Journal of the Society of Korea Industrial and Systems Engineering
Vol, 28, No. 4, pp.63－68, December 2005.

Ontology Modeling for Pattern Recognition of Information Flow Using Situation Theory

Young-Moon Leem

Department of Industrial Systems Engineering, Kangnung National University

상황이론을 이용한 정보흐름에 대한 패턴인식을 위한 ontology 모델링

임 영 문

강릉대학교 산업시스템공학과

주어진 시스템에서 정보와 정보흐름에 대한 패턴인식을 하기 위해서는, 정보를 내포하고 있는 문맥이 내용에 따라서 다른 단어나 다른 정보를 추론하여 원래의미를 전달함에 있어 오도할 수 있기 때문에, 문맥의 분해에서 정보조각의 묶음 형태로 전환하는 작업에서부터 연구는 시작되어야만 한다. 많은 연구자들이 정보의 저장, 재표현, 부호화, 검색 등에 관해 효과적인 방법론을 찾고자 노력해 오고 있다. 유사한 노력의 일환으로 본 논문에서는 군이론과 상황이론을 응용해서 정보 및 정보흐름의 패턴인식에 관한 새로운 모델링 기법을 제안하고자 한다. 정보처리에 관련된 선행연구와 비교해서, 본 연구에서 제안하는 방법은 수학이론인 군이론과 상황이론에서 사용되고 있는 개념과 정의를 사용하였다는 점에서 매우 새로운 접근방법이라 할 수 있다. 본 논문에서는 정보흐름의 패턴인식을 위한 모델링 기법으로 Abelian Pattern Semi-Group을 제시하는데 이러한 접근방법은 최근 중요한 연구 분야가 되고 있는 유비쿼터스 컴퓨팅 환경에서도 활용될 수 있을 것이다.

Keywords : ontology modeling, pattern recognition, abelian pattern semi-group

1. Introduction

To understand the pattern recognition of information and information flow from given a system, a study should be started from the decomposition process of context into a collection of information pieces because the context may infer different words or information. Since there are many possible ways of decomposing the patterns such as data mining techniques, this paper imposes a limit for decomposition up to a pre-defined resolution by using group theory and situation theory. In this paper, the collection of all the possible patterns is a set S. Each element in S represents a state of information (Infons, Actons) under the decomposition process. The set S together with the composition process forms an algebraic structure known as semi-group. The construction of such semi-group will be provided with simple examples. This process of construction of semi-group can be used as a retrieval tool from the decomposed information if necessary. Compared to previous research, this process is a very new approach in the fact that this paper makes applications of the concept and definition of group theory and situation theory. Finally, this paper presents Abelian Pattern Semi-Group using group theory as a modeling for pattern recognition of

This paper was accomplished with Research Fund provided by Kangnung National University, Support for Academic Research Fund in 2003.

information flow. There is no doubt that manufacturing systems are getting more and more complicated. In order to manage these complex manufacturing systems, it is vital to control information and information flow in the system. For effective information-based management in a system, information should be properly stored, encoded and represented when needed. Many researches [1][2][3][7][10] have been focused on finding of effective methodology for information store, retrieval, capture, representation, and discovery. As a similar endeavor, this paper presents a methodology for ontology modeling for representation of information flow. According to Webster's Third new International Dictionary, the second definition of ontology given is "a theory concerning the kinds of entities and specifically the kinds of abstract entities that are to be admitted to a language system." Ontology provides a vocabulary for representing and communicating knowledge about some topic and a set of relationships that hold among the terms in the vocabulary and so they are very powerful resources to share knowledge. Ontology is an inventory of the kind of things that are presumed to exist in a given domain together with a formal description of the salient properties of those things and the salient relations that hold among them (KBSI, 1996). In general, process modeling and ontology modeling play leading roles for systems modeling to capture and share information flow in systems. Process modeling is the basis for developing, optimization, performance prediction, control and decision making in systems [4], whereas ontology modeling can be considered a prerequisite task for the successful process model. As an ontology modeling technique, this paper proposes a situation-theoretic approach. Leem [7] created IAST Model as an application of ontology modeling based on situation theory and this paper addresses an extension of this and other prior work in situation theory.

2. Group Theory

Group theory is a study of an operation on a set of elements [6]. When each element represents a state, the binary operation is interpreted as the transformation of the states. For example the set of all possible rotations of an object can form a group. A finite group, which means a group with finite number of elements, has many applications in the study of physics and mathematics [11]. A less restricted version of group is called the semi-group. It is less restricted because it does not require the existence of inverse elements for each element. Semi-group theory has also been applied in many disciplines such as modeling the automata in computer science, and modeling genetic code in biology [5].

2.1 Abelian semi-Group

A semi-group G is a collection of both a set S and an associative binary operation ⊗ [5]. Mathematically, we write G=(S,⊗), S is a set, ⊗ is a binary operation : S × S → S and that means :

$\forall x, \forall y \in S, x \otimes y \in S$ (closed), $\forall x, \forall y, \forall z \in S,$ $x \otimes (y \otimes z) = (x \otimes y) \otimes z \in S$ (associative). Furthermore, if the operation ⊗ commutes, the semi-group is called an abelian semi-group ; $x \otimes y = y \otimes x$ (commutative).

Some special elements are also defined for a semi-group. These are identity element, e, zero element 0, and idempotent element i.

Identity element, e

Property : $e \otimes x = x, \forall x \in S$

Zero element, 0

Property : $0 \otimes x = 0, \forall x \in S$

Idempotent element, i

Property : $i \otimes i = i$

2.2 Semi-Group Table

A semi-group table is a table that records the domain and range of the operation ⊗. Given S = {a ,b ,c}, a semi-group table is as shown in <Table 1>. The semi-group for an abelian semi-group is symmetric about the diagonal line : $i \otimes i = i, \forall i \in S$, since $a \otimes b = b \otimes a, \forall a, \forall b \in S$.

2.3 Subsemi-Group

Let S be a semi-group. Then, subsemi-group S' is defined as :

- $S' \subset S$
- S' is a semi-group.

In general, intersection of subsemi-groups is again a subsemi-group. the proof of this can be seen in [5]. <Table 1> shows us a simple operation of ⊗.

<Table 1> The semi-group table

⊗	a	b	c
a	a⊗a	a⊗b	a⊗c
b	b⊗a	b⊗b	b⊗c
c	c⊗a	c⊗b	c⊗c

3. Situation Theory

Situation Theory(ST) has been devised to develop a unified mathematical theory of meaning and information content and to clarify and resolve various long-standing problems through the use of an interdisciplinary effort from cognitive science, computer science and artificial intelligence, engineering, linguistics, logic, philosophy, and mathematics. The mathematical foundations of the theory are based on intuitions basically coming from set theory and logic, In short. ST is a theory about the "flow and support of information". Use of a holistic approach means that the whole system is viewed together rather than each piece individually. In this approach, object and subject are directly unified in an experiential view of truth. The most vital aspect of information flow is accuracy and simplicity. However, there are often significant problems in the fact that there are no current techniques to apply rigorous mathematics to semantic conveyance of information flow. A promising solution is ST, a new mathematical technique that we are proposing to apply in a new way as part of a holistic approach.

As a technique of holistic approach, this paper introduces the concept of Situation Theory (ST).

There are four major concepts of ST such as [7,8,9] :

Infons

Situations

Constraints

Actons

Infons are the basic informational units, discrete items of information, semantic objects not syntactic representations, denoted as $\ll$ P, a_1,...a_n, i $\gg$ where P is n-place relation, P, a_1,...a_n are objects appropriate for the respective argument places of P, i is the polarity (0 or 1). Situations are defined intentionally and a situation is considered to be a structured part of the reality that an agent manages to pick out. It is desirable to have some computational tools to handle situations and abstract situations are the mathematical constructs that are amenable to mathematical manipulation, For given a real situation s, the set { α | s | = α } is the corresponding abstract situation, where, s supports α (denoted as s | = α) means that α is an infon that is true of s. The flow of information is realized via constraints. We represent a constraint as $\ll$ involves,S_0, S_1, 1 $\gg$ where S_0 and S_1 are situation-types between which the information is carried out. Cognitively, if this relation hold, then it is a fact that if S_0 is realized(i,e., there is a real situation s_0 : S_0) then so is S_1 (i,e., there is a real situation s_1 : S_1). Actons are a formal statement of actions, which the given situation supports, or not. In short, Infon is about "true" or "false" and acton is about "succeed" or "fail". As a notation of acton,

$\ll$(action), (preconditions, an infon), (postconditions, another infon), (polarity)$\gg$

will be used. Having actons as a basic element in constraints gives us near instant access to a family of analytical tools and methods based on communicative acts. The merits of having actons are not only to have powerful self-organizing simulation and control systems, but also to utilize a strong area of information representation and its tools. The specific application of infons and actons can be seen in [7].

3.1 Basic Ontology

This paper uses ontological approach for the technique. According to Devlin [9], the basic ontology of situation theory consists of entities that a finite, cognitive agent individuates and/or discriminates as it makes its way in the world : spatial locations, temporal locations, individuals, finitary relations, situations, types, and a number of other, "higher order" entities. The objects(known as uniformities) in this ontology include the following.

- Individuals; objects such as tables, chairs, people, hands, etc. that the agent either individuates or at least discriminates(by its behavior) as single, essentially unitary items usually denoted in situation theory by a, b, c, ...
- Relations; uniformities individuated or discriminated by the agent that hold of, or link together specific numbers of, certain other uniformities; denoted by P,

Q, R, ...

- Spatial locations; denoted by $l, l', l'', l_0, l_1, l_2$, etc. These are not necessarily like the "point" of mathematical spaces but can have spatial extension.
- Temporal locations; denoted by t, t', t'', t_0, t_1, t_2, etc. As with spatial locations, temporal locations may be either point in time or region of time.
- Situation; structured parts of the world(concrete or abstract) discriminated by(or perhaps individuated by) the agent---denoted by s, s', s'', s_0, ...
- Types; higher order uniformities discriminated (and possibly individuated) by the agent denoted by S, T, U, V, ...
- Parameters; indeterminate that range over objects of the various type---denoted by $\dot{a}$, $\dot{s}$, $\dot{t}$, $\dot{l}$, etc.

The precise ontology is assumed to derive from a scheme of individuation. A scheme of individuation is determined by the individuation and discriminatory capacities of a given agent or, more generally, species of agent [4].

4. Proposed Modeling Method

In this section, we present Abelian Pattern Semi-Group using group theory and situation theory as a modeling for pattern recognition of information flow. Then the definition of a hasse diagram is mentioned in this section for the description of inclusion and priority of information. Finally two examples are given for the understanding of the proposed modeling method.

4.1. Abelian Pattern Semi-group

Let P^2 and P^3(P stands for pattern of information) be a set of patterns, which is a set of static information and a set of dynamic information respectively. For example, consider the following sentence : This is a new computer (1). This machine is operating (2). In this case, (1) is static information and (2) is dynamic information, In this paper, we refer P to the set of patterns in the following discussion. The element g is chosen to represent the pattern for content with information. The operation $\oplus$ is chosen to be the composition of infons and actons (*Definitions of these are given in the previous sections*). Since the set P contains all possible combination of the infons and actons, we say that P is generated by the infons and actons. The subset in P that contains all infons and actons in system is called basis. Let APSG(Abelian Pattern Semi-Group) = (P, $\oplus$), and g, P_1, P_2, P_3 be elements in P. Each element p in P represents a set of words(nouns and verbs) in content with information and $\oplus$ is defined as : $\oplus$: $P \times P \rightarrow P$ and explicitly, $p_1 \oplus p_2 = p_3$ (p_3 is the pattern that corresponds to the total meaning p_1, and p_2 represent). Note that $\oplus$ is by definition closed. To see that $\oplus$ is associative, let p_1, p_2, p_3 represent meaning m_1, m_2, and m_3 respectively : $p_1 \oplus (p_2 \oplus p_3)$ = $\{m_1 \cup \{m_2 \cup m_3\}\}$ represents the same meaning as $\{\{m_1 \cup m_2\} \cup m_3\}$ = $(p_1 \oplus p_2) \oplus p_3$ (associative). Note that the operation $\cup$ is the set union. Furthermore, $P_i \oplus P_j$ = $\{m_i \cup m_j\}$ = $\{m_j \cup m_i\}$ = $P_j \oplus P_i$ (commutative) for all i = 1, 2, 3; j = 1, 2, 3. This completes the construction of the abelian semi-group. Furthermore, the zero element is g, the final pattern, while all elements in P are idempotent patterns. The identity element is the empty set. Since the operate commutes, the semi-group table is symmetric over the diagonal.

4.2 Hasse Diagram

Before giving the definition of a hasse diagram, it is necessary to know the concept of partial ordered set. A partial ordered set is a set with a binary relation $\leq$, which is reflexive, transitive and symmetry [6]. Mathematically, we write : O = (S, $\leq$), S is a set, $\leq$ is a partial order on S a subset of S $\times$ S, and $\forall$x, $\forall$y, $\forall$z $\in$ S :

- $x \leq x$, $\forall x \in S$ (reflexive)
- if $x \leq y$, $y \leq z$, then $x \leq z$, (transitive)
- if $x \leq y$, $y \leq x$, then x=y, (symmetry)

Now a hasse diagram is a tree diagram (figure 1) representing the relation $\leq$ in the partial ordered set, with x on top of y if and only if $y \leq x$. Therefore if the tree has only one root, it is the greatest element. Conversely, if the tree has only one end leaf, it is the least element. This concept can be used for the description of inclusion and priority of information.

4.3 Example of Abelian Pattern Semi-Group

Consider the APSG A = {e, na, ve, g} with basis {na ve}, where na is subset of nouns, ve is a subset of verbs in content, e is an identity, and g is a final pattern of information. Using the operation ⊕, the result is as follow.

<Table 2> Semi-group for the APSG A

⊕	e	na	ve	g
e	e	na	ve	g
na	na	na	g	g
ve	ve	g	ve	g
g	g	g	g	g

As can be seen in table 2, semi-group for the APSG A has a very simple structure and operation but given information flow can be classified by typical patterns as easy understandable deliverables. However, in order to have more useful model, a proposed model has to be connected with Inf-Act On Net [7] and informators [8,9]. Leem made IAST (Inf-Act in situation Theory) model using Inf-Act On Net in [10]. This model is based on situation theory and is to aid holistic views by mathematical tool in systems design. Also, Leem and Rogers [9] introduced informators as a new tool for efficient information sharing in manufacturing system. Timely conveyance and relevant analysis of information flow are key element for efficient systems management. The generated Inf-Act On Net with informators is based on situation theory and is a powerful structure for sharing timely and relevant information in a complex manufacturing systems that can be used continuously and efficiently throughout systems operation. In this model, Inf-Act On Net makes it possible to understand overall structure of the relationship of information and informators used as an auxiliary tool in the specific structure of information with surrounding conditions in systems.

Although the modeling method for pattern recognition that is introduced in this paper needs more specific rules and operations, it will play a useful role with Inf-Act On Net and informators for the analysis of information flow.

4.4 Example of a Hasse Diagram

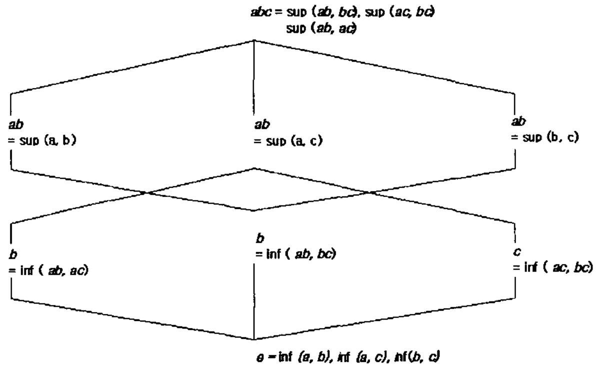
Given S = { e, a, b, c, ab, ac, bc, abc}, with the following relation :

$e \le a \le ab \le abc$, $a \le ac \le abc$,

$e \le b \le ab \le abc$, $b \le bc \le abc$,

$e \le c \le ac \le abc$. $c \le bc \le abc$.

Then a hasse diagram can be described as figure 1.



<Figure 1> Hasse diagram

A relation $\le$ is a total order, if $\le$ satisfies the additional property of either $x \le y$ or $y \le x, \forall x, \forall y \in S$.

The hasse diagram of a total ordered set is a straight line. Practically, it is useful sometimes to induce more relationships into a partial order to make it a total order. As mentioned before, this hasse diagram will play an important role for the description of inclusion and priority of information in our model.

5. Conclusion

In order to manage and understand information flow, it is essential to have a simple and compact model. The main objective of this paper is to construct a model for pattern recognition of information in manufacturing systems using group theory and situation theory. In general, situation theory provides a framework for studying the way information and context interact to provide meaning. Group theory is to study an operation on a set of elements. This paper presents an initial model for pattern recognition using the above theories and proposed model can be used to drive both helpful insight and useful information with abelian pattern semi-group and a hasse diagram. However this model has a very weak structure to represent the specific information flow such as location, tense of information, etc. As an ongoing research, this paper proposes a study of more specific operations to be a convenient and effective toolbox. Also, future research will be focused on the development of technique connecting proposed model with Inf-Act On Net and infomators.

References

[1] Annelise Mark Peitersen, "SemanticInformation Retrieval," Journal of Communication of The ACM, Vol. 41, No 4, pp.90-92, 1998.

[2] Armistead, Colin, "Knowledge Management and Process Performance." Journal of Knowledge Management, Vol. 3, no. 2, pp. 143-154, 1999.

[3] Carla E. Brodley, Terran Lane and Timothy M. Stough, "Knowledge Discovery and Data Mining," Journal of American Scientist, Vol. 87, No, pp. 54-61, 1999.

[4] Devlin, Keithand Rosenberg, Duska, Language at Work : Analyzing, Communication Breakdown in the Workplace to inform Systems Design. Stanford, CSLI Publication, 1996.

[5] Howie, J.M., An Introduction to Semi Group Theory, Academic Press, london, 1976.

[6] Lang, S., Undergraduate Algebra, 2nd ed., Springer-Verlag, New York, NY, 1990.

[7] Leem. Y. M., "Construction of IAST Model for Agile Process Design with Holistic Concept", Journal of the Korean Institute of Industrial Engineers, Vol. 24, No. 1, pp. 1-9, 1998.

[8] Leem, Y.M., "Partitioning and Conveyance Technique of Information flow for systems Design ", Journal of Industrial and Systems Engineering, Vol. 23, No. 56, pp. 35-43, 2000.

[9] Leem, Y.M. and K.J. Rogers, ""An Method of sharing Information Flow for Ontology Modeling in System," Conference on Engineering Design and Automation, Canada, Vancouver, Aug., 1~4, Proceedings, pp. 164-167.", 1999.

[10] Leem. Y. M. and K.J. Rogers, "Methodology for Effective Information-Based Management in Manufacturing systems", The 4th International Conference on Engineering Design and Automation, Orlando, Florida, USA, July 30 - Aug. 1, Proceedings, pp. 793-796, 2000.

[11] Lomont, J.S., Application of Finite Groups, Dover Publication. Toronto. 1987.