Fast Dynamic Link Matching\(^1\)

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Introduction

We present a model for the rapid self-organization of a mapping between two patterns. Such correspondence patterns play a role for various visual tasks, such as object recognition, stereo matching and motion estimation. All being fast and effortless to humans, these tasks are, nonetheless, computationally difficult, because invariance to transformation parameters such as scaling, rotation and translation have to be dealt with.

Our model is an extension of Dynamic Link Matching (DLM, Häusssler and v.d.Malsburg 1983, Wiskott and v.d.Malsburg 1996). DLM is functionally powerful but too slow in the light of neurophysiological and psychophysical data. We present here a model that has significantly shorter convergence time than DLM. The model is based on synaptic control units, which mediate interactions between rapidly switching synapses. Whereas individual synapses are ambiguous in terms of transformation parameters, each control unit stands for a fixed set of values of these parameters.

The Model

The patterns to be matched are grey level patterns and are represented by fields of feature-specific neurons. As features we use Gabor components. As in the original DLM, synaptic weights between the neural fields are rapidly changing system variables, and their growth is controlled by cooperation and competition. The main difference is on how cooperation is computed. Cooperation is mediated by control units, each of which corresponds to a local group of synapses ("synaptic pool"). Control has the following form: 1. the activity of control units is computed from their groups of synapses; 2. control units that are consistent with each other in terms of transformation parameters exchange cooperation through pre-established connections; 3. synaptic strengths are computed directly from the locally dominant control unit. Competition between synapses acts to keep the sum of synaptic weights constant for all synapses that converge on one location and all that diverge from one location. The initial connection strengths between pairs of points in the two neural fields are set equal to the feature similarities between the points.

Our simulations for the one-dimensional case show that a correct continuous mapping can be formed quickly, independent (within bounds) of variation in relative scale and position. (Local scale may be non-uniform, representing deformation.) A rough mapping forms in as few as 10 iterations. The transformation parameters of the mapping can be read out immediately from the activity of the control units.

Analysis and Discussion

The main factor enabling our model to speed up dynamic link matching lies in the fact that the control units, each of which corresponds to a specific combination of transformation parameters, can afford to have fairly specific long-range cooperative interactions (whereas individual synapses, which are vastly ambiguous as to their transformation parameters, can correspondingly only have very unspecific cooperative interactions). In consequence, slow local symmetry breaking is not necessary and a specific coherent projection pattern between image and model can grow by rapid propagation like a brush-fire.

Our model is conceptually related to C. Anderson’s shifter circuits (Anderson and van Essen, 1987). Unlike in that proposal, however, we consider the control units of our model as a mere computational device standing in for direct group-wise interactions between pools of synapses. Another, more important, difference lies in the local control of synaptic modification which doesn’t require a third party to exert control.

This work demonstrates how control units can speed up the process of map formation. We envisage that the connections between control units (or rather synaptic pools) are learned in a quasi-Hebbian fashion. Thus, once a consistent mapping has been formed by slow conventional DLM within several seconds, the resulting structure can be stored in the connections between control units such that the original map can be recalled within small fractions of a second. This process of learning is, however, beyond the scope of the present model.

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