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Dynamics at the interface dividing collective chaotic and synchronized periodic states in a CML

Marcelo M. Disconzi, Leonardo G. Brunnet*

Instituto de Física, Universidade Federal do Rio Grande do Sul, Caixa Postal 15051, 91501-970 Porto Alegre, RS, Brazil

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Abstract

A study is developed focusing the loss of stability of the interface dividing two regions of different spatial patterns on a coupled map lattice using coupling as the parameter guiding the transition. These patterns are constructed over local periodic/chaotic attractors generating regions of synchronized/collective behavior. The discrete feature of the underlying lattice, the anisotropy that stems from such discreteness and its possible change to an isotropic system through coupling with large number of neighbors are also investigated.

Keywords: Coupled map lattices; Extended chaotic dynamical systems; Collective behavior

1. Introduction

During the last three decades we have been dealing with a great increase in researches related to non-equilibrium systems. Words such as "chaos", "dynamical systems", "complex behavior" and "non-equilibrium" have been found more often in literature. Particularly interesting in physics are the systems with large number of

*Corresponding author. Fax: 55 51 316 6483.
E-mail addresses: disconzi@if.ufrgs.br (M.M. Disconzi), leon@if.ufrgs.br (L.G. Brunnet).
URL: http://pcleon.if.ufrgs.br.

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degrees of freedom. However, methods imported from equilibrium statistical mechanics seem to be insufficient to describe such systems in a number of situations called "out of equilibrium". Often new mathematical tools are developed to deal with them, but a complete "non-equilibrium statistical mechanics" is far from being completely built up.

The powerful computers developed during the last decade enabled us to intensively investigate those systems using numerical methods. Coupled Map Lattices (CML) is a very well-studied case. Since the pioneering works of Kaneko [1], lattices of coupled maps have been used as toy models to investigate universal properties associated to extended non-equilibrium systems.

Different dynamical behaviors can be observed in such lattices, particularly when the coupling produces an average among the nearest neighbors—what is called the *diffusive coupling*. Frequently, the dynamical systems with such coupling exhibit the *non-trivial collective behavior* (NTCB) [2], which is characterized by a well-defined and regular time evolution of lattice *average* quantities—*despite* the local chaos—indicating the existence of a low-dimensional global attractor. The more the lattice size is increased, the sharper these average quantities become.

Among the states which characterize the lattice, different kinds of transition can be observed according to the map parameters, the coupling or the dimension used. The first investigations have shown that one way to reach NTCB is to use a chaotic local map [2]. At very low coupling we expect that each site follows its chaotic route without being significantly perturbed by its neighborhood, what leads to a stationary regime of lattice average quantities. As the coupling is increased a dynamical average behavior diffuses over the lattice resulting in an emerging NTCB characterized by periodic global averages. Such behavior remains up to the highest coupling values and up to the high lattice dimensions [3,4]. Briefly, the works from Chaté and collaborators [5] state that a sufficient condition for NTCB to exist, either in a CML or in a lattice of coupled ordinary differential equations, is the presence of local chaos, even if periodicity windows exist for particular parameter values. In a previous work [6] this problem was explored in the presence of multiple basins of attraction. According to that work, we can find NTCB if the local phase space contains multiple attractors coexisting at finite distances in parameter space. This last situation was investigated deeply by Martins [7], who used a map with a local period-two attractor. In that work one finds a collective behavior emerging from a local periodic attractor surrounded by chaos in the parameter space—i.e., the chaos plays its role indirectly; it is not found in the uncoupled map.

In this work we introduce a local map which presents two basins of attraction of equal size: one in which every initial condition is attracted to a (linearly) stable fixed point and another where the initial conditions converge to an invariant non-periodic set with typical chaotic behavior. In this way we can better investigate the competition between chaotic and periodic states taking into account only the behavior driven by the coupling. Specifically, we are interested in the dynamics at the interface of the lattice that divides two regions of different spatial patterns—collective and synchronized—in as much as a good understanding