics is related to the function of 'Switching' in this proposed system.

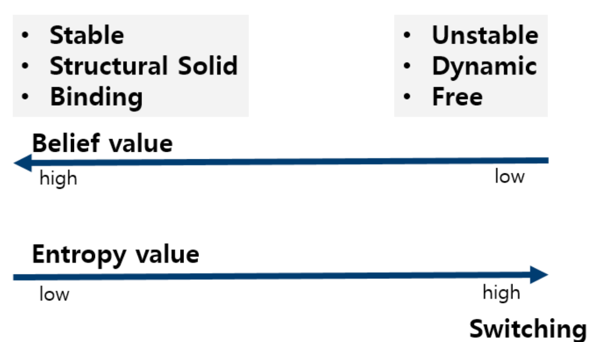


Figure 3. Dynamics.

In the stable state, the values of entropy, structural solidity, biding rate and Belief are high. As the value of entropy is higher, the property of disorder, freedom and dynamics is higher. If the degree of dynamics arrives to the threshold value, the network frame is changed by switching mechanism[8].

2.1.4 Entropy

As described in the previous section, the high value of Entropy means that it has a high freedom degree and dynamics. In this point where the entropy value is greater than threshold value, Switching mechanism starts for changing the structure of network.

The entropy value can be obtained by Equation (2), (3), (4), (5).

$$\mathbf{H}(\mathbf{Y}|\mathbf{X}) = \sum_{x\in\mathbf{X}} p(x)H(Y|X=x) \tag{2}$$

$$= -\sum_{x\in\mathbf{X}} p(x)\sum_{\mathbf{y}\in\mathbf{Y}} p(y|x)\log p(y|x) \tag{3}$$

$$= -\sum_{x\in\mathbf{X}}\sum_{\mathbf{y}\in\mathbf{Y}} p(x,y)\log p(y|x) \tag{4}$$

$$= -E\log p(Y|X) \tag{5}$$

3. Dynamic Switching Mechanism in the Belief Network

In the previous section the structure of IoT based Knowledge capsule and Belief network was described. In this section, the various intelligent mechanisms occurred in the proposed Belief network are explained. The main mechanisms of IoT Knowledge Capsule based Belief Network System consists of Type matching, Selection, Switching, Reconfiguration and Data extraction.

3.1 System Overview of IoT Knowledge Capsule based Belief Network System (IKCBNS)

The system structure is as following Figure 4. IKCBNS has TM, Selection, Switching, Reconfiguration, Data Extraction module and Belief Network as a knowledge base. If input data is coming to IKCBNS, it goes through TM, Selection, Swtching, Reconfiguration and Data Extraction module. Sometimes the input data may include the information of new network structure. In this case much switching and changing in the network reconfiguration can be occurred. In TM module, Type Matching mechanism is made by the way which explained in the paper. The activated nodes by TM mechanism are selected in SELECT module and the reconfiguring process is made by same mechanism in paper. In this paper focusing on Switching function, the switching mechanism performed by Belief type and Belief value will be explained.

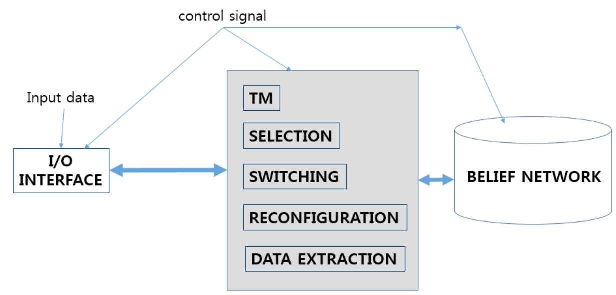


Figure 4. The system structure of IKCBNS.

3.2 Switching Mechanism by Belief Type and Belief value

Switching mechanism is closely related to Reconfiguration of Belief Network because the switching results are directly reflected to the network structure. In the switching process, the prime consideration is Belief Type.

First, in the case of Belief Type 'F', the network structure related to this type can't be changed in any case because this relation is naturally fixed, for example, the relation between parent and their children. Second, in the case of Belief type 'M', competition and replacement process about the new incoming IoT knowledge Capsule network is made by evaluation process and belief calculation. When the new coming IoT Knowledge Capsule network is approaching to the common field of the main Belief Network, Competition process is made. If the impact factor is stronger than the previous link, the new coming network replace the previous branch and change the structure of the Belief Network. Then the link of previous attached branch is broken and it is separated from the state of Belief Type 'M', name mutual exclusion state. The main belief network has a big change and reconfiguration process. Third, in the case of Belief type 'F' or 'M', multiple choosing phase or Correlation process is performed.

4. Experiments

In these experiments, we had a test of Switching mechanism and reconfiguration focusing on switching function and investigated the change of network structure according to incoming data and Type. We applied to the virtual system which has a network structure including ID, Type of IoT Knowledge Capsule connected with their Belief Types and Belief value. As shown in Figure 5, this tested Belief network has 13 IoT Knowledge Capsules in the initial state.

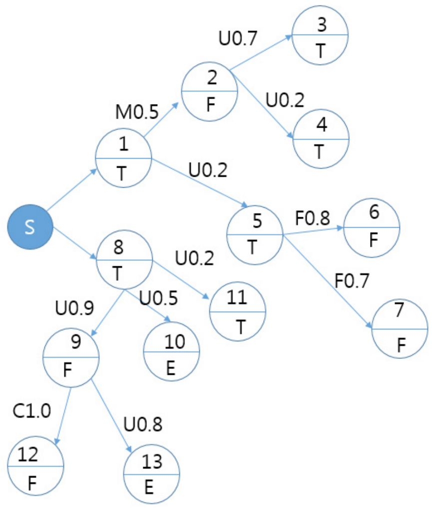


Figure 5. IoT knowledge capsule based belief network: Initial state.

The reconfigured changed networks about incoming data1 and incoming data 2 of Figure 6 are shown in Figure 7 and Figure 8 respectively. As shown in the results, the structure of Belief network was not changed because the value of Mutual exclusion of IoT Knowledge Capsule node 1,0.5 is greater than the incoming value, 0.3. But in the case of incoming input data structure 1, the new incoming network replaced the connected node 2 and 3 because mutual exclusive value is higher. Figure 9 shows the Type Matching degree of IoT Knowledge Capsule nodes in the Belief Network.

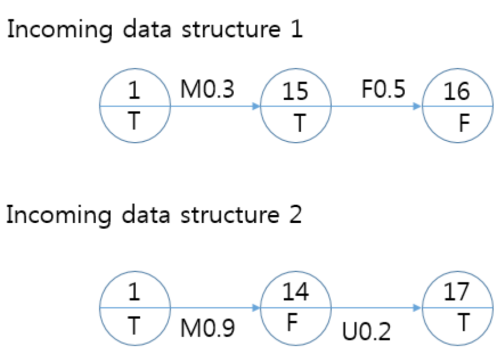


Figure 6. Incoming data structure.

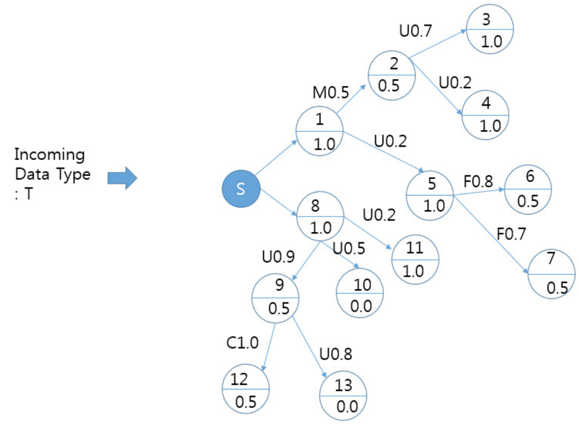


Figure 7. The reconfigured structure: Incoming type = T, Incoming data structure 1 Fi.

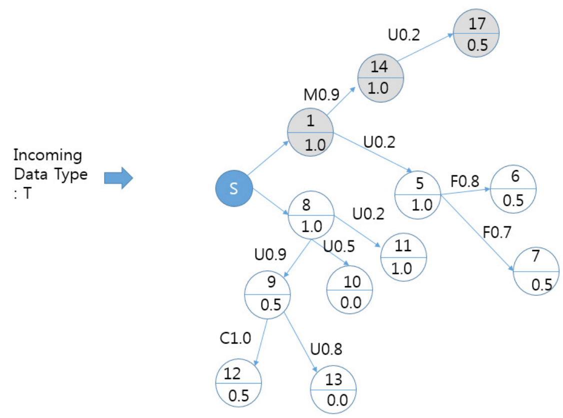
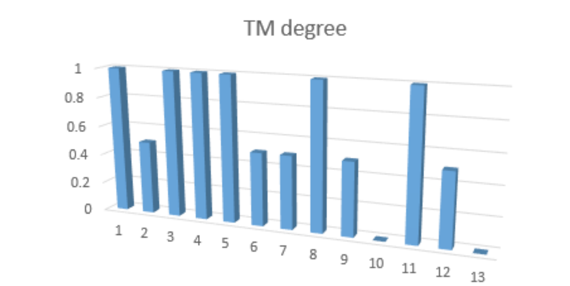


Figure 8. The reconfigured structure: Incoming type = T, Incoming data structure 1.



	1	2	3	4	5	6	7	8	9	10	11	12	13
TM	1	0.5	1	1	1	0.5	0.5	1	0.5	0	1	0.5	0

Figure 9. TM degree of IoT knowledge capsule node.

5. Conclusions

Dynamic Switching Belief Network System which can be worked intelligently is proposed. As a basic structure

IoT based Knowledge capsule was defined and Dynamic Switching Belief Network system was designed to have functions of Dynamic Switching, Selection, flexible structural reconfiguration and data extraction. As a result of experiment, we could find that this proposed system works well in the dynamic information environment. This can be usefully applied to IoT based information system as an intelligent information system for implementing Smart Home.

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