Reliable switching between partially synchronized cluster states of globally coupled phase oscillators

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In weakly connected neural networks the voltage oscillations of individual neurons has not been modified significantly by the coupling. Consequently, synchronization can be described adequately by using only the phase of these oscillations.

We consider a highly connected network with all-to-all connections. Both the oscillators and the connections are considered to be identical. By using an asymmetric coupling function partially synchronized states are found which consist of several clusters of synchronized oscillators. By symmetry, several cluster states can be found with the same number of clusters containing the same number of neurons [1].

For saddle-type cluster states stable heteroclinic connections are detected between the states; these realize 'winnerless competition' dynamics between cluster states. A typical trajectory of the system approaches this heteroclinic network spending more and more time close to the synchronized cluster states.

Exploiting the structure of the network we demonstrate that it is possible to navigate around such networks by applying arbitrarily small pulses on individual oscillators [2]. This navigation may be done reliably even in the presence of noise, as long as the time between required transitions is in a suitable range and the input-to-noise ratio is large enough [3].

For stable cluster states excitable behavior can be found. Extra equilibria appear along the heteroclinic connections which determines a threshold for the pulses. If the pulse is below threshold the system relaxes back to the considered cluster state. Large enough pulses excite the system and drives it to another cluster state along the heteroclinic connection. We also show that the heteroclinic network may be destroyed by varying its parameters leading to phase chaos in the system.

The above dynamics may allow a very high number of partially synchronized states to encode information in a neural system in a robust way.

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[1] P. Aswin and J. Borresen. *Physical Review E*, 70(2):026203, 2004.

[2] P. Aswin and J. Borresen. *Physics Letters A*, 347(4-6):208?-214, 2005.

[3] P. Aswin, G. Orosz, J. Wordworth, and S. B. Townley. *In Preparation*, 2006.