GENERAL SYSTEMS THEORY THROUGH LINGUISTIC MODELLING

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ABSTRACT

A brief historical background suggests that although the 'systemic or structural' description of parts of the world appears to be universal, an acceptable general systems theory has not been put forward. A scheme for empirical research is described which can be used to evaluate to what extent constituents of 'human intellectual endeavour' including a GST, fits into such a scheme. Past suggestions for GST are compared with that currently under consideration. Basic notions of the proposed GST are outlined leading to a set of concepts for this GST which can then be used for operational descriptions of either quantitative or qualitative aspects of things. These aspects are embodied in mathematical or linguistic models having a common origin in 'processed natural language', the primary model. The generalised model of purposive system is considered as the basis of production and consumption of 'product' by living things. Connection between 'conventional' and 'systems' sciences is demonstrated pointing to their application in problem solving and design. Thus, an integrated scheme of analysis and synthesis together referred to as GST dealing with scenarios labelled 'natural', 'technical', 'living' and 'social' systems has emerged.

Keywords: general systems theory, empirical research, linguistic modelling

INTRODUCTION

The term 'system' [Anon. 1994] has been used sporadically and widely over the past like the 'Ptolemaic or Copernican views of the solar system ', 'systems of rigid bodies' or a 'system of differential equations' by men of science and by people in the course of their lives like 'road system', 'communication system' and so on. This usage usually arises when an object or activity is perceived as **complex** i.e. it appears to consist of many parts and needed to be referred to in some, usually, vague manner. Also, in the literature we meet : manual system, mechanised system, man-machine system, administrative system, physical system, living system, social system, technological system, open/closed systems and so on.

The term came into technical use with the development of servomechanisms or control systems during the 2nd WW for directing antiaircraft guns, for example, followed by the huge expansion of control theory [Brown, Campbell, 1948, Nise, 2008, Korn, 2012]. Concurrently and later topics like 'operational research', 'cybernetics', 'systems dynamics', 'viable systems', 'living systems theory' etc emerged. Strands of thinking like 'interpretive, emancipatory, critical approaches', 'chaos theory', 'complexity science', 'reflexivity' and so on have opened up. Thus, fragmentation of the 'systemic or structural view' of parts of the world has taken place with topics discussed by and large in highly abstract, **speculative** terms with little or no interest in their ‘truth relation’ to the empirical world [Jackson, 2000, Hyeronymi, 2013].

Speculative language in abstract terms is essential for generating ideas, beliefs, views, describing **trends,** innovative ideas, making general suggestions and formulating objectives to be achieved as part of ‘purposive activity’. Such language has been invented for economy in expressing thoughts. In the majority of verbal exchanges by people ‘speculative language’ is acceptable and sufficient. However, when it comes to testing ideas, when a prototype model has to be produced in design and in constructing predictive, reasoning schemes, more organised thinking is desirable which is to be expressed in terms of concrete ‘means with meaning or models’ such as processed natural language and/or mathematics [Korn, 2009, 2010, 2013].

In addition, there is a variety of ‘systems tools (such as influence diagrams)’, ‘techniques (black box technique, Petri nets, UML, agent based modelling and so on)’ and ‘methodologies (soft system methodology, viable systems method)]’ without appropriate theoretical basis. Such ‘tools’ usually cannot be read by means of natural language. Their appearance and development may be due to a ‘feeling’ that there are vaguely defined ‘related objects’ acting as the subject matter of the ‘systemic view’ in technology, society, in animate and inanimate nature. A number of these approaches appear to be ‘static’ although they are trying to represent ‘dynamic’ phenomena (viable systems method, for example) [Beer, 1972, Checkland, 1982, Jackson, 2000, Fowler, 2004].

Thinkers like von Bertalanffy and Boulding realized the general applicability of the term ‘system’ or the ‘systemic view’ for describing states and events which appeared complex resulting in ideas like ‘general systems theory [GST]’ [Bertalanffy, 1950, Boulding, 1956, Rapoport, 1986].

Developments aimed at a general systems theory had been made based on the idea of homologies between disciplines of mainly ‘conventional science of physics’ that have traditionally been considered as being separated by their different subject matters [Bertalanffy, 1950, Troncale, 1985]. Mathematics is the favoured symbolism by which this idea is expressed. GST was considered as some kind of meta theory [Klir, 1969, Yi Lin, 1999, Skyttner, 2006]. Lately interest in GST has been revived and is referred to as ‘general systems research agenda’ [Rousseau, 2014].

However, GST has not been expressed as a pervasive and coherent ‘systemic or structural view’ of parts of the world or ‘things’ in the form of an empirical theory. The intention of this expression would be for GST to form a basis for ‘systems science’ and that of a ‘discipline of systems’ and would contribute to **problem solving** as an intellectual exercise practiced by all living things. The objective of this paper, based on past and recent more detailed views, is to discuss the reasons why an acceptable development of GST has not emerged and to suggest an approach which may be seen as a possible way to such development subject to debate regarding its acceptability [Korn, 2009, 2012, 2013].

MEANING OF GST

GST is part of the 'systemic view' which is part of the larger spectrum of 'human intellectual endeavour' shown in Figure 1. [Korn, 2013]. Broadly speaking each constituent of this spectrum can be divided into two parts:

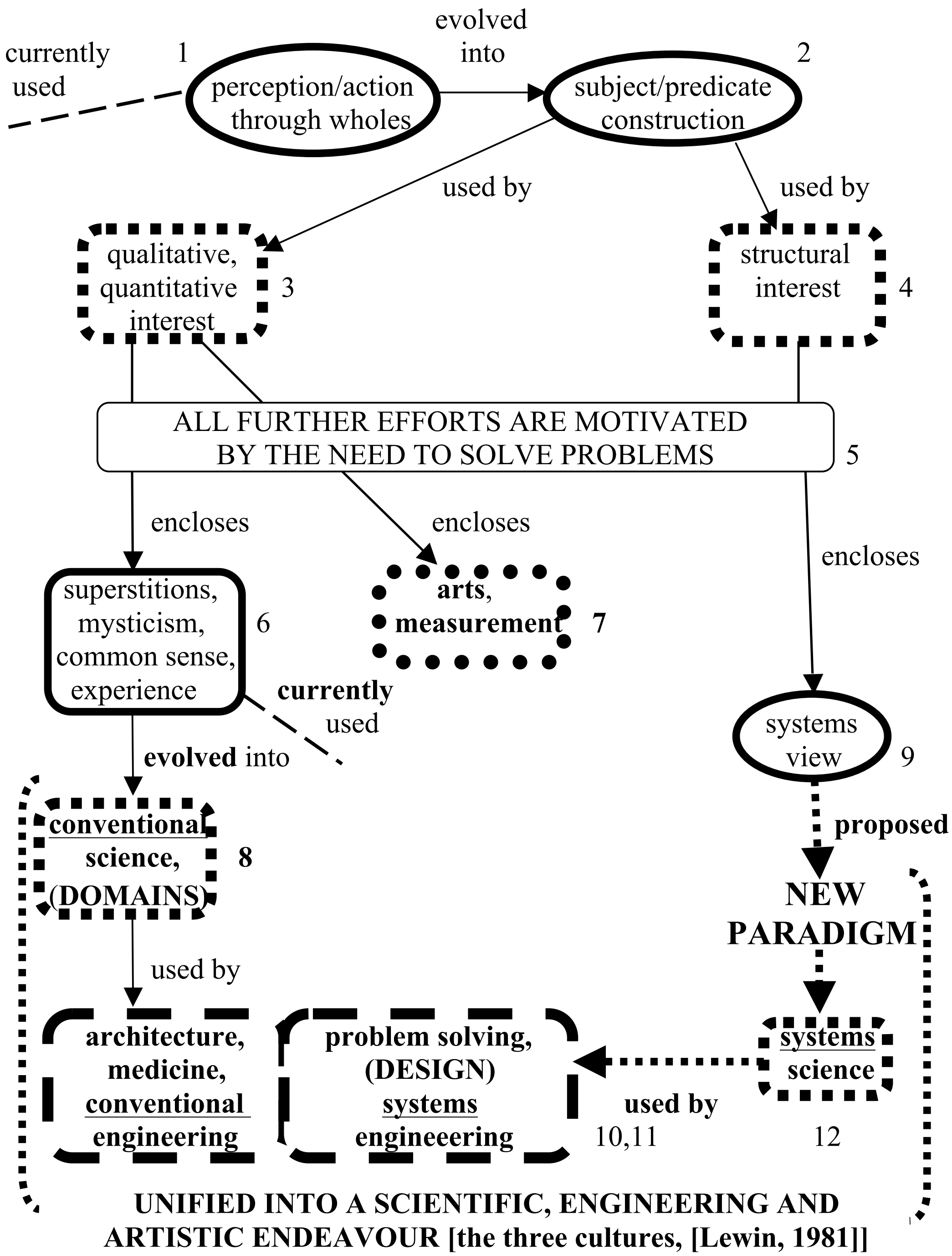


Figure 1. Diagram of constituents of human intellectual endeavour

1. Development and theories of symbolisms to represent concepts residing in the mind. Such symbolisms are natural language, informatics or signs, signals, gestures, the languages of arts, mathematics etc, and

2. The application of particular symbolisms to description of parts of the world or to stand for figments of imagination.

We are interested in part 1. as far as it is concerned with application to part 2. i.e. **empirical research**.

Any part of the world capable of reception i.e. equipped with sense organs and organs capable of processing sensory input, is exposed to a vast array of inputs from its surrounding. Most of such inputs is ignored but one or more may be considered of interest, for example, for survival [is this grain edible ?], further action [is this person or animal hostile ?] or study [is this state or event or idea problematic, can this cross word puzzle be solved ?].

Response to inputs can be 'instinctive' or 'considered'. The totality of 'human intellectual endeavour' summarised in Fig.1. is devoted to the latter except contour 1. The diagram in Fig.1. also locates the 'systemic view' in its context and points towards further developments as indicated by contours 10, 11 and 12 which is the topic of interest in current work [Korn, 2009, 2011, 2012, 2013].

We outline a scheme intended to describe how empirical research appears to proceed :

I. The **first step** in empirical research appears to be invention, evolution and use of a particular symbolism to cater for the urge of the mind [human and that of other living things] to express views, beliefs or opinions about the physical, mental, emotional or intellectual aspects of things in the surroundings. For example, the ancient man used 'drawings' to picture animals on walls of caves or 'ballet' which selects 'dance' as the symbolism for carrying views or emotions.

Part of this stage includes contour 1 in Figure 1. in which we perceive a part of the world in its entirety as a 'whole' and respond, or not, to such impressions. The response may use a symbolism such as a 'cry [to signal danger] by a monkey on seeing a tiger [whole carrying the impression]'[Korn, 2013].

II. The **second step** is concerned with the objective or purpose or use of efforts in the 'first step' which is to begin to bring intellectual order or sense into the bewildering variety of things and happenings or 'states and events' in the surrounding world. This can be done by creating classes or **domains** of things by selecting those aspects of things which can be described by the same symbolism or by the **same** set of symbols which stand for **concepts abstracted** from parts of the world by the mind by examination and contemplation. This method has evolved into a major intellectual exercise in 'conventional science of physics' and subsequently by other branches of learning. This effort follows its widespread but perhaps unintentional practice in every day life of people and all living things although without necessarily consciously assigning symbols.

'Conventional science' by and large has retained the **concrete** concepts whereas every day practice of 'representation or modelling' and 'communication' evolved the idea of **abstract** concepts for economy and effectiveness of communication, especially in 'natural language' [Burton, 1984]. In every day life trends, feelings, speculation and so on given by abstract terms are sufficient and there is usually no time to go into details. In 'conventional science', however, concreteness is demanded by its methodology of using statements which can then be exposed to tests to assess their truth value and refuted if found lacking [Magee, 1985, Korn, 2013].

For example : In the science of mechanics we have 'quantifiable properties' as the symbolism (first step) leading to a set of well defined concepts such as 'force', 'velocity', 'density' and so on to be designated by symbols. This leads to the 'domain of mechanics' (second step) [Korn, 2012].

In a similar way observation and inquiry may result in a 'selection of properties' (first step) formulated as : 'Over 65 years old [age], formerly professionals, owner occupiers [social status], tend to worry, generous, habit forming [personality], hard of hearing, loss of eyesight [state of health] where the expressions in brackets are 'parameters'. [Korn, 2009, 2013]. This set of properties can be used for forming the class of 'retired of people' (second step).

Also, we can select 'names' or 'designations' of things (first step) such as '4 chairs', 'a table', 'a cupboard' and 'a chest of drawers'. We can say that they are 'all used in the kitchen' which is the concept symbolised by natural language leading to the set of things regarded as 'kitchen furniture' forming the class or domain (second step). This kind of classification is common practice.

In general, we are concerned here with assignment of 'predicates' to objects which define the circumstances or domains or scenarios in which an object finds itself. For instance, in the example above a group of individuals find themselves in the circumstances of 'retired people' or a 'person' may be predicated as a 'cook when at home' or a 'computer operator when in the office'.

III. The **third step** is about making statements referring to the whole class or **domain** which are of more or less generality depending on the kind or size of a domain. Hypothetical, law-like statements of varying generality to describe a state of affairs prevailing over a domain serve as examples. They are prevalent in 'conventional science' which primarily deals with natural phenomena with a high degree of **repeatability**. Newton's 1^{st} law, the 1^{st} and 2^{nd} laws of thermodynamics are examples.

IV. The **fourth step** is the creation of **relations** among 'members of a symbolism standing for concepts' as described in the 'second step'. In 'conventional science' mathematical relations of quantitative properties or mathematical models [Korn, 2013] are the most common. Such relations are precise but the identity of the theoretical object which is the carrier of the properties is lost. Mathematical relations provide the precision required when comparing theoretical with experimental results, a mark of a 'science'.

Any part of the world perceived as a 'whole' within contour 1 in Figure 1. is called 'empirical object', any other which is qualified or commented on by statements of the 'subject-predicate' form is referred to as 'theoretical object'. The intellectual efforts named inside the rest of the contours deal with such objects.

V. The **fifth step** is concerned with application of a relation obtained in the 'fourth step' to a **particular** member of the set of things in a class or in a domain. This particular instant of relations is the one which may or may be capable of being exposed to experimental or observational test as long as it can be manipulated or can form a 'reasoning scheme' [Korn, 2013]. The validity of a relation obtained in the 'fourth step' cannot be assessed because it refers to a class or a domain. Thus, in science validity of a 'general theory' is inferred from the validity of its particular instance. This happens to be in accordance with Popper's view [Magee, 1985].

We can consider the constituents of 'human intellectual endeavour' as shown in Figure 1. from the point of view of how they fit into the 'scheme of five the steps'. For example, the 'arts' in contour 7 do not go beyond the 'second step'. 'Conventional science of physics' and the proposed 'systems science' as developed by current work and indicated by contour 12 in Figure 1. are accommodated by the 'scheme' and can serve as reference to judge other constituents of 'human intellectual endeavour' [Korn, 2009, 2012, 2013]. For this reason we consider how far the notion of GST fits into the 'scheme'.

The hitherto accepted practice of interpretation of the 'scheme' in Figure 1. begins with contour 3 and proceeds along the left side. We are now interested to begin with contour 4 and suggest the use of the concept 'structure' as a means of description (first step). Description of the structure of parts of the world (concrete [table], abstract [sadness], symbolic [word] and imaginary [centaur]), requires **relations** [for description of steady state] or **interactions** [to describe dynamic state]. The description of things in terms of their 'structure' is **general** implying a **limitless** domain (second step). This suggest a single law-like statement inclusive of 'concepts' for producing symbols to be related for the production of models of particular cases (third and fourth steps). Accordingly, any theoretical object of interest can be chosen as particular case or example irrespective of its kind [natural (rock), living (plants, animals, groups or societies), technical (artefacts : kitchen knife to an aeroplane) and their conceivable mixture] (step five).

This is the meaning of GST as suggested by the 'scheme' of empirical research and proceeds along contours 12,11,10 in Figure 1. We now consider the views of a sample of proponents of GST to see how far any of them comes close to the view as held by the 'scheme'.

General Systems Theory

SUMMARIES OF VIEWS OF PROPONENTS OF GST

A brief summary of view expressed by a proponent of GST is outlined. The views have been selected by their immediate availability and relevance not as a result of a thorough literature search but perhaps may be accepted as a representative sample.

Von Bertalanffy [1950] --- Von Bertalanffy is generally credited as the thinker who introduced the idea of GST. He thought that sciences explain phenomena by reducing them to an interplay of elementary units which could be investigated independently of each other. Examination of each science would result in the emergence of 'isomorphic laws' to be described by differential equations. This idea is similar to that of 'classification of variables' in engineering systems [Korn, 2012]. These laws are also called 'general systems laws' which would presumably lead to a 'logico-mathematical discipline' called general systems theory.

Boulding [1956] --- Boulding proposed five principles as the starting point for the development of a modern GST. These are :

1. Order, regularity and non-randomness are preferable to irregularity and randomness.

2. Orderliness in the empirical world makes the world good, interesting and attractive to the systems theorist.

3. There is order in the orderliness of the external or empirical world (order to the 2^{nd} degree).

4. To establish order, quantification and mathematisation are highly valuable aids.

5. The search for order and law necessarily involves the quest for those realities that embody the abstract laws and order – their empirical referents.

Klir [1969] --- Based on set theory, relations and mappings Klir introduces a number of concepts which lead to a GST. He also gives a review of past approaches to the creation of a GST such as von Bertalanffy, Ashby [Ashby, 1956] etc.

Laszlo [1973] --- Laszlo proposed a theory of natural systems, a descriptive treatment interspaced by mathematical expressions and ideas of wholeness and order.

Troncale [1985] --- Troncale appears to advocate the discovery of isomorphisms which are supposed to prevail in the various branches of sciences leading to GST. He gives 33 obstacles in the way of development of a GST such as 'Need for a consensus of glossary of precise definitions for the principal concepts used in systems science'.

Skyttner [2006] --- His book is a large and comprehensive collection of concepts from diverse fields with the idea of GST based on concepts like order and entropy.

General Systems Theory

Based on the sample of views, once the idea had been proposed approaches to the development of a GST have been going on along either mathematical or speculative lines:

1. The mathematical line is an unsuitable candidate for GST because it is restricted to the quantifiable aspects of things and leaves out the majority of topics of interest such as human activity scenarios driven by qualitative aspects and affected by emotive factors.

2. The speculative line is also unsuitable because the 'systems phenomenon' is empirical and speculation although necessary but eventually needs to be translated into 'concrete propositions' capable of being exposed at least to thought experiment.

Although the 'systemic view' of parts of the world is based on empirical evidence or 'we need to examine a thing to perceive its structure' its evolution has not been going on along the lines of empirical investigation as outlined in the 'scheme'. Also, when thinking about 'science' pioneers of GST appear to have meant 'conventional science of physics'. We propose to introduce an approach to GST based on 'systems science' which follows the 'scheme' and leads to a comprehensive method to incorporate aspects of **conventional science** and is an essential part of **problem solving** and **design.** Details are available in [Korn, 2009, 2012, 2013].

BASIS OF GST

Further to Figure 1. basically we are interested in a structure of qualified theoretical objects in qualified relations defining steady states OR qualified interactions which define dynamic states of entities respectively irrespective of the nature of objects (natural, living [human, social], technical). Two propositions are suggested :

1. Belief about the nature of parts of the world : 'The **identity** of concrete, abstract, symbolic or imaginary entities is defined by structure. Thus, the 'systems or systemic view' of parts of the world as referred to in Figure 1. is **pervasive, indivisible** and **empirical'.**

This proposition defines the 'domain' of GST to be infinitely large.

2. View of existence of parts of the world : 'There is an agreed number and kind of parts or theoretical **objects** each with its own **qualifiers** AND these parts are connected into =

X. A static **structure** [recognised by qualified relations designated by stative **verbs**] to represent parts of the world or states, OR

Y. A dynamic **structure** [recognised by qualified interactions designated by dynamic **verbs**] to represent activities or changes of state.

This proposition suggests a hypothetical **statement** leading to the analytical means or a **symbolism** for the structural description of any part of the human intellectual endeavour in particular that of the 'systems view'.

The 2nd proposition is followed by a **symbolism** based on 'processed natural language' derived from a 'story of a scenario' which is the most general means of representation and communication or a **model**. In details : Four **invariants** or concepts are used for organised description of a scenario ----

I. Class of theoretical objects or **related pertinent properties** [called functional elements at the primitive level] which can be concrete, abstract, symbolic or imaginary,

II. Relations producing static state recognised by stative verbs which describe spatial, kinship, logical etc relations,

III. Interactions producing dynamic state recognised by dynamic verbs signifying physical power (carrying energy) or influence (carrying information or impression of use [requirements and fitness] or meaning [of symbols, signs, gesture, works of art or carriers of messages etc),

IV. Qualifiers (adjectives [properties], adverbs) for focusing on **individuals** from a class so that the statements containing them can be 'predicated more specifically' to be exposed to test for assessment of their **truth value** [in science] or simply to make them more concrete and/or colourful [in conversation],

At this stage we recall [Korn, 2009, 2013] that 'any part of the world can be viewed in terms of an infinite number of statements one or a few of which is selected to constitute a **model** of a scenario'. The titles in Figure 1. cover the variety of models which have been constructed by humanity over the millennia of existence. 'Religions' and 'beliefs' may be included in contour 6, 'laws and rules' are excluded since they are not about producing models of parts of the empirical world. However, natural language is regarded as the **primary model** in which all other models can be expressed. Specific models are created by living things as the most effective ways to express the 'subjects or topics' of their thoughts.

At this stage we need to introduce a **divergence of development** in the 'systemic view :

First case --- The 'invariants' or concepts are quantifiable leading to **mathematical models**

There is a number of approaches to the 'structural description' of things such as 'systems dynamics' of [Forrester, 1961] which is still in use and 'network analysis of engineering systems' [Korn, 2012]. The mathematical models for both are sets of first order differential equations similar to those used by von Bertalanffy [1950]. The second approach is based on the idea of 'classification of variables' with the intention of unifying the diverse disciplines in engineering and bringing the treatment of technical control systems closer to 'physics'. Perhaps a significant result of this approach although not recognised is the possibility of inclusion of the 2nd law of thermodynamics or **external to internal** energy conversion as an integral part of the dynamics of systems.

The common basis of these approaches is description of examples or **scenarios** in terms of 'natural language', the primary model, from which the **quantitative** aspects are extracted usually leading to a mathematical model. The loose construction of 'influence diagrams' serves as an example.

Second case --- The 'invariants' or concepts are qualitative leading to **linguistic models**

This approach to the 'structural description' of things which is of predominant interest here, is shown in Figure 2. It is developed through :

Meaning preserving linguistic **transformations** to convert a story into **'basic constituents'** of one - and two – place sentences of which complex static or dynamic structures can be constructed in terms of **'ordered pairs'** [representing relations in linguistic networks as stative verbs in steady states] or **'predicate logic statements'** [representing interactions in semantic diagrams as dynamic verbs in dynamic states]. This procedure is called static [X] and dynamic [Y] **linguistic modelling of scenarios** [Korn, 2009, 2013]. **Reductionism** is restored to the 'systems view' [Checkland, 1982].

All this forms the description of an entity or **whole** so as to be capable of producing, or not as the case may be, an '**outcome**' [emergent **novelty]** or change of **physical, mental, emotional** or **intellectual** state affected by **topology, properties/qualifiers of objects** **[**simulation of the dynamics of a scenario**].**

Such a description [for representation of a part of the world or as subject for communication] is referred to as a **model** which can be 'static' [scale model of a ship, gesture, viable systems model etc.] or 'dynamic' which can be manipulated [mathematical, linguistic model] [Korn, 2009, 2012, 2013].

At this stage we recognise :

Context free sentence = Unqualified objects in unqualified relation OR in unqualified interaction, and

Context dependent sentence = 'Qualified' objects in 'qualified' relation OR in 'qualified' interaction which may then be capable of being refuted [Magee, 1985].

Elements of a context free sentence are not anchored within their 'space of meaning'. For example, the sentence 'Person eats' has meaning, we can visualise the action that appears to take place but the action can cover an infinite number of particular instances each of which can be true. So, theoretically the **informatic content** of a context free sentence is zero and the **probability** of its occurrence is 1 if we assume that there is always somebody somewhere 'who eats'. This interpretation conforms to Popper's view of 'what is and what is not science' and to the relation between the logarithm to base 2 of the inverse of probability and informatic content. The logarithm of 1 is zero [Magee, 1985, Korn, 2009, 2013].

In order to convey **information** elements of a declarative sentence need to be anchored to specific points in the 'space of their meaning'. This is done by 'qualifying' the elements or turning a 'context free' into 'context dependent' sentence. A single set of qualifiers for each sentence element locates the element in the 'space of its meaning' at a single location and the sentence expresses **certainty** in the sense that it refers to a single state of affairs true or otherwise. There is no choice and the probability of certainty is 1, thus, informatic content is again zero. For example, 'Person [hungry] eats [quickly]' is such a sentence.

Information is carried as a 'subordinate clause' of special dynamic verbs like 'man **noted** that…..'. The response of a recipient to information input or how information affects his/her state of mind may or may not be **action.** There is no other choice, the decision is limited. To introduce choice we need to vary the qualifiers such as 'Person [hungry, full up] eats [slowly, quickly, in a rush]'. This gives a number of locations in the 'space of meaning' of a sentence element with varying probabilities and informatic content. Choice for a recipient of instances of information or uncertainty has been introduced. Thus, the recipient can make a decision regarding which 'instance of information' he/she will accept and subsequently act or not [Korn, 2009, 2013].

The relationship between elements of natural language and the **empirical concepts** of 'systems science' is shown in Figure 2.

We have introduced the 'basis of GST' which can then be expressed in **operational** terms by means of **linguistic modelling** the scheme of which is depicted in Figure 3. We pursue the 'second case' as being of interest in the present context.

The development is justified as a candidate for a part of GST with 'linguistic modelling' to provide the symbolism of ordered pairs and predicate logic sequences describing static and dynamic structures carrying qualitative as well as quantitative qualifiers. The method is applicable to scenarios with technical, living, human [plants, animals] and natural constituents and can be exposed to at least thought experiment. The structure of the method of linguistic modelling is given in Figure 3. which shows the sequence of preparation of the **same kind** of model for any application, a feature of a GST.

The suggested approach provides a unifying basis for the 'systemic view' and may serve as a 'systems discipline', it is based on accepted branches of knowledge of linguistics, logic, mathematics, computing etc, eminently teachable and is an essential part of **problem solving** inclusive of design which is the second part of GST. Problem solving, the most fundamental activity of all living things, may facilitate the spread of 'systems thinking' in society, education and the professions.

General Systems Theory

Elements	**Function in a sentence**	**Relationship to a part of the world**
Nouns	Subject, Direct and indirect objects	Topic or chosen **initiating** or **affected** objects
Verbs	Stative verb – being Dynamic verb – action	**Relations** **Interactions**, impression
Adjectives	Qualifiers of nouns	**Properties**
Adverbs	Qualifiers of verbs	**Adverbials** of manner, time etc of action
Conjunctions	Joining words, clauses to create arguments, symbolic logic	Relations, complex scenarios AND, OR

Figure 2. Isomorphism between natural language and invariants of systems science

Story/narrative of a scenario in natural language including
those generated by **abstract terms** (when such term is attached to an object)

Meaning preserving linguistic transformations

Homogeneous language of one – and two – place sentences
with qualified constituents (adjectives (dp, ip, ep, cp) and adverbials

<u>Ordered pairs</u> (statics) AND <u>Pairs of predicate logic conditionals</u> (dynamics)
(mathematical model) (logic model carrying mathematics and/or measures of uncertainty)

Linguistic networks, Semantic diagrams
(emergence of outcomes, novelties)

Evolutionary hierarchies, Sequences of conditionals

(ALL united in DESIGN and PURPOSIVE SYSTEMS)

Computing (Prolog ????)

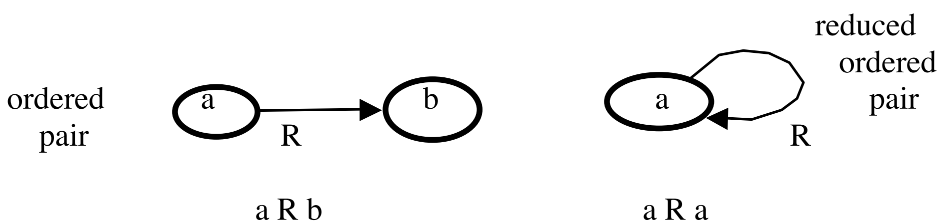
Figure 3. Structure of linguistic modelling

DEMONSTRATION OF LINGUISTIC MODELLING

Static and dynamic linguistic modelling construct models of the large variety and diversity of complex structures of scenarios out of **elementary constituents** rather like ‘bricks’ are used for constructing a variety of buildings. This is the way to produce variety and diversity in natural evolution with novel features to be exposed to the test of survival just as it happens in human activities when products with novel features are invented. Products facilitating convenience, saving labour, increasing effectiveness etc are likely to survive with the systems that use them. Elementary constituents are now introduced.

Static linguistic modelling

$$\text{ordered pairs} = (n_i\ rel_i, n_k) \qquad 1.$$



Vessel (contains) water [systems science]   Vessel (is deep) [conventional science]

Figure 4. Elementary graph or network representation of ordered pairs

<u>**Story :**</u> ‘Top of the table is supported by legs which stand on the carpet’ which is expressed as :

i = 1 = ‘top (is supported by)’, i = 2 = ‘legs (stand on)’ and i = 3 = ‘carpet (is)’ to be cast into the array of eq.2.

$$\begin{pmatrix} n_{11} & n_{12} & n_{13} \\ 0 & \underline{\text{top is supported by legs}} & \text{top is supported by carp} \\ n_{21} & n_{22} & n_{23} \\ \text{legs stand on top} & 0 & \underline{\text{legs stand on carp}} \\ n_{31} & n_{32} & n_{33} \\ \text{carp is top} & \text{carp is legs} & \underline{\text{carp is carp}} \end{pmatrix} \qquad 2.$$

$$\text{number of structural trees} = n^{(n-2)} \qquad 3.$$

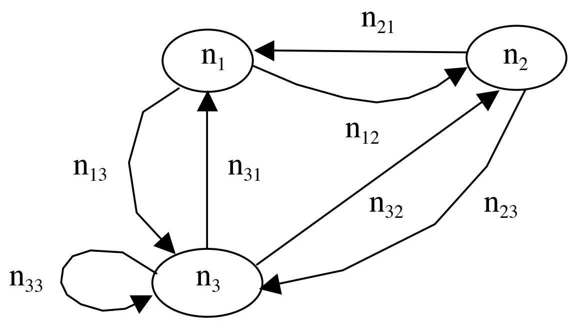


Figure 5. Directed graph representation of eq.2.

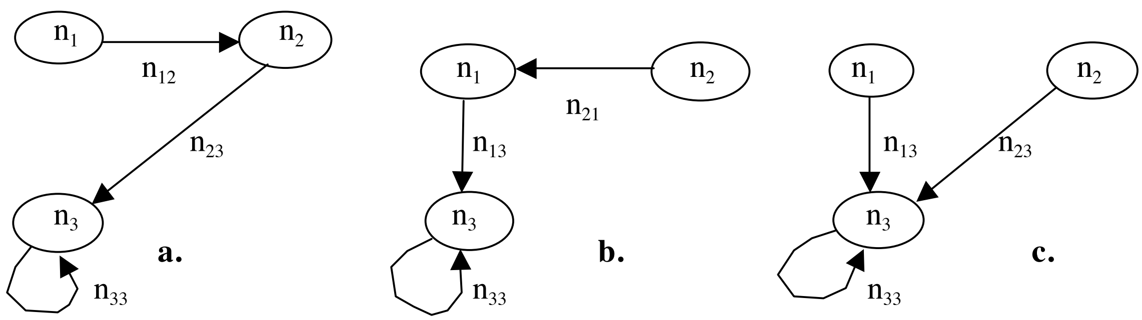


Figure 6. Trees from directed graph in Figure 5.

From Figure 6.a. we can write **:**

n_{12} = 'top is supported by legs'
n_{23} = 'legs stand on carpet'
n_{33} = 'is carpet'

Also, from b.

n_{21} = 'legs stand on top'
n_{13} = 'top is supported by carpet'
n_{33} = 'is carpet'

Also, from c.

n_{23} = 'legs stand on carpet''
n_{13} = 'top is supported by carpet'
n_{33} = 'is carpet'

n =	1	2	3	4	5	………
number of trees from eq.3. =	0	1	3	16	125	……..

For calculation of number of 'trees', see [Korn, 2009]. If n = number of nodes, the **maximum** number of branches in a digraph = n (n – 1) where n – 1 = number of branches in a 'tree'. Hence,

number of 'trees' that can be obtained from n (n – 1) branches is given by

$$C = (n\,(n-1) \text{ times } (n\,(n-1)-1) \text{ times } (n\,(n-1)-2)\ldots)/(n-1)! \qquad 4.$$

n = 5 C = (20 x 19 x 18 x 17)/1x2x3x4 = 4845 where the number of terms = (n – 1).

The actual number of branches < maximum number.

Dynamic linguistic modelling

Story : 'A number of trained and willing girls who needed money, looked for well paid and interesting jobs'

$$dp(1,1) \wedge ip(1,1) \rightarrow in(1,1) \quad \text{and} \quad in(1,1) \wedge ep(1,1) \rightarrow ap(2,2) \qquad 5.$$

To expand with uncertainty inserted for a **one – place** sentence shown in Figure 7. as a **semantic diagram** :

dp(ngirls,1,1,(needmon(badly,100/1.0))) (1.0) ∧
ip(ngirls,1,1,(traid(vhigh,80/0.4, high,70/0.9, low,50/0.3), wilg(st,90/0.8, wk,40/0.5)))
(0.61, 0.43, 0.84, 0.75, 0.62, 0.39) →
(cf of rule = 1, .8, .6, .4)in(lookedfor,ngirls,1,ngirls,1,
(wellpaid(verywell,well),interesting(very,just))) 6.

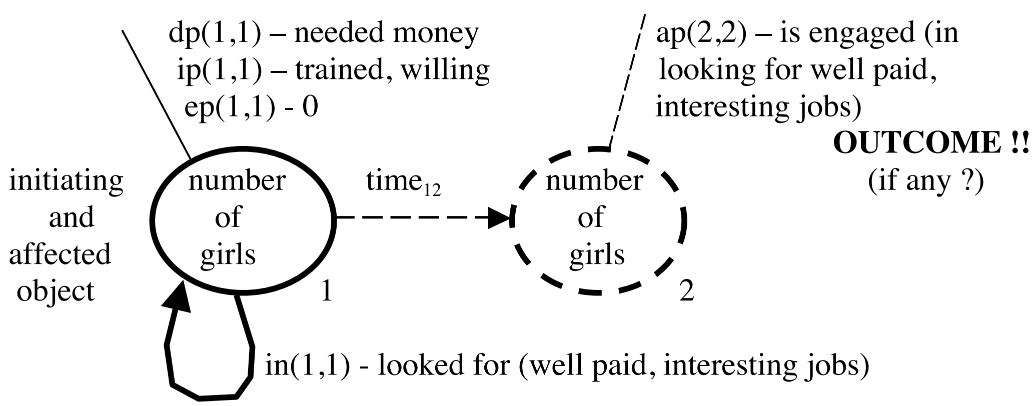


Figure 7. Semantic diagram of a one –place sentence

in(lokedfor,ngirls,1,ngirls,1,(wellpaid(verywell,well),interesting(very,just))) with 24 terms of cf values, 6 for each : ((verywell, very), (verywell, just), (well, very), (well, just)) $\rightarrow$
(1) ap(ngirls,2,2,(engagedinlookingfor (wellpaid, interestingjobs)))(with 24 terms of cf values, 6 for each : ((verywell, very), (verywell, just), (well, very), (well, just)) 7.

A particular instance of eqs.6. and 7. chosen for demonstration is

dp(1,1) (1.0) $\wedge$ ip(1,1) (0.61) $\rightarrow$ (0.8) in(1,1) (0.8 x min(1.0, 0.61) = 0.49) for : (verywell, just)

in(1,1) (0.49) for : (verywell,just) $\rightarrow$ (1.0) ap(2,2) (1.0 x 0.49) = 0.49 for : (verywell, just)

Descriptively using the equivalence between 'uncertainty numbers' and 'words' [Durkin, 1994] :

'If there is a number of girls with (probably) very high training and strong willingness who badly needed money then (may be) they looked for very well paid and just interesting job'.

'If (may be) they looked for very well paid and just interesting job then they (may be) became engaged in looking for very well paid and just interesting job'

which display the objects, properties and their precise role in the scenario.

The semantic diagram representation of a **two – place** sentence is given in Figure 8. using the **story :** 'Postman with good eyesight, sense of duty and care for the job, sorts addressed letters according to code'.

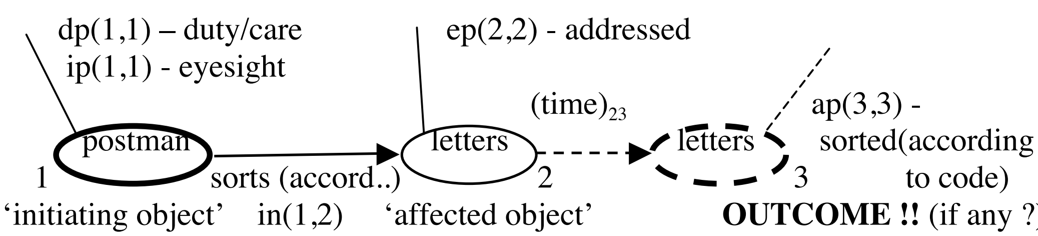


Figure 8. Semantic diagram of a two – place sentence

EXAMPLES OF APPLICATIONS OF 'SYSTEMS SCIENCE'

Having introduced the 'elementary constituents' we present a few simple examples of their application involving 'structures with relations' and 'structures with interactions'.

Scenarios of related objects

Concrete objects –

'There is an apple which appears to consists of core, edible meat, pips and stem covered by smooth skin. They are spatially related.'

Parts of the sentence can be seen to form a pattern :
Parts = pips, core, meat, (smooth) skin, stem,
Apple as a structure = pips (sit inside) core,
core (is inside) meat [edible],
(smooth) skin (covers) meat [edible],
stem (is attached to) core,
[edible] meat (surrounds) core,
Outcome (if any) = emergence of a (bounded whole of an edible object and its 4845 variations of five related objects [Korn, 2009]).

Symbolic objects –
We consider a word such as 'mile',
Parts : letters = m, i, l, e,
Mile as a structure = m (is before) i,
i (is next to) l,
e (is just after) l,
all of which is shown as a 'linguistic network' in Figure 9. [Korn, 2009].
Outcome = emergence of a (word with **meaning**).

The effect of topology on change of meaning.

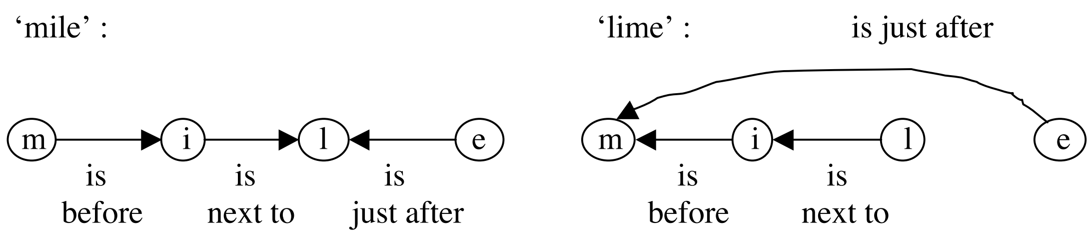


Figure 9. Effect of topology on meaning

Abstract objects **---**
'The audience is dissatisfied with the theatre for a number of reasons in other words there is dissatisfaction (with theatre).'
Parts : stage, audience, actors, scene,
Dissatisfaction with theatre as a structure = stage (partly covers up) scene,
audience (shouts at) actors,
actors (face away from) audience,
which occur simultaneously connected by an **AND** function for an outcome to exist.
Outcome (if any) = emergence of a (feeling).

A scenario of interacting objects

The narrative or story of the scenario : 'There is a farm with land for grazing but in the winter for the cows to be able to give milk, they must eat hay which is delivered to them by the farmer who uses a tractor, from the store to the shed twice a day. The cows are milked every morning by means of machines. Having accomplished these jobs, the farmer is content'. Ignoring 'meaning preserving linguistic transformations' representation as a semantic diagram is given in Figure 10.

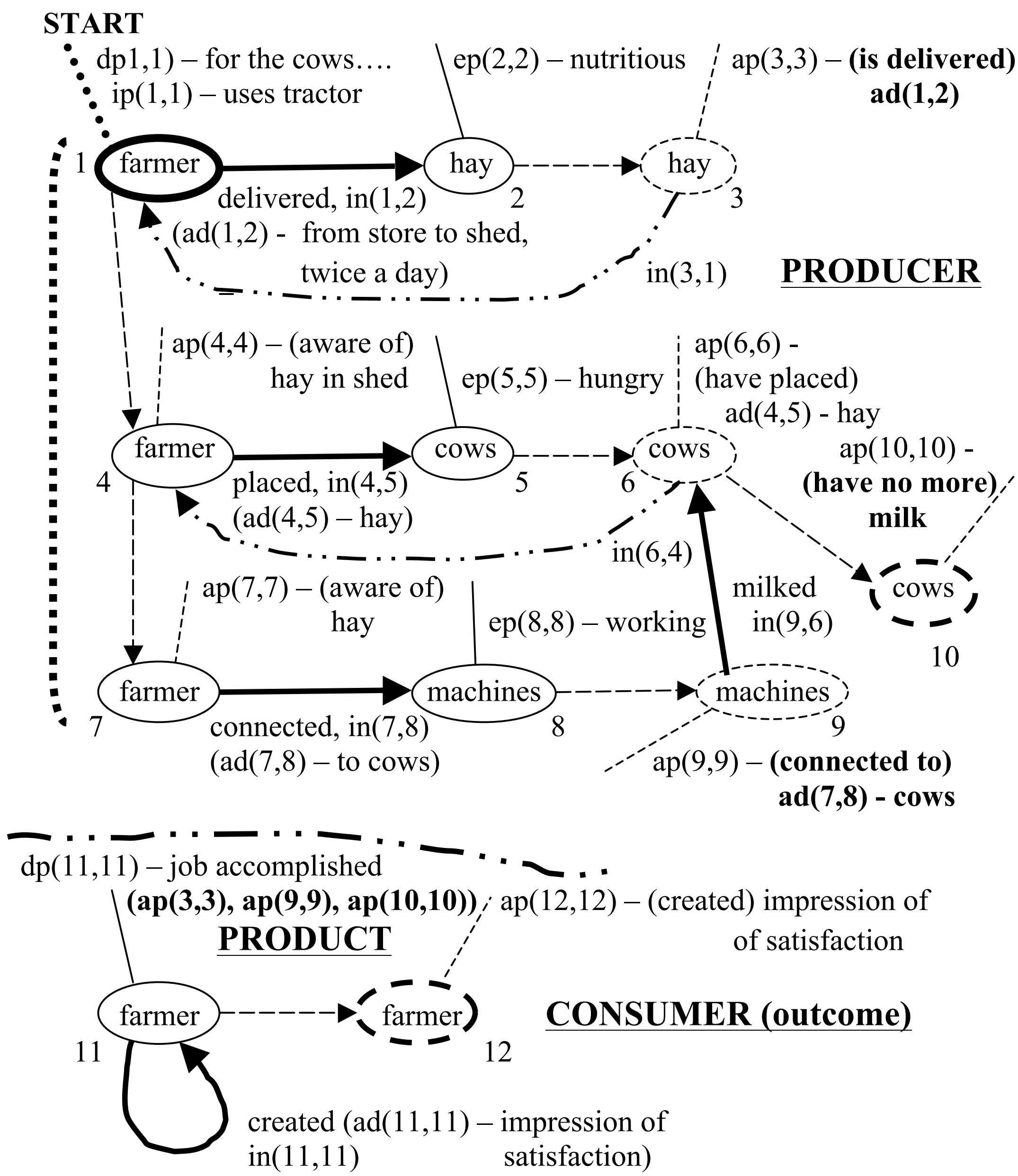


Figure 10. Semantic diagram of the farmer, hay, milk scenario

From Figure 10. we obtain predicate logic sequences which describe the topology of a scenario :

Causal chains : 1. 3,2,1 2. 10,6,5,4 3. 9,8,7 4. 12,11

For causal chain 1.
dp(1,1) ∧ ip(1,1) → in(1,2)
in(1,2) ∧ ep(2,2) → ap(3,3) no more change of state, therefore, object 3 'hay', is an **output**

For causal chain 2.
ap(3,3) → in(3,1) feedback link 'prompts' change of state ap(4,4),
in(3,1) → ap(4,4) **decision junction**
ap(4,4) → in(4,5)
in(4,5) ∧ ep(5,5) → ap(6,6)
in(9,6) ∧ ap(6,6) → ap(10,10) link in(9,6) is assumed to exist, no more change of state, therefore, object10 'cows', is an **output**

For causal chain 3.
ap(6,6) → in(6,4) feedback link 'prompts' change of state ap(7,7),
in(6,4) → ap(7,7) **decision junction**
ap(7,7) → in(7,8)
in(7,8) ∧ ep(8,8) → ap(9,9) no more change of state, therefore, object 9 'machines', is
ap(9,9) → in(9,6) an **output**, link in(9,6) can be generated as ap(9,9) exists

The term 'output' refers to 'output of the product' which together change the state of the 'farmer', the changing object as shown in Figure 10.

For causal chain 4.
dp(11,11) → in(11,11)
in(11,11) → ap(12,12)

Each term in the sequences can be expanded to include **uncertainty**, **graded adjectives** and **mathematics** [Korn, 2009, 2012].

Development of product

At object 11 we have the 'product' as produced by the 'producer' systems as follows

ap(3,3) --- [nutritious] hay (is delivered, twice a day, from store to) shed (n_{34})
ap(9,9) --- [working] machines (are connected to) cows (n_{51})
ap(10,10) --- [hungry] cows (have no more) milk (n_{12})

which results in a disjointed linguistic network as depicted in Figure 11. by the continuous directed lines. A disjointed network cannot represent a **product** because this would mean a **disjointed product** which cannot function so at least another ordered pair should be added which can be, for example, 'hay (is eaten by) cows (n_{31})' and added to the network by the dotted line.

Addition of an 'ordered pair' to create a joined linguistic network requires an 'additional producer system'. A need that has come out of the **analysis of the scenario**.

We can calculate the number of groups of ordered pairs in a digraph which for 'n = 5',

(20 x 19 x 18 x 17)/(1 x 2 x 3 x 4) = 4845. These are the candidates for 'trees' or 'bounded objects' of which one just mentioned functions as the **product** in this problem.

Each 'ordered pair' in a linguistic network such as shown in Figure 11. has to be produced by a 'producer system' as in Figure 10. in accordance with the prevailing algorithm. Thus, we can use the number of 'ordered pairs' in a scenario as a 'measure of complexity' of that scenario as given by eq.8.

$$\text{measure of complexity} = \text{number of ordered pairs} \qquad 8.$$

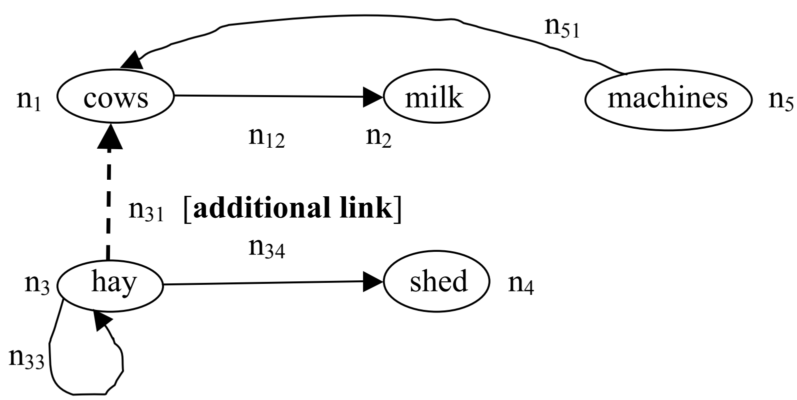


Figure 11. Linguistic network of 'hay/cows'

Here we are concerned with **business science** (finance, accounting, law, marketing and so on) with a story as a continuation of the narrative of the scenario :

'The herd of cattle consists of 56 cows each eating 15 kg of hay a day during winter time assuming there is no grass and gives 18 litres of milk a day. The price of hay is £250 a tonne. The question for the farmer is --- If the winter lasts 90 days what is the minimum selling price of milk to break even ???'

Mathematical model : Total cost of hay is 56 x 0.015 x 250 x 90 = £18900 from which the minimum selling price of milk 18900 = 56 x 18 x 90 x price which is about £0.2 per litre.

GENERAL PURPOSIVE SYSTEM

The basic notions suggested in section 'BASIS OF GST' lead to the development of 'linguistic modelling' of scenarios as demonstrated in section 'DEMONSTRATION OF LINGUISTIC MODELLING'. In section 'EXAMPLES OF APPLICATION OF 'SYSTEMS SCIENCE' a **social system** is considered demonstrating the elements of a 'purposive system'. Based on this 'system' we can say :

Change of existence of parts of the world : 'Any part of the world can be seen to change as a result of activity by 'sets of objects in informatic and/or energetic interactions operating in an algorithm [the **producers**] intended to create or to destroy a physical, intellectual/mental or emotive **product** the function of which is to induce changes in individuals (natural, artificial, living, social) [the **consumers]** for their benefit or otherwise'. Figure 12. is a diagrammatic representation of this statement.

Change of state due to **chance** takes place when the feedback links are removed.

Figure 10. although uses a single feedback loop, is a particular case of the general purposive system in Figure 12. details of which are described in [Korn, 2009, 2013]. Any living individual operates in accordance with the scheme in Figure 12. for the production of a **product** leading to a 'change of state'. However, in general any individuals inanimate or animate '**aggregate** either by chance or in accordance with a purpose to contribute functionally but modulated by emotions, prejudices etc, when appropriate, to the working of the resulting aggregation so as to produce novel/emergent features [at static state] or an outcome [at dynamic state] which an individual cannot produce on its own'.

When an individual is living, in particular human, aggregations produce **social systems** for the production of outcome. For example, 'lions aggregate into a pride for hunting to kill', 'a squad of soldiers commanded by a sergeant [an aggregation] can fire a volley [modulated or spoilt if there are conscientious objectors] at the enemy but to surround the enemy needs three squads commanded by a lieutenant [a further aggregation]'. The 'cells', 'organs', 'body' hierarchy is common.

The basic 'units of aggregation' vary with the level of hierarchy. We use 'elementary constituents' as described in 'DEMONSTRATION OF LINGUISTIC MODELLING' of which complex structures can be built up. The practice is widespread in nuclear physics and chemistry. Searle [1984] used the idea to describe the connection between 'brain' and 'mind' based on the connection of global features like 'solid', 'liquid' and 'gas' and the molecular structure producing them.

Aggregation is the basis of **hierarchy,** both 'evolutionary' and 'organisational' [Korn, 2013] as we have seen in the 'soldiers' example. Here 'one squad [novel feature : volley]' aggregates into 'three squads [novel feature : surround]' constitutes 'evolutionary hierarchy' and 'sergeant' into 'three sergeants commanded by a lieutenant' forms 'organisational hierarchy'.

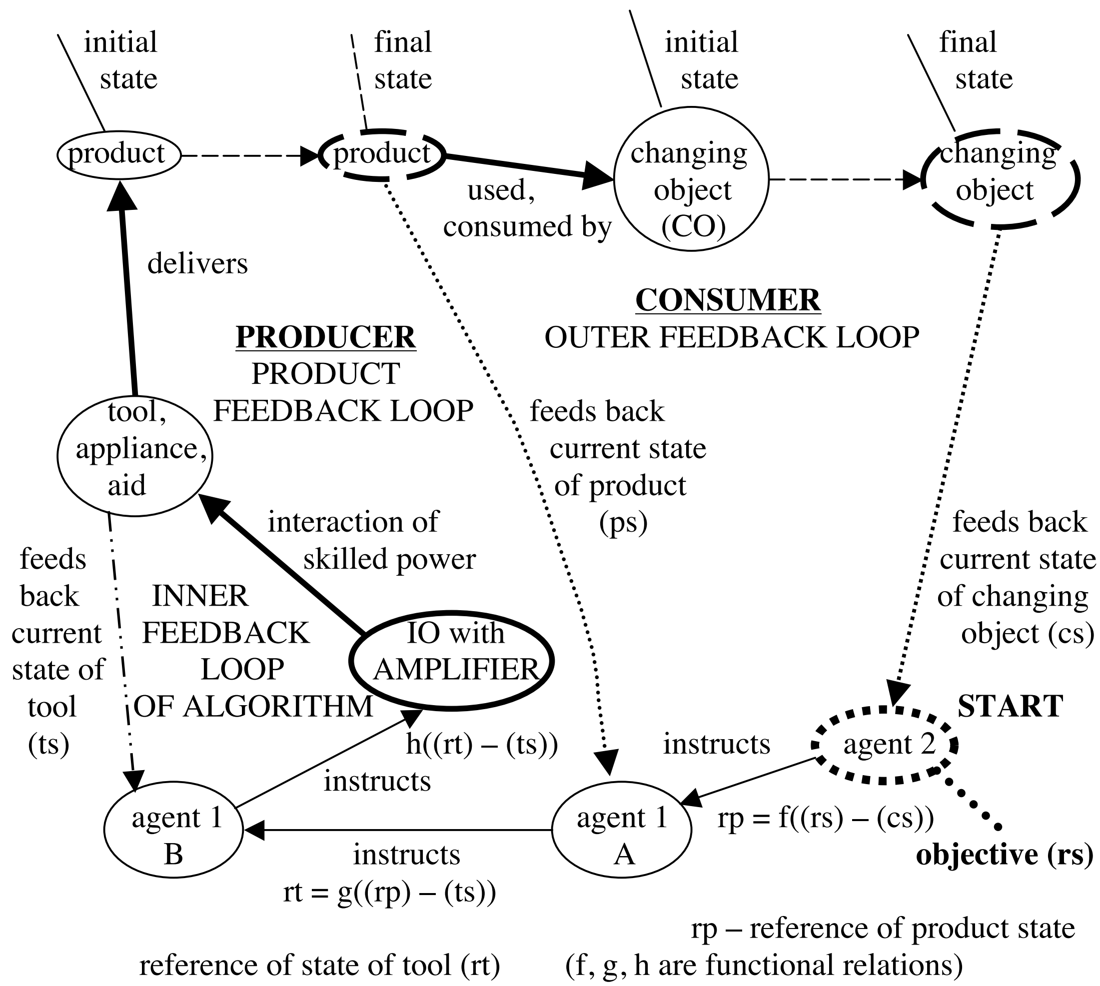


Figure 12. Diagram of production and consumption as a purposive system

BASIC STRUCTURE OF POBLEM SOLVING

The analytical apparatus of 'linguistic modelling' with its empirical basis described so far may be used in problem solving and design. The basic idea of problem solving is shown in Figure 13. It consists of a 'problematic IS' which usually takes a minor or major 'leap of imagination' to recognise, alleviation of this state by an envisaged 'final' or 'previous' state and the purposive systems or **prototypes** depicted in Figure 12. which are the means of transformation from IS to FS or PS. The identification of IS and recognition of FS or PS is subject to debate. Design or the **designer** makes use of 'systems science' in creating the prototype for the transformation of a problematic IS into FS or PS if such prototype can be agreed on and unless it already exists [Korn, 2009, 2012, 2013].

From Figure 1. we have the impression of generality of the means of 'intellectual' problem solving devised by men/women of science in case of 'conventional science', for example, for solving ‘physical’, ‘mental’ and ‘emotional’ problems incurred by **living things**. This idea gives rise to the statements as follows :

1. The world may be seen as a conglomeration of **related** OR **interacting** things and ideas in static or dynamic state respectively **any chosen part** of which may be regarded by a living in particular human being as a candidate for change. Thus, an **object** to be **changed** (concrete (chair) or abstract (transparency (of the window))) can be selected with features any of which is perceived to fail to fit an **expectation** and as such is regarded to be in a **problematic initial state**.

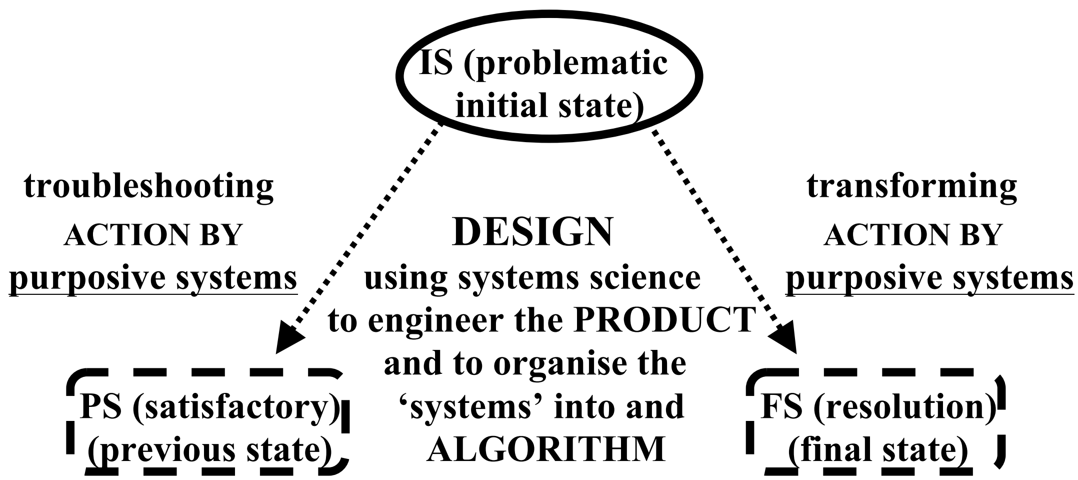


Figure 13. Structure of problem solving

2. Problem solving in the **living sphere** is as common as **gravity** is in the material sphere.

3. The possibility of **unlimited change** acts as the breeding ground for innovation, source of **novelty,** exercise of human ingenuity and so on.

4. Based on the formal structure of Figure 13. **any change** may be seen as a process of problem solving although an IS may not be perceived as problematic through any of its **physical, mental, intellectual or emotive** properties.

CONNECTION BETWEEN ‘CONVENTIONAL’ AND ‘SYSTEMS’ SCIENCES

There are two branches in Figure 1. headed by contours 3 and 4. We demonstrate the connection between these i.e. how the qualitative/quantitative and structural views of parts of the world can be seen tied into one scheme. We consider simple examples to see the basic idea.

1. There is a flat table top with length [a] and width [b] at right angle to each other.

This is represented as a linguistic network in Figure 14.

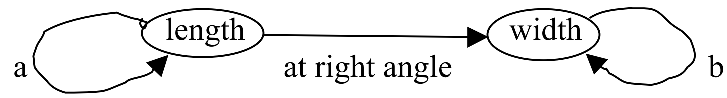


Figure 14. Linguistic network of ‘table top’

From Figure 14. we note that the ‘qualitative properties’ of the theoretical object, table top, are carried by the self-loops as indicated in Figure 4. and its ‘structural description’ is given by the directed line representing the **relation** between the properties. Thus, we can express the relation as an ‘ordered pair’:

‘[a in units of cm] length (is at right angle to) width [b in units of cm]’

Each property is quantifiable and qualified by the symbols next to the self-loops representing the concepts ‘length’ and ‘width’ with the appropriate ‘units of length’ assigned.

The mathematical model of ‘area’ is given by : ‘area = a times b’ 9.

which is not a ‘static model’ like the scale model of a ship but can be manipulated.

2. There is an ‘apple’ which looks red and ripe on the outside but rotten in the core.

Assuming this to be the same ‘apple’ considered in section ‘EXAMPLES OF APPLICATION OF ‘SYSTEMS SCIENCE’, following the relations, we represent the ‘apple’ as a linguistic network shown in Figure 15.

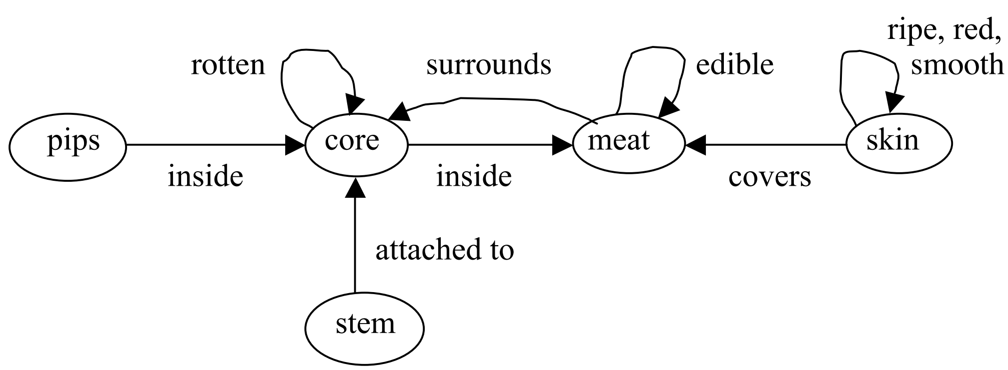


Figure 15. Linguistic network of ‘apple’

In this case, a 'conventional scientist' would be looking for relations between the properties or adjectives attached to parts of the 'apple'. There could be a relation between being 'rotten' and grades of 'ripe' such as 'overripe'.

3. We have an 'electrical capacitance' consisting of two, flat plates of area of 4 cm^2, each joined to one side of the medium with permittivity of 100 F/m and thickness of 0.5 cm. This device is shown as a linguistic network in Figure 16.

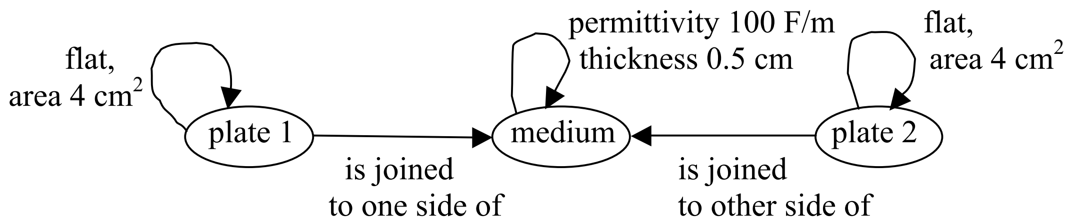


Figure16. Linguistic network of 'electrical capacitance'

There is a well known relation between the properties carried by the 'self-loops' [Korn, 2012].

Although we have used simple, concrete, technical examples the method is likely to general.

CONCLUSIONS

We have outlined an approach to GST based on empirical generalisations which leads to the symbolism of 'linguistic modelling'. The approach is based on branches of existing knowledge such as linguistics, logic, mathematics, network theory etc. It is highly teachable and can introduce studies of processed natural language into curricula as a symbolism for modelling in addition to mathematics. It acts as an aid in design and can be used in 'systems and product' engineering. All this is subject to debate, software development and more extensive applications.

GST as seen here consists of **two** integrated parts :

I. Application of the basic ideas in 'BASIS OF GST' to the **analysis** of scenarios as shown in 'DEMONSTRATION OF LINGUISTIC MODELLING' and in 'EXAMPLES OF APPLICATIONS OF 'SYSTEMS SCIENCE''. The intention is modelling 'products' and 'systems' for the occurrence of **hierarchies** and **outcomes** i.e. **emergence** of novel features [statics] and **simulation** for changes of state of chosen objects [dynamics] [Korn, 2009, 2012, 2013]. This idea is pervasive throughout the spectrum of natural, technical and living things. In other words :

X. Static linguistic modelling generates a choice based on **linguistic networks** for structures with emergent properties to facilitate survival of products and, thus, the systems carrying them.

Y. Dynamic linguistic modelling states the conditions based on **semantic diagrams** for the existence of outcomes. A condition can be translated into practice by selecting objects, interactions and qualifiers from people and machines. These points are seen in Figure 10.

The ‘analysis’ part of a GST needs to satisfy the conditions :

1. It conforms to the ‘scheme’ of empirical research described in ‘MEANING OF GST’,

2. A particular instance or example is constructed from a combination of ‘elementary constituents’ as introduced in ‘DEMONSTRATION OF LINGUISTIC MODELLING’,

3. It should be applicable to problem solving, design or synthesis.

II. Synthesis of ‘products’ and ‘systems’ along the lines outlined in ‘BASIC STRUCTURE OF PROBLEM SOLVING’ and depicted in Figure 13. The methodology of design follows the following steps based on the structure of purposive system shown in Figure 12. [Korn, 2009, 2013] :

1. Identification and statement of ‘problematic initial states’ followed by consistent, **desired** final states, physical [existence of a tunnel under the river], mental [satisfaction of the client with the service], emotive [relief of anxiety] or intellectual [agreement is signed between the warring fractions] .

2. Identification of and agreement on a range of products [energy, information (impression or informatic content), use or meaning flow]. Generation of **requirements** to narrow the range of products leading to an assessment of the extent to which the products can accomplish changes of state. This depends on matching, size and causal relation between product and changing object. Selection leads to the construction of the linguistic network of ‘ordered pairs’ of a product.

3. Based on linguistic network, construction of the **algorithm** of ‘systems’ for producing and/or delivering the ‘product’ to the changing object leading to ‘semantic diagrams of predicate logic sequences’ and simulation of the **prototype**.

In addition we suggest the following points for further consideration :

i. The structure of purposive system in Figure 12. is regarded as the **fundamental** unit of activity by a ‘living thing’. As such it acts in the same role in **social systems**. A social system is a collection of fundamental units or individuals each performing a specific task in accordance with the scheme in Figure 12. modulated by interests, emotive issues, prejudices and so on.

ii. We have introduced a view of ‘connection between conventional and systems sciences’ which aims at creating a unity of the scientific endeavour.

iii. There are points for further development in both : the ‘systems science’ and ‘problem solving’ parts of GST such as further elucidation of the question of hierarchy, software development, explicit introduction of time variations in dynamic simulation and so on.

iv. Generality of the ‘systemic view’ as outlined here is offered so as to :

Supplement the currently practiced ‘speculative view’ as referred to in the ‘INTRODUCTION’,

Suggest a set of **fundamentals** for the ‘systemic view’, thus, reducing the fragmentation in this field lately manifested in the appearance of the idea of **‘esystem’** or the application of ‘computerised systems’ to real world problems,

Be used as a basis for a **teaching scheme** and as a means of influence of thinking in branches of **society**.

Generation of ideas or speculation is essential for invention, expressing views, leading to objectives for purposive systems as depicted in Figure 12. and so on. To recognise this aspect of human intellect, it has been added to ‘Aristotle’s four causes’ as the fifth cause which all together embraces all intellectual activity [Korn, 2013].

The question of ‘cause and action’ in context of predicate logic statements in dynamic linguistic modelling needs further consideration [Korn, 2013]. There is a very strong correlation between ‘cause and action’ in natural scenarios such as ‘If there is an elastic member [force source of sufficient strength] (cause) which is applied to a body with mass (action), the result is a body [with acceleration]’. The antecedent is a sufficient condition for the event to take place in the consequent.

However, in living in particular human activity scenarios action is subject to ‘decision’. For example, ‘If there is a man [angry and with sufficient force in his arm](cause) hits his neighbour [a timid person](action) which results in the latter [becoming hurt]’. There is a weak correlation between ‘cause and action’ : no matter ‘how angry the man is he may decide not hit [he remembers the consequences of such action]’.

This sentence describes a fixed scenario but introduction of certainty factors attached to ‘graded adjectives’, mathematics of differential equations and ‘informatic content’ discussed briefly in ‘BASIS OF GST’ introduces more **uncertainty,** scope for decision making and exploration of human fickleness, exercise of will, prejudices, caprices etc.

If the ‘systems phenomenon’ is regarded as **all pervasive** then GST as suggested here may be seen as an approach to match this **generality** due to its use of basic, empirical generalisations and the symbolism of ‘processed natural language’ of stories of scenarios, the primary model of equal generality. It follows that GST is applicable to scenarios with living, in particular human components exhibiting will, caprices, ambitions, prejudices etc which limit their repeatability and reduces their predictability. However, the ways is open to **organised speculation** in the light of an empirical theory**.**

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