◆ Research Paper

Partitioning and Conveyance Technique of Information Flow for Systems Design

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Abstract

In order to obtain rigorous systems analysis and design, it is essential to understand accurate information flow in the system. For the effective capturing of accurate information flow in a system, it is vital to control information flow in the system. Also, information and information flow have to be simplified as a deliverable form. This paper presents partitioning and conveyance technique based on the application of situation theory. First, historical background of situation theory will be given. Then necessary conditions and definitions will be provided. Lastly, this paper provides specific technique with example. This introduced technique will be a powerful tool for sharing timely and relevant information in a complex manufacturing system that can be used continuously and efficiently throughout systems operation.

1. Introduction

Timely conveyance and relevant analysis of information flow play an important role not only for saving cost but also for increasing production in manufacturing systems. In addition, these conditions are essential factors for good systems design. Recently, many researchers and practitioners [3,7,10,11,15,24,25] have been focused on finding of effective tools for knowledge (information) store, retrieval, capture, representation, and discovery. Data mining [18,29], neural network and pattern recognition [2,23] can be good examples for the above research. As a similar endeavor, this paper introduces a technique that is based on the application of situation theory. Situation theory is a collection of mathematical tools designed to provide a framework for the study of information and is intended to provide methods by which one may gain a measure of understanding of communication and action. Situation theory (ST) was developed initially by a multidisciplinary community, whose members each brought their own perspectives to bear on what is meant by information and information flow. The basic ideas of ST were first put forward in Barwise and Perry (1983). In 1987, Barwise and Etchemendy brought together ideas from ST and Aczels work in set theory to provide a solution to the semantical paradoxes, as well as a model of propositional content that permits circularity. Barwise (1989) [5] applied ST to a variety of problems, including the semantics of natural-language conditionals, the nature of constraints, and the characterization of common knowledge. Gawron and Peters [1] applied the theory to construct a semantic account of scope and anaphora in natural language in 1990. Finally, Devlin [12] gives a more up-to-date version of ST, cataloging numerous

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developments that had not previously appeared in print. ST has its name from the mathematical device introduced in order to explain context. ST has been used as a guide to find out which aspects of the real world communication can be formalized.

2. Necessary Definitions and Notations

It is necessary to know three important definitions in order to apply situation theory: Infon, Constraint and Situation. Infons are the basic informational units, discrete items of information, semantic objects not syntactic representations, denoted as $\ll P, a_1, a_2, \cdots, a_n, i \gg$ where P is an n-place relation, $a_1, a_2, \cdots, a_n$ are objects appropriate for the respective argument places of P, i is the polarity (0 or 1). In the above notation, i=1 or i=0 indicates that given infon is true or false respectively. Information flow is made possibly by a network of abstract linkages (called constraints) between higher-order uniformities known as type. The constraint links not the actual situation but types of situation. Situations are defined intentionally and a situation is considered to be a structured part of the reality that agent manages to pick out. For given a real situation s, the set $\{\alpha | s \models \alpha\}$ is the corresponding abstract situation, where s supports α (denoted as $s \models \alpha$) means that is an infon that is true of s. The flow of information is realized via constraints. We represent a constraint as $\ll \text{involves}, S_0, S_1, 1 \gg$ where S_0 and S_1 are situation-types between the information is carried out. If this relation holds, 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 $s_1: S_1$). Constraints provide the means by which representations store and convey information. Misuse of constraints can result in the conveyance of misinformation. As a new concept in situation theory, actons are used in this paper. Notation and usage of actons will be given in the next section.

Table 1. Definitions of Ontology

(Source: http://www.ladseb.pd.cnr.it/infor/Ontology/Papers/OntologyPapers.html)

Anouncer(Year)	Definition
Gruber (1994)	An ontology is an explicit specification of a conceptualization
Wielinga, Schreiber (1993)	An ontology is a theory of what entities can exist in the mind of a knowledge agent
Albert (1993)	An ontology for a body of knowledge concerning a particular task or domain describes a taxonomy of concepts for that task or domain that define the semantic interpretation of the knowledge
Van Heijst et al.(1996)	An ontology is an explicit knowledge level specification of a conceptualization, (…) which may be affected by the particular domain and task it is intended for
Guarino, Giaretta (1995)	An ontology is a logical theory that constrains the intended models of a logical language
Schreiber (1995)	An ontology is an explicit, partial specification of a conceptualization that is expressible as a meta-level viewpoint on a set of possible domain theories for the purpose of modular design, redesign and reuse of knowledge-intensive system components

3. Basic Ontology

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). This paper uses ontological approach for the technique. As can be seen in table 1, there exist many definitions. According to Devlin [12], 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 points in time or region of time.
- Situations; structured parts of the world (concrete or abstract) discriminated by (or perhaps individuated by) the agent---denoted by $s, s', s'', s_0, \cdots$.
- 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 [13].

Representation and capturing information flow in systems are very important not only for systems modeling but also for systems understanding. In this section, the procedure of situation theoretic approach is outlined with its semantic concept. Given information, basic questions have to be answered for more understanding:

-What is the propositional content of a given information?

-What is the meaning of the information uttered?

For the proper answers, let's consider a situation. Suppose Park utters the information. Φ: Kim is singing in the room. In this case, there are two situations. One situation, call it, u, is the one where Park makes his utterance (utterance situation). The other situation is what we called described situation. In making the utterance, Park makes a claim about some particular situation e, a situation such that |= << singing, Kim, t, l, 1

>> (*). In this notation (*), t means a temporal location. Because the relation of one temporal location preceding another (in time) is such a common one, $t < t'$ indicates that t temporally precedes t'. Likewise the notation $t \circ t'$ indicates overlap of the temporal regions t, t' . Let' s consider E |= [$\dot{e}$| $\dot{e}$ |= << singing, Kim, t, l, 1 >>]. In this case, the propositional content of Park's utterance u is defined to be the claim e:E and the meaning of Φ can be defined to be the abstract linkage (denoted by ||Φ||) between the two situation-types

U = [$\dot{u}$ | $\dot{u}$ |= {<<singing, $\dot{p}$, $\dot{l}$, $\dot{t}$, 1>>, <<saying, $\dot{p}$, Φ, $\dot{l}$, $\dot{t}$, 1>>, <<refers- to, $\dot{p}$, Kim, $\dot{q}$, $\dot{l}$, $\dot{t}$, 1>>}] where $\dot{p}$, $\dot{q}$ are parameters for persons and E |= [$\dot{e}$| $\dot{e}$ |= << singing, $\dot{q}$, $\dot{t}$, 1>>].

Thus, if u is a situation of type U, there must be some person that fulfils the role of speaker and that person are saying the utterance Φ. The meaning, ||Φ||, of the information Φ provides the link between the utterance situation and described situation, enabling an utterance of Φ to be informational. Given such a definition, situation semantics can be regarded, at least as a first approximation and when restricted to simple assertive information, as a study of linkages ||Φ|| for various information Φ, and of the related "meanings" ||Φ|| of expressions a that are only parts of information (nouns, pronouns, verbs, etc.). In situation theory, information is information about some situation and e:E means two forms in use: e is a situation and E is a situation-type, or e is an object and E is an object-type defined over some grounding situation. In order to represent some information, all propositions are essentially of the form <situation> |= <infon> or <acton> (*infon or acton is true of given situation*), where, the notation "|=" means "support" [12].

4. Partitioning Analysis Technique

In this section, IDEF0 is used to show the technique of information partitioning and conveyance. Figure 1 is the diagram described by IDEF0. Actually, this is a part of whole diagram which is consists of four categories. IDEF0 is widely used technique for the structured analysis and design for systems. Its use in improving the productivity and communications in computer integrated manufacturing system and more recently, as a tool for business process reengineering efforts are widely documented [26]. There are five elements to the IDEF0 functional model: the activity (or process) is represented by boxes; inputs are represented by the arrows flowing into the left hand side of an activity box; outputs are represented by arrows flowing out the right hand side of an activity box; the arrows flowing into the top portion of the box represent constraints or controls on the activities; and the final element represented by arrows flowing into the bottom of the activity box are the mechanisms that carries out the activity. The inputs, control, output and mechanism arrows are also defined as ICOM's [21].

Now, using the situation theory's concepts, information flow in figure 1 can be represented by the following:

S = [SIT| $\dot{s}$ |= << VE_{40}, ($\dot{IP}$, << VE_{310}, NA_{520}, $\dot{l}$, $\dot{t}$, 1>>), ($\dot{OP}$,<<VE_{310}, NA_{520}, $\dot{l}$, $\dot{t}$, 1

>>), 1>>] ----------(1)

Where $\dot{IP}$: type of inputs = { NA_{30}, NA_{51}, NA_{55}, NA_{410}, NA_{500}}

$\dot{OP}$: type of output = { NA_{40}, NA_{80}, NA_{450}}

$\dot{s}$: type of situation which the system is performed.

$\dot{t}$: some location which the system is performed.

$\dot{t}$: some time which the system is performed.

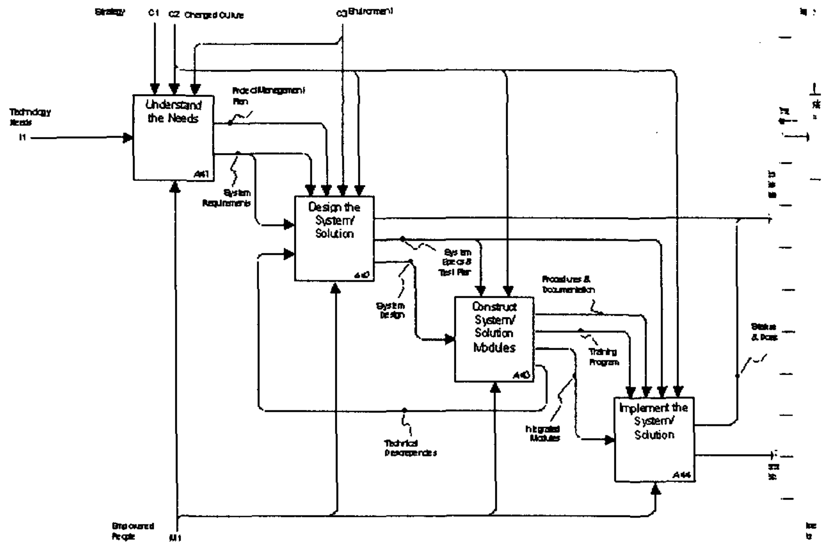

Figure 1. Develop Technology Solutions.

The above representation (equation 1) is made by an acton' s concept [17] and an example of partitioning technique. Using this representation technique, any information flow of given systems can be represented by partitioning forms. In situation theory, infons are formal statements of facts which a situation supports or not, whereas actons are formal statements of actions which the situation supports or not. In short, infon is about "true" or "false" and acton is about "succeed" or "fail" . As can be seen, << (action), (preconditions, an infon), (postcondition, another infon), (polarity) >> is used as a typical notation of an acton.

Table 2. Inf-Act ON Net for figure 1 with Polarity

	VE_{32}	VE_{35}	VE_{40}	VE_{81}	VE_{90}
NA_{100}	0	0	0	0	1
NA_{410}	0	0	0	0	0
NA_{420}	0	0	0	0	0
NA_{433}	0	1	0	1	0
NA_{440}	1	0	0	0	0
NA_{520}	0	0	1	0	0

As an auxiliary tool for easy understanding of information flow in the system, table 1 indicates the relationship between infons and actons which is very helpful to capture information flow in the partitioned system. In this table, 0 means no relationships and 1 means relationships between infons and actons.

5. Conveyance Technique

Table 3 shows the NAs-VEs Table for the figure 1 and table 2 shows the Inf-Act On Net for the figure 1. As shown in table 3, the NAs table contains nouns and the VEs table contains verbs that are very related to the concept of infon and acton. Table 3 plays a role as an information library and table 2 shows us information flow in the given syste m' s structure. Thus, these tables (2&3) are very useful to convey information in given systems. The Inf-Act On Net (table 2) described in the previous section is a very simple case. If given systems have a complex structure with many components, the generated Inf-Act On Net could be a very powerful tool for sharing timely and relevant information.

As shown in figure 1, each box contains some surrounding conditions (inputs, outputs). For the explanation of these conditions, a new notation is introduced as an auxiliary tool of Inf-Act On Net. As far as infons and actons have a relationship, the notation " $\genfrac{}{}{0pt}{}{A}{B} \boxplus \genfrac{}{}{0pt}{}{C}{D}$ " will be used to represent informational unit and is called as an informator. In this notation, A, B, C, D mean acton' s number, infon' s number, input' s number, and output' s number, respectively. Applying this notation into figure 1, each box can be represented by the following simple forms.

Box 1 (A41): $\genfrac{}{}{0pt}{}{90}{100} \boxplus \genfrac{}{}{0pt}{}{30,51,55,410,500}{280,430}$ ----------(2)

Box 2 (A42): $\genfrac{}{}{0pt}{}{35}{433} \boxplus \genfrac{}{}{0pt}{}{30,51,55,280,430}{30,420,530}$ ----------(3)

Box 3 (A43): $\genfrac{}{}{0pt}{}{32}{440} \boxplus \genfrac{}{}{0pt}{}{30,51,420,530}{40,90,540}$ ----------(4)

Box 4 (A44): $\genfrac{}{}{0pt}{}{81}{433} \boxplus \genfrac{}{}{0pt}{}{30,40,51,90,530,540}{40,80,450}$ ----------(5)

In the above forms, equation 2 means that VE_{90} has a relationship with NA_{100} and surrounding conditions (inputs, outputs) are NA_{30}, NA_{51}, NA_{55}, NA_{280}, NA_{410}, NA_{430}, and NA_{500}. Like equation 2, equation3, equation4 and equation 5 can be explained similarly. As can be seen, informators can be used as a retrieval tool of information and information flow in each box. So far, we have basic operation rules with operators as follows.

$\genfrac{}{}{0pt}{}{A}{B} \boxplus \genfrac{}{}{0pt}{}{C}{D} \wedge \genfrac{}{}{0pt}{}{A}{B} \boxplus \genfrac{}{}{0pt}{}{E}{F} \Leftrightarrow \genfrac{}{}{0pt}{}{A}{B} \boxplus \genfrac{}{}{0pt}{}{C,F}{D,F}$ ----------(6)

$\genfrac{}{}{0pt}{}{A}{B} \boxplus \genfrac{}{}{0pt}{}{C}{D} \wedge \genfrac{}{}{0pt}{}{A}{a} \boxplus \genfrac{}{}{0pt}{}{C}{D} \Leftrightarrow \genfrac{}{}{0pt}{}{A}{B,a} \boxplus \genfrac{}{}{0pt}{}{C}{D}$ ----------(7)

In equation 6 and equation 7, the notation "$\wedge$" is a logical connective and the notation, "$\Leftrightarrow$" means "equivalence" . Equation 6 is the case that two informators have the same infon and acton. In this case, there are no restrictions. Equation 7 is the case that each informator only has the same acton. In this case, each informator should have the same surrounding conditions. The IAST model has been used to represent information and its flow in systems, whereas the revised IAST model provides the method of conveyance technique of information flow. In addition, as can be seen in equation 2 ~ equation 7, it is possible to handle and calculate information in part with informators in the revised IAST model. In order to capture and share more information unit, it is necessary to develop various operation rules for informators and this will be a future research.

6. Conclusion

Although there are many definitions of ontology, the important element in ontology

Table 3. NAs-VEs table for figure 1

NAs	VEs
Changed Culture (NA_{30}), Documentation (NA_{40}), Empowered Person (NA_{51}), Environment (NA_{55}), Implemented Solutions (NA_{80}), Integrated Modules (NA_{90}), Needs (NA_{100}), Project Plan (NA_{280}), Strategy (NA_{410}), System Design (NA_{420}), System Requirement (NA_{430}), System/Solution (NA_{433}), System/Solution Module (NA_{440}), System/Solution Feedback (NA_{450}), Technology Needs (NA_{500}), Technology Solution(NA_{520}), Test Plan (NA_{530}), Training Program (NA_{540})	Construct (VE_{32}), Design (VE_{35}), Develop (VE_{40}), Implement (VE_{81}), Refer-to (VE_{310}), Understand (VE_{90})

modeling is to define terms and their effective use for representation with proper meaning in systems. In this paper, we borrowed some terms and notations from situation theory for ontology modeling. In general, situation theory provides a framework for studying the way information and context interact to produce meaning. As we have seen, a situation theoretic approach can be used as a tool in ontology modeling with its basic ontology (temporal, spatial locations, individuals, relations, parameters, types, etc.). This approach enables us to have semantic representation for use of partitioning and conveyance of information flow.

Timely conveyance and relevant analysis of information flow are key elements for efficient systems management. This paper provides the Inf-Act On Net with infomators as a new tool for efficient information-sharing in manufacturing systems. The generated Inf-Act On Net with informators is based on situation theory and will be a powerful structure for sharing timely and relevant information in a complex manufacturing systems that can be used continuously and efficiently throughout systems operation. Inf-Act On Net makes it possible to understand overall structure of the relationship of information. Informators have been introduced as an auxiliary tool aid in the specific structure of information with surrounding conditions in systems.

However, for more rigorous Inf-Act On Net, it will be necessary to develop operation rules for informators like the notion of addition, subtraction, multiplication, and division in number systems. Also, it is desirable to study about convenient NAs-VEs tables as an information dictionary according to given systems. Thus, as an ongoing research, this paper proposes semantic computation of infomators and simple form of NAs-VEs table for advanced ontology modeling in situation theory as future research.

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