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# Asynchronous Connectionist Binding

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## Introduction

Historically, connectionist systems have not excelled at representing and manipulating complex structures. How can a system composed of simple neuron-like computing elements encode complex relations? Recently, researchers have begun to appreciate that representations can extend in both time and space. Many researchers have proposed that the synchronous firing of units can encode complex representations. I identify the limitations of this approach and present an asynchronous model of binding that effectively represents more complex structures. The asynchronous model is a generalization of the synchronous approach. I argue that our cognitive architecture utilizes a similar mechanism.

directional bindings, providing greater representational power.

A more complete description of this work can be found at:

<http://www.psych.nwu.edu/psych/people/grad/love/CogSciAsynch.ps>

## The Binding Problem

Simple connectionist models can fall prey to the "binding problem". A binding problem occurs when two different events are represented identically. For instance, if the units JOHN, HIT, and TED are activated to represent "John hit Ted", a binding problem occurs because the same pattern of activation would also be used to represent "Ted hit John". The binding problem is ubiquitous and is a concern whenever internal representations are postulated. Classical symbolic systems can circumvent the binding problem by adopting a LISP-like representational syntax which has the expressive power of the lambda calculus. Unfortunately, this mode of representation is fairly unconstrained and makes few predictions about performance. Still, classical symbolic models can represent complex relational information effortlessly.

## Connectionist Binding

Synchrony models of binding represent bindings through the synchronous firing of units. While this approach does utilize time to mark bindings, synchrony is limited in its expressive power and is better characterized as a grouping mechanism than as a binding mechanism.

Unlike the synchronous approach, the asynchronous approach fully exploits time resources and allows for