SURF Proposals, IFISC 2018

1. Autonomous Operation of Optolectronic Reservoir Computing Systems

Advisors: *Miguel C. Soriano and Ingo Fischer*

Nowadays, it has become possible to implement machine learning concepts in analogue hardware. In particular, physical implementations of photonic systems with learning abilities represent a breakthrough that paves the way towards practical uses of photonic computing. In this project, we will use an optoelectronic non-linear system with output feedback to generate arbitrary waveform signals in an autonomous manner. This controllable hardware platform allows the study of novel machine learning concepts in an efficient manner and in real-time.

2. Synchronization in a model of coupled neural oscillators

Advisor: *Claudio R. Mirasso*

The emergence of synchronization in brain networks is a fundamental issue in neuroscience. For instance, when two or more neurons or neuronal populations are unidirectionally coupled, delayed synchronization is expected. In this case, the sender predicts the dynamics of the receiver. However, depending on the oscillation frequency between the nodes or the type of coupling, other types of synchronization can be observed (zero-lag, anticipated, etc.). In this work it is proposed to study the dynamics of a chain of coupled oscillators to better understand the mechanism that yield the different kind of synchronization depending on the circuit structure. The results will be contrasted against numerical simulations of a chain of coupled neurons.

3. Nonlinear thermoelectric transport in a selective spin environment

Advisor: *Rosa López*

We propose to investigate the transport of charge, heat and spin in a localized interacting quantum level (a quantum dot) when it is coupled to two electronic reservoirs that are spin polarized and a temperature gradient is applied. Such setup undergoes decoherence effects due to inelastic processes mediated by the energy exchange with the environment and the dot. We assume that the interaction between the dot spin and the environment depends on the spin index. We will compute the charge, heat and spin currents and their fluctuations, and derive the thermoelectrical efficiency of this device as a function of the system parameters, and its coupling with the environment.

4. Quantum machine learning with spins

Advisors: *Roberta Zambrini and Gianluca Georgi*

The project aims to study a simple toy model to explore quantum machine learning. We will build on a recently proposed probing scheme of an out-of-equilibrium spin, based on quantum synchronization.

For candidates with basic knowledge of quantum physics.

5. Data Science: prediction of air passenger's flows

Advisors: *Riccardo Gallotti and Jose Javier Ramasco*

We seek a student in physics, mathematics, or computer science with good programming skills for the data analysis of the evolution of the air passenger's flows across Europe in the last decade. The work will rely on publicly available data released from the European Union, where the number of passenger between two European airports is provided on a monthly basis.

The student is expected to develop the statistical and visualisation tools necessary to map the evolution of the air transport market over the years. The correlation in the signals will be highlighted through the projection of the observed time series over a basis of Empirical Orthogonal Function. The result obtained with the statistical forecast developed on this basis will be compared with that of black-box machine learning methods.

6. Modeling and dynamics of the power grid

Advisor: *Damià Gomila*

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.