DEALING WITH DIALECTICS

:OR SOME PROBLEMS IN APPLYING EXPERT SYSTEMS TO BUILDING CONSTRUCTION

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Introduction

Karl Marx made much of dialectics in his theory of political events. The way social forces are brought into conflict with Man´s material needs. The notion of a dialectic however is not limited to a political sense, it can also be used to describe a situation where two processes are each influenced, one by the other. In human thinking, for example, there is a dialectic between previous and new experiences. When we enter a new situation in life and are confronted by a new problem, we bring with us the prejudices of the past and our previous experiences of problem solving. These prejudices we project upon the new problem and they colour the reality of a situation as we perceive it. New experiences in their turn, then colour our prejudices for the future (See Figure 1).

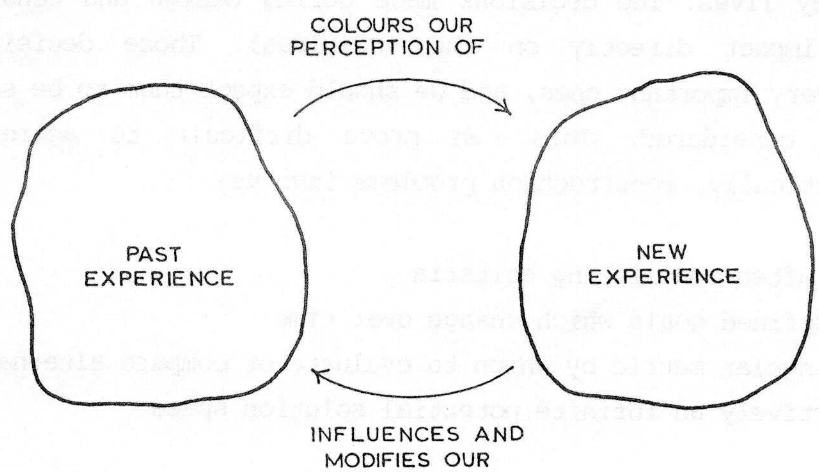

FIGURE 1: The dialectic of new and past experiences.

This paper will argue that the dialectic nature of human thinking is fundamental; that current Expert Systems technologies are unable to accommodate a dialectic approach; that targetting their development at modelling decision-making processes is therefore grossly inappropriate; and that our research energies might better be employed in trying to deal with dialectics rather than, as would appear to be the current trend, in continuously shifting ground over the ´intelligence´, ´expertise´ or otherwise of our computer systems.

Central to the argument is the notion of analogy, considered basic to the successful solving of complex problems (complex problems in the sense of this paper, refer to those systems whose behaviour is strongly influenced by human judgement, perception or emotions). Unfortunately the current crop of Expert Systems are lodged firmly within the concept of a ´simple functional dependency´ (SFD). Unfortunate because, as this paper suggests, reasoning by analogy - a necessary and key aspect of decision-making in construction - is incompatible with the SFD approach.

<u>The problem is all in the mind</u>

It may be considered rather trite by some to restate that building construction is a special kind of manufacturing problem. Special in the sense that its product - the built environment - both reflects and forms our everyday lives. The decisions made during design and construction therefore impact directly on the individual. Those decisions are naturally very important ones, and we should expect them to be seriously and fully considered. This can prove difficult to achieve when characteristically, construction problems involve;

(i) many often conflicting criteria
(ii) ill-defined goals which change over time
(iii) no singular metric by which to evaluate or compare alternatives
(iv) effectively an infinite potential solution space

- characteristics of what Rittel [RITTEL(1966)] terms a ´wicked´ problem. It is in the nature of building design and construction that those involved exercise perhaps the highest level of human reasoning and thought. It is the role of models and computer systems to service that reasoning process in the most effective and appropriate way. Our problem is not so much about modelling cost or site operation or resources, as it is about communicating information and knowledge to the decision-maker - not what we say but how we say it [NEWTON(1986a)]. The ´real´ problem is all about supporting the decision making process. To do that usefully we need to understand how people use information; how people think.

Despite much research effort we as a society do not yet sufficiently understand human thinking processes adequately to predict or formalise (theorise) on ones as complex as those involved in the design or management of construction. However, we do now know certain things about human thinking. We know that whilst it is not yet something exact and well defined, it does have a recognisable form or structure , and we can be assured that is is not something magical or entirely unpredictable. As Katz [KATZ(1986)] puts it, "deep in the brain, Pablo Picasso, not Jackson Pollock, is actively at work on our neural maps".

Informally, it is now a fairly widely accepted view that whilst the actual processes involved are poorly understood, we can at least consider the mind to operate on what might usefully be called ´patterns´ - equivalent in Artificial intellingence terms to ´frames´ [MINKSY(1975)], ´schema´ [BARTLETT(1961)], or ´semantic nets´ [QUILLIAN(1968)]. These patterns are important both because they impose a determinancy on the world as we perceive it at any point in time (we form the world in our minds into discrete ´things´ with boundaries and subject to abrupt change [CARTER et al(1984)]), and because our perception shapes how we interpret new situations (our prejudices). Thus whilst it is not necessary to propose that people do or should use patterns in thinking, it is acceptable to consider patterns as if they were the basic building blocks for human thought.

One does however step out of the ´widely accepted view´ when contemplating the process involved in constructing cognitive activity out of those basic building blocks. Simply, how one composes a new pattern from a new experience and incorporates it within the existing framework. The snap-shot representation of a pattern is fairly standard, but expert opinion varies significantly on how the mind then manipulates and operates on such patterns.

Increasingly consistent scepticism however is being voiced about the suitability of conventional quantitive techniques of systems analysis to explain complex decision processes [ZADEH(1973)]. This paper takes as its point of departure the notion of metaphor or reasoning by analogy, but other possibilities include fuzzy logic [BELLMAN AND ZADEH(1970)], self referential systems [HOFSTADTER(1981)] and higher-order logics [BOWEN and KAWALSKI(1982)]. The main conclusion however is consistent which ever notion is adopted; that the simple functional dependency (SFD), into which all but a few notable exceptions of current Expert Systems appear to be locked, is fundamentally inappropriate.

Reasoning by analogy

We all use analogies. It is only through analogy (and in this paper the word is used in a fairly loose sense to include the family of similar processes - metaphor, simile, etc.), that we can link language to the world: i.e. communicate and learn [KUHN(1979)]. Analogy is not a simple concept however. How, for example, does analogy ´work´?

Certainly there needs to be some correspondence between the referent and the analogue, usually in terms of certain properties. But how ´similar´, how many shared properties, how much correspondence between the two makes for an analogy. No correspondence renders the linkage redundant; total correspondence makes the systems equivalent, and it is the ambiguity of an analogy which gives it its very richness.

The short answer is that analogy cannot yet be formalised fully. It can certainly be shown to be fundamental to human thinking "... the very possibility of learning something radically new can only be understood by presupposing the operation of something very much like metaphor." [PETRIE(1979)], but basic problems are yet to be solved in terms of how an analogy ´works´. Once again however, whilst the process itself cannot be well defined, the concept of reasoning by analogy is sufficiently understood to allow the characteristics of the problem to begin to be identified. Thus the problem is to be addressed in an epistomological not psychological sense.

Different people may have different styles of learning [NEWLAND et al(1987)] but essentially we all experience the world indirectly, through our modes of representation and understanding - our ´minds eye´. There is a context for understanding we call our experience and we learn, or take-on-board new experiences, either by assimilating information to fit within the existing context (far and away the most general situation), or by accommodating information by changing the context (See Figure 2). The critical factor here is that if the decision-maker is unable to fit the information within his/her existing context, or unprepared to change his view to accommodate the misfit, then the information will be rejected and not learned. This is why analogy is so important. It provides the basis of a structure, but it provides also the critical ambiguity which enables a variety of links to be made and explored as a dialectic. Analogy works because it identifies the elements/properties involved, how those elements interrelate, and most importantly it is sufficiently ambiguous to accommodate a variety of views, or ways of interpretting a problem.

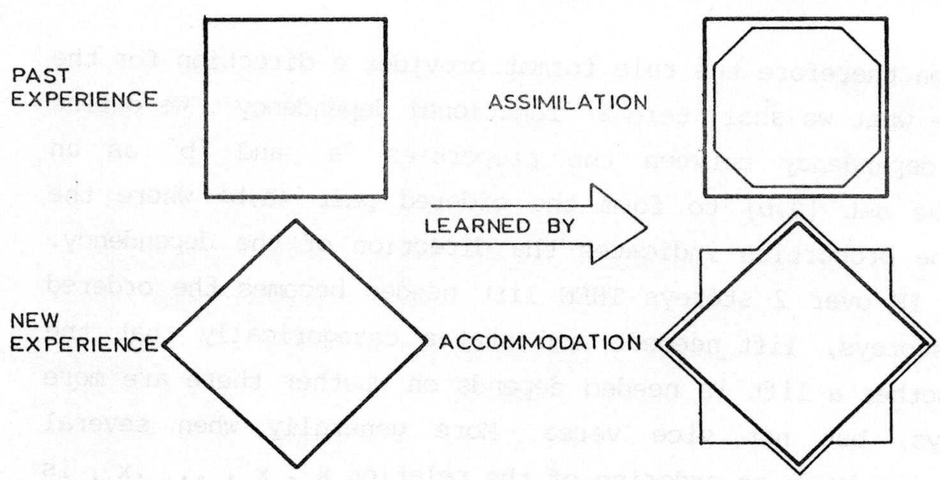

FIGURE 2 : Assimilation v. Accommodation

Thus there is a tacit recognition that the role of models (including computer based models and Expert Systems) is to furnish knowledge to the decision-maker in some abstract sense. The notion of analogy has been introduced to illustrate that such knowledge or information is of little or no use if it cannot be assimilated by the decision-maker. As with analogy, the critical factor in assimilating information is the perceived structure or link points which give the learner access to the new information, and the flexibility needed to accommodate a dialectic approach.

Expert Systems which are not

Expert Systems are used to represent relationships between variables. The most common form of representation is the production rule which takes the form IF certain conditions are true THEN certain outcomes/actions can be implied. We shall use this form of representation to illustrate the discussion, but any of the major forms would be more or less equivalent (See for a description of each, [LANSDOWN(1982)]).

(i) the representation is used to identify the properties, values, attributes appropriate to a particular problem domain. This is necessary if the system is to convey information - it must have some ´information´ to convey - but an undifferentiated set of properties is inadequate to capture the structure of a problem [LOGAN(1985)].

(ii) in addition therefore the rule format provides a direction for the relationships - what we shall term a ´functional dependency´. We define a functional dependency between the properties ´a´ and ´b´ as an ordering of the set {a,b} to form the ordered pair <a,b> where the ordering of the properties indicates the direction of the dependency. Thus the rule IF over 2 storeys THEN lift needed becomes the ordered pair <over_2_storeys, lift_needed> and states categorically that the question of whether a lift is needed depends on whether there are more than 2 storeys, but not vice versa. More generally when several properties are involved, an ordering of the relation $x_1, x_2, \ldots, x_n$, is the ordered n-tuple $\langle t_1, t_2, \ldots, t_n \rangle$ for some unique assignment of x_i to t_j $(i,j = 1,n)$. That is, each property in the relation appears only once in the n-tuple.

In determining an ordering we immediately nominate one constraint (t_n) as the focus of attention, since in it the only one on which nothing else depends. We can therefore group the $t_1, t_2, \ldots, t_{n-1}$ and use the notation $F((t_1, t_2, \ldots, t_{n-1}), t_n)$ or $F((x_1, x_2, \ldots, x_m), y)$. ´y´ is said to be the dependent variable and the ´$x_1, x_2, \ldots, x_m$´ the independent variables. More generally we can write $F(x,y)$ with the intention that $F(x,y) =/= F(y,x)$: that is the dependency between x and y is not the same as the dependency between y and x.

(iii) this formulation has the very significant advantage of transitivity, in so far as two first level dependencies $F(x,y)$ and $F(y,z)$, together imply a second level dependency $F(x,z)$, and so on. Complex dependency structures can be constructed using this feature [NEWTON(1986b)], but the notion of dependency itself has been shown to be a rather simplistic one [LOGAN and NEWTON(1987)]. We refer to $F(a,b)$ type of dependencies, linked through common variables, as ´simple functional dependencies´ (SFD´s).

(iv) the critical short fall in adopting an SFD approach relates to its incapacity to deal with multiple views. The consequence of having a single direction imposed on a dependency is to deny what is common in complex problem solving - namely that at different times, different information will become available at different times. Gross floor area may be dependent on number of storeys, number of storeys may be dependent on gross floor area. Conventionally this problem is either ignored, forcing the user to adopt a prescribed mode of working, or several alternative views are consolidated into a single knowledge base. Unfortunately in a problem involving only 10 variables the theoretical number of alternative dependency structures is over 3.5 million. In a practical situation the number of these alternative ´views´ of a problem can become legion, and the idea of having each alternative listed as a possible option is untenable.

(v) finally, the SFD approach also limits operations to numeric functions. The suggestion that key elements in human thinking are not discrete numbers which adhere strictly to the principle of excluded middle (ie. that a statement must either be true or false) has gained some support. Classes of objects in which the transition from membership to non-membership is gradual rather than abrupt have been termed ´fuzzy sets´ [BELLMAN and ZADEH(1970)]. Fuzzy probabilities are already features of some Expert Systems, but their use as ´hedges´ (eg. IF over_2_storeys THEN lift_needed has a likely hood of 0.6) cannibalises Zadeh´s original conception based on fuzzy set theory involving variables whose values are not numbers but imprecise words or sentences in a natural or synthetic language (the concept of a ´linguistic variable´ [ZADEH(1975)]). Effective ambiguity or imprecision again lies outwith the theoretical scope of an SFD.

It is just the start

To question if an Expert System is ´expert´ or ´intelligent´ is not new. It is a question raised increasingly by those involved in developing the technology and it tends to be answered in the universal negative. Expert Systems are not expert, they do not equate with human intelligence - except that they do encapsulate some expertise, and they do display a kind of intelligence. And so the discussion goes on, and as peoples perceptions and expectations change so the accepted ´role´ of Expert Systems changes also. In the construction industry however, where effective and regularly used applications are about as common as rain in the Sahara, so the potential role for Expert Systems drift around like the proverbial sand dune - expert, assistant, advisor, controller, monitor, ...

But the basic fabric of an Expert System, the simple functional dependency, is absolutely unsuited to modelling within a human thought process. The potential which Expert Systems have demonstrated in other problem domains, fade to insignificance when transfered to a complex decision-making environment such as building construction. It is suggested that this is due to at least two critical factors out of the four identified:

(i) it does have an information content

(ii) it does provide a direction for the relationships, BUT

(iii) it does NOT enable multiple views of the problem

(iv) it does NOT provide the necessary ambiguity to accommodate dialectical exploration of the problem.

It is not sufficient to build a dependency structure, which may contain the very best information and adopt the most standard of methodologies, because without multiple views and ambiguity the user will be unable (even ignoring the strong possibility that he is also unwilling) to locate within and learn from the model. Methodologies are important - though more important to novices who have less ´intuitive experience´ (ie. few analogies) on which to draw [DeGROOT(1965)] - but have only a peripheral role (not decisive) in solving complex problems.

"In the expert, the whole-situation recognition capacity is refined to the point that predictions or decisions, learned through experience ..., intuitively accompany situation recognition without need for calculation." [SILVERMAN(1985)]

We cannot choose to address the problem at any lower level of complexity. The problem resides in the human decision-makers´ mind and we must aim to better understand that process - involving as it does analogy, fuzzy reasoning, self-referencing and many other complexities. The SFD approach has fundamental short-comings. Unless and until we can better understand and deal with these complex problems, Expert Systems will have no firm base in the decision-making of building construction. Dealing with dialectics is just the start.

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