*Journal of the Korean Institute of Industrial Engineers*
*Vol.24, N0.1, March, 1998*



# Construction of IAST Model for Agile Process Design with Holistic Concept

## 전체론적 접근으로서 기민한 프로세스 디자인을 위한 IAST 모델의 건설

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**Abstract**

In a competitive environment, systems design should be agile to accomplish business goal. However, there are often significant problems with systems design that is manifested in the fact that there are no current techniques to apply rigorous mathematics to semantic conveyance in the design framework. As a promising solution, this paper introduces situation theory (ST) and provides an application of ST for information flow in manufacturing systems design (IDEF0). The described work in this paper addresses the procedure of creation of IAST Model (Inf-Act On in Situation Theory) which is the first application of ST in engineering fields. Finally, we show that IAST Model is very helpful for effective information capturing in systems by comparison existing methodology with developed methodology as a practical application of ST.

## 1. Introduction

The aim of situation theory is to develop a unified mathematical theory of meaning and information content with an interdisciplinary effort from cognitive science, computer science and artificial intelligence, engineering, linguistics, logic, philosophy, and mathematics. In short, situation theory 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. Agility is defined as the ability to thrive in a competitive environment of continuous and unanticipated changes to respond quickly to rapidly changing markets driven by customer based valuing of products and services [10]. In a competitive environment, systems design should be agile to accomplish business goals. However, there are often significant problems with engineering design that is manifested in the fact that there are no current techniques to apply rigorous mathematics to semantic conveyance in the engineering design framework. A promising solution is situation theory, a new mathematical technique which we are proposing to apply in a new way as part of a holistic approach to systems design. There are three major concepts of situation theory such as infons, situations and

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constraints.

Infons are the basic informational units, discrete items of information, semantic objects not syntactic representations, denoted as ⟨⟨ P, $a_1$, $a_2$, ... $a_n$, i ⟩⟩ where P is an n-place relation, $a_1$, $a_2$, ... $a_n$ 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. Abstract situations are the mathematical constructs that are amenable to mathematical manipulation. For given a real situation s, the set { $\alpha$| s | = $\alpha$} is the corresponding abstract situation. Here, s supports $\alpha$ (denoted as s| = $\alpha$) means that $\alpha$ is an infon that is true of s. In situation theory, the flow of information is realized via constraints. A constraint is represented as ⟨⟨ involves, $S_0$, $S_1$, 1 ⟩⟩ where $S_0$, $S_1$ are situation types between which the information is carried out. In addition to the above major concepts, it is necessary to consider the concepts of temporal, spatial locations and anchoring for the construction of IAST (Inf-Act On in Situation Theory) Model. Spatial locations are denoted by $l$, $l$, $l''$, $l_0$, $l_1$, $l_2$, etc. They are not necessarily like the 'points' of mathematical spaces, though they may be either a point in space or a region of space. This endows the collection of all locations with a fairly complex structure: one location may be a point within another, two (regional) locations may overlap in space, and so on. Temporal locations are 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 regions of time. $t$ can be some interval of time. Because the relation of one temporal location preceding another (in time) is such a common one, $t \langle t'$ indicates that $t$ temporally precedes $t'$. (Each of $t$, $t'$ may be either a point or a region here.) Likewise the notation $t° t'$ indicates overlap, and $l° l'$ indicates overlap of the spatial regions $l$, $l'$. Related to parametric infons, there is a construct by which parameters can be assigned "values". For technical reasons connected with the mathematics of situation theory, there is a need to have available a formal means of assigning "values" to parameters. Formally, an anchor for a set, A, of basic parameters is a function defined on A, which assign to each parameter $\dot{T}_i$ in A an object of type T. If f anchors $\dot{a}$ to the individual "Young" we write f( $\dot{a}$) = Young to denote this anchoring. Thus, if f is an anchor for A and $T_n$ is an parameter in A, then the infon ⟨⟨ of-type, f($T_n$), T, 1 ⟩⟩ is a fact. Suppose $\dot{l}$ is to be a parameter for a location. Then $\dot{l}$ should be a restricted form of parameter such that whatever f anchors $\dot{l}$ to an object a in a situation s, then $l$ (in a) is a location. A parameter such as $\dot{l}$ will be obtaining by tagging a parameter $IND_i$ by the "condition" C of being a person, writing $\dot{l}$ = $IND_i \uparrow$ C.

In the following two sections (2, 3), we introduce IDEF0 Model and new created framework (acton, NAs & VEs table and Inf-Act On Net) for the construction of IAST Model. In the section 4, the method that is used for capturing information flow in systems by IAST Model is provided.

## 2. IDEF0 Model

In order to construct an agile process design as an application of situation theory, we adopt IDEF0 Model in this section. During the 1970s, the U.S. Air Force Program for Integrated Computer Aided Manufacturing (ICAM) sought to increase manufacturing productivity through systematic application of computer technology. The ICAM program identified the need for better analysis and communication techniques for people involved in improving manufacturing productivity. As a result, the ICAM program developed a series of techniques as the IDEF (IDEF Definition) techniques which included in IDEF0, IDEF1, and IDEF2, and so on. Among them, IDEF0 (Integration DEFinition language 0) is based on SADT (Structured Analysis and Design Technique), developed by Douglas T.Ross and SofTech, Inc. and is used to produce a "functional model". A functional model is a structured representation of the functions, activities or processes within the modeled system or subject area. Currently, IDEF0 techniques are widely used in the government, industrial and commercial sectors, supporting modeling efforts for a wide range of enterprises and application domains. For new systems, IDEF0 can be used first to define the requirements and specify the functions, and then to design an implementation that meets the requirements and performs the functions. For existing systems, IDEF0 can be used to analyze the functions the system performs and to record the mechanisms by which these are done. Researchers at the University of Texas at Arlington have developed an Enterprise Engineering approach represented in IDEF0, see figure 1. The A0 level discusses the importance of developing a vision and set of supporting strategies, changing culture, integrating and improving technology solutions [Liles, 1991; Presley, 1993].

## 3. New Framework

As shown in figure 1 (PCEI Model), there are four boxes to represent "perform continuous enterprise improvement." For the use of situation theory, let's divide those boxes into four categories (I, II, III, IV): Category I: Develop Vision and Strategy, Category II: Change Culture, Category III: Integrate and Improve Enterprise, Category IV: Develop Technology Solution. Each category

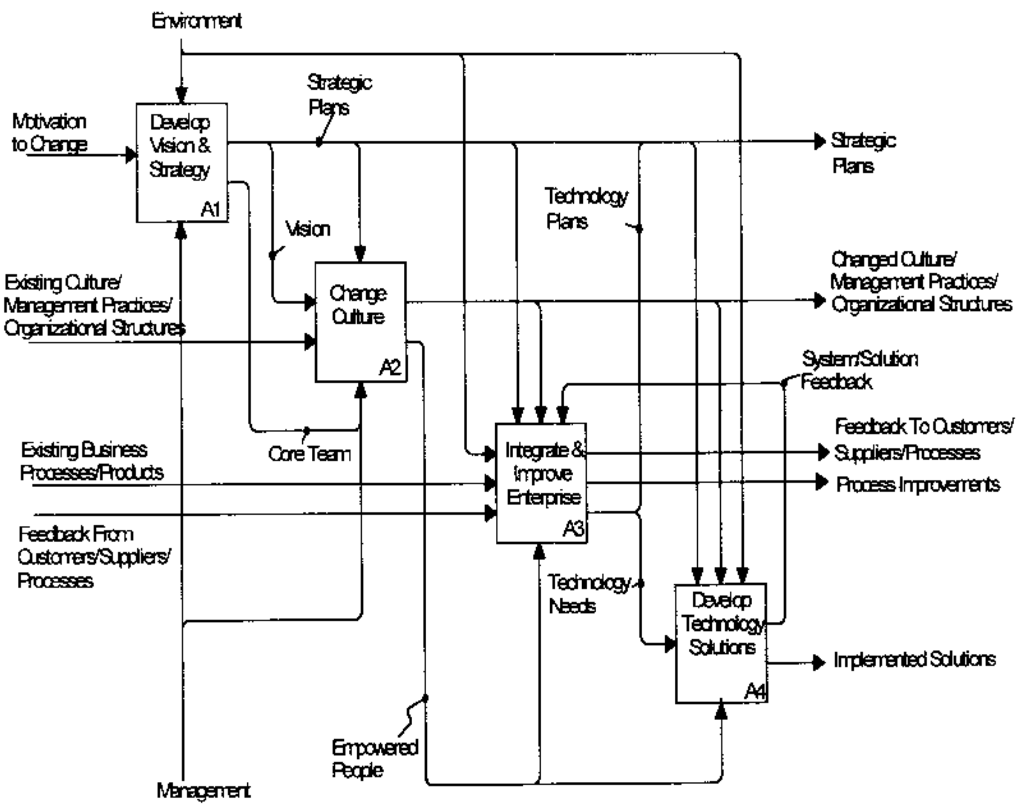


Figure 1. Perform continuous enterprise improvement methodology.

has its own objects as elements to fulfill the processes. The main objective of this paper is to construct IAST Model as an application of situation theory. For the above objective, a new concept and auxiliary tools are proposed in this paper (acton, VEs and NAs tables, Inf-Act On Net). Before approaching to model representation by situation theory, let's look at acton's concept.

### 3. 1 Acton

Typical differences between infon and acton are as follows:

- Infons are formal statements of facts which a situation supports or not
- Actons are a formal statement of actions which the situation supports or not.

In short, infon is about "true" or "false" and acton vs. action is about "succeed" or "fail".

As a notation of acton,

⟨⟨ (action) vs. (action), (preconditions, an infon), (postconditions, another infon), (polarity) ⟩⟩

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 strengthen the area of knowledge representation and its tools.

### 3.2 NAs and VEs table

Consider NAs and VEs table which will play a role as the information library for systems design. As shown in tables (1 and 2), NAs table contains nouns and VEs table contains verbs including prepositions which are related to the concept of infon and acton. These tables are very helpful to represent systems in the PCEI Model (figure 1) and make the notation of situation theory simple (compared to using the original words in situation theory).

Table 1. VEs: Verbs (including preposition) for PCEI Model

| | |
|---|---|
| As | Analyze ($VE_{10}$), Assess ($VE_{11}$) |
| Bs | Bound ($VE_{20}$), Build ($VE_{21}$) |
| Cs | Cause ($VE_{30}$), Change ($VE_{31}$), Classify ($VE_{32}$), Commit ($VE_{33}$), Conduct($VE_{34}$), Construct ($VE_{35}$) |
| Ds | Determine ($VE_{40}$), Design ($VE_{41}$), Develop ($VE_{42}$), Document ($VE_{43}$) |
| Es | Empower ($VE_{50}$), Evaluate ($VE_{51}$), Exist ($VE_{52}$) |
| Fs | Facilitate ($VE_{60}$), Formulate ($VE_{61}$) |
| Gs | Generate ($VE_{70}$) |
| Is | Identify ($VE_{80}$), Implement ($VE_{81}$), Improve ($VE_{82}$), Integrate ($VE_{83}$) |
| Ms | Model ($VE_{90}$) |
| Os | Organize for ($VE_{100}$) |
| Ps | Perform ($VE_{200}$), Plan ($VE_{210}$) |
| Rs | Review ($VE_{300}$), Refer-to ($VE_{310}$) |
| Ss | Sell ($VE_{400}$), Set ($VE_{410}$), Share ($VE_{420}$), Simplify ($VE_{430}$), Stabilize ($VE_{440}$) |
| Ts | Test ($VE_{500}$), Translate ($VE_{510}$) |
| Us | Understand ($VE_{600}$) |
| Vs | Validate ($VE_{700}$) |

Table 2. NAs: Nouns for PCEI Model

| | |
|---|---|
| As | Acceptance($NA_{10}$), Area of Input($NA_{11}$) |
| Bs | Business Plan ($NA_{20}$), Business Strategy ($NA_{21}$) |
| Cs | Changed Culture ($NA_{30}$), Competitors ($NA_{31}$), Conceptual Design ($NA_{32}$), Continuous Enterprise Improvement ($NA_{33}$), Core Team ($NA_{34}$), Culture ($NA_{35}$), Customer ($NA_{36}$) |
| Ds | Detailed Design ($NA_{40}$) |
| Es | Effective Control ($NA_{50}$), Empowered people ($NA_{51}$), Enterprise ($NA_{52}$), EntEng ($NA_{53}$), EntEng Strategy ($NA_{54}$), Environment ($NA_{55}$), Existing Business Processes ($NA_{56}$), Existing Culture ($NA_{57}$) |
| Fs | Feedback Mechanism (customers,, suppliers, processes) ($NA_{60}$), Feedback Paths ($NA_{61}$) |
| Gs | Goals for Future Levels of Service ($NA_{70}$) |
| Is | Implemented System ($NA_{80}$), Implemented Solutions ($NA_{81}$), Improved Communication ($NA_{82}$), Improvement ($NA_{83}$) |
| Ms | Management ($NA_{90}$), Management Practices ($NA_{91}$), Module into Operational Elements ($NA_{92}$), Modules ($NA_{93}$), Motivation to change ($NA_{94}$) |
| Os | Needs ($NA_{100}$) |
| Ps | Organizational Structures ($NA_{110}$) |
| Rs | Performance ($NA_{200}$), People ($NA_{210}$), Procedures and Documentation ($NA_{220}$), Process ($NA_{230}$), Process Improvement ($NA_{240}$), Product ($NA_{250}$), Product Characteristic into Process Specification ($NA_{260}$), Product Provided into Customers ($NA_{270}$), Project ($NA_{280}$), Prototype ($NA_{290}$) |
| Ss | Relationship ($NA_{300}$), Required Feedback Mechanisms ($NA_{310}$) |
| Ts | Satisfaction ($NA_{400}$), Strategy ($NA_{410}$), System Conversion ($NA_{420}$), System Requirements ($NA_{430}$), System/Solution ($NA_{440}$), System/Solution Feedback ($NA_{450}$), System/Solution Modules ($NA_{460}$) |
| Us | Technology Need ($NA_{500}$), Technology Plan ($NA_{510}$), Technology Solution ($NA_{520}$), Training ($NA_{530}$), Training Program ($NA_{540}$), Trust ($NA_{550}$) |
| Vs | Vision ($NA_{600}$), Vision and Strategy ($NA_{610}$) |

### 3.3 Inf-Act On Net

Table 3. Inf-Act On Net for figure 1

| Acton / Infon | $VE_{31}$ | $VE_{42}$ | $VE_{82}$ $VE_{83}$ |
|---|---|---|---|
| $NA_{34}$ | ($IP_i$, $OP_i$, $t_2$)<br>$Ob_{CAII}$ | | |
| $NA_{52}$ | | | ($IP_j$, $OP_j$, $t_3$)<br>$Ob_{CAIII}$ |
| $NA_{520}$ | | ($IP_k$, $OP_k$, $t_4$)<br>$Ob_{CAIV}$ | |
| $NA_{610}$ | | ($IP_l$, $OP_l$, $t_1$)<br>$Ob_{CAI}$ | |

Where

t (I = 1, 2, 3, 4) is temporal location and $t_1 \langle t_2 \langle t_3 \langle t_4$,

$Ob_{CAi} \in CA_i$ (i=I, II, III, IV),

$Ob_{CAI}$ = {($VE_{42}$) R($NA_{600}$), ($VE_{42}$) R($NA_{54}$), ($VE_{42}$) R($NA_{21}$), ($VE_{100}$) R($NA_{83}$)}

$Ob_{CAII}$ = {($VE_{51}$) R($NA_{55}$), ($VE_{11}$) R($NA_{55}$), ($VE_{31} \wedge VE_{60}$) R($NA_{81}$), ($VE_{400} \wedge VE_{420}$) R($NA_{60}$), ($VE_{22}$) R($NA_{550}$), ($VE_{50}$) R($NA_{210}$)}

$Ob_{CAIII}$ = {($VE_{600}$) R($NA_{55}$), ($VE_{600}$) R($NA_{240}$), ($VE_{600} \wedge VE_{82}$) R($NA_{230}$), ($VE_{41} \wedge VE_{81}$) R($NA_{230}$)}

$Ob_{CAIV}$ = {($VE_{600}$) R($NA_{100}$), ($VE_{41}$) R($NA_{440}$), ($VE_{35}$) R($NA_{450}$), ($VE_{81}$) R($NA_{440}$)}

This Inf-Act On Net shows us information flow in the overall system's structure on PCEI Model (figure 1). Note that in the form of Ob, VEs are used with " ∧ " but NAs are not. This means that VEs are freely used with logical connectives as actons to prevent confusion from infons. The R means a relationship between infons and actons.

## 4. IAST Model

IAST (Inf-Act ON in Situation Theory) Model is based on situation theory (in particular, infons and actons) and is constructed by typical steps. The IAST Model is to aid holistic views by mathematical tools in systems design. For the general representation of systems design by IAST Model, this paper also proposes a guideline to generate situation theory's representation for systems.

Step 1] Decide categories $A_i$ ($i$ = 1,2,3,...,N) in systems for the purpose of system analysis (or, system's characteristics).

Step 2] Specify the whole system's components for the use of NAs-VEs tables and make the NAs-VEs tables.

Step 3] Make the Inf-Act On Net of overall categories.

Step 4] Formalize information flow (by situation theory's notation) in the order of temporal locations.

Step 5] Make relationship (Inf-Act On Net with polarities) between infons and actons in order to see objective's structure in systems.

In this section, the main issue is to create the IAST Model with new concepts such as acton, VEs, NAs tables, and Inf-Act On Net. This guideline can be used to create IAST Model for given systems as basic rules.

### 4.1 Justification of IAST Model compared to original method

The IAST (Inf-Acton in situation theory) Model is created by a new approach compared to original approach in situation theory (ST). So, in this section, let's compare representative methods between IAST Model's approach and original approach in situation theory by an example. Consider the following system as shown in figure 2. This system has two inputs, two outputs and one objective.

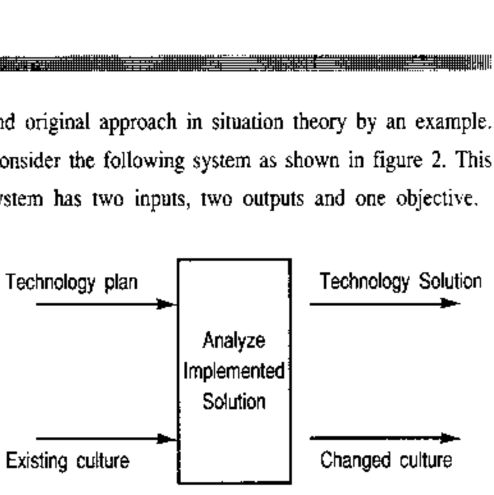


Figure 2. A simple system

Method 1: Original Method: In this method, the system can be represented by infon as a main framework. Because this method does not have NAs and VEs Tables, a given system has to be represented by own words.

First the situation of system with input =

S = { ⟨⟨ Analyze, Implemented Solution, Technology Plan, Existing Culture, $l_I$, $t_I$, 1⟩⟩ }

Second the situation of system with output =

$S_2$ = { ⟨⟨ Analyze, Implemented Solution, Technology Solution, Changed Culture, $l_2$, $t_2$, 1⟩⟩ }

Now, the overall situation to be realized in the system

= $S_3 = S_1 \cup S_2$

= { ⟨⟨ Analyze, Implemented Solution, Technology Plan, Existing Culture, $l_I$, $t_I$, 1⟩⟩ } ∪ { ⟨⟨ Analyze, Implemented Solution, Technology Solution, Changed Culture, $l_I$, $t_I$, 1⟩⟩ }

Where $l_I$, $t_I$ are some location and some time which the system with inputs is performed, respectively. $l_I$, $t_2$ are some location and some time which the system with outputs is performed, respectively.

Method 2: IAST Model Method: In this method, we have infon, acton, and VEs-NAs tables as a main framework. So given system can be represented by more conveyable and simple forms (not literal languages but symbolic forms). This type of model:

$$S = [SIT|\dot{s}| = \langle\langle VE_{10}, (\dot{I}P, \langle\langle VE_{310}, NA_{81}, \dot{l}, \dot{t}, 1\rangle\rangle), (\dot{O}P, \langle\langle VE, NA_{310}, NA_{81}, \dot{l}, \dot{t}, 1\rangle\rangle), 1\rangle\rangle]$$

Where

$\dot{I}P$: type of inputs = $\{NA_{57}, NA_{510}\}$

$\dot{O}P$: type of outputs = $\{NA_{30}, NA_{520}\}$

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

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

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

As shown in the above two methods, method 2 (IAST Model) is more convenient to capture the information flow in the system and easier to understand the overall system's structure. The above example is a very simple case. If given systems contain many categories, inputs and outputs, it is very tedious and long job to represent systems by the original ST method 1. However, if we use method 2 (IAST Model) with new concepts (acton, NAs-VEs tables, and Inf-Act On Net), it will be a powerful and rigorous tool to represent and design systems with efficiency and efficacy. Each system representation will use NAs and VEs tables relevant to that system. Thus, these tables are very helpful to represent systems in the engineering model and make the notation of situation theory simple (compared to using the original words in ST). Inf-Act On Net shows us information flow in the overall system's structure on engineering model.

Now, let's apply IAST Model to represent information flow in figure 3. If we can apply IAST Model for figure 3, it is also possible to construct IAST Model for other IDEF0 Models with same manner. Information flows in figure 3 can be described by:

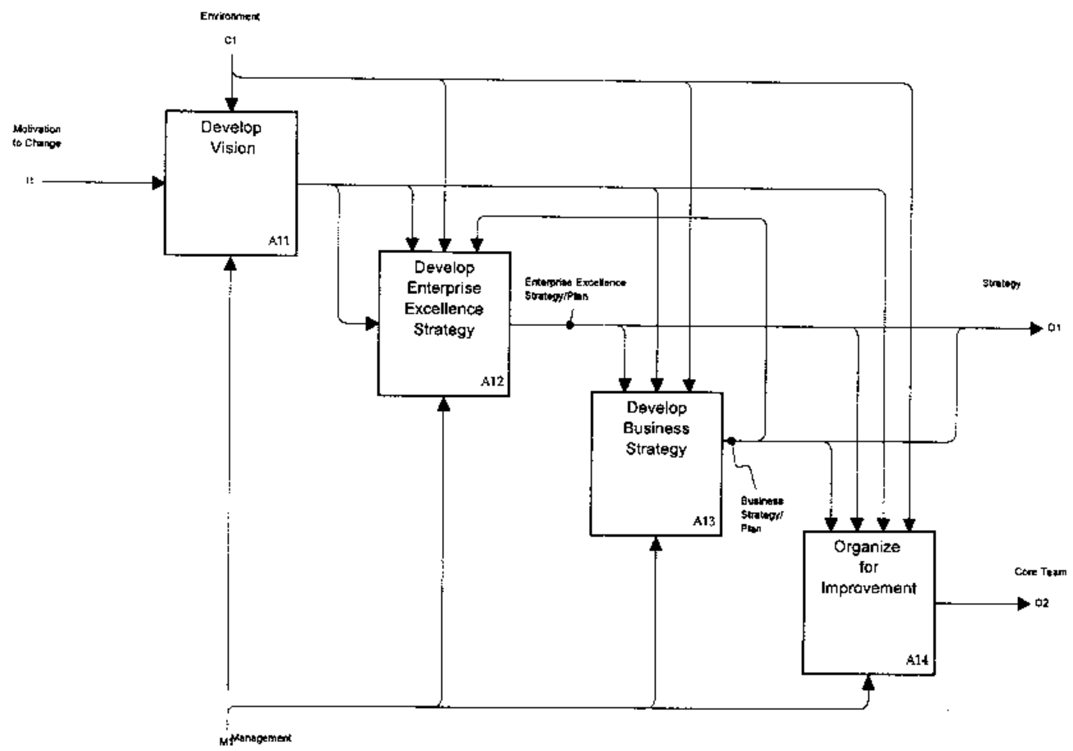


Figure 3. Develop vision and strategy

$S_1 = [SIT_1 | \dot{s}_1| = \langle\langle VE_{42}, (\dot{IP}_1, \langle\langle VE_{310}, NA_{610}, \dot{l}_1, \dot{t}_1, 1 \rangle\rangle),$
$(\dot{OP}_1, \langle\langle VE_{310}, NA_{610}, \dot{l}_1, \dot{t}_1, 1 \rangle\rangle), 1 \rangle\rangle ]$

Where

$\dot{IP}$: type of inputs = $\{NA_{55}, NA_{90}, NA_{94}\}$

$\dot{OP}$: type of output = $\{NA_{20}, NA_{34}, NA_{53}, NA_{410}, NA_{600}\}$

$\dot{s}_1$ type of situation which the category I in the system is performed.

$\dot{l}_1$: some location which the category I in the system is performed.

$\dot{t}_1$: some time which the category I in the system is performed.

Now, denote all situations that cause "vision and strategy" to develop. Taking parameter

$\dot{r}_1 = SIT_1 \uparrow \langle\langle VE_{30}, SIT_1, SIT_{10} \uparrow \tau, 1 \rangle\rangle$

where $\tau = \langle\langle \models, SIT_{10}, \sigma, 1 \rangle\rangle$

$\sigma = \langle\langle VE_{42}, IND_1 \uparrow \nu, LOC_1, TIM_1, 1 \rangle\rangle$

$\nu = \langle\langle \exists NA_{610}, IND_1, 1 \rangle\rangle$

Following through the recursive definition that leads to this, let's start with the parameter

$\dot{b}_1 = IND_1 \uparrow \langle\langle \exists NA_{610}, IND_1, 1 \rangle\rangle$

Then, forming the parameter

$\dot{s}_1 = SIT_{10} \uparrow \langle\langle \models, SIT_{10}, \sigma, 1 \rangle\rangle$

Where

$\sigma = \langle\langle VE_{42}, \dot{b}_1, LOC_1, TIM_1, 1 \rangle\rangle$

Finally,

$\dot{r}_1 = SIT_1 \uparrow \langle\langle VE_{30}, SIT_1, \dot{s}_1, 1 \rangle\rangle$.

Suppose that f anchors $\dot{r}_1$ in some situation $s_1$. Then f must anchor both $SIT_1$ and $\dot{s}_1$, $f(\dot{r}_1) = f(SIT_1)$ and $s_1 \models \langle\langle VE_{30}, f(SIT_1), f(\dot{s}_1), 1 \rangle\rangle$.

In order for f anchor $\dot{s}_1$, f must anchor $SIT_{10}$, $\dot{b}_1$, $LOC_1$, $TIM_1$ and $f(\dot{s}_1) = f(SIT_{10})$ and

$s_1 \models \langle\langle \models, f(SIT_{10}), \langle\langle VE_{42}, f(\dot{b}_1), f(LOC_1), f(TIM_1), 1 \rangle\rangle, 1 \rangle\rangle$.

Moreover, f has to anchor $\dot{b}_1$ with $f(\dot{b}_1) = f(IND_1)$ and

$s_1 \models \langle\langle \exists NA_{610}, f(IND_1), 1 \rangle\rangle$.

Thus, if $f(IND_1) = b_1$, then $b_1$ is $NA_{610}$, and if $f(SIT_{10}) = s_1$, $f(LOC_1) = l_1$, and $f(TIM_1) = t_1$ then, $s_1 \models \langle\langle \models, s_1, \langle\langle VE_{42}, b_1, l_1, t_1, 1 \rangle\rangle, 1 \rangle\rangle$.

If $f(SIT_1) = e_1$, then $\dot{s}_1 = \langle\langle VE_{42}, e_1, s_1, 1 \rangle\rangle$.

But $f(\dot{r}_1) = e_1$. Since, in $s_1$, $e_1$ causes "develop vision and strategy" to perform the given system, this means that $\dot{r}_1$ is anchored as intended, to a situation "develop vision and strategy" with $Ob_{CAI}$ in the system.

Where

$Ob_{CAI} = \{(VE_{42})\, R(NA_{600}), (VE_{42})\, R(NA_{54}), (VE_{42})\, R(NA_{21}), (VE_{100})\, R(NA_{83})\}$

In this form, R means a relationship between infons and actons.

**Table 4. Inf-Act On Net for figure 3 with Polarity**

| | $VE_{31}$ | $VE_{42}$ | $VE_{82}$ | $VE_{83}$ | $VE_{100}$ |
|---|---|---|---|---|---|
| $NA_{21}$ | 0 | 1 | 0 | 0 | 0 |
| $NA_{54}$ | 0 | 1 | 0 | 0 | 0 |
| $NA_{83}$ | 0 | 1 | 0 | 0 | 1 |
| $NA_{520}$ | 0 | 0 | 0 | 0 | 0 |
| $NA_{600}$ | 0 | 1 | 0 | 0 | 0 |
| $NA_{610}$ | 0 | 1 | 0 | 0 | 0 |

Table 4 shows us information flow in the system's structure on figure 3. In this table, 0 means no relationships and 1 means relationships between infon and acton.

## 5. Conclusion

Situation theory as part of a holistic approach has been developed and studied over the last decade. Thus far, many efforts of the theory have been focused only on linguistic and social issues. This paper provides new framework and an application of situation theory for engineering field. As we have seen the situation theoretic representation on IDEF0, the IAST Model can be useful for systems modeling, systems analysis, and holistic design as an agile process design.

However, we still need more rigorous theory's concept to be developed to capture more informational units. Thus, this ongoing research and development activity will focus on enhancements to semantic and computational aspects.

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97년 10월 최초 접수, 98년 2월 최종 수정