DISAGREEMENT IN CREATIVE PROBLEM SOLVING

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Abstract. This paper examines the claim that differences of opinion play an important part in creativity, and discusses how Artificial Intelligence research can help us to understand the dynamics of creative conflict. Research is described in which many different points of view are represented in knowledge bases, and the resulting conflict used to generate debate. The domain of this research is environmental problem solving, and examples are taken from agroforestry land-use planning in developing countries, the construction of simulation models by ecologists, and the impact of the greenhouse effect as perceived by people in Great Britain. Finally, some methodological issues concerning acquisition of inconsistent knowledge are raised.

1. Introduction

This paper examines the claim that differences of opinion play an important part in creativity, and discusses how Artificial Intelligence research can help us to understand the dynamics of creative conflict. Conflict is generally treated as a *problem* to be eliminated from computer systems. Instead it can be viewed as an important stimulant for new ideas – an opportunity to start a discussion. I advocate creating AI systems which, when asked a question, do not produce 'the answer', but respond with something along the lines of *"Well, on the one hand, it could be such and such... but on the other hand, it could be the other..."*

The view of conflict as a problem can be traced to classical logic, in which inconsistency is considered 'fatal', in the sense that any proposition can be deduced from a contradiction (*ex falsio quod libet*). However, by being imaginative with the semantics of our logical system it is possible to evade the problem of all-pervasive contradictions, and treat them instead as 'logical singularities'. The laissez-faire attitude towards inconsistency which is the basis of this paper is inspired by Rescher and Brandom's Logic of Inconsistency (Rescher&Brandom, 1980) in which they legitimise both schematic (underdetermined) and inconsistent (overdetermined) possible worlds. The suggestion here is that we should embrace these ideas, and investigate the possibilities presented by allowing inconsistencies into knowledge based systems.

This paper describes ongoing research in which many different points of view are represented in knowledge bases, and the resulting conflict used to generate debate. The domain of this research is environmental problem solving, and examples are taken from agroforestry land-use planning in developing countries, the construction of simulation models by ecologists, and the impact of the greenhouse effect as perceived by people in Great Britain. However, it is intended that the main claim presented here is not restricted to thinking about the environment, and infact characterises an important feature of creative thinking in general.

The structure of the paper is as follows.

- First (in section 2) some examples are presented which are intended to suggest that disagreement plays an important role in creativity.
- Section 3 focuses specifically on environmental problem solving and discusses *why* it is essential that we find ways of using situations in which conflict occurs, to stimulate new creative solutions to problems.
- Section 4 looks at the implications of this for Artificial Intelligence and discusses *how* to use logical techniques to harness the possibilities presented by inconsistencies.
- Section 5 makes some methodological comments, particularly pertaining to knowledge acquisition.

2. Disagreement and Creativity : Some Examples

2.1 Conflict between Systems of Ideas

Creative thinking generates new ideas which, almost by definition, challenge current thinking. If they did not, they would not be considered creative. The music of Beethoven was considered wild and undisciplined to many of its first audiences, that of Bruchner broke many of the structural rules of classical symphony writing, and later Schoenberg challenged ideas about 'correct' tonal systems. Einstein disagreed with Newton. Wittgenstein disagreed with Russell. When we talk of what Margaret Boden (Boden, 1990) refers to as H-creativity (creativity which is historically interesting) we are often talking about the generation of new systems of ideas, which conflict with an entire existing system in a fundamental way. Koestler's theory of the bisociation of matrices (Koestler, 1975) gives us an intuition of how conflict at this level might arise.

At first glance, it may seem obvious that creative ideas often conflict with what has come before. But as Margaret Boden points out, it is the process of generating these ideas which is really interesting from an AI perspective, rather than the ideas themselves. In the case of Wittgenstein, it is rather banal to state that he and Russell had different opinions about logic, but it is something quite different, and much more interesting, to attempt to *explain* how disagreement with some of Russell's fundamental ideas about the foundations of mathematics, might lead Wittgenstein to some of his most creative philosophical insights.

2.2 Disagreements within a culture

Not all creative conflicts are about the foundations and assumptions underlying systems of ideas or cultures. Insights do not need to be revolutionary in order to be creative. Infact, although they are undoubtably notable, such bursts of creativity are also extremely rare. It is also possible to find creativity of a less dramatic nature, generated by disagreements which are much more mundane.

The best examples of this are to be found in the houses of parliaments of every democratic nation. The different points of view of the various parties is what lubricates the process of government. Disagreement and challenge are considered so important for effective government that we condemn as totalitarian, societies in which they are not allowed. Creative politicians construct arguments against proposed laws, suggest ammendments and argue for them. Debate has emerged as a fundamental mechanism for decision making in our society.

This is true not only on a national level. Every day in institutions and organisations around the world there are countless meetings in which opinions and ideas are proposed and justified, and then argued against and sometimes rejected. Amendments are made and consensus is sought.

At an individual level, the person who unquestioningly agrees with everything we tell them will often be considered boring. We associate creativity with eccentricity and rebelliousness, not because there is some accidental coincidence here, but because an essential part of creative thinking is the questioning of assumptions and the ability to look at something 'from a different point of view'. A person who thinks like this is also likely to question authority or disagree with accepted norms of behaviour.

Finally, narrowing our view even further, we can of course find contradictions even among our own beliefs. The notion that our individual belief sets may be inconsistent is by no means new to Artificial Intelligence – the particular family of problems caused by trying to represent knowledge of the *changing* aspects of our world has given rise to a considerable body of research under the banners of, 'Truth Maintenance Systems', nonmonotonic logics, and more recently, 'Belief Revision'. It is worth mentioning these early in order to point out the significant difference between them and the approach suggested in this paper. Researchers into changing knowledge still seek to provide mechanisms for *eliminating* conflict and inconsistency. The research described here *embraces* inconsistency at all levels. The following, rather provocative, quotation from Walt Whitman may be taken as a suggestion that such tolerance may, at the very least, be an ingredient in creative thinking!

> *"Do I contradict myself?*
> *Very well, then, I contradict myself.*
> *(I am large, I contain multitudes.)"*

3. Disagreement in Environmental Problem Solving

3.1 Inconsistencies between environmental models

Ecosystems are extremely complex phenomena, they change rapidly and in diverse ways and they are radically difficult to make predictions about. We attempt to make them easier to predict by artificially simplifying them, for example, by replacing forests with monoculture arable farming. Unfortunately these simplifications often have unforseen and unpredictable side-effects, like polluting water courses or changing rainfall patterns.

Recently 'Environmental Impact Assessment' has become a popular piece of jargon amongst decision makers. Environmental scientists are asked to make predictions as to the effects of hypothetical changes to an ecosystem. These effects are judged to be either 'costs' or 'benefits' and can thus be conveniently included in budgets, costings and profit-margins. However, given the complexity of ecosystems as stated above, predictions of this sort are extremely difficult and often impossible to make accurately. Advances in computer-based simulation modelling of ecosystems are hoped to improve matters, but in reality any feasible model is also based on simplifications, assumptions and guesses. Two environmental scientists, asked to model the same ecosystem, will almost certainly make different simplifying assumptions and thereby produce models which make different predictions. We cannot assume that environmental models are 'right', nor that predictions from different sources will be consistent. (Whether infact the 'real world' is itself ontologically consistent does not therefore need to be questioned (*cf* (Rescher&Brandom, 1980)).

One response to this situation has been to attempt to build modelling systems which make the assumptions behind models explicit (Haggith, 1990), (Robertson et al., 1991). However, we need to go further than this if we are to take seriously the need of decision makers to use conflicting information from disparate sources. Truly *creative* environmental problem solving (which we undoubtably need to encourage) will involve opinion from widely differing sources (not just scientists), based on a range of evidence (not just quantitative data) assessed according to a variety of criteria (social and aesthetic in addition to logical and scientific criteria). It is my contention that if we do not have the means of being objectively 'correct' about an environmental question, then we should consider as great a variety of opinion about it as possible.

3.2 Disagreement between lay people

The environmental sciences are only one source of knowledge about the environment. People's experiences of living in a habitat, perhaps for generations, are an equally rich and interesting source of knowledge. There have been many well-publicised cases (particularly in developing countries) of plans made by western scientific experts, against the wishes of the local population, which backfire, proving belatedly that the scientific predictive machinery can get things wrong. The informal, practical, orally-transmitted knowledge of an indigenous culture often has the benefits of being detailed, site specific, well tried and tested, gained over long periods of time and supported and made intelligible by songs, customs and stories. It is becoming clear that decisions which are informed by both scientific and indigenous knowledge are likely to be more robust than those based on one or other alone, and in particular that when there is conflict between the two we should look closely at why this is the case (Conroy & Litvinoff, 1988).

The British Overseas Development Administration are currently funding a project to acquire and formally represent in a knowledge based system, indigenous knowledge about the environment (in particular agroforestry) in Thailand, Tanzania, Sri Lanka and Nepal (Walker et al., 1991), (Haggith et al., 1992). One of the aims of the project is to provide improved decision support to land-use planners in these countries. This is achieved by presenting a broader range of opinion to the decision-maker than they may otherwise have access to, and allowing them to explore the justifications for, and contexts of, the different points of view expressed. An important realisation in this project is that the knowledge cannot be expected to be consistent and that representing only the viewpoints on which there is consensus will impoverish the knowledge bases. People simply do hold different opinions, which are rationally based on different experiences, goals and priorities. Decision making which does not take this into account cannot be expected to flourish.

To give a flavour of this disagreement, here is an example of how a knowledge based system containing representations of local people's knowledge could inform a decision maker. A planner in Nepal who intended to distribute pine seedlings to grow for firewood might suggest this to the system, and request 'objections' to the proposal. Some possible objections might be the following (these are based on early fieldwork results from the current knowledge acquisition phase of the project).

- An objection from women may be that they always collect animal fodder and firewood together, and because pine is no good as fodder for goats and cows, collecting it for firewood will only increase the amount of work they have to do.
- Farmers may object that pine has an acidifying effect on soil causing a decrease in crop yields.
- Children who herd animals may object that pine forests are dark and shady and that there is very little undergrowth for animals to graze on.
- Farmers may object that pine grown near farm land shades crops, thus reducing their yield.

There may well, of course, be points of view which support the growing of pine. For example,

- Farmers may say that pine grown at the edges of farm land acts as a wind break, thus increasing the survival of crops in harsh weather.
- Similarly, this sheltering effect of the pine might promote the health of livestock, increasing the breeding season, and reducing their food requirements.
- Women may say that pine is worth collecting separately as firewood because it burns quickly and produces a lot of heat, thus reducing the amount of time needing to be spent on cooking.
- Pine grows quickly and produces good quality timber which may be considered beneficial by some people.

In addition to particular comments about the benefits or otherwise of pine trees, other comments may well be relevant to this particular decision. Hence, if a decision maker was presented with these arguments they may want to know some of the following :

- Are there similar statements about other trees (for example, comments about the shading effects of other species)?
- Are there other statements from the same people (for example, if one person's comments seem particularly pertinent it may be useful to see if there are more of them recorded)?
- Are there more general comments which can distinguish between some of the 'for' and 'against' arguments (for example, higher level statements which compare the effects of shading and wind-protection)?

In the next section, mechanisms are presented for automating debate along these lines, whereby the user of a knowledge based system can 'choreograph' a debate in order to explore the various points of view expressed within it.

4. Disagreement in Artificial Intelligence

This section describes a system for investigating disagreements. This system consists of a set of knowledge bases (each containing knowledge from a different person), and some inferencing tools for recognising and analysing differences of opinion between the knowledge bases, and then generating 'discussion' between them. This system is not yet implemented, so this description is hypothetical and theoretical. It is principally a description of two logics, and a suggestion of how they could be integrated.

In this system, people's opinions about the Greenhouse Effect, and its likely impact on the climate of Great Britain will be represented in knowledge bases, along with information about the people whose opinions they are, and the sources they cite for their beliefs (personal experience, media experts, their background scientific knowledge, deduction etc).

Conflicts can then be detected between entries in the knowledge bases, some automatically, by noticing logical contradictions, others with the help of the user. The deductive and semantic basis of this stage is the *logic of inconsistency* of (Rescher&Brandom, 1980).

Once conflicting propositions are chosen, supporting arguments and evidence for them are generated from the knowledge bases using a type-theoretic theorem proving technique derived from the *logic of argumentation* as developed in (Krause et al., 1992), (Fox & Krause, 1992).

The following sections describe these logical systems in a little more detail.

4.1 The Logic of Inconsistency

Rescher and Brandom argue that we can 'live with' contradictions and provide a non-standard possible world semantics for a logic containing them (*ie:* they define possible worlds which are overdetermined, in which, for some P, P is true in the world and so is its negation, although the conjunction of P and not-P is not allowed).

Interestingly they talk of the 'ideology of inconsistency' – a philosophical attitude towards inconsistency which is prepared to tolerate it, if this is the necessary price of gaining large bodies of knowledge. They see this tolerant attitude spreading amongst logicians :

> "Over this past generation, logicians are increasingly drawn to the view that one may distinguish between pervasive inconsistency (of the disastrous "anything goes" form) and merely local anomalies, isolable incompatibilities whose logical perplexity is confined to within a small, localised region of a wider system."

They see consistency as a desirable, though not absolutely essential, aspect of rationality :

> "The keystone of cognitive rationality is the idea of doing as well as we possibly can in the cognitive enterprise – of optimising our attainment of its defining objectives."

They illustrate this with an example :

> "Consider the circumstance of a choice betwen two situations : (1) we have only a small area of knowledge – only a handful of our key questions are effectively answered – but there are no contradictions, vs (2) we have a substantial area of knowledge – a great many of our key questions are answered – but there is one small, localized area of inconsistency. Confronted by such a choice, is there anything irrational about preferring a situation whose structure is of the second kind to one whose structure is of the first? Surely not!"

The first situation is what they call a *schematized* (underdetermined) world, one in which for some proposition P it is not possible to decide whether P or not-P is true, so neither P nor its negation hold. This is a common and familiar situation in AI. Most current knowledge based systems have incomplete knowledge in this sense. Why then should we not build knowledge based systems which are instances of *inconsistent* (overdetermined) worlds?

Rescher and Brandom describe how to construct such worlds by the super-position of two or more self-consistent worlds (*ie*: for self-consistent worlds X and Y, the superposed world W is formed by taking the union of the propositions true in X and those true in Y). I propose doing precisely this with knowledge bases, to build systems that contain a collection of representations of different people's knowledge, happily tolerating the inconsistencies between them.

Here is a particular instance of the second of Rescher and Brandom's situations. This is a real example resulting from an experiment involving knowledge acquisition from a small sample of lay informants. This experiment was intended as a pilot stage of a larger study, and was designed to shed light on some of the methodological problems with acquisition of inconsistent information.

In this experiment, informants were asked the open-ended question "What do you speculate will be the impact of the Greenhouse Effect on the climate of Great Britain within your lifetime?" The informants were asked to talk as freely as possible, about anything they thought relevant to this issue, and were also prompted to speculate about how food production may be affected by the Greenhouse Effect. The only other input from the researcher during interviews were occasional prompts of "Why do you think that?" to encourage the informants to offer justificiations of their opinions.

One informant (A) at one point stated that they did not think that global warming would cause sea-levels to rise. Another informant (B) stated precisely the opposite, that global warming would cause (and is already causing) sea-levels to rise. Informant A justified their position with a detailed explanation of why melting the ice caps would not cause an increase in sea-levels. This reasoning involved considering the relative densities of water and ice at different temperatures, the distribution of ice between the Arctic and Antarctic, the proportion of this ice currently displacing sea water, and so forth. Informant B justified their position by reference to their own experience of low-lying tropical islands which are already experiencing flooding due to rises in sea-level, and an extrapolation of this experience both spatially (to Britain) and temporally (to the future).

This is clearly a case of Rescher and Brandom's situation (2), in which we have learned much of interest from the two informants despite the fact that we have a contradiction on the particular question of sea-level rises.

Note that the example in section 3 concerning whether or not to grow Pine in Nepal is also an instance of Rescher and Brandom's situation (2). We learn a lot about pine and its effect on the environment from all the expressed opinions, but the price that we pay is that we can conclude that pine is both beneficial and harmful. But why should we worry about this? We have reduced our level of ignorance, and have learned enough to enable us, if nothing else, to ask more detailed questions.

4.2 The Logic of Argumentation

The logic of argumentation (Fox & Krause, 1992), (Krause et al., 1992) is a logic for providing supporting and opposing arguments for statements in a knowledge base (these can be thought of as shorthand representations of informal proofs of the statements, and are analogous to endorsements (Cohen, 1985)). An Argumentation Theorem Prover (ATP) has been implemented by Paul Krause to automate the generation of arguments and I intend to use it as the main object level inference engine in the system described below.

The purpose of the Logic of Argumentation is to provide a rigorous, symbolic characterisation of probabilistic or uncertain reasoning, which is not necessarily based on numbers. There is philosophical support (for example (Toulmin, 1956)) for their claim that, in contrast to numerical or probabilistic models, (for example, (Lindley, 1985)) a more general model of commonsense reasoning is that of identifying and appraising *arguments* using whatever sources of information are available or relevant to the problem at hand. We need to record the reasoning leading to a conclusion, and not merely a numerical value for the confidence we can have in it, because our confidence in a conclusion may be affected by the source of the information leading to it, or by the validity of the reasoning (which we therefore need to be able to inspect).

The Logic of Argumentation allows inference at two levels:

1. at the object level, to generate arguments for given propositions and
2. at the meta level, to reason about the arguments themselves, in order to assess how confident the arguments allow one to be in the conclusions.

It is important to make clear at this stage that I hope to borrow from their object level work, however my aims at the meta level are quite different from theirs. They reason about arguments in order to come to some assessment of how *certain* the arguments allow one to be of the conclusion. A conclusion for which it is possible to construct several different arguments is treated as having a high level of certainty. In addition, arguments for the negation of a conclusion reduce the level of certainty in that conclusion, and arguments of different sorts (for example, based on experimental evidence, or due to some medical authority) confer different levels of sureness to their conclusions.

Instead what is needed here is a meta-level inference tool which uses arguments for and against a proposition to generate a series of exchanges which together form a debate about that proposition. This will involve analysis of aspects such as the level of generality or specificity of points in the arguments, the source of the arguments, the particular reasoning steps taken in the arguments and so on. The overall direction of the debate (for example, towards consensus) will be controlled by (meta-meta-level) debating strategies, under the user's control. Hence the aim of this research is not to provide a qualitative measure of certainty of a proposition, but to interact with a user in exploring arguments, counter-arguments, contextual information, and in general guiding a user to other relevant information within the set of knowledge bases.

The logic which Krause et al. have chosen to use at the object level is intuitionistic logic, using only conjunction and implication. They have chosen this because it is constructive and rejects the law of excluded middle (ie: that either P or not P is true for all propositions, P), because they want to explicitly allow propositions, for which we claim neither belief nor disbelief. This object level logic is used by the Argumentation Theorem Prover which, given a proposition, attempts to find all possible arguments for it, derivable in the logic.

The full Logic of Argumentation is a labelled deduction system, with the object level logic as described above, augmented by labelling propositions with representations of their arguments (x:A is used to mean that x is a representation of an argument for proposition A). An argument is defined as a proof of a proposition in the object level logic. These arguments are contingent proofs because they may fail due to untrue premisses or incorrect implications. Therefore the underlying logical inferences need be neither valid nor sound, and can hence represent genuinely fallacious (though plausible) reasoning such as people really use. The arguments are represented as typed lambda terms, thus it is possible to give a formal statement of when arguments are equal by reducing them to a normal form. These lambda terms are shown to correspond to proofs in the object level logic by the Curry-Howard Isomorphism. A detailed presentation of the axiom and rules of the Logic of Argumentation can be found in (Krause et al., 1992), presented as a sequent calculus.

The system described below contains a collection of meta-level mechanisms for the comparison of arguments and basic debating mechanisms such as rebuttal, counter-argument, back-up and so on. These constitute a family of meta-level extensions to the Logic of Argumentation.

4.3 System Components

The following is a summary of the principal components of the knowledge based system currently being designed.

Conflict Detector The conflict detector is given a proposition, P, together with information about the person whose knowledge base it comes from, CP (Context for P). It browses through a named knowledge base seeking another proposition Q (with context CQ) which is

- about the same topic, T, as the given proposition, and
- inconsistent with P.

This module will use some automatic conflict detection, based on Rescher and Brandon's logic of inconsistency (Rescher&Brandom, 1980). The types of conflict that it can detect will be governed by a set of definitions given in a conflict definition base. The user will also be able to point out statements from within the knowledge base which they perceive to be in conflict.

Justifier The justifier takes a proposition, P, together with its context label, CP, and constructs justifications, JP, for this propostion from the named knowledge base. JP consists of a set of *arguments*, Ai, each of which is in turn a set (usually with some ordering) of propositions which together form an informal (or possibly formal) proof or refutation of P.

Debater The debater takes a proposition, P (together with context and justifications, CP and JP) and another proposition Q (with CQ and JQ) which is inconsistent with P. For some Ai in JP, the debater searches JQ for an argument Bi, some conclusion of which, Conc, is in conflict with one of the propositions in Ai. Applying the debater repeatedly produces a series of exchanges of the form : *X is the case because Y (a series of justifications, including Z). But Z isnot the case because W (another series of justifications)*. The debater uses meta-level inference in reasoning about the arguments, their structure, and the various techniques available for constructing them at the object level (see below). The debater will be constructed to be controlled by a family of debating strategies each of which runs the debate along different lines - for example, seeking a consensus, 'squabbling', focusing on contextual reasons for disagreement and so on.

User Interface The user will be able to direct the running of the system by interacting with each module (including submodules) to influence the way in which conflicts within the knowledge bases are explored. That is, theuser will be able to intervene in most of the flow of control of the system.

Working Memory This is where the current conflict and justifications will be 'written' for access by all the inference modules. It is analogous to a blackboard in a blackboard system.

The Justifier itself will consist of several submodules each of which generates arguments of different sorts for (or against) a proposition. The modules described briefly below are speculative, as their descriptions may change somewhat on the basis of the knowledge acquired about the domain and the ways in which people are observed to construct arguments.

Context Analysis The context analysis produces arguments in the form of background information about the person whose knowledge or belief P is. For example, whether someone drives a car may have some impact on how prepared we are to believe what they say about cars. This information may make us more or less likely to be convinced by their statements, according to the situation.

Theorem Prover The argumentation theorem prover constructs derivations of P using the axioms and rules of the object level logic of argumentation (see section 4.2).

Corroborator The corroborator seeks propositions which are about the same topic as P, but not inconsistent with it, from other knowledge bases containing other people's statements.

Doubter The doubter seeks statements in other knowledge bases which are in conflict with P (using methods similar to the conflict detector) and thus would cast doubt upon it.

Prober The prober attempts to assess the depth of knowledge in P's knowledge base. It gathers other statements made about the same topic or closely related topics from the same knowledge base, using information about relevance which is either hardwired into the knowledge representation or represented in some neutral semantic base (like a thesaurus). Note that the latter option presupposes a common language and model of the meanings of terms in that language which may be too restrictive a requirement to place on the system.

Note that all of the modules described above involve inference at the meta-level, except for the theorem prover (which is the object-level inference engine) and the user-interface.

5. Further Comments

5.1 The Social Context

It is tempting in talking about creativity and conflict, to talk purely in terms of ideas, systems of ideas, theories, new inventions, works of art and so on. However, to do so exclusively is to run the risk of missing the crucial importance of the role of *people* in disagreement. Although it is true that there are many different, conflicting theories of the Greenhouse Effect (Pearce, 1989), to understand why this is the case we need to accept that it is people who disagree with each other, and that very often the spur for a new theory, or explanation, is an argument with a colleague or rival. Analysis of the assumptions behind models, and the reasoning processes involved in constructing them is only part of the explanation.

One of the crucial things about this way of looking at creativity is that it explicitly takes into account the social context in which creativity happens. This goes some way towards explaining the *motivation* necessary for creativity, which Margaret Boden acknowledges she 'underplays' in her purely psychological account of creative thinking. We need to consider debate, discussions, and even the personal urge to take an independent stance, as important aspects of the creative process. Perhaps a crucial part of Wittgenstein's creativity was the desire to prove himself to be thinking distinctly from his earlier mentor. It was perhaps not enough to doubt some of Russell's ideas. He needed to disagree with the man himself.

For this reason, the knowledge bases in the work described here contain explicit representations of the people whose opinions are contained within them, and this information is used in the analysis of conflicts. For example, when constructing knowledge bases of people's opinions about how to grow and use trees and woodland in the hills of Nepal, or the plains of Tanzania (Haggith et al., 1992), records are kept of whose opinions they are, and under what conditions they were stated. When analysing inconsistencies in the knowledge bases this information can be used to try to take the implicit goals and priorities of these people into account, in presenting a debate intelligible to a user of the system. Likewise, whether or not someone has a car has a bearing on how we interpret what they tell us about the effects of cars on the atmosphere.

5.2 Notes on Knowledge Acquisition

In the construction of most knowledge based systems, the aim is for a consistent knowledge base. This is a tacit acceptance of the traditional positivist notion that science is aiming to gather knowledge which is objective. Knowledge acquisition usually presupposes that it is possible to abstract away the effect of the 'knowledge engineer' and produce a knowledge base which is 'the god's eye view' of the subject at hand. In building expert systems, we deify the expert, removing any information which expresses 'personal bias' or 'speculation'.

Clearly this approach and attitude is inappropriate for a study of the sort described here. We need to be candid and honest that the knowledge bases will contain a variety of opinion. To do justice to people's actual views we also need to be conscious of the effect that the 'knowledge engineer' can have on the content of the knowledge bases. We must be honest about the fact that every statement within them is an interpretation of what someone has said, and may therefore be a misrepresentation of that person's actual beliefs. Explicit efforts must be made to minimise the level of interpretation by the researcher and verify the accuracy of the representations. We cannot claim that consistency and completeness checks will help us to verify our knowledge bases, as we have explicitly rejected these as possible criteria for useful knowledge base design. Methodologically speaking, therefore, the research described here is more difficult than conventional knowledge based systems research.

6. Conclusions

It is erroneous to think of creativity solely in terms of mental processes going on in any single mind. Our creative skills include debating, discussing, negotiating on what constitute explanations, generating consensus and compromising. Any account of creativity which treats it as if in a social vacuum, will therefore be impoverished. Interactions between agents with different points of view can, by negotiation, generate new ideas, and these interactions can be modelled using logical techniques and integrated into knowledge based system designs. In particular, differences of opinion about our environment can be explicitly represented in knowledge bases and used to provide informative, interactive decision support. Perhaps such support will help us to be less dogmatic and more creative in tackling our global environmental problems.

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