SURF-IFISC proposals (2017)

1. Entanglement generation and distribution through tiled/structured lattices

Advisors: Fernando Galve and Roberta Zambrini

Nanostructured materials have progressed to the point where they can be engineered to produce phononic bandgaps and other interesting structures with amazing transport/isolation properties. Several tiling patterns will be tested regarding the possible generation of distant entanglement and its distribution.

2. Implementing Neuro-Inspired Information Processing in Autonomous Boolean Networks

Advisors: Miguel C. Soriano and Ingo Fischer

Neuro-inspired information processing implemented in specific hardware is a fascinating perspective, raising fundamental questions and offering manifold applications.
Digital systems are typically programmed to obtain a well-defined sequence of outcomes and analog or even unpredictable behaviors are undesired. When digital systems operate without a synchronous clock, however, they can operate autonomously and exhibit complex switching dynamics. This particularly holds if the switching rates between the different logical states become comparable to their processing speed.
In this project, we will employ Field-Programmable Gate-Arrays (FPGAs) to define networks of Boolean elements that can be perform neuro-inspired information processing. This controllable hardware platform allows the study of complex networks and their functional capabilities in an efficient manner at unprecedented speeds.

3. Berry phases and transport through Majorana devices

Advisor: Llorenç Serra

In this project we want to investigate the manifestation of geometric Berry phases in the transmission through Majorana zero modes in hybrid nanowires. It is known that, in the appropriate conditions, a Majorana nanowire spontaneously develops a spin magnetization helix [1]. The propagation of a quasiparticle traversing this magnetization texture can probably be understood as a fixed quasiparticle in a rotating field, for which an adiabatic Berry phase appears. We intend to calculate the quantum transmission using a simplified modeling of a 2D nanowire junction with a spin helix in order to clarify the physical mechanisms.
Recent experiments on similar types of helical systems are indicative of the current interest on these phenomena [2,3].

[1] Majorana bound states in magnetic skyrmions, Guang Yang, Peter Stano, Jelena Klinovaja, and Daniel Loss, Phys. Rev. B 93, 224505 (2016).
[2] Signatures of interaction-induced helical gaps in nanowire quantum point contacts, S. Heedt, et al. (2017), arXiv:1701.08439v1
[3] Conductance through a helical state in an InSb nanowire, J. Kammhuber, et al. (2017), arXiv:1701.06878

4. Anticipated synchronization in Hodgkin-Huxley neuronal circuits
Advisor: Claudio R. Mirasso

Anticipated synchronization (AS) is a phenomenon that can occur when two dynamical systems are coupled in a sender-receiver configuration when the receiver is subject to an inhibitory feedback loop. It AS occurs; the receiver predicts the dynamics that the sender is going to do in the future. AS has been found initially in general autonomous systems but in the last year it was extended to simple neuronal models as well as neuronal population models. Moreover, AS has been also observed experimentally in monkey performing a visual discrimination task (between cortical areas) and the cat's primary visual system.
In this work, it is the aim to numerically study a neuronal microcircuit whose elements are described by the Hodgkin-Huxley model and analyze how the transition from the well-known delayed synchronization to the less intuitive anticipated synchronization occurs for different parameters of the model. These parameters include, among others, neuronal frequencies, synapses time constants and synaptic conductances.

5. Modeling and dynamics of the power grid
Advisors: Damià Gomila and Pere Colet

The power grid is a socio-technical system where users and machines interact on a network supervised by the system operator. Traditionally the control is applied at the supply side, such that power plants adapt continuously their power to deliver all the energy demanded by the users. This model is however very expensive, as it requires fast response idle power plants to ensure the supply at demand peaks, and which typically consume very expensive fuels. The increase of the demand and the integration of renewable energy sources are also increasing the fluctuations of the system due to fast demand-supply unbalances, challenging the traditional system operation. Recently, control systems applied to the demand side, such that users adapt their energy consumption to energy availability, have been proposed. In this case consumers may interact leading to the emergence of collective phenomena.
In this project we will explore the dynamics of the power grid under demand side control methods.

6. Network inference: deducing network structure from dynamics
Advisor: Víctor M. Eguíluz and Konstantin Klemm

System identification deals with the problem of finding out about entities and their interactions based on observations of the system's dynamics. In astronomy, for instance, existence and approximate orbits of planets, invisible from earth, may be inferred from the observable movement of the central star. Likewise for a living cell, the time course of protein concentrations provides information on the protein-protein interaction networks and even about the role of proteins not observed directly. In this internship, we will explore the information processing for such network inference. We will work on the theory with small examples and then handle larger problems by writing and applying computer programs.

7. Data Science: the attraction basin of the New York City airports
Advisors: Riccardo Gallotti and Jose Ramasco

We seek a student in physics, mathematics, or computer science with strong programming skills for the data analysis of Taxi trajectories in New York City.
The work will rely on publicly available Big Data, where all the origin and destination of all Taxi in NYC are recorded for several years.
The student is expected to develop the statistical and visualization tools necessary to map the decision behavior of the NYC citizens when facing the choice between the three airports that are serving the city for national or international flights.

8. The sensorimotor bases of the preference for curvature
Advisors: Enric Munar and Marcos Nadal.

Human beings tend to prefer some objects than others, and it considerably determines our behaviour. The way these preferences emerge especially interests to behavioural sciences. Some of these preferences are linked to physical traits that are captured by our perceptual systems. We focus on preference for curvature on this project. This preference means that we prefer curved shapes more than sharp-angled ones. The experimental interest for this effect is intensified from Bar and Neta's (2006) article. Many studies have endorsed, sometimes explicitly and others implicitly, the hypothesis that the preference for curvature is a consequence of the aversion to the sharp-angled contours due to its threatening connotation. Nonetheless, new results have appeared that call into question the possibility that this hypothesis is enough to explain the effect. In this project, we propose an alternative explanation, o maybe complementary. This preference would be the outcome of the emergence of a sensorimotor link that underlies the biological motion, even its execution and its perception. The project proposes to test this hypothesis in a basic version. Experimental procedures of implicit measures will be used: the assessment will not be directly on preference. Different experiments have been designed. An experiment is based on the paradigm of stimulus-response compatibility. Another is a visual research task using an eye-tracker system. If sensorimotor link to the curvature exist we hope to find an ocular fixation faster with curved stimuli. We expect that the data from these experiments confirm or demarcate our hypothesis on a sensorimotor link towards the curvature or, at least, let us go in depth about the knowledge of the effect.