CRM 9 ?.....

Neural fields with auto-associative memories: collective activity, pattern formation, and memory dynamics | Akke Mats Houben

Modelling large populations of neurons as a homogeneous and isotropic continuous medium has been valuable for the investigation of collective dynamics of large neuronal networks. These neural field models have led to insights into the formation and stability of spatially inhomogeneous (Turing) patterns, travelling waves, and localised (bump) solutions, among others.

However, biological neuronal networks contain heterogeneous connections, which seem to be crucial for their dynamics and functioning. Existing results show that incorporating either simple (two-point) heterogeneous connections or spatial modulations in the connectivity strengths into neural field equations affects the formation and stability of the collective dynamics. However, the effects of numerous, structured and functionally relevant heterogeneous connections on neural field dynamics, as well as the potential novel dynamics arising from these heterogeneities, are still left to be explored.

This work embarks on this exploration by endowing neural fields with auto-associative memories. After a simple derivation of the equations governing the neural field with auto-associative memories, it will first be shown that the system supports collective activity dynamics much like homogeneous neural fields. Secondly, by deriving a set of coupled amplitude equations for the memory patterns, pattern completion and competition dynamics are investigated and shown to be similar to the dynamics of auto-associative neural networks. Third, a novel spatio-temporal phenomenon will be demonstrated: the amplitude equations take the form of coupled parabolic diffusion equations; hence a travelling wavefront solution exists where a memory pattern invades a spatially homogeneous domain, for which the typical propagation speed can be determined analytically.

PRBB, Barcelona

CRM 9 Para

Finally, the work concludes with a demonstration of the application of the neural field with auto-associative memories to the investigation of the maturation of in-vitro cultured neurons, which constitute a biological model for large-scale neuronal networks organised on a plane without innate –yet with heterogeneous– connectivity structure.

Authors:

Akke Mats Houben

(Departament de Fisica de la Materia Condensada & Institute of Complex Systems, Universitat de Barcelona)

&

Jordi Soriano

(Departament de Fisica de la Materia Condensada & Institute of Complex Systems, Universitat de Barcelona)

INTERNATIONAL CONFERENCE O MATHEMATICAL NEUROSCIENCE O June 17 - 20, 2025

PRBB, Barcelona