A Process-Centered Knowledge Model for Analysis of Technology Innovation Procedures

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Abstract

Now, there are prodigiously expanding worldwide economic networks in the information society, which require their social structural changes through technology innovations. This paper so tries to formally define a process-centered knowledge model to be used to analyze policy-making procedures on technology innovations. The eventual goal of the proposed knowledge model is to apply itself to analyze a topic network based upon composite keywords from a document written in a natural language format during the technology innovation procedures. Knowledge model is created to topic network that compositing driven keyword through text mining from natural language in document. And we show that the way of analyzing knowledge model and automatically generating feature keyword and relation properties into topic networks.

Keywords: Knowledge model, Semantic analysis, Technology innovation, Topic network

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1. Introduction

The growing codification of knowledge and its transmission through communications and computer networks has led to the emerging information society and innovation systems. The knowledge management and analysis has been recognized important issue and to be most essential process on technology innovation and using resource in knowledge based economic environment. But how to organize and inter-operation of information and knowledge integration is to solve complex and very difficult problems[1].

This study is intended as integrating knowledge resources and identification of business activities prior to implementation of knowledge model, focused on verification and optimization of knowledge model for supporting technology innovation. Some change in environment that knowledge based industries and economic development can produce a variety of complexity to the problem. Therefore, business organization for innovation is needed more rapid decision making and strategic analysis. In particular, rapid change of external environment and increase of complex systems require investment strategies and more intelligent decision making process and utilization system[2].

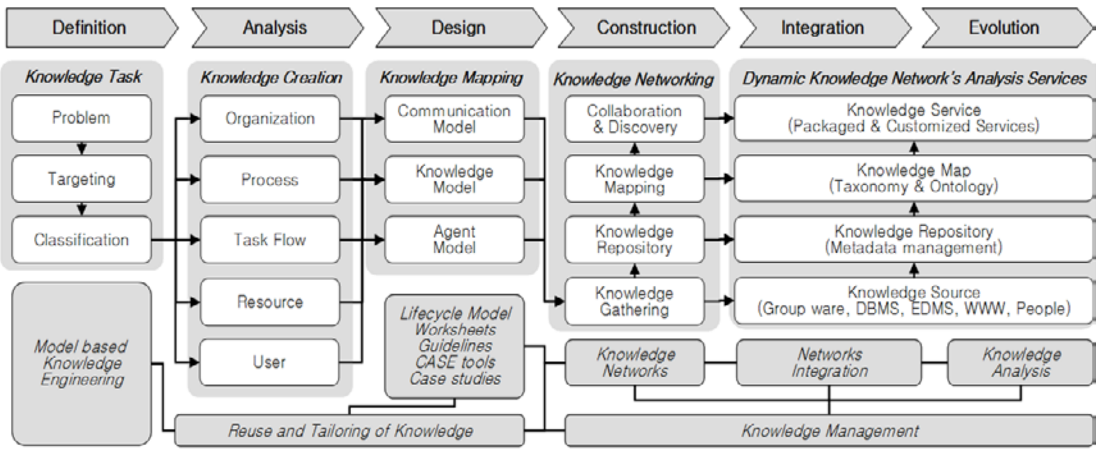

Fig. 1. Sequential framework for development of unified knowledge model

The existing research on knowledge management and analysis is re restricted to syntactic search and classification of data and documents, or the static relationship analysis between data[3][4]. However, as the development has recently been accelerated in the areas of the natural and formal language processing and semantic technology including artificial intelligence, it has be made possible to design a variety of knowledge models and analyze semantically[5][6]. **Fig. 1** reflects to design knowledge model of supporting innovation and validating structured process models. And, i have been derived the topic keyword of the process model from task information, generated hierarchical structure model by relation between topic keyword. This topic mapping for process models to model the knowledge network configuration and it is converted into the equivalent relationship.

This is a topic of unstructured information to extract meaning from the process model is mapped to the abstract model is transformed to the equivalent relationship network. This analysis and generation of knowledge model makes possible the design of knowledge maps and analysis of large scale data in the process. Thus, procedure of semantic analysis and relation between processes base on path of tracking evidence of decision making. As shown in figure1, it is to express the logical structure for creating of new knowledge model.

2. Process based knowledge model

Knowledge model in this study is conceptually defined as classification and expression of the relationships between knowledge and concepts in knowledge management. It could also map the meaning of knowledge such as typology, property, and pattern. It features the contexts and features of topics, relations between topics, computations, restrictions, which allows topic-based knowledge model to conduct semantic expression and automatic inference and in turn help understand effectively tacit knowledge through knowledge analysis and utilize knowledge[6]. Traditional business model was designed using the BPML(Business Process Modeling Notation), Activity Diagram, UML EDOC, IDEF, ebXML, BPSS, ADF(Activity Decision Flow), RossettaNet, LOVeM, EPCs(Event Process Chains), Petri Nets etc. In study be in a language that was utilized kripke structure[7][8][9][10]. In this study, I was divided and pre-defined a type for classification of knowledge and information on process of technology innovation. In recent research for business process design and validation, and have been investigated actively standardized graphical notation. Graphical notation for the specification of the model is easy to extend[11][12]. This context, semantic analysis based on knowledge model could be viewed as “the processes to understand semantic structures and relations of knowledge” and must consider dynamic changes and continuous expansion of knowledge in designing knowledge model. A resource element of integrated knowledge model is a constituent that maps representative features of information resources like data and documents into a unit of topic and even a piece of data or document could produce various topic relations[13][14].

In this paper, as shown in **Fig. 2** and **Fig. 3**, on business activities in technology innovation was defined as abstracted process model. Here we denoted variables of the process Model(M) and Process(P) and Relations(R), Label(L). The relationship between the process(p) on abstracted process model(M) are denoted through transition and condition, interaction, reference etc. A process(p) has element(E) and element(E) has proposition(X). Each process(P) in the model is defined as follows : each transition(p, p') and has relation(R). Kripke structure’s process model is defined as follows.

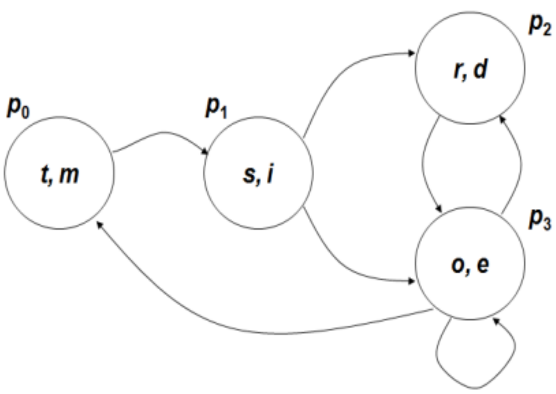

Fig. 2. Kripke based abstract process model

$$\forall s \in P \bullet \exists p' \in P \bullet (p,p') \in R \qquad (1)$$

M : Process Model = <P, P0, R, X, L>, P : Process = Set of finite process(p), P_0 : $P_0 \subseteq P$: Set of initial process, R : $(p,p') \in R \subseteq P \times P$ =Process transition($\forall p \in P$, $\exists p \in P$), X : True | False = Set of AP(Atomic Proposition), L : $P \rightarrow 2X$ = assigns to each process the set of atomic propositions that are true in that process. P_0 : Business Foresight={Trend t, Road Map m}, P_1 : Business Planning={Strategy s, Invest i} P_2 : Performance Management = {Research r, Development d}, P_3 : Measurement Evaluation = {Outcome o, Evaluation e}

Heterogeneous model checking in this study is easy to use for conceptual learning and analysis of knowledge model. And model checking to satisfy in a given model, the path of the property violated the state are presented. In this way, knowledge model to analyze can be continuously refining. The model properties are expressed in CTL(Computation Tree Logic)[9][10]. CTL according to the passage of time representation of the property and it is easy to define a specific scope in model. CTL's syntax and semantics of temporal quarter is defined by the BNF(Backus Normal Form) as follow.

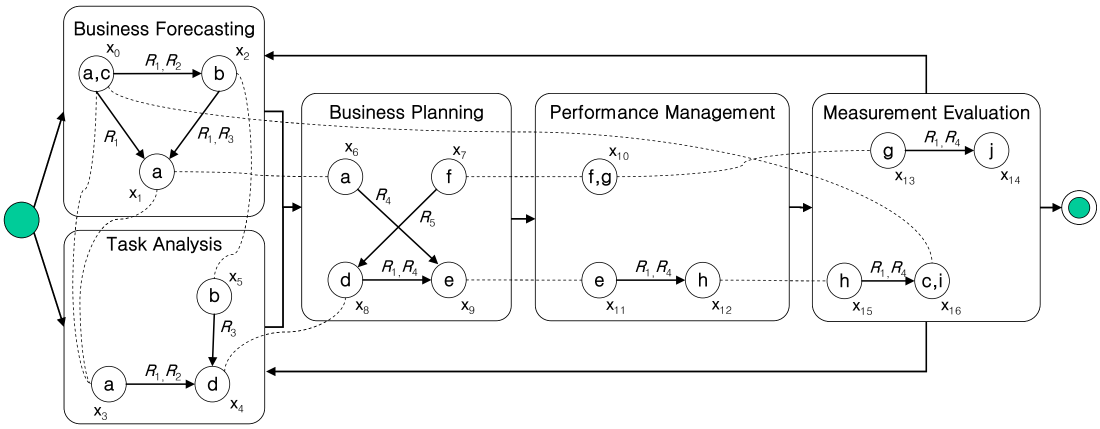

Fig. 3. Business process driven topics based knowledge model

$$\Phi ::= true \mid x \mid \neg \Phi \mid \Phi_1 \vee \Phi_2 \mid AG\ \Phi \mid A(\Phi_1\ W\ \Phi_2) \qquad (2)$$

As existing in CTL, 'A' is universal operator and 'G' is global operator. And 'W' is until operator. Intuitively 'AG Φ' is always true in all paths(true) means and 'A(Φ_1W Φ_2) means that Φ_1 is forever true until Φ_2 to be true for all paths in model.

Assuming a finite model M and CTL formula is true in the process. P_0 is written as $p_0 \vDash \Phi$.

A transition(p, p') in the model(M) indicated reachable from current process(P_n) to next process(P_{n+1}). Abstract process model(M) has the set of the transition(R). Transition relation $(p_0,p_1) \in R$ and by a single transition from p_0 to p_1 is reachable[15].

On reaching it from current process's forward and backward as the successor the predecessor said. As above, the current process(P_n) can be reached through a transition from one of the hollowing conditions to obtain the 'image computation' is called a calculation or reachability analysis.

In the model, as the process reached the bottom of the 'image computation' algorithm and the same calculation when to stop is called fix-point. And the 'reachable' meaning in CTL formula is defined as follows.

$$R = \vee\ p \in P\ ((\wedge\ p \rightarrow \wedge\ p')\ \vee\ (\wedge\ p' \rightarrow \wedge\ p)) \tag{3}$$

$R = \{(p_0, p_1), (p_1, p_2), (p_1, p_3), (p_2, p_3), (p_3, p_2), (p_3, p_3), (p_3, p_0)\}$, successor($P_{\{\}}$, R) = $\{p' | \exists p \cdot p \in P \wedge (p,p') \in R\} = pre\forall(P)$, predecessor($P_{\{\}}$, R) = $\{p | \exists p' \cdot p' \in P \wedge (p,p') \in R\} = post\exists(P)$

The Symbol μ is operator of least fix-point, and ν is operator of greatest fix-point.

$$R\Phi(P) = \mu Z.((P \cup post\exists(Z)) \cap |[\neg\Phi]|) \tag{4}$$

Find(AG(true), P) = R true(P) , Find(A(true $\vee$ AG($\neg\Phi$)) W Φ), P) = $R^{\neg\Phi}$(P))
Find(AG($\Phi \Rightarrow$ AG true), P) = $R_{true}(|[\Phi]| \cap post\exists(R^{\neg\Phi}(P)),$
Find(AG($\Phi_1 \wedge \neg\Phi_2 \Rightarrow A|[true \vee AG(\neg\Phi_2) W \Phi_2]|$), P) = $R^{\neg\Phi 2}(|[\Phi_1 \wedge \neg\Phi_2]| \cap R_{true}(P))$

$$\begin{aligned} AG\ \Phi &= A(\Phi\ W\ \Phi \wedge false) = A(\Phi\ U\ \Phi \wedge false) \vee AG\ \Phi \\ &= \nu Z.(\Phi \cap pre_{\forall}(Z)) = P_{init} \cup R_{\Phi} \cup post_{\exists}(R_{\Phi}) \end{aligned} \tag{5}$$

Find(AG(true), P) = R true(P), Init Process = $\{p_0\}$, $P_{\{\}} = \{p_0\}$ Until($Step_{i+1\{\}} = Step_{i\{\}}$), Fixed Point = $R_{\Phi} = \{p_0, p_1, p_2, p_3\}$, $R_{\{p0, p1, p2, p3\}}$ = Topic = $(t \wedge m) \vee (s \wedge i) \vee (r \wedge d) \vee (o \wedge e)$

In figure2, the process based Knowledge model is a tuple $<X, X_0, R, T, L>$, where
X is a finite set of places$X_0 \subseteq T$ is the set of initial places.
$R \subseteq X \times X$ is the transition relation of places which is assumed to be total:
$\forall x \in X \bullet \exists s' \in X \bullet (x,x') \in R$.
That is, for every place $x \in X$, there exists a successor $x' \in X$ with $(x,x') \in R$.
T is a finite set of atomic propositions(called semantic topic),
$L: T \rightarrow 2^T$ assigns to each place the set of atomic propositions that are true in that place.

For example, a model is given in Figure 3 and used throughout this paper. In this case, $X_1 = \{x_1\}$ and $R = \{(x_2,x_1), (x_2,x_3), (x_3,x_1), (x_4,x_5), (x_6,x_5), (x_9,x_{10}), (x_7,x_{10}), (x_{12},x_{13}), (x_{16},x_{17}), (x_{14},x_{15})\}$. $(x,x') \in R$ means that s moves to x' in a step. That is, x' is an image of x. Given the subset T of places, the set of images of T is $image(T) = \{x' \mid \exists x \bullet x \in T \wedge (x,x') \in R\}$. $image(\{x_0\}) = \{x_1,x_2\}$;
That is, from x_0 we can move to both x_1 and x_2 in one step. A path is an infinite sequence of places in which each consecutive pair of places belongs to R. A place is reachable if it appears on some path starting from some initial place. In example, x_{16} is reachable since there is a path $x_0, x_1, x_2, x_5, x_6, x_7, x_8, x_9, x_{11}, x_{12}, x_{15}, x_{16}$ which leads to that place, while x_{10} is unreachable since there is no path leads to x_{10}, x_{13}, x_{14}. Every reachable place is computed by

successively applying the function *image* from initial places X_0 until the fixed point is reached. The following procedure is to find out every reachable place:

$P_0 := X_0$ repeat $P_{i+1} := P_i \cup image(P_i)$ until $(P_{i+1} = P_i)$ When $P_{i+1} = P_i$, it stops.

Thus, P_i is called the fixed point, which includes every reachable place. For convenience, let $Q = P_i$ denote the set of reachable places. $Q = \{x_0,x_1,x_2,x_5,x_6,x_7,x_8,x_9,x_{11}, x_{12},x_{15},x_{16}\}$. Only x_{10},x_{13},x_{14} does not belong to Q, since it is unreachable from the initial place x_0.

Syntax of propositional logic is as follows: $\phi ::= t \mid \neg\phi \mid \phi_1 \wedge \phi_2$

As usual, $t \in T$ denote atomic proposition, $\neg$ is the negation operator, $\wedge$ is the conjunction operator. We write $x \models \phi$, if a place x satisfies propositional formula ϕ.

In other words, $x \models \phi$ means that ϕ is true at a place x. The satisfy relation between x, ϕ is inductively defined as follows:

$x \models t$ iff $t \in L(x)$, $\quad x \models \neg\phi$ iff $x \not\models \phi$, $\quad x \models \phi_1 \wedge \phi_2$ iff $x \models \phi_1$ and $x \models \phi_2$

Theorem 1: Assume Y is the subset of atomic propositions true at x; that is, $Y = L(x)$.

$$\text{Given } Y \subseteq T,\ x \models \bigwedge_{t \in Y} t \wedge \bigwedge_{t \in T-Y} \neg t \tag{6}$$

where $\bigwedge$ is the generalized conjunction operator.

Proof: Proof by induction is used. Basis case: Literals is either t or $\neg t$. If the formula is t, $x \models t$ since $t \in L(x)$. Otherwise, $x \models \neg t$ since it is not the case that $x \models t$. Inductive case: Assume that $x \models \phi$, where the length of formula ϕ is n. In case the length of formula is n+1, ϕ is either $x \models \phi \wedge t$ or $x \models \phi \wedge \neg t$. According to the assumption, $x \models \phi$. Thus we have to show either $x \models t$ or $x \models \neg t$. But we have already proved them in the basis case. Q.E.D. Theorem 1 says local topics that is a property that holds in a place and computed easily. For example, local topics of x_0 is, $x_0 \models a \wedge \neg b \wedge c \wedge \neg d \wedge \neg e \wedge \neg f \wedge \neg g \wedge \neg h \wedge \neg i \wedge \neg j$ since $Y = L(x_0) = \{a, c\}$

Definition 1: Place topics is a property that holds in every reachable place and computed as follows:

$$I = \bigvee_{x \in Q} \left(\bigwedge_{x \in Y} x \wedge \bigwedge_{x \in X-Y} \neg x \right) \tag{7}$$

In the above definition, Q is the set of reachable places, $\bigvee$ is the generalized disjunction operator. In our example, place topics I is

$Q = \{ x_0,x_1,x_2, x_3,x_4,x_5,x_6,x_8,x_9,x_{11},x_{12},x_{15},x_{16}\}$, $I = x_0{:}(a \wedge \neg b \wedge c \wedge \neg d \wedge \neg e \wedge \neg f \wedge \neg g \wedge \neg h \wedge \neg i \wedge \neg j)$ $\ldots \vee x_{16}{:}(\neg a \wedge \neg b \wedge c \wedge \neg d \wedge \neg e \wedge \neg f \wedge \neg g \wedge \neg h \wedge i \wedge \neg j)$

The length of place topics generated in this naïve way is $n*m$, provided $|Q| = n$ and $|T| = m$. Although it contains a tremendous amount of useful information, it is likely to be too complex for the user to understand.

3. Generating topic based Model and analysis

3.1 Generating topics

Knowledge model(M) depending on the definition of the unit is supposed that every proposition is the topic. Some words in the document representation with a significant suppose a topic. If we represent a particular set of documents from the relationship between the feature keyword and topics to be able to abstract, this is a very simple but useful model is to gain knowledge. Topic as text based knowledge model could be set forth in detail generally as a formal language through insights by experts or be mechanically abstracted by text mining algorithm[16]. This study describes the algorithm to automatically generate knowledge elements by topic and the method to optimize integrated knowledge model.

Through natural language processing, we work activities that exist within specific processes and document analysis and text mining techniques to represent the document is extracted to terms with the characteristics of knowledge model(M) is mapped to an item. Document there is a repository of the address the process(P) is a detailed the task(T) name of directory to define that term for the extraction 'Weight Entropy' is shown below.

$$G_i = 1 + \sum_j \frac{P_{ij} log_2(P_{ij})}{log_2(n)} \quad (8)$$

$a_{i,j}$ = Frequency of terms is presented in the doc., G_i = Collected in the doc., indicated the frequency of term, n = The number of collected doc., d_i = number of documents with the term, $p_{i,j} = a_{i,j} / g_i$

Automatically extracted terms to find the usefulness of confidence intervals for the topic at creation of knowledge models in terms(Document Term) of the whole document, i calculated from the extracted terms (Detected Term) through analysis of the most appropriate derived values (Roll up Point).

AK : Author Keyword [{Termn}×X] == TM : Text Mining [{Termm}×(X+i)]

while Author Keyword : AK [{Termn}×X] == Text Mining : TM [{Termm}×(X+i)]

if AK ≠ TM, i = 100, m : Set of term in document

than (i = + 100), Result Return(Roll up rate) for(i) : Roll up

$$rate(\%) = \frac{Detected\ Term\ Point:\ [i \times term]}{Document\ Total\ Term\ point:\ [m \times Document\ term]} \quad (9)$$

else (AK = TM | Roll up rate ≤ 60), Step(end)

In our experiment as shown in figure3, abstract words and keywords automatically extracted from the concordance between the level should be approximately 80-90% effective when seen as an extract of the entire vocabulary of about 15% of the number of its induction into the most appropriate range. In addition, more than 90% of the keyword automatically in order to induce more than 30% of the full term should be induced to have confirmed that. The performance of general algorithm as Bayesian and weighted formula (Weight Entropy) algorithm do not differ.

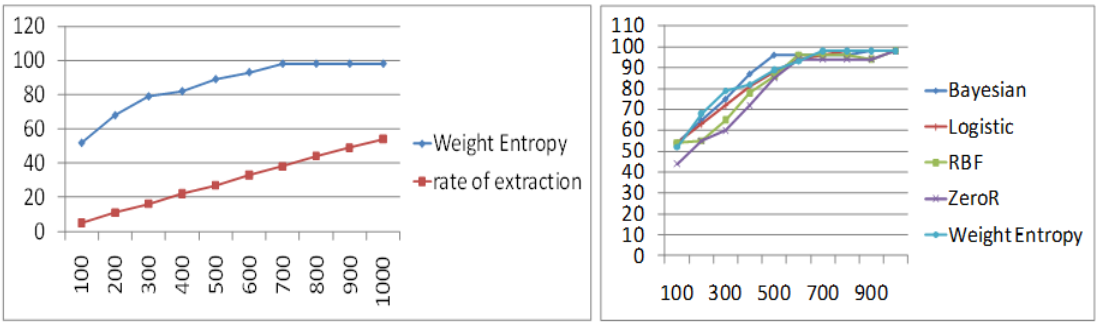

Fig. 4. Comparative results of weight entropy with general mining algorithms

Therefore, how to extract the keywords from documents is very effective for summarizing and defining of complexity document and knowledge model. In this study as **Fig. 4**, i used effective index that it calculate relationships between topics on knowledge model. Topics for the relationship between knowledge model extracted from the topics on document for the Closeness and Centrality of topic can be obtained through calculation[17][18].

3.2 Model Analysis

On generation of knowledge model, the structural traits are available through knowledge map and the relations between topics are available through approaches analysis of network model[19][20]. However, in order to understand the implied meaning of knowledge, the interaction and effects between topics should be analyzed in-depth as they are the meaning unit that consist the knowledge. In this chapter, Selton index was referred for using characteristics of connection degree, closeness, and between on certain topics. For the Selton index, the network based topic model was used for efficiency analysis of the topic, and this research analyzed the relations through the higher model which includes accessibility analysis and process. At first, the intensity of relations may be quantification based on the connection intensity between certain topics. P_i is the number of i in certain knowledge, and P_j is the number of j in certain knowledge, and P_{ij} is the number of i and j in certain knowledge.

If the intensity of relations is r, $$r = \frac{P_{ij}}{\sqrt{P_i P_j}} \quad (10)$$

The connection relations are divided into degree, closeness and medication, and have absolute value and relative value. The degree of centrality has higher connection intensity when certain topics reveal in other major knowledge, and it has central role in the knowledge. The Closeness Centrality has central role when certain topics are close to other topics, and D_{ij} is the shortest course which connects between i and j topics, and g is the number of overall node. Meanwhile, the Between Centrality is interpreted as central role when certain topics have more mediator roles in the relations between topics. g_{jk} is the shortest course number between two topics (j and k), and $g_{jk}(i)$ is the frequency of passing topic i between two topics j and k(j≠k). And g is the number of overall node. Through centrality analysis between topics, I can interpret meaningful characteristics of the knowledge model, and expand the range with difference and connection between knowledge models.

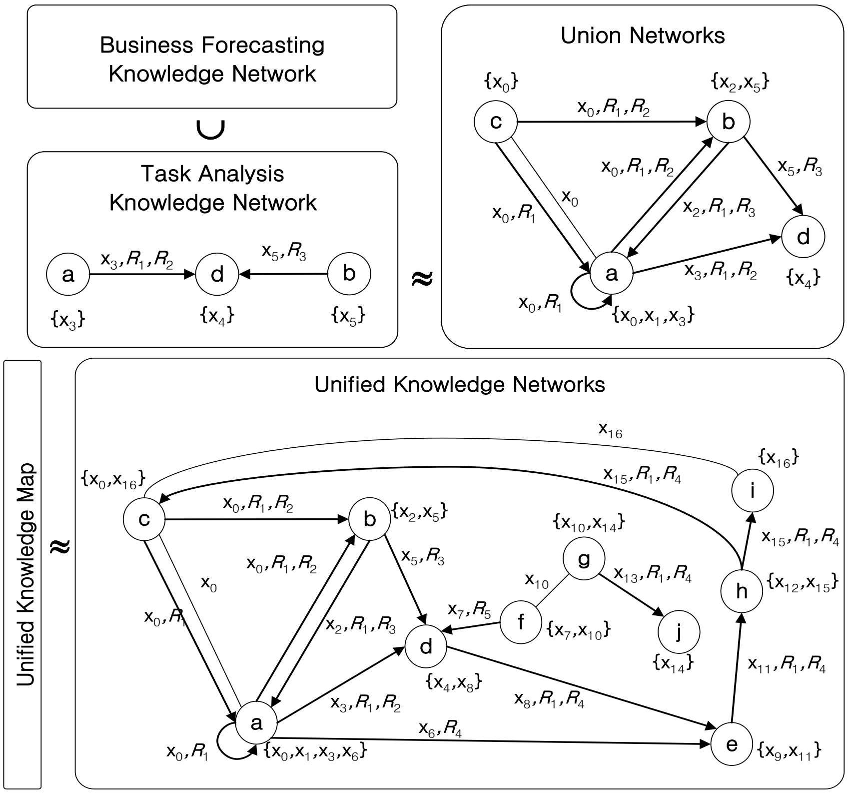

Fig. 5. Translation from topic map to knowledge network and integration method

A knowledge map takes a form of an topic in a reachable condition satisfying properties given by a knowledge model. Therefore, a knowledge map which satisfies different properties could unify knowledge networks as Figure 4 and its formula is as below:

Definition 2: Topic based knowledge map M is equivalence knowledge network N

Knowledge Map M → Knowledge Network N, M → N = {X→S, X_0→S_0, R, T→true, L→E}

$$\text{Unified Knowledge Network: } \bigcup_{n=1}^{m} N_n = N_1 \cup N_2 \cup \ldots \cup N_m \quad (11)$$

iff Knowledge Network $N_1 = \{S_1, s_0 \in S_1, R_1, T_1: \forall|E=\{true\}, E_1: \cup\{\}\}$

iff Knowledge Network $N_m = \{S_m, s_0 \in S_m, R_m, T_m: \forall|E=\{true\}, E_m: \cup\{\}\}$

then $\bigcup_{n=1}^{m} Nn = \{S_1 \cup S_m, s_0 \in S_1 \cup s_0 \in S_m, R_1 \times R_m, T_1 \cap T_m: \forall E=\{true\}, \cup E1:\{\} \vee E_m:\{\}\}$

The knowledge network as **Fig. 5**, is utilized in analyzing figuration and relationship of complexity systems as well as multi-dimensional analysis. And supports analysis of structural networks and paths, relationships, and behaviors of knowledge or topics through changes and unification of a particular knowledge model[20][21].

Definition 3: Anything properties Φ_1 and Φ_2 are satisfy knowledge network M

$$\text{Knowledge Network} \subseteq \text{Knowledge Map} \subseteq \text{Knowledge Model: M} \tag{12}$$

iff Knowledge Model $\rightarrow$ Knowledge Map(Φ_1) $\vee$ Knowledge Map(Φ_2)$\subseteq$M

$= R\Phi_1 (P)|\mu Z.((P \cup post \exists (Z)) \cap |[\neg\Phi]|) \vee R\Phi_2 (P') : M'$

iff Knowledge Map $\rightarrow$ Knowledge Network : M''

$= \vee[\cup_{n=1}^{m}[R\Phi_1(P)]n \vee \cup_{j=1}^{k}[\Phi_2(P)]l \subseteq M'' \subseteq M' \subseteq M$

Especially if i could be used to understand for the impact of the various topics and can get a variety of implications. In addition, as shown in **Fig. 6**, I created a visual analysis tool using the knowledge model structural analysis and hierarchical relationships between topics and took advantage of understanding.

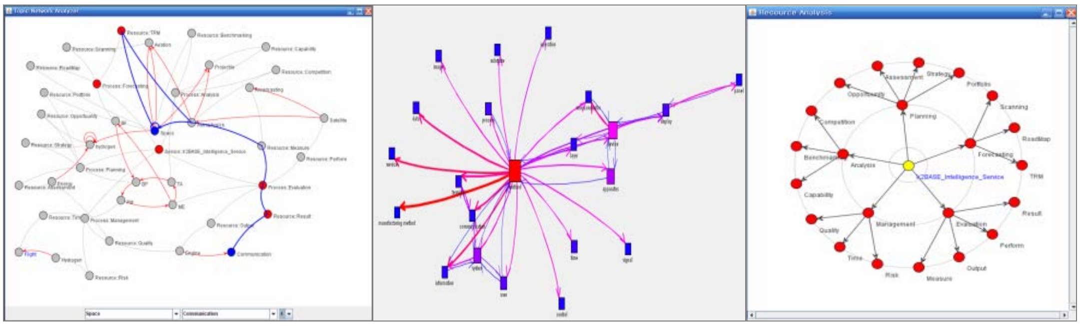

Fig. 6. Visualization and analysis of unified knowledge network

4. Conclusion

Many researchers have investigated useful ways of verifying and validating knowledge based model for ontologies and rules, but it is not easy to directly apply them to checking process models. The goal of our research is to generate a set of place topic in given knowledge model, to understand the relation between complex knowledge map and analytical knowledge networks. In previous works every reachable place was to be considered to generate place topic. The complexity of place topic is strongly dependent upon the size of places to be considered. Given a scope in CTL, forward reachability analysis is used to find out a set of states inside it. Obviously, a set of places calculated in this way is a subset of every reachable place. Therefore, generated place topic is used to optimize and translate knowledge map and networks. In this paper, I hoped to generate simple knowledge model for easy interpret and understanding of technology analysts. In this regard, we have suggested extraction algorithm of semantic keyword from complex technical document. To do this, we have defined process model of technology innovation, extracted semantic keyword and relationship property from technical document of each process. The extracted keywords and property is utilized to create and analyze knowledge model.

The keyword in knowledge model is a property and semantic topics that holds in every reachable process on knowledge model. Not only can be used in understanding and analysis of complex knowledge's relationships. For doing so, we let the user focus on some interested parts rather than a whole process state in a semantic model. Obviously, a set of process calculated in this way is a subset of every reachable process. Therefore, generated process and keyword is used to optimize and translate knowledge model. In future research, effective integration method of the extracted knowledge model and it based innovation trends will be applied actual system.

References

[1] Foray, Dominique, and B. A. Lundvall, "The Knowledge-Based Economy," *OECD*, Paris, 1997.
[2] S. Haag, Baltzan, "Business Driven Technology," *Published by McGraw-Hill*, 2006.
[3] H. Shah, Kourdi, "Frameworks for Enterprise Architecture," *IEEE computer society*, IT Professional, pp. 36-41, September, 2007. Article (CrossRef Link).
[4] Scholer, A., Rickel, "Learning domain knowledge for teaching procedural task," *AAAI-2000*, 2000.
[5] David Y.W. Park, "Static Analysis to Identify Invariants in RSML Specifications," in *Proc. of Formal Techniques in Real-Time and Fault-Tolerant '98*, LNCS 1486, pp. 133-142, Springer, 1998. Article (CrossRef Link).
[6] M. D. Ernst,(ed.), "Dynamically Discovering Likely Program Invariants to Support Program Evolution," ICSE, 2000.
[7] M. B. Dwyer, "Property specification patterns for finite-state verification," in *Proc. of the Workshop on Formal Methods in Software Practice*, 1998. Article (CrossRef Link).
[8] William Chan, "Temporal-logic Queries," in *Proc. of CAV 2000*, LNCS 1855, pp. 450-463, Springer, 2000. Article (CrossRef Link).
[9] R. Bryant, "Graph-Based Algorithms for Boolean Function Manipulation," *IEEE Transactions on Computer*, Vol. 100, No. 8, pp. 677-691, 1986. Article (CrossRef Link).
[10] W.Y. Liu, "Using IDEF0/Petri net for Ontology based task knowledge analysis: the case of emergency response for debris flow," *System Sciences*, HICSS Volume 4, 2006. Article (CrossRef Link).
[11] S. Edelkamp, S. Jabbar, "Action Planning for Directed Model Checking of Petri Nets," *Electronic Notes in Theoretical Computer Science*, Vol. 149, No. 2, pp. 3-18, 2006. Article (CrossRef Link).
[12] J. B. Rosser, "On the Complexities of Complex Economic Dynamics," *Journal of Economic Perspectives*. Vol. 13, No. 4, pp. 169-192, 1999. Article (CrossRef Link).
[13] D. Ruan, F. Hardeman, "Intelligent Decision and Policy Making Support Systems," Vol. 117, Springer, 2008. Article (CrossRef Link).
[14] Robert J. Thierauf, "Optimal Knowledge Management," *IDEA Group Publishing*, 2006. Article (CrossRef Link).
[15] V. Devedzic, "Knowledge Modeling - State of the art," *ACM integrated computer aided engineering*, Vol. 8, No. 3, pp. 257-281, 2001.
[16] Edmund M. Clarke, "Model Checking," in *Procs of the 17th Conference on Foundations of Software Technology and Theoretical Computer Science*, pp. 54-56, 1997.
[17] A. Neuser, "A GUI for Real-time Visualization of On-line Model Checking with UPPAAL," *Institute for Software Systems*, Hamburg University of Technology (TUHH), 2014.
[18] Savas Konur, "Towards Light-Weight Probabilistic Model Checking," *Journal of Applied Mathematics*, Hindawi publishing corporation, 2014. Article (CrossRef Link).

[19] Dou, Wei, “A Model-Driven Approach to Trace Checking of Temporal Properties with OCL,” *Open Repository and Bibliography*, S&T Centre, University of Luxembourg, 2014.
[20] Campos, J. Creissac, Machado, “A specification patterns system for discrete event systems analysis,” I*nTech*, repositorium.sdum.uminho.pt, 2013. Article (CrossRef Link).
[21] DR Kulkarni, “Improved model generation and property specification for analog/mixed-signal circuits,” async.ece.utah.edu, 2013.

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