Basic Notions and Models in Systems Science

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Abstract. The development of the idea of seeing parts of the world as 'related objects' or the 'systemic view' and its relation to conventional science is briefly described. Concepts in the systemic view regarded as fundamental and their expression as linguistic and mathematical models which would turn this view into 'systems science', are introduced. Products are represented as sets and linguistic networks of ordered pairs. Semantic diagrams describe the dynamics of change. A case study to illustrate the basic notions and models is given.

Keywords: systemic view, linguistic modeling, sets of ordered pairs, sequences of predicate logic statements.

1 Introduction

People have been trying to create *symbolic structures* for expressing thoughts about aspects of the surrounding world of concrete objects including parts of their own bodies since ancient times. In particular, they have been using this kind of structures for the pursuance of knowledge to understand and possibly to change parts of the world.

Concepts formulated in the brain/mind assembly as a result of abstraction of observation of parts of the world are used for producing *descriptions, explanations and predictions* by means of 'things which stand for other things'. The history of human knowledge of the world may be seen as the history of development of *'things which stand for other things'*. Ancient and current methods of predictions like heated bones of selected animals, flight of birds, tarot cards, lines in the palm of hand or patterns of tea leaves at the bottom of a tea cup, are *things* which are claimed to stand for *other things* but there is *no* recognised *relation* between the two. There is no systematic correlation between the change of shape of a heated bone and the outcome of a forthcoming battle.

The idea of viewing parts of the world as *combinations of 'building blocks'* as models in terms of which parts of the world could be seen like Thales' water, Aristotle's suggestion of earth, water, air and fire, Democritos' 'atoms' or the modern 'binary digits', had been an advance. These notions were empirical concepts with relations to parts of the world for which they claimed to have stood as 'things which stand for other things'.

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Conventional science of physics, chemistry etc, the first organised and methodical body of 'things which stand for other things', views parts of the world in terms of groups of *quantitative properties*, the 'building blocks', usually classified into mechanical, electrical etc and arranged in mathematical relations of varying complexity. Its generalisations are based on regular recurrence of phenomena found mostly in the inanimate world. Pursuance of *truth* of views and the acceptance or rejection of a view through testing against experience, are marks of the scientific method. Irreversible thermodynamics, information theory, multidisciplinary, especially dynamic, purposive or control activities in technology and in animate, especially human scenarios together with design thinking are by and large *outside the scope* of conventional science. Conventional science is unhappy with dealing with more than one object as happens in network analysis, for example.

A part of the world called 'object' in static or dynamic states or events, can also be viewed as an ordered collection of 'related properties or related other objects' which is the *systemic view*, the view of complexity and hierarchy. The view is applicable to inanimate and animate, technical and human objects with *qualitative* as well as *quantitative properties* joined into *related* or *interacting wholes* such as relations like 'diameter -'is perpendicular to' - length', 'john – 'is father of' – mary ', 'john – 'tells' - tom (to cut the grass)' or 'engine – 'pulls' the long train (fast)'.

We may say that by and large:

Conventional science deals with 'Groups of quantifiable properties of objects organised into mathematical models to be exposed to *tests of experience*' in pursuance of reliable knowledge, and

Systems science deals with 'Groups of properties or objects organised into explicitly stated linguistic relations or interactions which can carry mathematical models, to be investigated for the occurrence of specific *outcomes*'. The aim of current work is to develop the details of this topic.

The relatively recent systemic view, perhaps began in earnest with the development of servomechanisms in the 2nd world war and has created immense interest. The result has been: A vast amount of verbal and written discussion on a variety of topics loosely if at all related to the systemic view or systems thinking presented at conferences and courses at university departments but not in schools (!) together with the appearance of a large number of books and papers. And the activity is going on unabated. All this is of great interest but the essentially *pervasive, empirical* and *indivisible* systemic view has remained by and large fragmented, speculative and a subject of discussion.

The 'founding fathers' of the 'systemic view' concentrated on the horizontal view or complexity and discarded conventional science *in its entirety* as inapplicable to describing this view. This, with hindsight, was a mistake since the approach or the methodology of conventional science appears to be not only applicable but needed if we want to turn the systemic view from a view into *systems science*. The search for general, fundamental notions behind the immense *diversity and variety* of the systems phenomenon has ceased after the initial enthusiasm in the 1950's to 1990's. Systems thinking has become fragmented into information systems, systems engineering, 'soft'/'hard' methods, systems dynamics, chaos theory and other interesting ideas [1], [2], [3], [4].

The objective of current work is to suggest what may be regarded as *fundamental notions* of the systemic view and the *symbolism* that is capable of expressing these notions in operational form so as to lead to models with *outcomes* which can be exposed to at least thought experiments. This comprehensive approach perhaps can turn the systemic view from being a view into systems science, can lead to a general design methodology including elicitation of requirements and to a more concrete view of organisations and management [5], [6], [7], [8], [9].

2 Basic Notions and Models

A part of the world in static state is viewed as *related* concrete properties or qualified objects with relations signaled by *relation indicators* of space (left), order (first), kinship (father), stative (to support) and passive voice of dynamic verbs (is kicked). A part of the world in dynamic state is viewed as *interacting* objects qualified by properties with interaction signaled by *dynamic verbs* like 'to kick'. Interaction in terms of physical power carries the appropriate *energy* and interaction in terms of influence carries relevant *information*. There is no 'change of state' without interaction. Only one property can be changed at a time by a *product* which is produced by a collection of interacting objects acting in accordance with an algorithm, called an *organisation*.

The starting point of modeling static and dynamic states is a story of a scenario in natural language, the primary model, which, due to linguistic complexities, is transcribed by linguistic analysis through meaning preserving transformations, into *homogeneous language* of one – and two – place, context dependent sentences. These sentences are regarded as *building blocks*. Static states are modeled by identifying these sentences with 'ordered pairs' leading to 'linguistic networks'. Dynamic states are modeled by turning similar sentences into 'semantic diagrams' from the topology of which sequences of 'predicate logic' statements qualified by mathematics if there is need, can be derived.

In general, linguistic modeling exhibits the *structure or topology of products* (through sets of ordered pairs and linguistic networks) and the *structure or topology of systems* (through semantic diagrams and sequences of logic statements). Elements of these structures can carry qualifiers with *uncertainties and mathematics*, aiding or hindering the appearance of '*emergent properties*' of products and '*final states as acquired properties*' of systems as outcomes.

3 A Case Study

The story of a scenario is as follows: 'A shopkeeper wants to increase his takings from customers who appear rather unhappy at present possibly because their level of satisfaction is low. This is the shopkeeper's impression and he is seeking ways and means to effect improvement which is in the interest of customers as well. His main line of merchandise is cheese, ham and tuna sandwiches which are delivered to the shop all mixed up. The shopkeeper thinks that easy access and selection of sandwiches may lead to improvement. A single assistant operating sequentially in purposive mode, is used to implement a scheme'.

The terms 'access' and 'selection' are abstract. They need to be expressed in concrete terms:

'Access' means that 'sandwiches' are *placed* on 'shelves' when the latter are *cleaned*.

'Selection' means that 'sandwiches' are to be *arranged* and *priced* according to their 'contents (cheese, ham or tuna)'.

'Priced' means that labels (cheese, £, ham, £, tuna, £) are *attached* to sandwiches.

We construct a set of ordered pairs or an array based on data in (1). There are 4 common nouns or objects**:** sw (sandwiches), sh (shelves), co (contents) and la (labels). We assign relation indicators as stative verbs and the passive voice of dynamic verbs to the objects i.e. introducing ordered pairs**:**

$$\begin{aligned} &i = 1 = \text{sandwiches, sw1 (are placed on, pl)} \\ &i = 2 = \text{shelves, sh (are clean, cl)} \\ &i = 3 = \text{sandwiches, sw2 (use to arrange, us)} \\ &i = 4 = \text{sandwiches, sw3 (carry, ca)} \\ &i = 5 = \text{contents, co (used to arrange, ar)} \\ &i = 6 = \text{labels, la (to mark prices, ma)} . \end{aligned} \qquad (1)$$

Here we have three 'sandwiches' as distinguished by the relations representing the roles which the same object can play in different scenarios.

(2) shows the set of ordered pairs which gives a large number of choices the number of which can be precisely calculated. A particular choice or subset is selected from considerations of *particular product* which defines the *conceptual boundary*

$$\begin{array}{cccccc} n_{11} & n_{12} & n_{13} & n_{14} & n_{15} & n_{16} \\ 0 & \underline{\text{sw1 pl sh}} & \text{sw1 pl sw2} & \text{sw1 pl sw3} & \text{sw1 pl co} & \text{sw1 pl la} \\ n_{21} & n_{22} & n_{23} & n_{24} & n_{25} & n_{26} \\ 0 & \underline{\text{sh cl sh}} & 0 & 0 & 0 & 0 \\ n_{31} & n_{32} & n_{33} & n_{34} & n_{35} & n_{36} \\ \text{sw2 us sw1} & \text{sw2 us sh} & 0 & \text{sw2 us sw3} & \underline{\text{sw2 us co}} & \text{sw2 us la} \\ n_{41} & n_{42} & n_{43} & n_{44} & n_{45} & n_{46} \\ \text{sw3 ca sw1} & \text{sw3 ca sh} & \text{sw3 ca sw2} & 0 & \text{sw3 ca co} & \underline{\text{sw3 ca la}} \\ n_{51} & n_{52} & n_{53} & n_{54} & n_{55} & n_{56} \\ \underline{\text{co ar sw1}} & \text{co ar sh} & \text{co ar sw2} & \text{co ar sw3} & 0 & \text{co ar la} \\ n_{61} & n_{62} & n_{63} & n_{64} & n_{65} & n_{66} \\ \text{la ma sw1} & \text{la ma sh} & \text{la ma sw2} & \text{la ma sw3} & \underline{\text{la ma co}} & 0\,. \end{array} \qquad (2)$$

with an *emergent property* which, in this case, is labeled as, 'creator of easy access and selection of sandwiches'. (3) is a conceptual boundary and Fig. 1. shows the tree which corresponds to this subset.

$$\text{creator} \ldots. = \prod_{i=1}^{i=6} (n_{12} \text{ x } n_{22} \text{ x } n_{35} \text{ x } n_{46} \text{ x } n_{51} \text{ x } n_{65}) \,. \tag{3}$$

where**:** n_{12} = sw1 are placed on sh, n_{22} = sh are clean, n_{35} = sw2 use to arrange co, n_{46} = sw3 carry la, n_{51} = co used to arrange sw1, n_{65} = la mark co.

We ignore those ordered pairs in (3) in which the first element is the second element in those ordered pairs in which the first element undergoes change of state, i.e. n_{51} = co used to arrange sw1 and n_{65} = la mark co. This step is *recognisable by computer software* and will affect the tree in Fig. 1. which is modified to that in Fig. 2.

The modified network in Fig. 2. will be isomorphic to the semantic diagram representing the dynamics of scenario which is shown in Fig. 3.

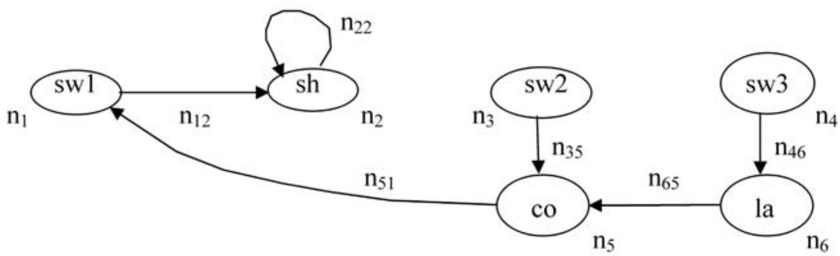

Fig. 1. Linguistic network of tree of subset

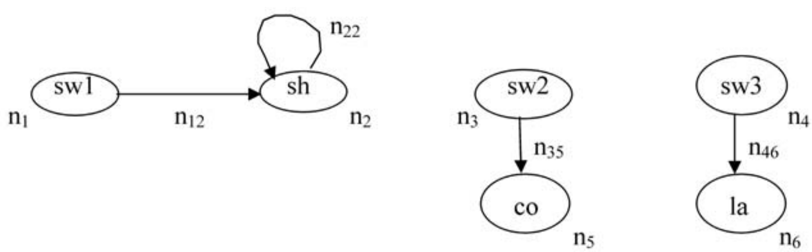

Fig. 2. Modified linguistic network from Fig. 1

A representative sample of predicate logic sequences in which the numerals designate objects in Fig. 3., is as follows:

For causal chain 1.

1/1 $dp(15,15(I1),16(I2),...) \wedge ip(15,15) \wedge cp(19,15) \rightarrow in(15,1)$

1/2 $in(15,1) \wedge ep(1,1) \rightarrow ap(2,6)$

and so on….

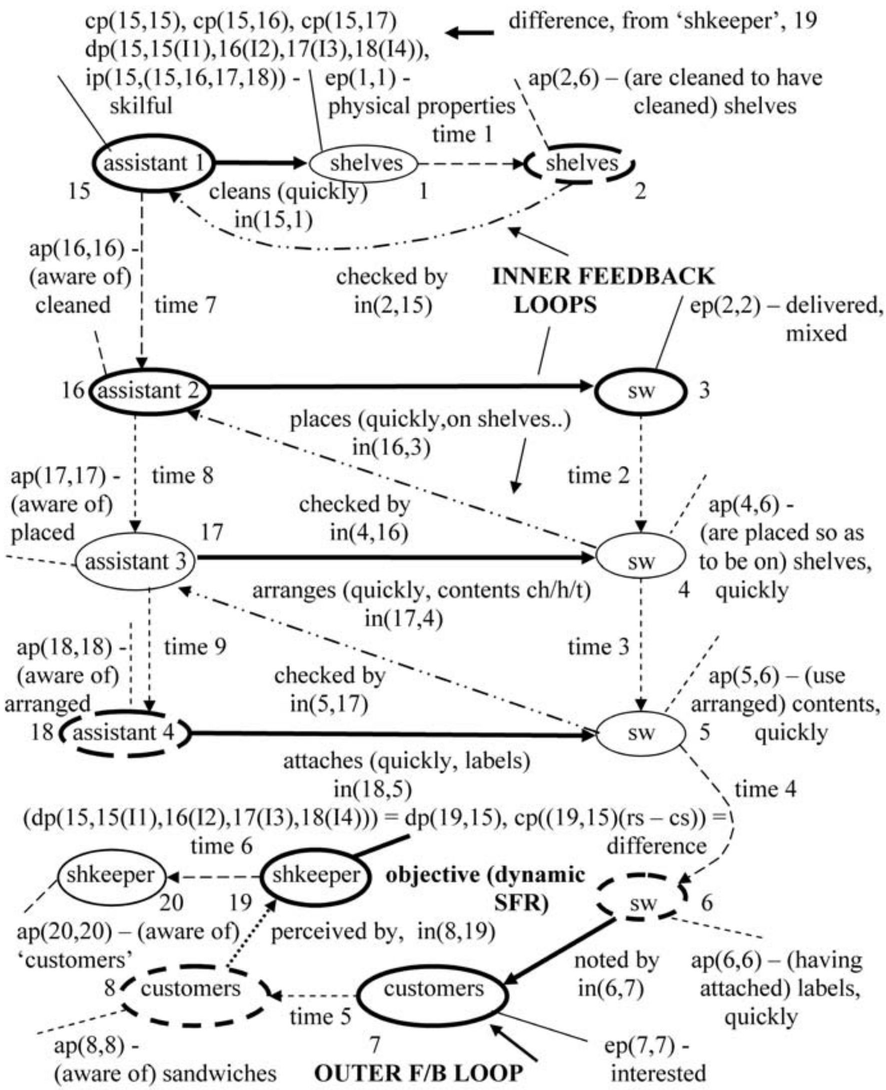

Fig. 3. Semantic diagram of concrete objects

4 Conclusions

We have introduced the basic notions and models which appear to be needed for an attempt at developing a comprehensive approach to viewing parts of the world as 'related objects' in more concrete terms. In particular, using these notions we aim at modeling human activity scenarios with their immense diversity, variety and uncertainties operating in purposive mode. We can perhaps say that purposive operations in animate activities are as common as gravity in nature [9].

The model of 'product' as in (2) offers a large number of choices one or more of which survive through selection by *evolution* or *design*. A product is constructed by an organisation and generates interaction to accomplish a change of state as shown in a semantic diagram such as Fig. 3. Dynamic linguistic modeling demonstrates how changes of state propagate in time towards *final state* of a changing object or outcome (customers). The large number of choices of product and elements of organisation is not shown. The example shown here is part of a *design* case study.

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