Development of Science and Design of Systems

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ABSTRACT

Parts of the world are perceived in their entirety as wholes, or objects which can then be viewed as aggregates arranged in horizontal (complexity) or vertical (hierarchy) relations in static or dynamic state, the *systemic view*. Basic principles involved in existence and operation of aggregates are given. A story in natural language, the primary model, is formalised into *basic constituents* combinations of which are used for constructing : arrays for *choice* in evolution and design (mechanism of emergence) and predictive, *reasoning* structures in time towards *outcomes* (linguistic modelling). Elements of a particular choice with *emergent property* and selected by natural environment or customer, consumer or market, are assembled into a functional whole by an *organisation* which can be represented by linguistic modelling to be tested as 'prototype'.

Keywords : systemic view, processed natural language, organisation, design

1. INTRODUCTION

Apart from sporadic references through the term 'system', human intellectual effort directed to creating *descriptive, explanatory and predictive* symbolic structures in the arts and sciences, by and large, has disregarded the notion of viewing parts of the world as *related objects*. Conventional science focuses on classes of objects as wholes about which it makes hypothetical statements intended for description or explanation. To create intellectual order it trends to classify or compartmentalise its subject matter. Its interest lies in gathering empirical knowledge, hence its preoccupation with truth which can be ascertained through *quantitative properties* of objects using mathematics which leads to predictive structures. Conventional science is uncomfortable with the notion of related objects, it tends to treat them as wholes. Lagrangian mechanics is an example of related objects which science regards as its own [1]. Others like multidisciplinary networks or control theory [2] is outside conventional science.

In general, the ideas of irreversibility, information, purposive activity involving machines and human activity, and design are of little interest to conventional science. Perhaps the first organised effort to consider the notion of related objects was the subject matter of control theory [2,3] which evolved into control engineering. In the 1950's pioneers of the systems view [4] drew attention to the generality of the notion of related objects and attempts were made to develop a general theory using isomorphism or mathematics [5,6]. Perhaps because of the immense *variety and diversity* of particular manifestations of related objects, no general underlying principles and a suitable symbolism were found. The subject matter of the systems view became fragmented into energetic and information systems, living systems, ecosystems, management (people and project), organisations, social science and others. The term currently used to refer to this view is 'complexity'. Perhaps the development of and preoccupation with technology, computers, internet etc have lessened the desire for search for fundamental ideas. The immense interest in the subject is reflected by the large number of people engaged in universities (not in schools) and at conferences in the production of views, theories expressed in abstract language with no systematic attempts at relating such terms to observables [7]. A variety of superficial diagrams reflecting systems views, has been produced without proper basis in symbolism like mathematics or language.

Current work is aimed at search for *unifying, basic principles* which pervade the view of the notion of related objects and at the use of *formalised natural language* (based on stories of scenarios) as the symbolism which fits the generality of this view. Such symbolism is used for creating schemes for *predictive reasoning* and for *design of products (artefacts, energy and information) and systems* [8,9,10,11,12]. This paper describes : 1. Systemic view of parts of the world and 2. Formalisation of natural language for showing how *emergent properties* appear to evolve and their *application in design* of products. *Linguistic modelling* is outlined and used to represent a simple organisation to which a *measure of complexity* is assigned details of which are given in separate ABSTRACT of this paper.

2. WHOLES AND RELATIONS

Human and animate beings appear to receive impressions of chosen parts of the world *static or dynamic*, not so much in detail as in their entirety called *wholes*. In many cases, they are capable of recognising and reacting (intuitively) to such impressions usually to aid survival, there is no time for thought (snake(dangerous) = jump). An intellectual response to impressions may begin with classification into 1. *Physical or concrete objects* which impinge on the sense organs to create sensations for the mind to work on : inanimate (rock, volcano,..), animate (tree, zebra, man,..), technical (gear box, control and computer systems,..) and animate activity fields (groups of : plants (forest), animals (herd), people (organisations of all kinds) and 2. *Symbolic objects* with meaning which are carried by a *medium*, the physical object : images (pictures, sculptures, diagrams, signs..), natural language (letters, words, sentences..), music (symbols of tunes and rhythm..), mathematics (numbers, letters, relations..).

A particular instance of objects, a whole, can be viewed as aggregate or 'system' of functional parts or constituents with *properties contingent* on the situation or scenario in which the object finds itself [13]. The *direction of aggregation* is towards production of a property which is meaningful to the whole but not to any of its constituents and is called *emergent* [14]. Classification of wholes results in the assignment of a *name or a label* to a whole judged to belong to a *class*. A name or label may also be seen as an expression of an emergent property and enables the *identification of a particular whole*, without having to elaborate further details. Objects are seen to be connected by relationships (relations : static, interactions : dynamic) forming a new aggregation with an emergent property, a member of a new class. This is called the *horizontal view* or view of *complexity* of objects in the world [11]. Energy and information [8] cannot be viewed as consisting of related objects, they are the means of creating interaction. However, material or *medium* carrying energy and instructions or algorithms with information can be. In the latter case *order* is an important parameter.

An object can be divided into its related constituents any of which can be further divided and so on *indefinitely*. End of division is signalled by reaching a constituent which is regarded as *'limiting'*. The role of limit is depends on particular situations or scenarios and it can be : atoms, molecules, geometric and material properties like length or density in conventional science ; functional elements like a steel shaft as part of a component such as an electric motor in engineering ; components like a technical or social amplifier in an engineering or social system ; leaves, branches etc of a plant, cells, organs in a human body ; individuals in a human activity scenario like a family on holiday or organisations cooperating in production of a produce like a motorcar.

Constituents aggregate or assemble until a *conceptually bounded whole* is reached surrounded by *environmental objects* with constant properties [10]. Such a whole is reached when its constituents are so related that a new feature called *emergent property* will have been perceived. This property designates *existence or potential use or potential ability to accomplish change* and places the whole in a class of wholes sharing this property. This is called the *vertical view,* or the view of *hierarchy*, of parts of the world. The horizontal and vertical views together are called the *systemic* view.

Symbolic objects like a painting, language or a piece of music, are used to say something about concrete objects or wholes by means of statements organised into the *'subject, predicate'* form. The subject identifies a class or a particular instance of it, the predicate alleges something about the subject. Parts of a statement carried by sentence are qualified (adjectival, adverbial phrases) otherwise the sentence would be *context-free* [8,9,10,15]. Symbolic objects, in particular natural language, are normally used as means of communication. Here such language is used as a model of the systemic view, a sentence is seen as an organised collection of related noun phrases.

It appears that new or novel properties are obtained by aggregating parts or adding/removing properties called changes of state. This requires viewing concrete as well as symbolic objects embodied in a medium systemically [16]. Since the world consists of the totality of concrete and symbolic objects, the systemic view is *pervasive, indivisible and empirical*.

3. BASIC PRINCIPLES

1. The concept of *property* is defined in physics as a means of description of initial and final states of a physical object which are independent of the path of reaching the latter from the former [13]. We use the concept in natural language extensively in much the same sense as *qualifiers*. There are *concrete* (geometric, material [17]) and abstract properties (mental (sad).., complex (numerical, energetic, young..), particular (phrases, clauses..)). Qualifiers make a sentence *context dependent* and enable the introduction of *semantic information* [8]. Theoretically a physical or a symbolic (through a medium) object may be seen as a conjunction of an *infinite number* of properties of which a few are used for creating *models*. These are *contingent* on the scenario. Perfect knowledge is thus impossible.

2. Interrelations between objects are expressed as *relations* (indicating static state) which can be spatial, temporal, kinship, relational (and, or..) or stative verbs (to be, to stay) [15] or as *interactions* (indicating dynamic state) which are physical power carrying the appropriate energy or influence with information, both attached to *medium* [3,8]. Relations and interactions are realised by *couplers*.

3. *No change of state* expressed as property is possible *by itself* either by chance or in accordance with purpose, interaction is required.

4. In a closed situation energy is conserved, information can be created or destroyed. Energy is a positive definite function [2], information is present or absent. There is no negative information.

4. BASIC CONSTITUENTS

We are interested in *sentences* organised into a *story* representing a *scenario* as the primary model. However, a story in natural language may have complex linguistic patterns. Linguistic analysis is needed to convert such patters into combinations of simple, one and two place sentences with a single, *stative or dynamic verb called basic constituents* [10]. A *homogeneous language* will have been created which is assumed to preserve the meaning of the original story to an acceptable degree and of which the story can be reconstructed. *Basic constituents* conform to the pattern of eq.1

qualified ((initiating)subject + verb + (affected) object) 1.

For example, we can have '*Tidy* man + shaves *every day* + ...' and '*Old* farmer + *still* uses + *strong* horses *for ploughing*'. Qualifiers select an instance from a class of objects or assign properties to an object which enables it to have a relation through a coupler : '*Round* bolt (*with thread*) is screwed *tightly* into the nut'.

5. FORMALISATION OF THE SYSTEMIC VIEW

To convert the descriptive treatment of the systemic view into a predictive, reasoning mechanism, we use *formalised, natural language* [10]. This method when applied to *static structures* is called 'Mechanism of emergence', *dynamic structures* are modelled by 'Linguistic modelling'.

5.1. Mechanism of Emergence

The intention is to use organised aggregates of basic constituents to construct reasoning mechanisms. These constituents are applied to : 1. concrete and 2. symbolic objects and 3. *abstract nouns attached to concrete nouns, abstract adjectives and verbs* so as *to relate them to experience*. Abstract terms need to be transformed into aggregates to be used as *executable design objectives*. Such objectives are usually formulated in abstract terms like 'Courage of the soldier is to be rewarded'. One and two place sentences are regarded as 'propositional functions' used for creating 'ordered pairs' [17] of objects or properties designated as 'nouns'. Stative (supplemented by relation indicators like left, together, before…) and dynamic verbs (in passive voice) create relations between the nouns. In general, a series of two place sentences as in eq.1. can be written as

$$n_i\,(adj_{ix})\ verb_r\,(adv_{iy})\ n_j\,(adj_{jz}) \qquad 2.$$

where adj - adjectival qualifiers of nouns 'n', adv - adverbial qualifiers of verb. These are *contingent properties* selected so as to be relevant to the nouns and relationship (aiding or hindering) expressed by the 'verb'. In a one place sentence the subscript $j = 0$. For each 'i', a noun, we can have a number of adjectival qualifiers

for $i = 1$ $x = 1,2,\ldots$ $i = 3 \ldots.$
$i = 2$ $x = 1,2,\ldots$ and so on….

The subscript 'j' can be similarly expanded. Each noun as the *subject* of sentence has at least one verb attached to it, therefore, for the verb we have $r \geq i$ as well as a number of adverbial qualifiers, $y = 1,2,\ldots Y$.

We assume that we have a set of qualified, unrelated objects designated by noun phrases 'B' which may be seen to be *randomly distributed* in a group

$$B = \{(n_i\,(adj_{ix}))\} \qquad 3.$$

To each object 'n' we attach at least one qualified stative or dynamic verb as in eq.1. which designates relationships that the *object is judged to be capable of entering into* forming another set 'A'

$$A = \{(n_i\,(adj_{ix}))\ (verb_r\,(adv_{iy}))\} \qquad 4.$$

When $r > i$ the objects represented by nouns can have access to *other objects outside the group*. Each unrelated object in eq.4. can enter into relationship with itself and with others designated by the subscript 'k' in the *same group* to form *ordered pairs* arranged as an array according to eq.5.

$$\{(n_{ik}\,(adj_{ix}))\ (verb_r\,(adv_{iy}))\} \qquad 5.$$

for $i = 1$ $k = 1, 2, \ldots. K$
$i = 2$ $k = 2, 3, \ldots. K, 1$
$i = 3$ $k = 3, 4, \ldots..K, 1, 2$
$i = 4$ $k = 4, 5, \ldots. K, 1, 2, 3$ …and so on…

where 'i' and 'k' indicate the vertical and horizontal expansions with '$i = k$' leading to a square array representing eq.5. with the number of relationships or ordered pairs

$$\text{number of relationships} = n^2 \qquad 6.$$

For example, we let $i = r = k = 4$, $x = y = 0$ i.e. we consider context-free sentences, then eq.5. becomes

$$\begin{matrix} n_{11} & n_{12} & n_{13} & n_{14} \\ n_{22} & n_{23} & n_{24} & n_{21} \\ n_{33} & n_{34} & n_{31} & n_{32} \\ n_{44} & n_{41} & n_{42} & n_{43} \end{matrix} \qquad 7.$$

Each term in eq.5., 7. is an ordered pair with a relationship. For example, the sentence or the story 'Top of the table is supported by legs which stand on the carpet' is expressed as eq.4. to form 3 relations for the 3 objects : i = 1 = 'top is supported', i = 2 = 'legs stand on' and i = 3 = 'carpet is'. From eq.5. we have

(top is supported by top) n_{11}	(top is supported by legs) n_{12}	(top is supported by carp) n_{13}	
(legs stand on legs) n_{22}	(legs stand on carp) n_{23}	(legs stand on top) n_{21}	8.
(carp is carp) n_{33}	(carp is top) n_{31}	(carp is legs) n_{32}	

In eq.8. one *selected term* in each row is part of the sentence. In the 1st row 'top is supported by legs', in the 2nd row 'legs stand on carpet' and in the 3rd row 'carpet is carpet'. The three relations together may be described as : 'table supporting arrangement', the *emergent* *property* of the whole conceptually bounded by the concatenation of the three ordered pairs.

However, the array offers a *choice of aggregation*. For example, we have in the 1st row 'top is supported by the carpet', in the 2nd row 'legs stand on the top' and in the 3rd row 'carpet is carpet'. This aggregate also makes sense, we can name it 'upside down table' as its emergent property.

We can conclude that the arrays in eq.5., 7. and 8. *offer a choice* of wholes and show how a variety of structures emerge from a collection of separate objects for *existence, possible use or potential accomplishment of change*. An emergent property is produced by a *new structure*. Varying the qualifiers of nouns and verbs enables an existing structure to *adapt* or fail to adapt to objects external to it called *environmental objects*.

We construct a pattern of relations which gives rise to an emergent property by *selecting one relation from each row of an array* like eq.7. or 8. The converse would mean that the same object would be related to more than one other object, an indeterminacy. In other words, we allow a single instance in the *domain* with *multiple range* which creates a *function* [17]. Accordingly,

$$\text{emergent property} = \prod(n_{ik}) = \prod_{i=1}^{i=I} ((n_{i(\text{with any one of } k = 1,2,3\ldots)} (adj_{ix}))(verb_r (adv_{iy}))) \qquad 9.$$

in which for each 'i' we select a specific 'k'. $\prod$ is the operator which defines the <u>*conceptual boundary of the whole*</u> and indicates that an emergent property describes a whole which is greater than the 'sum of its parts'. In other words, a whole is not an algebraic sum but an aggregate of parts with relationships.

Application of eq.9. to the example in eq.8. results

$$\text{table supporting arrangement} = \prod_{i=1}^{i=3} (n_{12} + n_{23} + n_{33}) \qquad 10.$$

where the '+' sign means simultaneous occurrence of parts with relationships.

5.2. Introduction to Linguistic Modelling

The adjectival qualifiers in eq.1. can be classified into properties with *specific roles*. The causal relations between a driving property (dp) and an interaction (in) and an interaction and an acquired property (ap) lead to expressing a one- or two-place basic constituent as a pair of *logical conditionals* [9]. For instance, the sentence 'As part of his duty with care about the job (dp) and with good eye sight (ip = facilitate/hinder interaction), the postman sorts (in) according to code (adverbial phrase) properly addressed (ep= facilitate/hinder change (ap)) letters' can be formulated into :
'IF (it is part of his duty and with care about the job) AND (he has good eye sight) THEN the postman sorts letters (according to code)'.
'IF the postman sorts letters (according to code) AND the letters are (properly addressed) THEN the letters *become* sorted (ap)'.

The result of the 'postman's' action in the example above is a change of physical property of the 'letters', referred to as *outcome*. Exercising his skilled power, the 'postman' converted letters from unsorted into 'sorted', *he has created order out of chaos* [10] or an *emergent property*. We use the example of the 'postman' to show the inferential structure [9] which demonstrates the *propagation of state in time* towards outcomes the possibility of which is subject to qualifiers assumed to be *relevant* and their associated *uncertainties* [18].

Homogeneous language of context-free sentences (from the story by linguistic analysis)
Postman sorts letters. (Skilled power carrier)

Semantic diagram
Shown in Fig.1. where the object labels are enclosed in contours connected by solid, directed lines of interaction pointing towards the affected object as in eq.1. A dotted directed line indicates change in time, not explicitly stated. Triangles indicate qualifiers.

Adjectival qualifiers with grading (from the story)
dp(1,1) – partofhisduty (strong,med,weak), care (high,low)
ip(1,1) – eyesight (excellent,poor)
ep(2,2) – addressed (perfect,mistake)

where the first numeral in the brackets designates the object which is described by the property and the second designates the object at which the property is active.

Logic sequences/topology of scenario (from the semantic diagram)
1/1. $dp(1,1) \wedge ip(1,1) \rightarrow in(1,2)$
1/2. $in(1,2) \wedge ep(2,2) \rightarrow ap(3,3)$

where the logical AND function is used, however, the properties 'ip' and 'ep' can be regarded as *additional evidence* which alters the calculations of certainty factors [18].

Interactions with adverbial qualifiers
in(1,2) – sorts : sorts(according to code)

Logic sequences with graded adjectives/data for cf
This part of the method deals with detailed expansion of the logical forms and with computation of uncertainty of outcome. A one-place basic constituent is given by the sentence 'Depressed, strong willed man with financial problems, tried to kill himself by jumping off a cliff 2 weeks ago'. This is diagrammed in Fig.2.

In the context - free sentence 'Man tried' each term is qualified by adjectival and adverbial phrases :

dp(1,1) - with financial problems
ip(1,1) - depressed
ep(1,1) - strong willed

Interaction and acquired property
in(1,1) - tried (to kill himself (by jumping off a cliff (2 weeks ago)))
ap(2,2) - man at the bottom of cliff

One and two place sentences into which a story representing a scenario is broken down by linguistic analysis, are recombined so as to reconstruct the story as a semantic diagram which can be *read*. However, the story is now in a form which is suitable for further analysis into a predictive, reasoning scheme.

6. APPLICATION TO DESIGN AND MODELING OF ORGANISATIONS

The envisaged *solution* of the problem elicited from a story or narrative of a scenario, or *emergent property*, final state of a *changing object*, lies in the future and is embodied in *overall objective* with *desired change of a particular aspect of the changing object*. This objective is usually expressed in *abstract terms* like a mission statement or a wish or intention : 'The chief constable wants to make the police force (changing object) *more accountable* to the local population (customer)'. The 'Mechanism of emergence' delineates an overall objective into a *hierarchy of objectives* until executable objectives are reached i.e. combination of *elements* : *properties or names or labels* (nouns) plus *relations* as discussed in BASIC CONSTITUENTS. Each element forms its *own objective* which can then be changed or related to others so as to fit into a number of feasible, *conceptually bounded wholes* which stand for the *overall objective*. *Each constituent* of this whole is changed by a scheme operating *in purposive configuration* [12]. The *number of constituents or* *schemes* needed to change ALL constituents of a whole, is regarded as an objective *measure of complexity of a scenario*. The *overall objective* is the totality of own objectives *organised or coordinated by the logic of algorithm* towards realisation of the desired change of a changing object. Thus, an algorithm is an *organised reproduction of own objectives which together constitute a particular envisaged, desired change expressed as overall objective*. The algorithm is translated into a programming language intelligible to a *particular collection of purposive schemes* like craftsmen or a computer. An example is included in the ABSTRACT.

7. CONCLUSIONS

We have suggested that senses, especially the sense of vision, perceive parts of the world as 'wholes'. The mind then appears to extract specific properties for commenting on the whole. This has led to conventional science which operates through the concept of quantitative property and mathematical modelling which creates relations but loses the identity of the whole. An abstract property is seen to consist of a number of concrete objects plus relation indicators which enable the scrutiny of such property and its use in design. We have described the systemic view of parts of the world consisting of the horizontal (complexity) and vertical (hierarchy) views, a major shift from the view of conventional science. The former sees a whole as an aggregate of parts necessary for an emergent property, or outcome, and the latter suggests the division of a part in an aggregate into its own constituents and so on. Division is carried out in terms of concrete objects plus relation indicators. Parts aggregate by chance or design to produce more complex wholes towards emergence of new properties. A part can be divided until a specific limit is reached but eventually a final non-divisible limit must be reached.

Based on general principles, natural language is formalised into basic constituents so as to be aggregated into predictive reasoning schemes according to the systemic view. These schemes may be used for showing how emergent properties appear and used for design of organisations (mechanism of emergence) and for analysis of suggested aggregates regarding their ability to produce outcomes in the face of uncertainty associated with constituents including human (linguistic modelling).

Further to Fig.1. in the ABSTRACT there is a general sequence or order in aggregation : assembly of concrete objects or properties followed by injecting energy and subsequently information as needed by these objects. Thus, presence of energy and subsequently information presupposes the existence of material.

The method of dealing with complexity as outlined under 'Method' and 'Basic elements' has a history in the development of science. Analytical mechanics of Lagrange, multidisciplinary network theories [2], control theory etc all use the method.

Current approaches to complexity or to 'complexity science' comprise ad hoc quantitative methods but to a large extent these approaches are descriptive using highly *abstract linguistic* terms and terms which may be referred to as *'jargon'*. An example, although extracted from context, is the following 'The distance within topology of reality does not, as a rule, substantially diminish the value of synergetic isomorphism'. The majority of discourse is conducted in abstract linguistic terms which is useful as abbreviations of concrete terms and as means of considering ideas, speculating and expressing high level objectives like mission statements. Critics of artistic work make extensive and effective use of abstract terms to convey their feeling, opinion or views. Use of such terms never lead to a 'science of complexity' since they are not related to experience and there is no intention to relate them by current practitioners. Abstract nouns have no concrete properties.

A way forward appears to be either aiming at development of an 'Art of complexity' or making a far reaching hypothesis regarding a view of the world : *'the world is systemic or complex'*. This hypothesis leads to models which can be related to experience, can be used for design and for speculation about possible future events or outcomes. However, the approach outlined here still needs to pass the test of debate. Development of software (for simulation and for creating a design tool for managers) and exposure to more substantial applications are needed.

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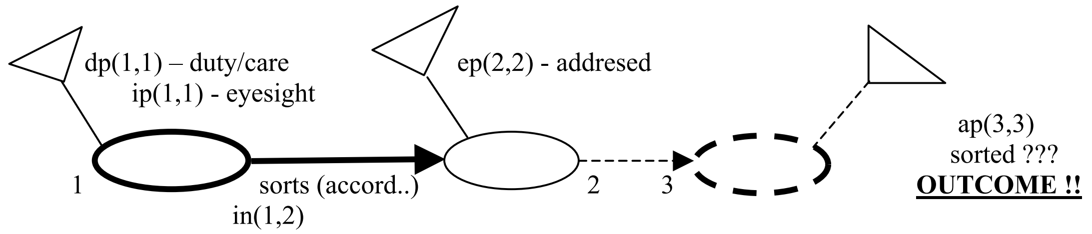

Fig.1. Diagram of a two-place sentence, a basic constituent

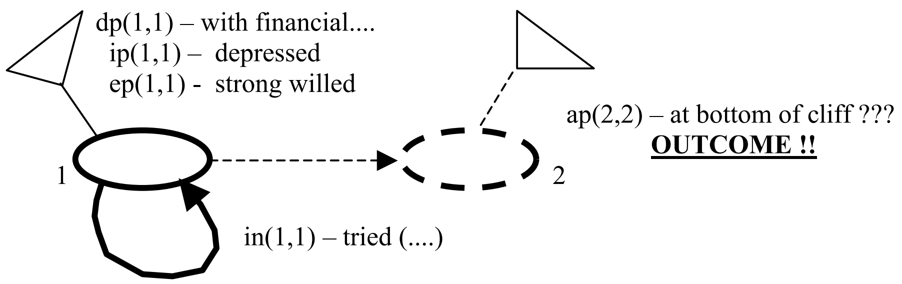

Fig.2. Semantic diagram of one-place sentence