Integrated Systems Thinking

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ABSTRACT

The purpose of the present article is three-fold: The first is to propose a structure map of systems movement to grasp an overview of current research areas/streams of systems research as a whole. The second is, based on it, to propose "First formal, then verbal" principle of systems thinking and to claim that integrative approach to plural streams is possible and useful to cultivate a new perspective in systems science. The third is to demonstrate meaning of the claim by showing as an example of such research, namely, integrated systems modeling of negotiation.

Keywords: integration, systems modeling, dramatic model

1. INTRODUCTION

A systems account of the world and a systems approach to its problems are called "the systems movement" [1]. It is the set of attempts in all areas of study to explore the consequences of holistic rather than reductionist thinking. The program of the systems movement might be described as the testing of the conjecture that these ideas will enable us to tackle the problem that the method of traditional science finds so difficult [1].

To understand what the systems movement has been and where it goes, it is useful to construct a map on which the activity of the movement is located. Checkland provided an excellent map for such purpose, though it was created in early 1980s [1].

We will now version it up for current use (Figure 1). To construct such a map we have to make a number of distinctions. First, we make a distinction between the systems idea as such and application of systems idea within an existing discipline (like systems revolution in geography).

Our interest here is in the former. Within the work on systems thinking as such, we distinguish between theoretical development of systems ideas and their relationships (denoted by TH in the figure), and work based on the notion of developing the idea by seeking to engineer systems and solve systems problems in the real world (denoted by PS in the figure).

General Systems Theory (GST), of which focus is on meta-systems modeling, is an example of the former. On the other hand, in the latter we may roughly distinguish between hard and soft systems thinking [1]. Hard systems thinking emphasizes systematic approach and constitutes a basis of Operations Research, Systems Engineering and Systems Analysis. We may say that it provides a powerful and helpful way to seek *efficient* solutions for a well-structured problem.

Soft systems thinking is concerned with problem structuring and tries to serve as a guideline for understanding and/or improving real problems. While hard systems thinking aims at clarifying *how* to solve a well-structured problem, soft systems thinking is interested in exploring *what* the problem is.

Recently, scenario simulation has attracted much attention as a third wave in PS. Scenario simulation methods not only can model with quite a large number of autonomous decision makers (or agents), but also may become a useful tool for accommodating conflicting stakeholders if we use it as discussion platform for diversified their opinions or worldviews. In particular, agent-based simulation is interested in understanding emergent properties from interactive behavior among agents in a social system [2].

In the following we will argue possibility of bridging and combining the streams distinguished in the map from an integrated viewpoint to open a new perspective in the systems movement.

2. INTEGRATION AT GST LEVEL

Let us begin with the theoretical development of systems thinking (TH). The original aim of Bertalanffy was to develop *general theory of systems* (TH1) under the name of general systems theory (GST). General theory of systems is concerned with abstracting general rules and principles applicable to every system. Indeed, the founding statement of the ISGSR clearly claims the aims as follows:

1. To investigate the isomorphy of concepts, laws, and models in various fields, and to help in useful transfers from one field to another.
2. To encourage the development areas which lack them.
3. To eliminate the duplication of theoretical efforts in different fields

Study of systems as such
- PH: Philosophical development of systems thinking (Systems philosophy)
- TH: Theoretical development of systems thinking (GST= General systems theory)
  - TH1: General theory of systems
  - TH2: Theory of general systems
    - TH21: Input-output systems modeling
    - TH22: Goal seeking systems modeling
- PS: Problem solving application of systems thinking to real world (SA= Systems approach)
  - PS1: Hard systems thinking
  - PS2: Soft systems thinking
  - PS3: Scenario simulation

Applications of systems thinking in other disciplines

Figure 1 Map of Systems Movement

4. To promote the unity of science through improving the communication between specialists

We may notice that the statement does not refer to *system* at all, but he did believe systems epistemology is the driving force for the ISGSR movement.
Since systems science at the TH1 level is meta science in the sense that it has no direct application areas in the real world but is expected to contribute to existing disciplines like economics or control engineering (Figure 2): While each discipline develops its own models or framework, for instance, economics develops economic models, TH1 tries to construct meta-models to deal with models uniformly. Actually, for example, Miller tried to develop "periodic table of models" [3].
However, we cannot deny efforts to realize the aims directly have not produced such "deep" insights that gave great impacts on other disciplines. A well-known criticism against TH1 is that it only provides "general nonsense". One of few exceptional contributions may be R. Ashby's law of requisite variety. The law gives impacts on organization theory (more precisely, the contingent theory), sociology and control theory.

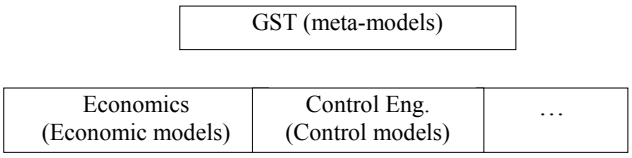

Figure 2 Models and Meta-models

To overcome such criticism, *theory of general systems* TH2 or *mathematical general systems theory* was advocated in 1970s [4]. It tries to develop a formal theory on "general systems" or "meta systems" in mathematical terms. By doing so, it aims at finding non-trivial propositions and insightful observations about systems behavior.
In TH2 we find two types of meta-models, i.e., *input-output systems model* and *goal seeking systems model*.

Figure 3 Input-output Systems Model

The former expresses systems behavior as a black box, concentrating on how an input is transformed to an output (Figure 3).
On the other hand, the latter is a white model describing decision making in a broad sense. It consists of two input-output systems, representing decision making and a transformation process, respectively (Figure 4).
The most essential with this model is that it explicitly expresses the goal. If a system is supposed to autonomously generate a goal intrinsically, then we call it purposeful [1]. The goal seeking systems model even refers to "purposefulness" of decision making behavior, because Figure 4 includes self-organization and adaptation function.
If a system is assumed to peruse only a given purpose or goal, then we call it purposive. In Figure 4, by focusing on the selection level and the transformation process and by assuming a goal is given to the selection level from the upper level, we can explicitly argue "purposiveness" of decision making behavior with this model (Figure 5).
Furthermore, the model explicitly expresses important systemic properties like hierarchy, communication and control.

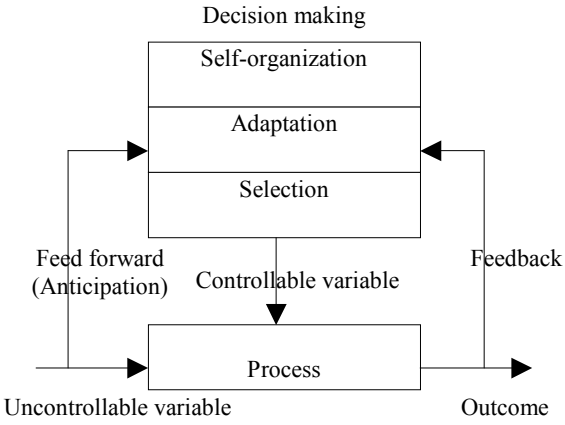

Figure 4 Goal Seeking Systems Model

Now let us show that these two models, which seem very different at a glance, indeed describe two sides of the same coin:

Input-output systems model is mathematically expressed as a relation S between sets X and Y of input objects and output objects, respectively. In other words, S is a subset of the girect product of X and Y. It is well known that for every input-output systems model S we can define a state space, a state transition function and an input-output function such that the behavior of S can be represented by them. This fact is essential for proving the following Proposition 1.

On the othe hand, to formulate goal seeking systems model at the selection level formally (Refer to Figure 5), we first need to define a decision problem D by

$$D = (M, U, Y, P, G, V).$$

M, U and Y denote sets of alternatives (controllable variances), uncontrollable variances and outcomes, respectively. P is a process function from M x U into Y, while a function G from M x U x Y into V is called an objective function, where V denotes a value space and is usually the set of real numbers.

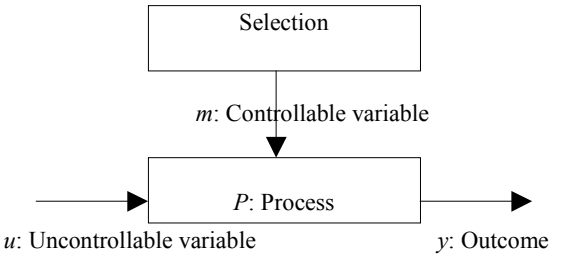

Figure 5 Goal Seeking Systems Model at Selection Level

To simplify the model description we often introduce a performance function g by

$$g(m, u) = G(m, u, P(m, u)).$$

Then, we can represent D simply by

$$D = (M, U, g).$$

We, next, define a decision criterion c as a function that generates a preference ordering on the set of alternatives M when a decision problem $D = (M, U, g)$ is given. A decision criterion is usually assumed provided by the adaptation level or self-organization level in the model. Then, a goal seeking system at the selection level S can be represented by a pair of a decision problem and a decision criterion, *i.e.,*

$$S = ((M, U, g), c)$$

Now we have the following proposition.

Proposition 1

Every goal seeking systems model can be described as input-output systems model, and, conversely, every input-output systems model can be expressed as goal seeking systems model.

The proposition guarantees that when we look at an object as a system we may employ either of the two models depending on your research objective, because they are equivalent.

3. INTEGRATION AT SA LEVEL

Dichotomy of hard and soft in systems approach (SA) has led hot argument in problem solving application of systems thinking to real world.

Hard systems thinking approaches to real-world problems in such a way that an objective or end-to-be-achieved can be taken as given. Then, to meet or achieve the objective, a system is engineered. The distinguishing characteristic of all hard systems thinking is the belief that all real-world problems can be formulated in the following way: there is a desired state, *S1*, and a present state, S0, and there are alternative ways of getting from *S0* to *S1*. Problem solving according to this view consists of defining *S1* and *S0* and selecting the best (*i.e.,* the most efficient) means or ways of reducing the difference between them.

Difference *S1- S0* defines the need, or the objective to be attained, and hard systems thinking provides an ordered way of selecting the best among the alternatives that could fulfill that need or objective. Problems of this kind are called hard problems or well-structured problems.

However, in real problematic situations, especially those at the strategic level, problem structuring (*i.e.,* finding out and identifying available set of alternatives, constraints on the problem) is much more crucial than problem solving (*i.e.,* deriving effective solutions under a given constraints).
Furthermore, it is quite rare for hard systems thinking to take into consideration social scientific aspects of the situation. For example, arguments on how effective bluff or threat affects negotiation process between conflicting stakeholders is out of the scope of it.
To overcome such criticism soft systems thinking was advocated in 1970s. Some methodologies adopting the thinking aim to structure messy problematic situations, while others try to encourage various stakeholders to participate in problem structuring process and to support them to accommodate.
The SOSM matrix Jackson proposed [5][6] provides a map where we can clearly position soft systems thinking, in relation with hard systems thinking (Figure 6).

	unitary	plural	coercive
simple	-Hard Systems Thinking	-Soft Systems Thinking	-Emancipatory Systems Thinking
complex	-Systems Dynamics -Organizational Cybernetics -Complexity Theory		-Post-modern Systems Thinking

Figure 6 System of Systems Methodologies (SOSM)

Now, in order to complement the both streams each other and integrate them, we would like to propose the following research principle to understand messy in systems framework. It is not the same as the "first soft (problem structuring) and then hard (problem solving)" principle [7].

(1) First, describe the problematic situation as *formally* as possible.
(2) Then, apply *verbal* approach to areas beyond the scope where such formal treatments do work.

We may call it "First formal, then verbal" principle.
The formal approach implies mathematical modeling, while the verbal approach includes soft systems thinking. It is true that there is strict limitation on capability of formal modeling approach for understanding or explaining messy reality, but it is ridiculous to abandon it without considering its possibilities at all, because it is certainly more powerful to dig out "deep", "insightful" and "non-intuitive" findings than verbal approach.
In this context, we would like to propose two integrative ways to enrich the formal approach given in (1).
One way is to include in formal modeling "soft aspects" of decision makers like irrationality, subjectivity, emotion, belief, doubt, misunderstanding and misperception. In the next section we will give an example on this line.
Another idea for enriching (1) is scenario simulation, if mathematical modeling is too difficult. By clearly declaring the assumptions on which algorithm of the simulation process is based, it should work as a good device for describing a variety of scenarios and accommodating conflicting stakeholders. We are now eager to developing such an approach under the name of agent-based soft systems thinking [2]. It is constructed by combining scenario simulation and soft systems thinking like the Soft Systems Methodology (SSM). In this approach to attain accommodation the stakeholders discuss referring to various scenarios generated by simulation. The scenarios should help them to understand what would happen if they would take such and such an alternative.

4. INTEGRATED SYSTEMS MODELING: DRAMATIC MODEL OF NEGOTIATION

The present author has tried to develop integrated models that incorporate "soft aspects" such as credibility or doubt of decision makers in a formal way [8][9].
This section illustrates one of such models, namely, dramatic model of negotiation. The model characterizes negotiation as reciprocal proposals of positions and threats. It claims that inconsistency between the positions proposed by the negotiators leads to the climax stage, where the negotiators face dilemmas and have to reconstruct the interactions in order to resolve dilemmas.

4.1. Negotiation as Drama

Negotiations are found everywhere, in business, government, politics and personal relations. In negotiation, facing with cooperation and potential conflict at the same time, we may decide what we want and guess what others will want. Conflict implies the possibility of cooperation and vice versa. Then do the best for ourselves, given what we think they will do.
In the process, however, we are inevitably guaranteed to face "dilemmas". In "prisoner's dilemma", for example, two irrational players do better than two rational ones. The dilemmas are much more than theoretical models.

Pollution problems are many-person prisoners' dilemmas: each individual benefits from polluting, but if all pollute, all are worse off.

Dramatic model of negotiation tries to formulate such negotiation process as a drama [8], focusing on its pre-play stage like lobbying, persuasion and behind-the-scenes work before the final decision is achieved.

The dramatic model of negotiation tries to analyze the dilemmas of rationality and how they affect people. It recognizes that in face of these dilemmas people feel and express emotion, positive or negative, depending on the dilemma they face. This motivates them to redefine the situation they all face by reexamining their beliefs and values. We will show that negotiation often generates two kinds dilemmas and if they are resolved, everyone agrees what to do and can trust each other to do it.

It is certainly true that the basic framework of the dramatic model comes from game theory, but there are essential differences: First, while the game theory is fundamentally interested in the final decision on what strategy should be taken, the dramatic model is concerned with the pre-play stage of how such a decision is agreed.

Moreover, the game theory adopts game metaphor, which treats the participants in negotiation as players behaving rationally to seek their given purpose. On the other hand, the dramatic model recognizes rationality as important but not only the factor for describing negotiation process. It adopts dramatic metaphor, which treats the participants in negotiation as characters who want to realize their positions, by using threats if necessary. In this sense, the game theory has close relationship with economics, while the dramatic model has similar interests as politics.

4.2. Process of Negotiation

The dramatic model of negotiation looks at negotiation process as a process along which the involved negotiators increase their energy through the pre-play stage to reach some consistent agreement (we call it a dramatic solution). It identifies five stages in it, i.e., scene-setting, build-up, climax, resolution and denouement (Figure 7).

In the following we will argue each stage in a little bit detail. To simplify the following arguments, we restrict our concern to negotiation with only two negotiators or characters involved.

(1) Scene-setting

At scene-setting stage each character identifies decision situation he/she faces and describes it as a non-cooperative game in terms of the strategies available and preferences. We assume every character shares the game as common knowledge and call it a frame.

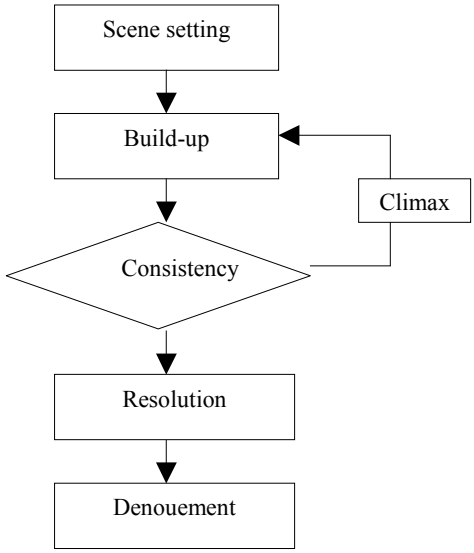

Figure 7 Negotiation Process

(2) Build-up of Interactions

Scene-setting is followed by build-up stage, in which each character proposes his/her positions and threats. We will focus on the stage later by giving precise definitions of positions and threats. This continues till a satisfactory dramatic resolution is attained.

(3) Climax

If there is inconsistency between positions at the build-up phase, or at least one character has distrust with implementation of the counterpart's position, emotional presser may increase to try to change the interaction constructed in the build-up stage. We call it climax. The climax continues until some resolution comes out by reconstructing the interaction to achieve some agreement.

(4) Resolution

At the present stage the pre-play ends up, though the agreement does not necessarily imply a happy end.

(5) Denouement

Resolution stage is followed by denouement stage in which the agreement obtained in pre-play communication is actually implemented. It may lead to the next scene-setting.

Table 1 The Frame shared by the US and Iraq

Iraq US	Acceptance of nuclear inspection	Change of the government	Terrorism attack
Withdraw of economic sanction	4 9	7 7	1 8
Continuation of economic sanction	6 6	9 4	2 5
Military intervention	5 3	8 1	3 2

4.3. Build-up of Interactions and Climax

Among the five stages of the dramatic process the most crucial are those of build-up of interactions and climax. To describe the process clearly, we call the negotiators *i* and *j* and focus on *i*'s behavior, though symmetric arguments are applicable to *j*. *i*'s position consists of requirement on *j*'s behavior and commitment to *i*'s own behavior.

At the stage of build-up the negotiators sharing the problematic situation as a frame (or non-cooperative game) propose a desired future state as their position and threats. However, it is often for *i* to persuade *j* to abandon *j*'s position and to follow *i*'s position, since each in general proposes his/her position independently. Hence, if *i* believes that *j* will not follow *i*'s position, *i* may issue a threat on *j*. Responding to the position and threat of *i, j* then may re-propose his/her new position and threat. In this way, the both negotiators repeat their proposals reciprocally and heat up to reach climax.

Formally, *i*'s position and threat is in general represented as follows: " I will do *A* so that you should X, otherwise I will do *B*". We call *(A, X) i*'s position while *B i*'s threat. Of course, *A* and *B* are strategies available for *i*, while *X* is a strategy available for *j*.

We can define *j*'s position and threat symmetrically, that is, " I (*j*) will do *Y* so that you (*i*) should *C*, otherwise I (*j*) will do *Z*". We call *(C, Y) j*'s position while *Z j*'s threat. *C* is a strategy available for *i*, while *Y* and *Z* are strategies available for *j*. For avoiding unnecessary confusion, we assume that strategy on the left hand side of every position represents one available for *i*, while strategy on the right hand side of the position means a strategy available for *j*. Furthermore, we call the pair of threats by the both negotiators, *(B, Z),* threatened future. Threatened future implies a future state appearing when the both implement their threats simultaneously.

To make the above discussion clearer let us take the Iraq war as an example. In December 2002 it was observed that the US would take military intervention against Iraq. President Bush claimed that there were definite reasons why they were eager to change political administrations in Iraq and pointed out Iraq's military threats against the neighbor countries and doubts about development of mass destruction weapons by Iraq. He also urged that the US should examine all kinds of alternatives towards Iraq.

Assume that Iraq and the US share the frame represented by Table 1 as common knowledge. It shows that the US has three strategies, i.e., withdraw of economic sanction, continuation of economic sanction and military intervention, while Iraq also possesses three strategies, i.e., acceptance of nuclear inspection by the UN, change of the government (resign of Saddam Hussein), and international terrorism attack.

Each cell represents outcome caused by the pair of strategies of the negotiators. In each cell of the matrix the figure on the left hand side shows payoff of the US, while the figure on the right hand side represents that of Iraq. We assume that these figures are ordinal and the bigger the figure is, the more desirable the outcome is.

According to newspapers and publication, we may describe the position of the US by "We will withdraw the economic sanction by the UN so that you (Iraq) should expel Saddam Hussein, otherwise we will intervene in Iraq militarily." In other words, the US's position is (withdraw of economic sanction, change of the government) while the US's threat is military intervention.

On the other hand, we may represent the position of Iraq by "We will accept nuclear inspection by the UN so that you should withdraw the economic sanction, otherwise we will make international terrorism attack." That is, Iraq's position is (withdraw of economic sanction, acceptance of nuclear inspection by the UN) while the Iraq's threat is international terrorism attack. Furthermore, (military intervention, international terrorism attack) is the threatened future.

Nash aquarium is a most well known concept of rationality for non-cooperation game. A pair of strategies is called Nash equilibrium if and only if each negotiator has no incentive to change his/her strategy, as far as the counterpart does not change his/her strategy. In the sense that once Nash equilibrium has been attained, then both negotiators has no incentive to deviate from it, so that Nash equilibrium illustrates an aspect of rational behavior of the negotiators.

It is shown that in the dramatic model with two negotiators, dramatic solution is equivalent to Nash equilibrium [9]. Hence we assume if Nash equilibrium is attained then the negotiation has settled down.
In real negotiation process positions and threats are often proposed independently of Nash aquarium. If the positions are different from Nash equilibrium they may be seen as irrational, but it seems rather essence of negotiation that the negotiators claim their positions and threats as an ad -balloon with assuming their alternations afterwards.
For example, though the frame shown by Figure 7 has one and only one Nash equilibrium, namely, (continuation of economic sanction, acceptance of nuclear inspection by the UN), we cannot see it really happened.

4. 4. Positional Dilemmas and their Resolution

The climax is resolved when the counterpart accepts a proposed position. However, if the positions are without credibility and/or the threats are not effective (we will give their rigid definitions later) then some kinds of dilemmas happen. Then the negotiators increase internal energy to resolve the dilemmas by re-building the interaction.
One of the main claims here is that the following two types of dilemmas are resolved if and only if the negotiation has settled down.
Let *(A, X)* and *B* be a position and threat of *i*, respectively, while *(C, Y)* and *Z* be a position and threat of *j*, respectively. We say *i* faces *dilemma of cooperation* if *j* cannot believe with credibility that *i* will really carry out *i*'s declared *A* even if *j* takes *X*. Formally, *i* faces dilemma of cooperation if there is a strategy *A'* available for *i* such that *(A', X)* is more preferable to *(A, X)* for *i*. It is the case where by taking another strategy different from *A, i* can realize more preferable outcome as far as *j* takes *X*. Then, *j* cannot expect with credibility that *(A, X)* is really realized. Dilemma of cooperation is a dilemma that threats mutual cooperation (Cooperate, Cooperate) in prisoners' dilemma.
On the other hand, we say *i* faces *dilemma of trust* with credibility if *i* cannot trust that *j*'s announcement of acceptance of *i*'s position. Formally, *i* faces dilemma of trust if there is a strategy *X'* available for *j* such that *(A, X')* is more preferable to *(A, X)* for *j*. It implies that *i* does not propose a future attractive enough to *j*. In this case *j* has no incentive to follow *i*'s position and hence even if *j* promises to carry out *i*'s position, *i* cannot trust *j*'s commitment.
Let us explain the two types of dilemmas by using the example of Iraq war. The position (withdraw of economic sanction, change of the government) of the US faces dilemma of cooperation as well as that of trust: Indeed, if Iraq follows the US's position and changes the government, then by continuing the economic sanction or taking military intervention, the US can realize more preferable results than the position. It implies the US faces dilemma of cooperation.
On the other hand, Iraq has got two strategies; accept of nuclear inspection and commitment to terrorism attack, by which Iraq can lead to more preferable results to the position as far as the US withdraws the economic sanction. It means that the US faces dilemma of trust.
Now we have [8][9]

Proposition 2
Let *(A, X)* be a position of *i*. Then, *i* does not face dilemma of cooperation nor dilemma of trust if and only if *(A, X)* is Nash equilibrium.
Then, *(A, X)* is implemented and the negotiation finishes.

What really happens when the negotiators face the dilemmas depends on various factors from the social context to individual physiological condition. If the social norm that you have to keep what you say is strong enough, then you may easily resolve the dilemma of cooperation.
We may use the dramatic model of negotiation presented here not only as a descriptive frame but also as a prescriptive method. Indeed, the Department of Defense in the US and UK is interested in applying it to manage international conflicts like those in Kosovo and Middle East [10][11][12].

5. CONCLUSIONS

This article first constructed a structure map of the systems movement and identified current research areas/streams on it. Then, we proposed "First formal, then verbal" principle of systems thinking and claimed that integrative approach is possible and maybe useful to cultivate a new perspective in systems science. Finally, to demonstrate meaning of the claim, we explained about dramatic modeling of negotiation as an example of such research.

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