

Preface

In this book I argue that a reason for the limited success of various studies under the general heading of cybernetics is failure to appreciate the importance of continuity, in a simple metrical sense of the term. It is with particular, but certainly not exclusive, reference to the Artificial Intelligence (AI) effort that the shortcomings of established approaches are most easily seen. One reason for the relative failure of attempts to analyse and model intelligence is the customary assumption that the processing of continuous variables and the manipulation of discrete concepts should be considered separately, frequently with the assumption that continuous processing plays no part in thought. There is much evidence to the contrary including the observation that the remarkable ability of people and animals to learn from experience finds similar expression in tasks of both discrete and continuous nature and in tasks that require intimate mixing of the two. Such tasks include everyday voluntary movement while preserving balance and posture, with competitive games and athletics offering extreme examples.

Continuous measures enter into many tasks that are usually presented as discrete. In tasks of pattern recognition, for example, there is often a continuous measure of the similarity of an imposed pattern to each of a set of paradigms, of which the most similar is selected. The importance of continuity is also indicated by the fact that adjectives and adverbs in everyday verbal communication have comparative and superlative forms.

Primitive organisms are more obviously dependent on continuous processing than are higher animals, though at all levels life depends on complex regulatory processes having continuous character. The suggestion here is that continuous processing should be seen as more primitive, with concept-based thought evolved from it. It is only possible to speculate about the mechanism of the evolutionary development, but a plausible theory is advanced. Because evolution does not erase traces of earlier forms, this may shed light on little-understood subconscious processes that underlie concept-based thought.

I realised the need to combine continuous and concept-based processing in connection with a project to make an automatic controller with learning capability for an industrial plant. Since then, the same need has been acknowledged and to some degree satisfied in many contexts by the advent and vast elaboration of fuzzy theory. From the evolutionary point of view this is wrong, as it amounts to accepting the

concept-based or “logical” part of the process as primary and grafting continuity onto it. In many applications of fuzzy theory, parameters of truth functions are chosen by a designer and retained if they prove successful, or modified otherwise. This means that the fuzzy controller relies on the collaboration of a human acting as a continuous adaptive controller.

Continuous measures come to be associated with intelligent information processing in subtle ways, as acknowledged in Marvin Minsky’s reference to measures of similarity, or *heuristic connection*, between problems, and in the associated *basic learning heuristic* of Minsky and Selfridge. The latter requires measures of similarity between situations and between responses. This reappearance of continuity supports a potentially valuable view of intelligence as having fractal nature, with structures at a complex level, interpreted in terms of measures of this subtle kind, mirroring others at a simpler level.

Criteria of similarity of situation and response are fundamental to any process of learning or adaptation, including biological evolution. The success of any process of adaptation depends on representation of the evolving structure in a way that allows rather major change, probably in small steps, but without too great a chance of complete disruption. It is difficult to see how this might be achieved other than by means that can be decomposed into nested processes of “adapting to adapt” and probably “adapting to adapt to adapt” and so on. The viewpoint implicit in early discussions by Minsky and Selfridge and expanded here may therefore have deep implications for biology.

Because the brain is the supreme example, adaptation and learning are frequently considered in terms of neural nets, and a chapter is devoted to this, with particular reference to a principle that I termed *significance feedback* in an early report. The later principle of *backpropagation of errors* is a special case and is the basis of most applications of artificial neural nets, a field that has flourished in recent decades. I argue that other forms of *significance feedback* also merit attention.

I have used the term “cybernetics” in my title, and in the first chapter I have tried to explain what I understand by the term. At the present time its interpretation has become surprisingly controversial, with some writers claiming that cybernetics and AI have nothing in common. Certainly there is increasing emphasis on sociology (communication and control *between* people and groups) often to the exclusion of the study of communication and control *in* the animal and the machine. The latter was specified in Wiener’s original title and if taken literally places primary emphasis on neurophysiology and computing, though it was understood from the start that the topic was interdisciplinary with wide ramifications. Its aim, with this emphasis, has been slightly paraphrased in reference to McCulloch as that of “understanding man’s understanding”, in a context that implies essentially mechanistic explanation, and for this the achievement of forms of artificial intelligence must be the ultimate “proof of the pudding”.

Another general point that should be made is in connection with the small amount of rather elementary mathematics that I have included. I have great respect for the many highly mathematical treatments that bear on systems theory but believe they are not relevant here because they provide tools for use by sophisticated people

whose thought processes in applying them have gone well beyond the origins of concept-based reasoning that I hope to illuminate. There is also much material under the headings of neuroscience and psychology that impinges on the theme and that I have ignored or mentioned only cursorily. For this my excuse is that these findings, sound and hard-won though they are, leave very major questions unanswered, and unravelling of the working of the brain will require combined assaults from many directions, of which I hope that what I have presented counts as one.

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