Forward to *Map-seeking circuits in visual cognition*

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Neuroscientists, psychologists, and engineers have long sought to understand how the brain transforms retinal images into meaningful representations of objects and surfaces in the environment. Among the biggest unresolved mysteries is the question of how one can recognize an object given that its projection on the retina almost never appears exactly the same way twice. That this even presents a problem comes as a surprise to most, but when one thinks in neural terms about what needs to be solved it looms quite large. The late neuropsychologist Karl Lashley summarized the situation as follows:

> Visual fixation can be held accurately for only a moment, yet, in spite of changes in direction of gaze, an object remains the same object. An indefinite number of combinations of retinal cells and afferent paths are equivalent in perception and in the reactions they produce. This is the most elementary problem of cerebral function and *I have come to doubt that any progress will be made toward a genuine understanding of nervous integration until the problem of equivalent connections, or as it is more generally termed, of stimulus equivalence, is solved.*[1] (emphasis added)

I believe this book by David Arathorn provides us with the first real glimpse at an answer to Lashley's dilemma. Arathorn has created a neural network which solves the correspondence problem—essentially, Lashley's 'stimulus equivalence' problem—by dynamically modifying connections between input and output layers. He calls his network a *map-seeking circuit*, as it seeks to find a mapping between incoming data (images) and stored knowledge that provides the best match between them. The idea is actually quite general, in that it could also be applied to correspondence problems involving comparisons across space or time, such as in stereopsis or motion. In fact, it seems quite possible that map-seeking circuits could be a central ingredient in solving many of the problems faced by the cerebral cortex.

Dynamic remapping circuits were first proposed in 1947 by Walter Pitts and Warren McCulloch in order to explain how we recognize "universals," such as musical chords independent of pitch, or visual forms independent of size.[2] Since then there have been a number of other proposals along similar lines[3−5]. What sets Arathorn's scheme apart is his utilization of the "ordering property of pattern superpositions," which allows all remappings of the input and stored patterns to be superimposed in the network during the map-seeking process. The best mapping is then quickly resolved via a recurrent computation in which connections between input and output layers are dynamically gated according to the degree of match between them. What is perhaps most impressive about this scheme is that it actually seems to work. Arathorn shows that the network is capable of recognizing objects embedded in fairly complex, natural scenes, and that the amount of time it takes to do so is consistent with physiological and psychophysical data on the timecourse of object recognition. A hardware implementation is currently in the works and is described in Chapter 8 [Editor: make sure this is correct for the final version].

This work comes as a refreshing development, and it is perhaps no accident that it has emerged from outside the traditional academic circles in neuroscience and psychology. Arathorn is a computer scientist working primarily in industry who has considerable experience devising practical solutions to complex problems. He has obviously thought long and hard about the problems of visual cognition and how to solve them using neural circuitry. What has emerged here is one of the most creative, insightful, and sophisticated computational models of visual cognition to date. For neuroscientists and psychologists, it should provide a framework for thinking about visual cognition in neural terms, something that is sorely needed in the design of experiments.

Only time will tell whether or not the brain actually uses map-seeking circuits. What we do know is that nature hides her secrets well, and it is through the construction and subsequent testing of models such as this one that we will eventually unravel the inner workings of the brain.

References

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