PROBLEM SOLVING AND SYSTEMS SCIENCE

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ABSTRACT

The structure of problem solving inclusive that of design thinking is outlined. The generality of change of physical or mental states of chosen empirical objects is stated. Any one of such states may be identified subjectively by an observer as a problematic initial state. This kind of state can then be reverted either into a satisfactory previous state from which it has arisen, or turned into a final state which is regarded as its resolution. Changes of state are caused to occur as a result of chance or by the action of purposive systems. The structure of such systems consists of interacting components of related elements. The components perform specific functions the performance of which may be subject to will, feelings, emotions or instinct in case of living in particular human components. The components are arranged in specific topology, all this is a matter for systems science.

Static and dynamic linguistic modelling is regarded to form the analytical basis of systems science and that of a design methodology. This methodology acts as a guide in creating symbolic models of purposive systems or prototypes which perform so as to transform a problematic initial state of a chosen object either into a satisfactory previous state or a final state. Problem solving and systems science are thus form a unique whole.

INTRODUCTION

Living things in particular human beings in the course of their every day lives observe by means of their sense organs, features or states of parts of the world including their own bodies and minds or 'central nervous systems' [Johnson-Laird, 1988] . In many cases, such states may pose :

1. A **perplexity** which can lead to a question, for example, when we are confronted with :

I. A 'descriptive or cross word puzzle, the question is 'how do we solve it ?'', or
II. An 'expression of an idea like 'eating too much fat can cause heart problems', 'heat flow is like the flow of a fluid of great subtlety' which begs the question 'is it true ?''

2. A **dissatisfaction** because a feature or state of an object is perceived to fail to fit an expectation which can also lead to a question, for example, when 'a person is running a high temperature', the question is 'how can such a state be altered'' ?

We usually try to answer these questions or devise 'means' which can provide the answers until the perplexity has been alleviated or the feature or state is seen to fit the expectation.

We conclude that we are considering 'problematic scenarios' which can be seen to consist of three parts as shown in the scheme in Fig.1. The 'problematic initial states' are transformed into 'satisfactory or resolved final states' by **'alternative means'** of which one which appears the most attractive may be selected for the accomplishment of the transformation.

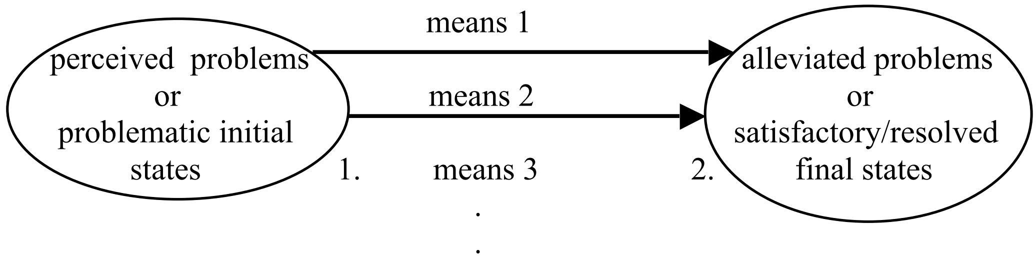

Fig.1. Scheme of problematic scenarios

Although attention is paid to the identification of initial and final states, workers in the 'problem solving' literature are mostly preoccupied with generating ideas or concepts for the realisation of 'alternative means' using 'methodical and/or creative thinking' [De Bono, 1967, George, 1986, Adams, 1987, Anon, 2009].

We conclude that :

1. Although the scheme in Fig.1. is clear and may appear to be precise, for it to emerge as such from an analysis of a scenario may require debate, discussion and agreement on the part of those interested in the scenario. This is especially the case when we are dealing with living in particular human activity scenarios which may be described as a 'mess' [Ackoff, 1999].

2. The transformation from initial to final state is not necessarily one to one, it can be one to more than one calling on more than one 'alternative means'. For example, initial state (problematic) = 'person is sitting (uncomfortably)' can be transformed into a final state (satisfactory/resolved) = 'person standing (comfortable)' or 'person lying down (comfortable)' which both appear to alleviate the problematic initial state.

3. We note that 'alternative means' have direction : they act from initial towards final states or from a source of problem towards its resolution.

4. Blobs 1. and 2. in Fig.1. may enclose a single object, empirical or theoretical [Korn, 2009] carrying a problematic feature such as 'this shoe does not fit' but an 'alternative means' is put into practice by a 'purposive system', it takes place by 'chance' only in nature [Nise, 2008, Korn, 2010a, 2011, Korn, 2012].

5. In many cases purposive systems acting as 'alternative means' already exist. For example, transformation from initial state (problematic) = 'person is sitting (uncomfortably)' into final state (satisfactory/resolved) = 'person is standing (comfortably)' normally takes place using 'leg muscles, nerves and brain generating and carrying information for governing power [Korn, 2010b] '. However, when such systems do not exist they must be **designed**. For example, the transformation as before when 'the person who is sitting (uncomfortably)' is 'disabled' may involve the action of a mechanism operating as part of a purposive system. Accordingly, design thinking [Hubka, Eder, 1996] is regarded as part of problem solving.

Purposive systems consist of functional objects arranged in specific topology and as such belong to the realm of 'systems view' of parts of the world or 'systems science' [Korn, 2010a, 2011]. Living things operate in accordance with purpose in their every day lives and in being engaged in creating small and large projects, they are as prevalent in the living sphere as gravity is in the material world. Although purposive systems occur in nature and in technology, such man made systems may need to be designed for the role of 'alternative means' as indicated in Fig.1. Thus, we see how the activity of 'design' as part of 'problems solving' meets the subject matter of 'systems science'.

Brief historical background to systems science

The term 'system' refers to a 'collection of **concrete**, **abstract**, **symbolic** or **imaginary** things that can be considered as a set of related objects or properties forming an entity recognised as a whole possibly yielding an outcome which can be referred to as 'emergent property'' [Checkland, 1982, Korn, 2009]. The term has been used sporadically over the past like '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, usually when a complex activity is perceived. The term came into wider use with the development of servomechanisms, or control systems during the 2nd WW for directing antiaircraft guns, for example. Concurrently and later topics like 'operational research', 'cybernetics', 'systems dynamics', 'viable systems' etc emerged. Strands of thinking like 'interpretive, emancipatory, critical approaches', 'chaos theory', 'complexity science', 'reflexivity' and so on have opened up (Jackson, 2000, McMillan, 2008).

Thinkers like von Bertalanffy and Boulding [Bertalanffy von, 1950] 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' as some kind of a super theory. They rejected the relevance of 'conventional science of physics' in its **entirety** which with hindsight was a mistake. Its content may not have been entirely relevant but its attitude of problem solving and its methodology could have been retained together with domain knowledge of entities which enters the 'systemic view' at specific points [Korn, 2009, 2011]. Developments aimed at a general systems theory were made (Klir, 1969, Yi Lin, 1999) but lately attempts along this line were abandoned. As an alternative, evolution of what is claimed 'systemic thinking or systemic view' has been going on along highly speculative lines of diverse topics interspaced by methods of modelling and attempts at systems design most with ill defined, vague concepts and difficult to apply to parts of the world (Checkland, 1982). A vast number of publications has appeared, conferences and courses at university but not at **school** level have been held. Control theory has been widely recognised as a separate discipline and had always been a problematic issue in engineering education which was recognised much later (Towill, 1975, Korn, 2009). The essentially **universally applicable** systemic view has become fragmented into information systems, social systems, soft/hard systems, control and computer systems and so on. And the trend continues unabated.

The systemic view of concrete, abstract, symbolic or imaginary things **related** or **interacting** within a specific **topology** is **empirical, indivisible and pervasive**. If this assertion is true then the **QUESTION** arises as to why 'systems' has not been generally recognised as a way of viewing parts of the world and why it is not taught as a discipline at school level continuing to higher education just like physics, chemistry, geology and so on.

An answer may be given as ---

1. There is no ***recognised and accepted*** set of empirical, domain independent **concepts** which underlie the systemic view and regarded as fundamental appears to exist as can be concluded from the discussion above. The systemic view is a collection of interesting topics **without organising principles**.
2. There is no ***recognised and accepted*** method of translation of such concepts into a **symbolism** for expressing them in operational terms so that **models** testable at least by thought experiments can be constructed for solving problems of analytical and design flavour at levels varying from school to postgraduate.

The development of static (concerns related objects and properties) and dynamic (concerns interacting objects) **linguistic modelling** (using the symbolism of processed natural language of 'sets of ordered pairs' and 'predicate logic sequences' carrying uncertainties and mathematics) is intended to provide these concepts and symbolism. They are firmly rooted in branches of existing knowledge and may serve as the basics of the 'systemic view' which can then be turned into 'systems science' (Korn, 2009, 2011). An approach which is subject to debate and applications to real world problematic scenarios.

The **objective** of this paper is to outline the structure of problem solving leading to the application of purposive systems as its constituent and to introduce their design as prototypes through a design methodology which uses static and dynamic linguistic modelling.

STRUCTURE OF PROBLEM SOLVING

A problematic scenario is regarded to have a 'selected changing object' carrying a feature or state which is perceived to cause **dissatisfaction** as mentioned at the start of the INTRODUCTION. This line of problem solving may be seen to consist of **'design thinking'** leading to the production of a purposive system or 'alternative means' called the **'prototype'** which acts so as to remove dissatisfaction.

Structure of design thinking

We have already alluded to the generality and subjectivity of problem solving at the beginning of the INTRODUCTION which is summed up in Remark 1, in the first of five parts of this section.

1. Remark 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, a **changing object** (CO) (concrete (chair) or abstract (transparency (of the window))) is 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 or current state** (IS)'.

Recognition of the possibility of unlimited change is the basis of innovation, invention of devices and that of evolution of intellectual movements like the appearance of 'postmodernism'. Such evolution is prompted by changes in shapes, colours and structures of objects.

Objects in states problematic or otherwise are recognised as part of a **scenario**, simple or complex. For example, 'this (chair) is in my way', 'the (channel) has no tunnel under it', 'the (calorific theory) of heat is unsatisfactory', 'this (car) is going too fast', 'the (bed) stands next to the wall', '(some people) create riots', 'the (boy) seems to feel restless', 'the (reliability of this engine) is not high enough', '(I) am disappointed', 'the (leaves) of the plant are not facing the sun', 'the (hungry lion)' is about 50 m from the antelope', '(church sermon) is not yet prepared' and so on endlessly.

The noun phrases, the subjects of the sentences in brackets name the selected changing objects and the predicates or comments describe their IS. A comment may be regarded as the descriptive **property** of the noun phrase. Thus, the subject – predicate form of natural language is a representation or model of a scenario [Burton, 1984, Korn, 2009]. A living thing in particular human acts as the 'agent' who having **elicited** a CO with IS in a scenario may perceive it as **problematic**, or not, which is an entirely subjective matter. He/she can in many cases express CO with IS in symbolic terms and may decide to take action [Korn, 2010a, 2011].

2. The **state** of an object exists in time as well as in space. It has a **previous state** (PS) regarded as **satisfactory** from which it has arisen through a **change of state**. The current state can also change into a **final state** (FS) if through nothing else but deterioration. This triad of PS, IS and FS is repeated endlessly. However, in a design context we regard IS (the perceived **problematic state**) as prevailing at **present**, PS existed in the **past** and FS is to be achieved in the **future** and regarded as a resolution of IS.

The scope of changes of state is restricted by :
Remark 2. 'Change of state of a changing object is subject to the condition that the properties of end states are **consistent**. A 'yellow wall' can be turned into a 'blue wall' but there is no process that could turn the same into a 'warm wall'.

3. Changes of state are 'caused' :
Remark 3. 'No change of state expressed as a **property** can take place by itself. Action is required for the accomplishment of a change arising either by 'chance' or as a result of 'purpose' and is subject to **will** in case of beings with central nervous system'.

Thus, we can say that

$$(\text{cause})_{\text{from p to i}} \text{ acts so as to result in } (\text{change of state})_{\text{from p to i}} \qquad 1.$$

$$(\text{cause})_{\text{from i to f}} \text{ acts so as to result in } (\text{change of state})_{\text{from i to f}} \qquad 2.$$

The term 'cause' refers to any state or change or event, concrete or abstract, which appears to prompt or to produce an 'effect' through a change of state [Hospers, 1978]. According to Remark 3. a **cause is executed by action** attributed to chance or taking place in accordance with purpose.

Design thinking is about :

A. Formulating a PS (satisfactory) or a FS (resolution) so that either can be regarded as a solution or alleviation of an IS (problematic),

B. Investigating, eliciting or debating the causes in eqs.1. and 2. as agents of change. Further to eqs.1. and 2., there are two ways in which **cause can be brought about by action** can lead to resolution of an IS (problematic) :

X. $(\text{cause})_{\text{from i to p}}$ acts so as to result in $(\text{change of state})_{\text{from i to p}}$ 3.

Y. $(\text{cause})_{\text{from i to f}}$ acts so as to result in $(\text{change of state})_{\text{from i to f}}$ 4.

In words :

I. Troubleshooting or detecting a root cause
In order to achieve a resolution of the problem we discover the causes which are thought to have transferred PS (satisfactory) to IS (problematic) in the first place as in eq.1. followed by remedial **action** to reverse IS (problematic) to PS (satisfactory) as in eq.3. For example,

IS (problematic) = '(the car) stopped running',
PS (satisfactory) = '(the car) was running',
Possible causes = 'fuel to engine stopped', 'no ignition of fuel', 'the devil interfered' etc,
Select the 'root which may turn out to be true, cause' = 'fuel stopped',
Take action = 'restore fuel supply'.

In practice performing this sequence is not always feasible : For example,

IS (problematic) = '(the grass) is covered by leaves fallen from nearby trees',
PS (satisfactory) = '(the grass) was free of leaves',
Possible causes = 'wind blew down leaves', 'men shook trees', 'a fairy threw the leaves',
Select a cause = 'wind blew down leaves',
Take action = 'restore leaves on to tree branches' which is not possible.

II. Transformation or selecting an appropriate cause
In order to achieve resolution of the problem we select an FS (resolution) to IS (problematic) then we discover the causes which can transform IS (problematic) into FS (resolution) as in eqs.2., 4. followed by remedial **action** to effect such transformation. For example, following the 'leaves problem'

FS (resolution) = '(the grass) is not covered by leaves',
Possible causes = 'leaves have been swept up', 'wind has blown leaves away',
Select a cause = 'leaves have been swept up',
Take action = 'employ gardener to sweep up leaves'.

In both cases selection of PS and FS in relation to IS is governed by the consistency condition in Remark 2.

As a further illustration we consider the following example : 'People (CO) who are healthy (PS (satisfactory)) are bitten by mosquitoes and become ill (IS (problematic))' which is in the form of eq.1.

Following 'Troubleshooting' I. : To get from PS to IS --- Possible causes = 'bitten by mosquitoes', 'healthy people have been in contact with ill people', Select the 'root or true cause' = 'bitten by mosquitoes', To get from IS back to PS --- Take action = 'exterminate mosquitoes so that people do not get bitten',

Following 'Transformation' II. : To get from IS to FS --- FS (resolution) = '(people) are not ill', Possible causes = 'antidote has been applied', 'miracle has happened', Select a cause = 'antidote has been applied', Take action = 'to take people to a doctor who will apply antidote'.

In both cases change from IS (problematic) into PS (satisfactory) or FS (resolution) is accomplished by **selecting** a particular **cause executed by action** which is intended to be used for accomplishing this task. This results in a single **problematic issue** (PI) with a single cause or action which defines the **direction of further design thinking**.

PI = CO + IS (with selected cause/action) 5.

C. The execution of cause to accomplish the change as in eq.5. either by intuition or inspiration or following methodical thinking is done by the **'product + purposive system'** mechanism driven by the **objective** i.e. the envisaged PS or FS. The construction of a scheme for this mechanism is the **primary task of design thinking** [Korn, 2009].

4. We need to make a few remarks concerning the 'Structure of design thinking' so far'.

I. In eq.1. the cause that takes PS (sat) to IS (prob) is :
Given by the state expressed as a phrase with property of object carrying IS (prob). For example, 'john (object) is poor (IS (prob)) because he is unable to find work (cause)', or
Generated by another object and is described by a phrase with a property carrying IS (prob). For example, 'john (object) is poor (IS (prob)) because there is widespread unemployment (cause) in the town where he lives (another object)'. PS (sat) does not have to be explicitly stated.

II. In the examples above it so happens that PS (sat) was the same as FS (res) but this is not necessarily the case. For example, 'the rudder of a ship is in position 1., PS (sat), which is then turned to position 2., IS (prob), which is then again moved to position 3., FS (res) or Transformation. To move it back to position 1. would be Troubleshooting.

III. Troubleshooting occurs when a PS (sat) needs to be restored from an IS (prob) usually because of the presence or lack, of something like 'poison' or 'fuel'. Transformation occurs when a new state, FS (res), is needed to replace an IS (prob). Action to remove a 'presence' or to restore a 'lack' is carried out by a **purposive system**.

5. There are **two modes of achievement** of either PS (satisfactory) or FS (resolution) :

1. When having formulated A. and B., C. (the product + purposive system) exists. For example, in the simple scenario 'this (chair)(CO) is in my way (IS) and 'I want the chair moved to where it was (PS as objective), I can pick up the chair and move it where it was (cause : product + purposive system)' where it is no longer in my way (PS)''. This mode of operation is prevalent in medical practice. Performing tests like an MRI scan is an example. Or in transport when moving an object from A to B is undertaken by existing means, all catering for FS (resolution).

2. When having formulated A. and B., C. does not exist. For example, 'the chair is too heavy for me to move and a scheme for a 'product + purposive system' driven by an 'objective' has to be designed. This mode of operation is prevalent in fashion design, architecture or engineering all of which 'create that which has never been (just like art) while scientists investigate that which already is' [Anon. I Mech E, 2011]. Art, science and design/engineering form the three cultures [Lewin, 1981], aspects of the latter are under consideration here. This mode is usually regarded as the subject matter of **design** and **invention** i.e. when the **product** does not yet exist. Only products no systems can be invented.

Structure of 'product + purposive system' scheme

A cause operates on an IS of CO so as to transform it into a PS or FS. We now describe the two parts of the **action** to execute a cause as mentioned in point C. above :

First : A plan for a thing or an object or a state of affairs called '**product**' like a 'shoe', a 'church building', a 'newspaper' or a 'mortgage offer' which is assembled so as 'to form **relations**' from 'elements' regarded as basic each with specific properties such that the resulting product can exhibit a specified function which is its '**outcome**' or 'emergent property' [Checkland, 1982]. Outcomes in this context range from production of **energy flow, information/impression flow, flow of use and meaning** [Korn, 2009].

Second : A scheme for a series of activities by entities called '**purposive systems'** for **fabrication** followed by **assembly** and **delivery** to CO of a product. For example,

Fabrication : 'to cut the sole of a shoe to shape', 'to fashion the heel of a shoe', 'to prepare the top part of a shoe' each with stated 'outcome' which can be the geometric and material properties of the 'sole', for instance.
Assembly : These activities are coordinated according to an **algorithm** so that the result of assembly can be identified as the 'product' i.e. a 'shoe'.
Delivery : Once the 'product' is assembled it becomes capable of exercising its function, in this case 'it becomes usable through wearing by a user'. It is then delivered to the 'consumer chain' until it reaches the 'human consumer' so that it can carry out its function i.e. to exert '**interaction'** or **'impression'** or **'use'** or **'meaning'**. In this case, CO = 'person's foot', IS (problematic) = 'foot is bare' which is turned into an FS (resolution) = 'covered foot' by delivery purposive system = 'the person's hands directed by 'his/her brain' through the appropriate 'muscles' so as 'to put the shoe on' monitored by 'eyes' which is compared with 'objective'. This activity fits into 'Transformation' in 'Structure of design thinking, point 3/B' [Nise, 2008, Korn, 1995, 2009].

Viewing activities as '**interacting** empirical (as part of the world) or theoretical (as part of a scheme) objects' is very common, it is 'domain independent'. A further example to show this is the following scenario : 'To organise or to coordinate a demonstration for trying to change a selected policy of the government'. Here 'demonstration' is the product which exerts influence carrying information [Korn, 2010b] on the 'government (CO)' to change its state hopefully leading to a 'FS (resolution) = new policy', the 'outcome' of the activities. Further investigation would identify the 'purposive systems' to bring about the 'demonstration/government' scenario.

SCHEME OF PURPOSIVE SYSTEMS

The activities of purposive systems are a **fundamental and universal feature** of living things at all levels from cell to social. They are the only means that can transform a stated ‘property’ or ‘objective’ not yet in existence envisaged as a feature or ‘final state’ of a changing object into an ‘existing final state’ in specified time using a ‘problematic initial state’ as the starting point. The final or previous state is perceived as a resolution of the problematic initial state.

The following ‘Remarks’ are intended to describe the basic features of a scheme shown in Fig.2. capable of accomplishing changes of state of selected changing objects expressed as properties in accordance with purpose.

Remark 4. ‘Perhaps with some exaggeration operations according to purpose are as common in living, in particular human activities as the action of gravity in the material sphere’.

Remark 5. ‘Any purposive system such as a technical or biological control system or that used in everyday life ‘to cut a slice of bread’ consists of two regions : that in which ‘information’ or signals as ‘influence’ and the other in which ‘energy’ as ‘physical power’, circulate. The two regions are interfaced by an ‘amplifier’.

Remark 6. ‘Only one property of a changing object used to specify a change of state can be altered at a time since only two properties can be ‘compared’ at the same time : that included in the objective with that indicating the current state through a feedback path’.

The function of components and products is to generate ‘interactions’ [Korn, 2009]. They are constructed of a ‘medium’, the physical structure in which the interaction is encoded such as a ‘motor’ which carries energy flow or ‘writing paper’ which carries information flow. The ‘product’ shown in Fig.2. is a special component which generates interaction to interfere with the changing object. A medium is seen to be constructed of **‘ordered pairs’** as will be demonstrated in section METHODOLOGY OF DESIGN using linguistic networks [Korn, 2009].

The scheme in Fig.2. is seen as the elementary representation that can be fitted in the ‘fabrication (excavation (gold)/formation (parts of jewellery)), (assembly (necklace) delivery to (shop) consumer (buyer)’.

Each ordered pair requires a ‘purposive system’ for its construction [Korn, 2009]. Thus, the number of ordered pairs of products in a scenario may be used as a

measure of complexity of a scenario = number of ordered pairs of products 6.

The diagram in Fig.2. is constructed from **one - and two – place sentences** [Korn, 2009]. The diagram has three feedback loops concerned with changes of state of : 1. A selected changing object, 2. The product, 3. A particular ‘system’ contributing in accordance with an algorithm to the production of the product.

We demonstrate the application of the scheme in Fig.2. by applying it to a simple, human activity scenario : ‘A bus with closed doors was standing at its stop when a gaudily dressed teenager knocked at the bus door asking to be admitted. The driver 'likes or does not like' teenagers and accordingly opens or does not the bus door by means of a switch'.

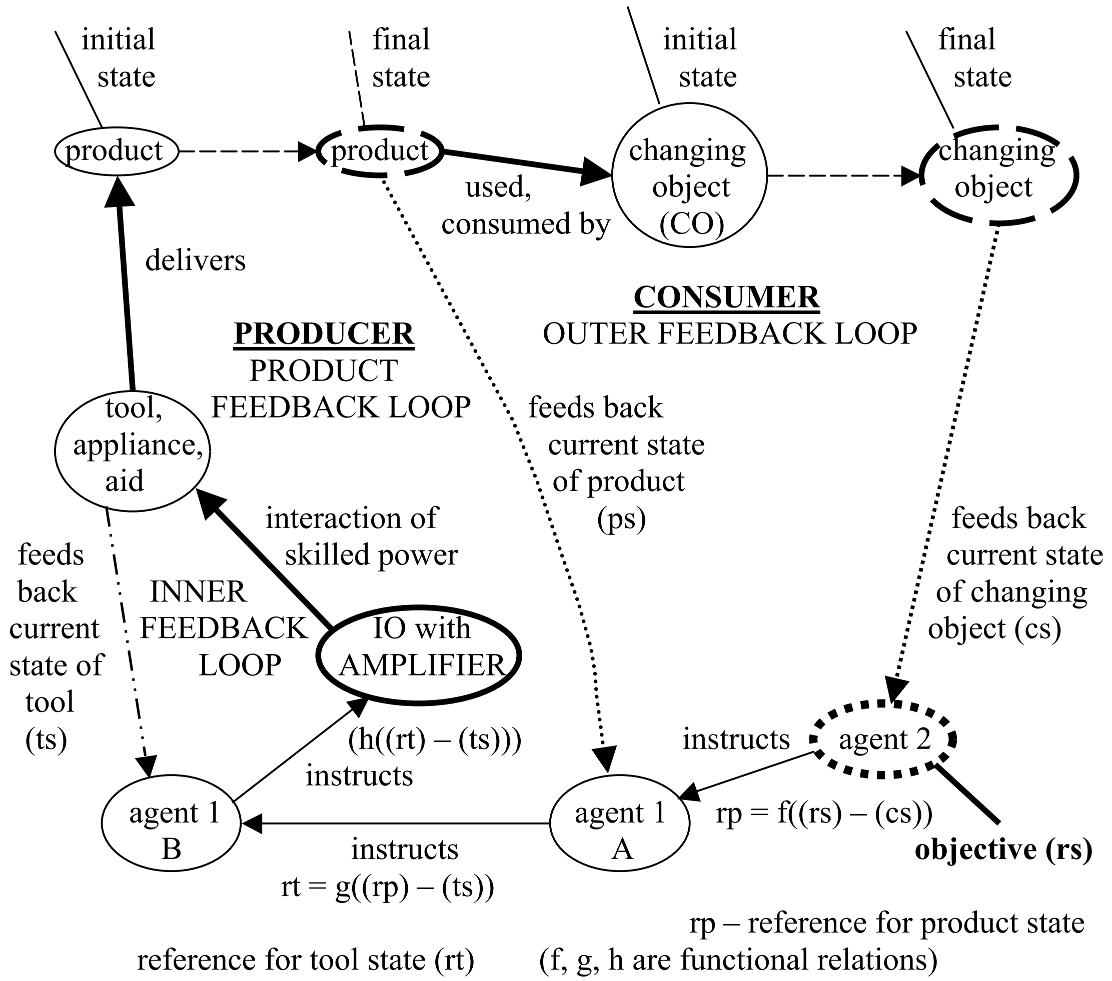

Fig.2. Scheme of general purposive system

The semantic diagram of a multiple purposive system in Fig.3. has four feedback loops, three as described above and the fourth, 'impression feedback loop' is superimposed on the three others due to the 'human characteristic' of 'prejudice'. This loop is bound to affect the operation of the three.

Thus, the fourth feedback loop has been introduced due to emotive feeling of 'driver'. From Fig.3. we can read the progression of the state of mind of the 'driver' which affects his/her **decision** whether 'to open **OR** not the door of the bus to let or not the t/ager in' :

'IF (driver 2 is aware of being asked to open the door) AND (driver 3 is aware that the door is closed) AND (driver 4 is aware of the gaudily dressed t/ager) THEN driver at driver 4 considers whether to open door and depending on that 'decision', he/she instructs driver 5 to act accordingly'.

From the scheme in Fig.3. we can obtain the formalism of inferential engine as a series of predicate logic statements capable of carrying aspects of mathematics such as uncertainty or differential equations [Korn, 2009]. This is not done here but demonstrated in section METHODOLOGY OF DESIGN.

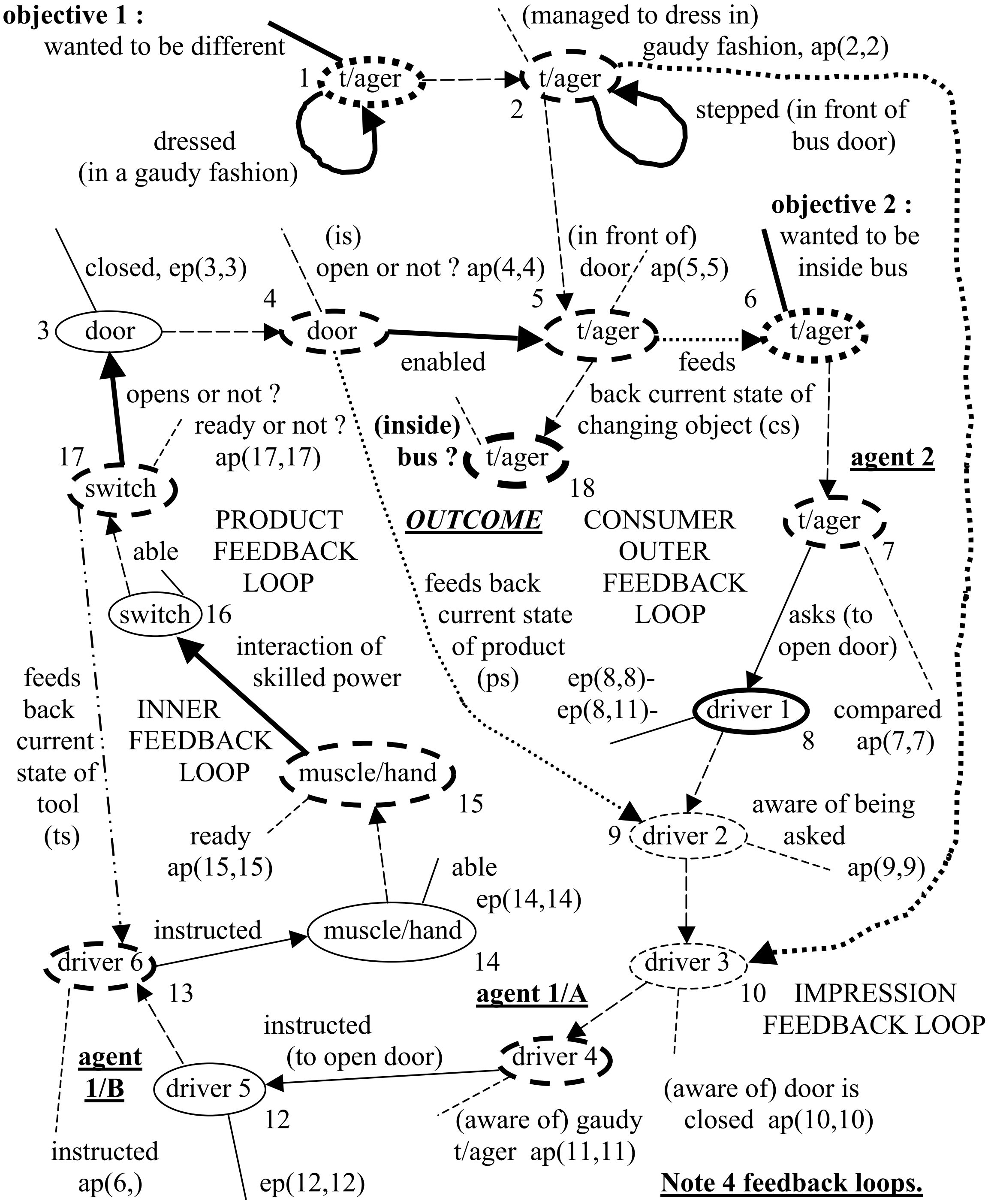

Fig.3. Driver/teenager scenario as a purposive system

METHODOLOGY OF DESIGN

By 'methodology of design' we mean a procedure which begins with identification of a 'problematic initial state of a selected changing object' and arrives at a 'model of a prototype'. The procedure is presented in 'stages' with general comments and illustrated by example [Korn, 2009].

STAGE 1. Analysis of the scenario

The intention here is to elicit :
1. The changing objects (CO),
2. Their initial states (IS (prob)) regarded as problematic,
3. Their envisaged, final (FS(res)) or (PS(sat)) states,
4. The causes of changes of states,
5. The environmental objects (EO) seen to be relevant to the events and conditions in the scenario and objects with functional roles such as 'agents' in Fig.2.,
6. Problematic issues (PI) with selected causes,
7. Changing properties (CP) which connect IS to FS or PS.
These points except 6 and 7 which are defined, are subject to discussion by those with interest in the design.

In general, a scenario can be expressed in terms of any kind of model depending on the intellectual taste of the person with interest in the scenario. For example, someone with interest in a 'battle ship' may prepare its 'scale model' or a 'rich picture' to include activities [Checkland, 1982]. In static and dynamic linguistic modelling 'stories or narratives' in natural language as the primary model are used to represent a scenario. We reiterate : 'Natural language exhibits the 'systemic features' of parts of the world', mathematics requires the extraction of 'quantitative features''.

In general, a story is subjected to 'linguistic analysis' to identify : Objects which appear to **initiate** action and those which are **affected** by action together with the nature of their interactions and properties to fit into the 'scheme of properties' used in linguistic modelling [Korn, 2009].

We use a simple problematic human activity scenario to illustrate the application of design thinking. Description of the scenario or story is : 'A large firm of estate agents intends to attract people to buy more accommodation in a fashionable part of the city.'

1st Step : Analysis of the story
The scenario is described by a single two – place sentence in a context free form 'firm intends.... people...' in which 'estate agent' or 'firm' is the initiating, 'people' is the affected object or CO. No **linguistic analysis** is needed. The mental process verb 'intends' refers to an envisaged event as an objective [Korn, 2009] which following the discussion 'Structure of design thinking' is called either PS (sat) or FS (res). Here we assume that there was a PS (sat) = 'there were more people buying…'.

Thus, we have

IS (prob) = '(people) are not buying enough accommodation'
PS (sat) = 'there were more (people) buying accommodation'
Possible causes = 1. People do not know about there being suitable accommodations,
2. People are unwilling to buy, and 3. People have insufficient resources.
Selected cause = 1.
Take action = 'inform people about there being suitable accommodation'

EO = Fashionable part of the city
Functional objects : 'estate agent' = 'to observe and to note CO's change of state starting from IS (prob), to specify PS (sat) and to initiate action

2nd Step : Statement of PI and elicitation of CP

From eq.5.

PI = 'people' + '(people) are not buying enough accommodation (devise means to inform people about there being suitable accommodation)'

Reproducing from above

IS (prob) = '(people) are not buying enough accommodation'
PS (sat) = 'there were more (people) buying accommodation'

We note the fulfilment of consistency condition and a change of mental state required to lead from IS (prob) to PS (sat) i.e. to a CP

CP = 'people are becoming aware of there being suitable accommodation leading from IS (prob) to PS (sat)'

STAGE 2. Identification of the product

Under this heading the 'product' part of the 'product + purposive system' is developed.

1st Step : Identification of the generic product

From description of CP

CP – is **caused** by – 'communication (encoded in medium) 'notifies' people about accommodation'
(using generic product = information + medium = means with meaning as message + medium' (Korn, 2009, 2011))

where 'notify' is a dynamic verb capable of carrying information as a subordinate clause (Korn, 2010b).

2nd Step : Identification of particular product

We need to generate specific **properties** describing CO and environments from properties to be included in the prototype are deduced by 'semantic functional relations' (SFR) [Korn, 2009] as shown below :

I. Flow of information
To find the information content of the particular product which will be used for countering the prevailing properties of mental state of CO as part of the **prototype**, we have

Age IP1 = youngish, 30 year +
Occupation IP2 = professional, high earners
Social status IP3 = qualified, predominantly married
Personality IP4 = go ahead, concentrate on job, impatient
State of health IP5 = excellent
EO1 = (fashionable, SF1) part of city

where IP – identifying properties, SF – specific features of environmental objects, EO.

Factual information content ---
From IP1,2,3,4, SF1 : 'COP1 = People themselves have little time to look', AND 'To acquire 'information'' REQUIRES : I1, 'Details of accommodation are to be available in the fashionable part of the city', cp(a,b)
Emotive information content --- None

where COP – properties of changing object deduced as part of SFR as possible consequences of IP properties, cp – calculating properties to counter or aid the effects of COP to be included in the semantic diagram of the prototype.

II. Adverbial qualifiers

From IP4 : 'COP2 = People expect 'information' with little delay', AND 'To cater for this' REQUIRES : A1, 'People are to be notified promptly', cp(c,d)

III. Selection of medium for carrying information flow

We use SFR and PSM, product selector matrix.

From IP2,3 : 'COP3 = a. People prefer communication in writing' and
From SF1 : 'COP4 = b. Confidentiality is desired' and 'To satisfy points a., b.' REQUIRES : 'Mediums such as x. e mail or y. letter or z. telephone'

ALTERNATIVE MEDIA	QP = a.	b.	
x. e mail	1	0	
y. letter	1	1	→ selected as medium
z. telephone	0	0	

IV. Adjectival qualifiers of medium

From IP1 : 'COP5 = People like colour', AND 'To cater for this' REQUIRES : 'Letters are to be illustrated in colour', cp(e,f)

V. Structure of the particular product

Assuming the 'letters' consist of : 'writing', 'illustration', 'envelope' with relations shown in the brackets [Korn, 2009]. We have

i = 1 = writing, w (is inside, s)
i = 2 = illustration, l (wrapped with, r)
i = 3 = envelope, e (contains, c)

$$\begin{array}{ccc} n_{11} & n_{12} & n_{13} \\ 0 & w\ s\ l & w\ s\ e \\ n_{21} & n_{22} & n_{23} \\ l\ r\ w & 0 & l\ r\ e \\ n_{31} & n_{32} & n_{33} \\ e\ c\ w & e\ c\ l & 0 \end{array} \qquad 7.$$

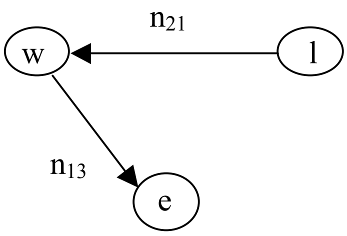

Fig.4. A tree from eq.7.

Eq.7. is the set of all possible arrangements of the constituents of ‘letter’. Here the number of constituents, n = 3, n – 1 = 2, branches = 6, hence, total number of choices is given by C(6,2) = 15 [Korn, 2009, 2010a,b] one of which is shown in the linguistic network of Fig.4.

An object or ‘tree’, a subset of eq.7., is depicted in Fig.4. [Korn, 2009]. The ordered pairs from Fig.4. are n_{13} = w s e = ‘writing (is inside) envelope’ and n_{21} = l r w = ‘illustration (is wrapped by) writing’ which can be written in eq.8., the conceptual boundary of the ‘product’ shown in Fig.4.

$$\text{particular product (letters)} = \prod_{i=1}^{i=2} (n_{13} \text{ x } n_{21}) \qquad 8.$$

STAGE 3. Construction of the semantic diagram of product and CO

Next we deduce the ‘activity’ expressed as dynamic verbs from considering ordered pairs as ‘results of changes’ or final states [Korn, 2009].

IS1 = ‘writing is not inside envelope’
IS2 = ‘illustration is unwrapped by writing’

FS1 = ‘writing is inserted into an envelope’
FS2 = ‘illustration is wrapped by writing’

CP1 = ‘writing is being inserted into envelope (due to agent inserting)’
CP2 = ‘illustration is being wrapped by writing (due to agent wrapping)’

Dynamic verbs ‘to insert’ and ‘to wrap’ designating interactions and representing ‘skilled power’ [Korn, 2009], can transform (or cause) IS1 into FS1 and IS2 into FS2. This description is depicted in Fig.5. as a semantic diagram.

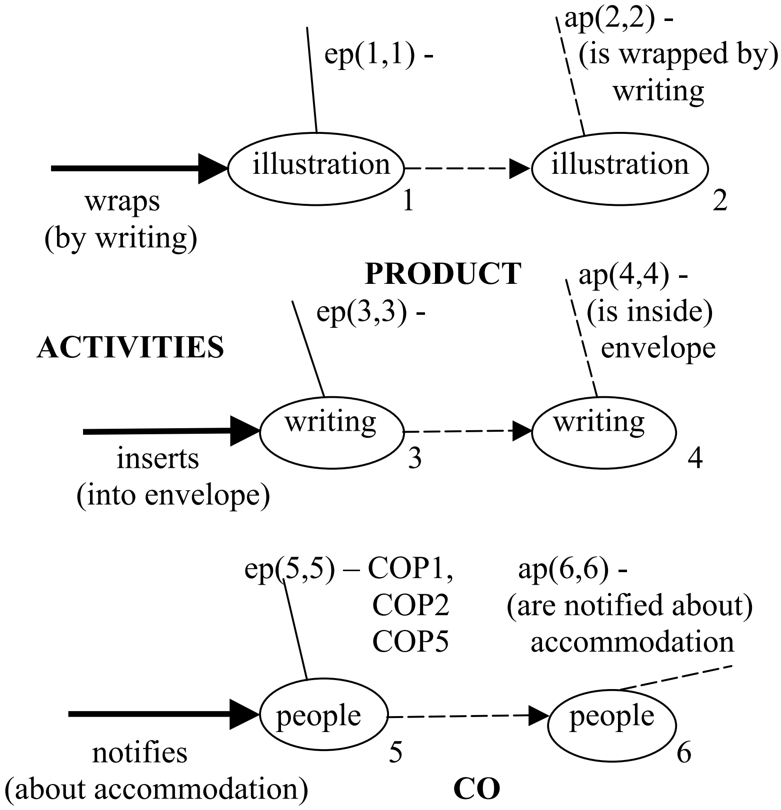

Fig.5. Semantic diagram of product, CO and activity

STAGE 4. Preparation of model of prototype as a semantic diagram

Fig.6. shows the dynamic linguistic model of the **prototype** as a semantic diagram which is the result of implementing the design stages. From this diagram we can deduce the following statements leading to predicate logic sequences which carry uncertainties and/or mathematics.

Homogeneous language of context-free sentences
Agent prepares
Agent 1 wraps illustration
Illustration is checked by agent 1
Agent 1 inserts writing
Post delivers writing
Writing is checked by post
Writing notifies people
Estate agent instructs post
People are perceived by estate agent
Estate agent initiates
People act OR not

Semantic diagram
Shown in Fig.6.

Adjectival qualifiers with grading
dp(10,10) – intends to notify people
dp(17,17) – instructs
ep(1,1,COP5) – people like colours, cp(1,1) – letters are to be illustrated in
ep(5,5,COP1) – people themselves …, cp(5,5,I1) – details of accommodation are…
ep(5,5,COP2) – people expect info…., cp(6,6,A1) – people are to be notified…

Interactions with adjectival qualifiers
in(17,17) – prepares (to act)
in(7,1) – wraps (by writing)
in(2,7) – checked by
in(8,3) – inserts (into envelope)
in(16,4) – delivers (1^{st} class)
in(9,13) – checked by
in(9,5,(I1,A1)) - notifies (about accommodation
in(11,12) – instructs (1st class)
in(6,15) – perceived by
in(10,10) - initiates
in(6,6) – acts OR not

Logic sequences/topology of scenario
Causal chains : 1. 16,13,12,11,15,10 2. 2,1,7,17 3. 18,6,5,9,4,3,8,7

For causal chain 1 :
1/1 dp(10,10) → in(10,10)
1/2 in(10,10) → ap(15,15)
1/3 in(6,15) ∧ ap(15,15) → ap(11,11) in(6,15) - Prompted link
1/4 ap(11,11) → in(11,12)
1/5 in(11,12) ∧ ep(12,12) → ap(13,13)
1/6 in(9,13) ∧ ap(13,13) → **ap(16,16)** in(9,13) – Prompted link

For causal chain 2 :
2/1 dp(17,17) → in(17,17)
2/2 in(17,17) → ap(7,7)
2/3 ap(7,7) → in(7,1)
2/4 in(7,1) ∧ ep((1,1,COP5) x cp(1,1)) → **ap((2,2,COP5) x cp(1,1))**

For causal chain 3 :
3/1 in(2,7) ∧ ap(7,7) → ap(8,8) in(2,7) – Prompted link
3/2 ap(8,8) → in(8,3)
3/3 in(8,3) ∧ ep(3,3) → ap(4,4)
3/4 in(16,4) ∧ ap(4,4) → ap(9,9) in(16,4) – Prompted link
3/5 ap(9,9) → in(9,5,I1,A1)
3/6 in(9,5,I1,A1) ∧ (ep((5,5,COP1) x cp(5,5,I1)) ∧ ep((5,5,COP2) x cp(6,6,A1))) → **ap(6,6,I1,A1)**
3/7 ap(6,6,I1,A1) → in(6,6) **Decision point !!!!**
3/8 in(6,6) → **ap(18,18)** **OUTCOME !!!**

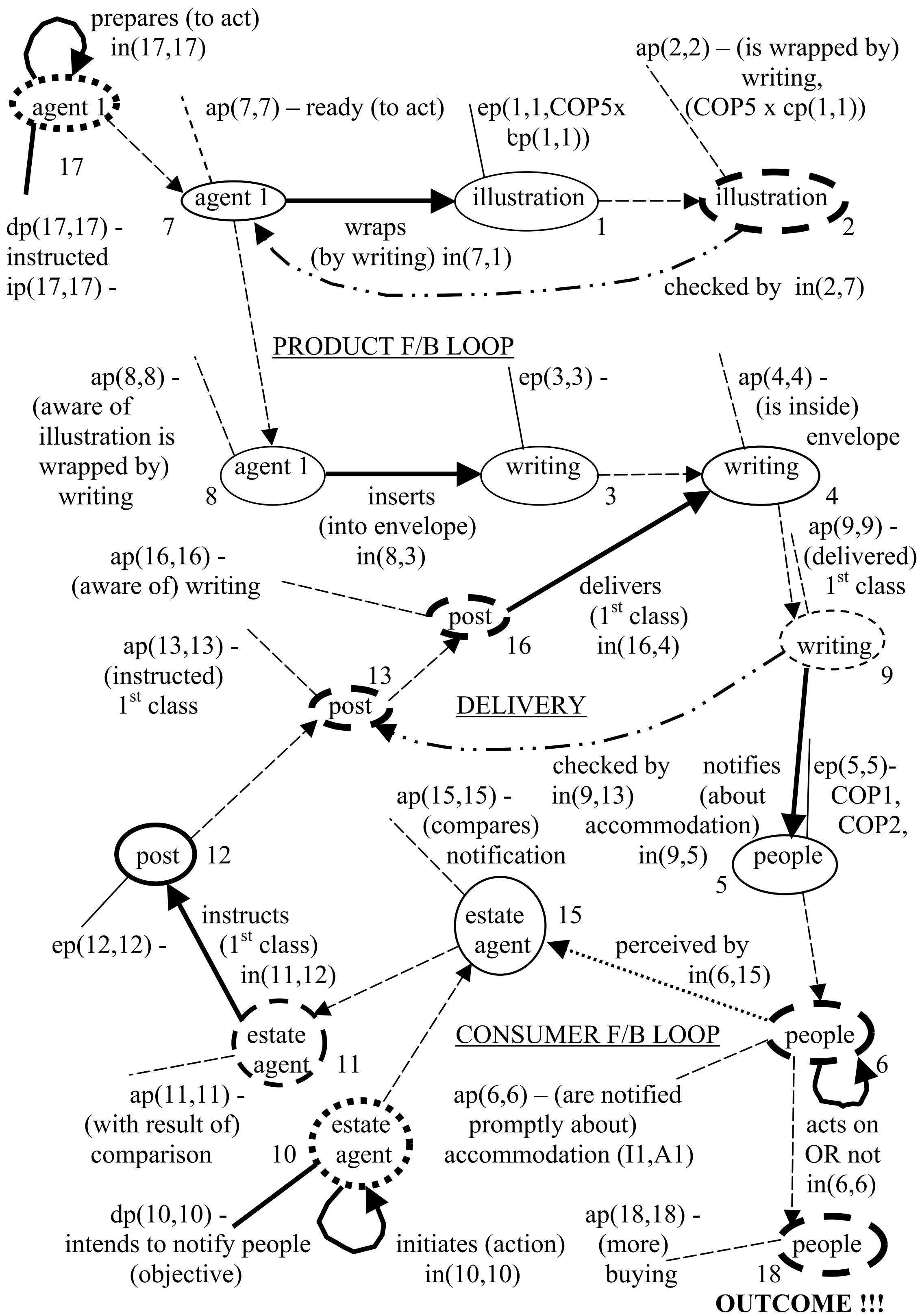

Fig.6. Semantic diagram of 'estate agent' prototype

Logic sequences with graded adjectives/data for cf
This section introduces variation of adjective, uncertainty [Durkin, 1994] and mathematics such as differential equations into the logic sequences. We show this only for statement 2/4 in which we use certainty factors (cf) [Korn, 2009].

2/4 in(wraps,ag1,7,ill,1,(wrap(yes)))(cf = 0.5) ∧
ep((ill,1,1,COP5),(col(like, - 0.3)) x cp(ill,1,1,(let(ill,0.6))))(cf = 0.43) →
(cf of rule = 1)ap(ill,2,2,(col(let)))(cf = 0.43)

We note that the effect of 'COP5' in the antecedent 'ep' on the outcome 'ap' in the consequent is cf = - 0.3 or 'may be not' [Durkin, 1994] which is improved to cf = 0.43 or 'may be' due to the introduction of 'cp'. This leads to cf = 0.43 of the outcome.

Remarks concerning the semantic diagram of scenario in Fig.6 :
I. Action in a purposive system begins with the object carrying the 'objective' or 'environmental disturbance' such as 'freezing outside initiates action by the room thermostat inside'. In Fig.6 the objects with 'objective' are '10' and '17' which are concerned with the 'consumer' and 'product' respectively.

Prompting links in a scenario are used to represent :

1.'Feedback links' such as in(2,7), in(9,13) and in(6,15) which delivers information regarding the state of CO, and
2. Links which originate at objects which 'no longer change' such as in(16,4).

As action propagates along a predicate logic sequence the states of objects from which prompting links originate i.e. '2', '9', '6' and '16' must be available or it must be zero. In causal chain 2., part of the 'PRODUCTION' chain action can proceed because there is no prompting links and state of 'object 2' becomes available. The other part of 'PRODUCTION', causal chain 3. leads to state of 'object 4' which completes production.

However, 'DELIVERY' and 'CONSUMER', the rest of causal chain 3. cannot be completed unless there is coordination in the **algorithms** of actions of 'objects 10 and 17', the 'estate agent' and 'agent 1'. This is necessary to ensure the availability of states of 'objects 9 and 16' at the right time.

II. In statement 2/4 the 'ep' property is transmitted to 'ap' since they are the same object in different states.

III. Interactions 'in' deliver adverbial phrases as I1 and A1, for example, to 'ep' which become properties of the whole of CO. COP properties of 'ep' can be modified by 'cp' properties as indicated by statement and 3/6. COP properties of 'ep' can also be modified by 'cp' properties directly introduced from 2nd Step of STAGE 2 as shown in statement 2/4.

IV. Once software is available it can be tested for performance or any other question built into it. A semantic diagram represents a story and as such it can be read, for example, the top line says 'Agent 1 is instructed (dp – driving property) and prepares to act. When ready to act , he/she wraps the illustration by writing until it becomes wrapped. When the illustration is checked to be complete, agent 1 becomes aware of this'. Or expressed as a series of predicate logic conditionals ‘If agent 1 is instructed then he/she prepares to act’, ‘If agent 1 prepares to act then he/she becomes ready to act’, ‘If agent 1 is ready to act then he/she wraps the illustration by writing’ and so on. Symbolically

$$dp(17,17) \rightarrow in(17,17)$$
$$in(17,17) \rightarrow ap(7,7)$$
.... and so on....

V. In Fig.6. we assume that according to an algorithm object 17, ‘agent 1’, begins action by preparing the product ‘letters’. When the product is completed object 10, the ‘estate agent’, takes over the arrangement of posting the ‘letters’ to ‘people’ 5. We note the **lack of communication** between ‘agent 1’17 and ‘estate agent’10.

VI. The ‘functional object’ from STAGE 1/1st Step is the ‘estate agent’ implied by the story.

VII. We note that the ‘reverse cause/action’ to turn IS(prob) carried by object 5 into PS(sat) of object 6 i.e. ‘in(9,5)’ requires the apparatus of ‘assembly of product’ and its ‘delivery’ as discussed in the INTRODUCTION and shown in Fig.2. This apparatus as a **whole** could be the ‘necessary and sufficient condition’ for this **turn**. We can see that ‘people’, objects 5, 6, 18 appear to **consume the product**.

VIII. The state of object 18, ‘people’, carries the **outcome** of the scenario or PS(sat) but it is object 6, ‘people’ which is monitored by object 10, ‘estate agent’. This is so because there is a mismatch between the intention of the ‘estate agent’ and desired outcome. A **problematic** point.

IX. The suggested METHODOLOGY OF DESIGN makes strong use of knowledge or estimate of properties of changing and environmental objects. If these are not known then the subsequent design is not anchored in a scenario that exists at time = 0 and can suggest **any prototype**. Such prototype will not include the ‘remedial’ or ‘cp’ properties.

CONCLUSIONS

Living things are incessantly engaged in problem solving or ‘engineering their surroundings to suit them or trying to satisfy their ambitions’. This activity which may be governed by the genetic code as in case of, for example, ‘a bird building a nest’ or by methodical or creative thinking as practiced mostly by human beings. The mental activity of problem solving involving physical processes, takes place at all levels of being from cell to social and raises the questions of recognition of the feature or state of an object that is judged of needing to be changed and the acceptance of change by the people involved. We have attempted to make the problem solving process more explicit and identified the role of cause, action and purposive activity as part of it. Systems science and problem solving have a common interest in the construction and operation of ‘purposive systems’. Design thinking enters problem solving when a purposive system which is intended to play the part of the model of **‘prototype’**, the end product of design, needs to be created and eventually produced.

A ‘methodology of design’ has been outlined and illustrated by a case study of a human activity ‘information system’. Static and dynamic linguistic modelling is used as the analytical background of this methodology. Linguistic modelling uses processed natural language as the symbolism commensurate with the generality of the 'systems view' of parts of the world described by factual as well as emotive properties and preoccupied with will, ambition etc. It carries uncertainty and mathematics as required and uses 'basic elements' abstracted from language, thus, introducing reductionism into systems science. It also accommodates conventional science and as such a continuity of the scientific endeavour has been achieved subject to linguistic modelling being debated, tried and will have proved itself acceptable. In this case it should influence education in all domains in particular that of **engineering** and draws attention of people of how parts of world can be seen to operate. A benefit of using linguistic modelling is that it introduces and emphasises **creating models or representations** of a part of the world not amenable to such treatment before.

However, before and if reaching this stage further development work is needed in the fundamental assumptions (such as 'conservation of meaning' in the course of linguistic transformations) and methods of linguistic modelling together with debating what kind of use a comprehensive, formal approach emphasising the fundamentals of the systems view, can be in living especially human activity scenarios.

The systems or systemic view of parts of the world is **pervasive, empirical and indivisible**. It includes the views of problem solving or **engineering** and purposive systems. Purposive systems are engaged in the production of specific outcomes which they maintain against environmental and other interferences by means of stated **objectives** which vary as demands change, **feedback** and **amplification** as shown in Fig.2. Service systems like transport, accommodation like hotels, banks, teaching etc are no exception, only the outcome or product is not 'hardware or artefact' but a state of an object like 'person has arrived' or information.

However, when we come to natural systems like mountains, plants and animals including man the pervasiveness or sphere of operation of purposive systems needs to be debated. Changes in inanimate things are subject to **chance**. The operation of cells in constructing bodies of plants is likely to be done in accordance with purpose or at least a 'plan' following the genetic code. Large scale operations, on the other hand, appear to be preformed by chance.

For example, water is an essential component in ensuring survival of a living thing. A plant ingresses water from the soil and if the soil dries the plant dies, an animal takes water from a river or lake and if the lake dries the animal looks for another lake, if it cannot find one it also dies. Man also takes water from lakes and rivers and when they dry in addition to look for others, he will invent means (product + purposive system) for search such as drilling a well. Perhaps here is a topic for further research.

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