Abstract

We present a model of binding of relationship information in a spatial domain (e.g., square above triangle) that uses low-order coarse-coded conjunctive representations instead of more popular temporal synchrony mechanisms. Supporters of temporal synchrony argue that conjunctive representations lack both efficiency (i.e., combinatorial numbers of units are required) and systematicity (i.e., the resulting representations are overly specific and thus do not support generalization to novel exemplars). To counter these claims, we show that our model: a) uses far fewer hidden units than the number of conjunctions represented, by using coarse-coded, distributed representations where each unit has a broad tuning curve through high-dimensional conjunction space, and b) is capable of considerable generalization to novel inputs.

1 Introduction

The binding problem as it is classically conceived arises when different pieces of information are processed by entirely separate units. For example, we can imagine there are neurons that separately code for the shape and color of objects, and we are viewing a scene having a red triangle and a blue square (Figure 1). Because color and shape are encoded separately in this system, the internal representations do not discriminate this situation from one where we are viewing a red square and a blue triangle. This is the problem. Broadly speaking, there are two solutions to it. Perhaps the most popular solution is to imagine that binding is encoded by some kind of transient signal, such as temporal synchrony (e.g., von der Malsburg, 1981; Gray, Engel, Konig, & Singer, 1992; Hummel & Holyoak, 1997). Under this solution, the red and triangle units should fire together, as should the blue and square units, with each group firing out of phase with the other.

The other solution can be construed as solving the problem by questioning its fundamental assumption — that information is encoded completely separately in the first place (which is so seductive that it typically goes unnoticed). Instead, one can imagine that color and shape information are encoded together (i.e., conjunctively). In the red-triangle blue-square example, some neurons encode the conjunction of red and triangle, while others encode the conjunction of blue and square. Because these units are explicitly sensitive to these