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"What is SP?": a Reply

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My interest in information compression as an explanatory principle in information processing was sparked originally by lectures given by Horace Barlow in Cambridge University describing phenomena in the workings of brains and nervous systems which could be understood in terms of economical coding of information (see, for example, Barlow, 1969; Barlow and Földiák, 1989). Later, an accumulation of evidence led me to the view that many aspects of language learning by children could be understood in these terms (Wolff, 1988).

About 1987, I began to realise that several aspects of 'mainstream' computing might also be understood as information compression. These insights suggested the possibility of developing a new kind of computing system with more flexibility and 'intelligence' than conventional computers. An article describing this thinking was published in this journal (Wolff, 1990).

Subsequent research has attempted to resolve the many questions which naturally arise from the 'SP' conjecture that *all kinds of computing and formal reasoning may usefully be understood as information compression by pattern matching, unification and metrics-guided search*. Recent publications in this programme of research include Wolff (1993) which describes the background and motivation for the research, Wolff (1994a) which describes how the design of software and its execution may be seen as information compression, Wolff (1994b) which describes an application of these ideas in best-match retrieval of information, Wolff (1995a) which is an overview of the research at mid-1994 and Wolff (1995b) which describes a recent model of the proposed new system. The latest thinking is described in Wolff (1995c) and in Wolff (submitted, a and b).

1 A RESPONSE

The purpose of this short article is to respond to an earlier article in this journal (Stephen and Mather, 1994, hereinafter referred to as WSP) which criticises the programme of research. That article is very similar to another article by the same two

authors published in another journal (Stephen and Mather, 1993). Both articles are riddled with inaccuracies and misconceptions.

A detailed response to WSP is not necessary here because a full response to the earlier article has already been published (Wolff, 1994c) and it answers all the main points in WSP. The previous reply has been written so that it is 'free standing' and may be understood without reference to earlier publications. Readers with an interest in these matters should find that it provides useful commentary on aspects of the research.

In the rest of this article I will briefly discuss three themes which seem to deserve more comment: questions of research strategy and 'vision', computational complexity, and determinism.

2 RESEARCH STRATEGY AND VISION

Like the earlier article, WSP demonstrates a basic misunderstanding of the strategy in this programme of research.

From the beginning, there has been the germ of an idea which has suggested the possibility of substantial benefits in terms both of science and of applications. These potential benefits constitute a 'vision' of where the research may lead which provide the motivation for doing the research. They cannot possibly be 'claims' for the SP theory because the central idea in that theory is still only a conjecture and has been clearly marked as such from the beginning.

Given the motivation for pursuing these ideas, the strategy has been to adopt the SP conjecture as a working hypothesis and to see how far it can be 'pushed'. If it turns out to be wrong, relatively little is lost. If it turns out to be right, the potential benefits are very large.

The central idea is embodied in a 'model'. Each area of potential application needs to be examined to see whether the model can be applied and, if so, how. Apparent contradictions or conflicts in the ideas need to be examined to see whether they provide sufficient reason to abandon the hypothesis or whether they can be resolved in other ways.

The model is progressively refined to accommodate as wide a range of concepts as possible. At all stages, the temptation to add *ad hoc* features to the model must be resisted. In accordance with good practice in science and engineering and, indeed, in accordance with the SP theory itself, the aim at all stages is to develop a model which combines simplicity with explanatory or descriptive 'power'.

WSP fails to recognise this process of progressive refinement and the need to preserve parsimony in the developing model. There is an implicit belief that a theory

springs into life fully formed with all its details in place. The article assumes that elements of the model like 'variable' or 'negation' can be given arbitrary formal definitions without regard to the overall framework of ideas.

The uncertainty about concepts like 'variable' and 'negation' has arisen because it has not been clear whether they could be accommodated as emergent properties of the core model or whether they should be adopted as primitives in the theory. I am now reasonably confident that there is no need for a concept of a variable as a primitive component of the model. Until recently it has appeared that a concept of negation would be required as a primitive but recent insights suggest that, like the concept of a variable, negation may be modelled by other constructs.

3 COMPUTATIONAL COMPLEXITY

Stephen and Mather seem not to have understood that there are many interesting problems in computing, especially in the area of 'artificial intelligence', where the abstract space of possible solutions is too large to be searched exhaustively. They seem not to have understood, either, that there are standard ways of dealing with this type of problem which are described in every elementary text book of artificial intelligence.

The basic idea is to search the solution space in stages, choosing the most promising path or paths at each stage and thus ignoring large parts of the space. With this approach, reasonably good solutions can often be found without undue computational effort but ideal solutions cannot normally be guaranteed.

There is a trade-off between computational complexity and the effectiveness of the search. However large the search space may be, there is always the possibility of searching it in such a way that the computational complexity of the process is acceptable. This normally means some sacrifice in the effectiveness of the search but, for many practical problems, acceptably good solutions can often still be found.

These ideas are found in different forms in a range of techniques including hill climbing (descent), beam search, genetic algorithms, simulated annealing and others. These kinds of techniques may be described collectively as 'metrics-guided search'.

3.1 Towards a general-purpose search method

The SP programme aims to develop a theory of computing which embraces 'AI' problems as well as the more traditional kinds of problem. That being so, the theory must necessarily embrace principles of metrics-guided search.

At present, this kind of search appears in many different programs and systems. If it is true that *all* kinds of computing and formal reasoning may be understood in terms of pattern matching, unification and metrics-guided search then there is the interesting possibility of developing *one* general-purpose search method which may serve many different purposes.

This idea is similar to the way in which search mechanisms in a database management

system or expert system shell may be used for diverse applications thus saving the need to reprogram those search mechanisms for each application. The SP programme seeks to push this idea further by generalising existing search methods to integrate learning, reasoning, information retrieval and other aspects of computing within one simple conceptual framework.

4 DETERMINISM

The remarks about determinism in WSP appear to reflect a naïf view of the nature of computing and formal systems. The authors appear to be looking for clockwork certainty in formal systems long after Gödel provided a negative answer to the question posed by Hilbert about whether such certainty was possible. Again: "I have recently been able to take a further step along the path laid out by Gödel and Turing. By translating a particular computer program into an algebraic equation of a type that was familiar even to the ancient Greeks, I have shown that there is randomness in the branch of pure mathematics known as number theory. My work indicates that - to borrow Einstein's metaphor - God sometimes plays dice with whole numbers!" (Chaitin, 1988, p. 80).

A Turing machine may be deterministic or non-deterministic depending on its transition function and the information on its tape. In a similar way, it appears that the proposed SP system may be deterministic or non-deterministic depending on its search method and the information with which it is supplied. But none of these systems can escape from Gödel's result: all computational systems are necessarily 'fuzzy at the edges'.

5 CONCLUSION

As already indicated, detailed answers to the main points in WSP are given in Wolff (1994c) which may be read as a free-standing commentary on aspects of the research. However, I hope that readers will judge for themselves the merits of these ideas by consulting other sources which have been cited. The best introduction is probably Wolff (1995, a and b). Background thinking is described in Wolff (1993).

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