A FOUNDATION FOR THE DEVELOPMENT OF HUMAN-LEVEL AI AND A NEW FOUNDATION FOR MATHEMATICS

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Abstract

Deep Neural Networks have led to some good applications so it is assumed that they will be a good foundation for the development of human-level AI. But other research suggests that a better foundation for that development is the *SP Theory of Intelligence*, including the powerful concept of *SP-Multiple-Alignment*, founded on much evidence for the importance of information compression in the workings of brains and nervous systems. That idea has led to the discovery that much of mathematics, perhaps all of it, may be understood as a set of techniques for compression of information, and their application.

AI is much in the news these days, with good reason. Some very impressive things have been done wih AI technologies as they are now: beating the best human players at the game of Go; greatly speeding up the process of discovering plausible 3D protein structures from sequences of amino acids; translation between natural languages such as English and French; recognising images of objects; distinguishing between email spam and ordinary emails; and several more.

It is natural to assume that the AI paradigm which dominates today—'Deep Neural Networks' (DNNs)—is largely responsible for successes like those outlined above. And it is natural to assume that, with DNNs and a little more work, we should be able to create human levels of AI, otherwise known as 'Artificial General AI' (AGI).

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But there are reasons to believe that DNNs are a cul-de-sac in the search for AGI, and that another approach to AI—the *SP Theory of Intelligence* (SPTI) and its realisation in the *SP Computer Model* [8, 11]—holds more promise. Unexpectedly, the new thinking for development of the SPTI has led to new foundations for mathematics.

DNNs began as extensions to 'Artificial Neural Networks' (ANNs), meaning networks of artificial neurons designed to represent, in their structure and workings, what was and still is our limited understanding of the structure and workings of natural networks of neurons in the brain.

ANNs were made 'deep' by adding several layers of artificial neurons—sometimes many such layers—between the input layer and the output layer. And those new DNNs (newly-created from ANNs) were adapted by adding methods of processing such as 'backpropagation' to each layer of neurons. Also, DNNs normally need to be 'trained' with large amounts data before they can do anything useful. With features like these, DNNs provided the basis of systems with capabilities like those outlined above.

The SPTI is rather different. It was inspired originally by research from the 1950s and later, pioneered by Fred Attneave [1, 2], Horace Barlow [3, 4] and Satosi Watanabe [5, 6], showing that much of the workings of brains and nervous systems, can be understood as information compression (IC)—which means making any given body of information smaller by extracting unnecessary repetition of information from it. There is now a lot of evidence for the importance of IC in the workings of brains and nervous systems [9].

It is interesting that, as long ago as 1959, Barlow recognised that IC might be the key to human intelligence [3]. Later, he wrote:

> "... the operations needed to [achieve IC] have a rather fascinating similarity to the task of answering an intelligence test, finding an appropriate scientific concept, or other exercises in the use of inductive reasoning. Thus, [compression of information] may lead one towards understanding something about the organization of memory and intelligence, as well as pattern recognition and discrimination." [4, p. 210],

These insights have led to the SPTI as it is now, including the powerful concept of *SP-Multiple-Alignment*, illustrated in Figure **??**.

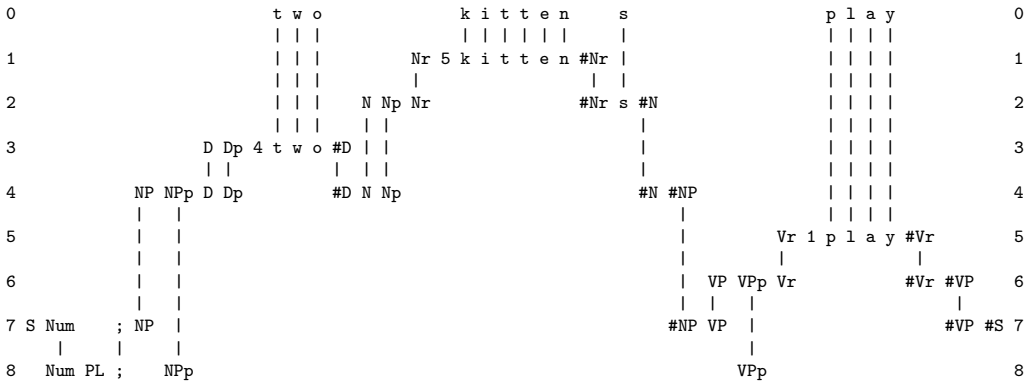

Figure 1: The best SP-multiple-alignment created by the SP Computer Model with a store of Old SP-patterns like those in rows 1 to 8 (representing syntactic structures, including words) and a New SP-pattern, '`t w o k i t t e n s p l a y`', shown in row 0, representing a sentence to be parsed. Adapted from Figure 1 in [7], with permission.

The general idea with SP-Multiple-Alignments within the SPTI is to align patterns so that the pattern in row 0 (a sentence in this case) can be encoded economically in terms of the patterns in rows 1 to 9.

The SP-Multiple-Alignment concept within the SPTI has proved to be very versatile in modelling many different aspects of human intelligence. *The SP-Multiple-Alignment concept is* **a major discovery** *with the potential to be as significant for an understanding of intelligence as is DNA for an understanding of biology. It may prove to be the 'double helix' of intelligence!*

Compared with DNNs, the main advantages of the SPTI include: greater accuracy in recognition; advantages in the processing of natural languages; and advantages in how the system learns. Those advantages in learning include: learning useful knowledge from a single example, and cutting out the huge volumes of data needed for the training of DNNs; the integration of old and new learning; and reducing or eliminating the corrupting effect of errors in the data which is the basis of learning.

As indicated earlier, the idea that intelligence may be understood as IC has led to **a second major discovery**: *that much of mathematics, perhaps all of it, may be understood as a set of techniques for IC, and their application [10].* From that discovery, potential advantages in science and beyond may flow from the creation of a *New Mathematics* as an amalgamation of mathematics with the SPTI [10, Section 9.2].

Further development of these ideas would be facilitated by the creation of an industrial-strength *SP Machine*, as shown schematically in Figure 2. The SP Machine would be derived from the SP Computer Model with the application of

high levels of parallel processing. For any research group or individual researcher, one or more SP Machines would be invaluable for exploring the pros and cons of each proposed development.

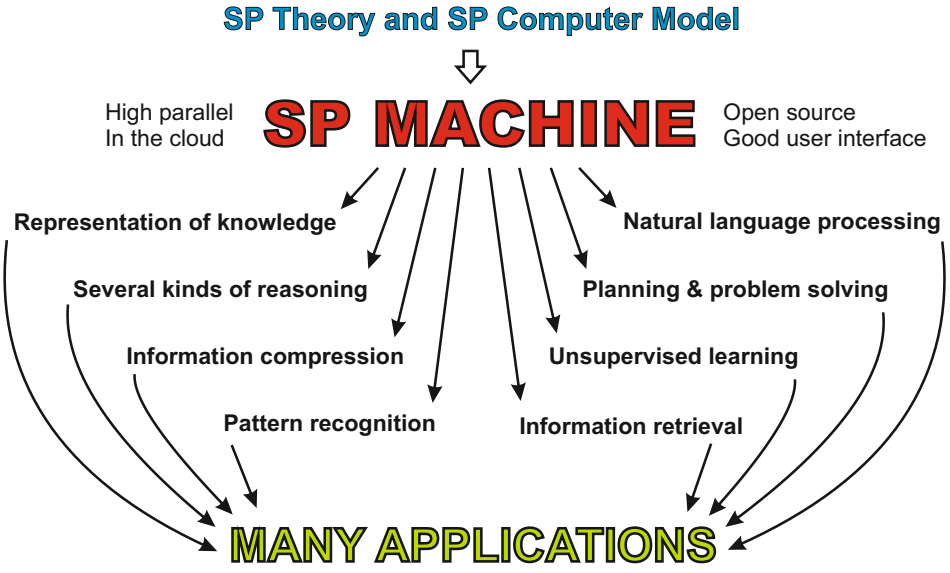

Figure 2: Schematics representation of the creation of the *SP Machine* from the SP Computer Model, and its operation.

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