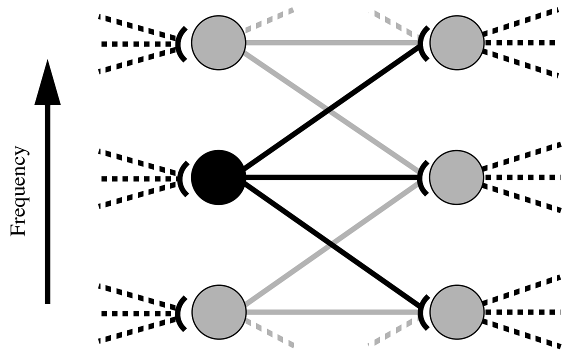
Synfire chains as a neural mechanism for auditory grouping

S.N. Wrigley and G.J. Brown, Department of Computer Science, University of Sheffield, 211 Portobello Street, Sheffield, S1 4DP

The fundamental goal of Auditory Scene Analysis (Bregman, 1990) is the separation of multiple simultaneous sounds into distinct perceptual objects, allowing the listener to attend to one component of the acoustic mixture. Computational solutions to this perceptual problem have been varied but few have been physiologically plausible (see Rosenthal & Okuno, 1998 for a review).

Our model concentrates on the issue of how information about acoustic features which is represented in a distributed manner in the auditory nervous system is bound together to form a perceptual whole - the "binding problem". The model consists of a simple network of integrate and fire neurons connected in a feedforward manner (Abeles, 1991).



Synfire chain of width 3

More specifically, the network consists of several parallel chains of neurons in which the feedforward connections synapse with adjacent cells (figure 1). As a result of this topology, desynchronised spike trains at the input to the synfire chain become synchronised at the output. Also, the lateral connections of the network give rise to grouping by frequency proximity; spatially close inputs give rise to synchronised activity, where as spatially distant inputs do not.

The current model differs from the work of Wang and Brown (Wang, 1996; Wang and Brown, 1999), in that synfire chains use action potential synchronicity as their processing substrate rather than oscillatory correlation. In the synchronicity framework, each auditory feature is represented by a cluster of synchronised synfire chains. Similarly, a stream is represented by a population of synchronised synfire chain clusters (features), and different streams are represented by desynchronised synfire chain clusters.

Initially, we have investigated the ability of the network to account for grouping according to frequency proximity. The model demonstrates a good match to the stream segregation/temporal coherence behaviour described by van Noorden (1975). In order to fully account for the perception of alternating tone sequences, however, the model must incorporate a mechanism for sequential integration. We discuss modifications of the synfire chain network which would achieve this.

References

Abeles M. Corticonics. Neural circuits of the cerebral cortex. Cambridge, UK: Cambridge University Press, 1991.

Bregman AS. Auditory Scene Analysis. Cambridge: MIT Press, 1990.

van Noorden LPAS. Temporal coherence in the perception of tone sequences. Doctoral thesis, Institute for Perceptual Research, Eindhoven, NL, 1975.

Rosenthal DF, Okuno HG (Eds). Computational Auditory Scene Analysis. Mahwah, NJ: Lawrence Erlbaum, 1998.

Wang DL, Brown GJ. IEEE Transactions on Neural Networks, 1999; 10(3):684-697.

Wang DL. Cognitive Science, 1996; 20:409-456.