SURF@IFISC 2022 Proposals

1. Prediction and assessment of childhood obesity using machine learning algorithms
Advisor: Silvia Ortín

The global prevalence of obesity nearly tripled between 1975 and 2016 and the global spread of obesity has been called a pandemic. Addressing obesity in childhood, before it occurred, would help to alleviate the problem. However, obesity is a complex problem influenced by multiple factors. The aim of this research is to identify the most significant factors that can predict weight development in children of different ages. This would help to personalize treatments and advice for children at risk of developing obesity. To do this, we will use state-of-the-art deep learning techniques on datasets that include information on diet, lifestyle, environment, as well as microbiota of children. Interested students should have a good knowledge of Python. Students with previous experience in machine learning and its standard libraries are especially welcome.

2. Stochastic thermodynamics and information
Advisor: Gonzalo Manzano

In the last two decades, thermodynamics has been extended to describe small systems, where the action of environmental noise “blurs” traditional thermodynamic constraints and information plays a central role [1]. While the first law of thermodynamics (aka energy conservation) holds at the microscale, the second law becomes more subtle and is manifested on a statistical level, through the emergence of a set of universal nonequilibrium fluctuation relations that may take the form of both equalities or inequalities. Stochastic thermodynamics can be applied to a number of systems ranging from molecular motors acting inside the cell, to synthetic electronic and quantum devices interacting with mesoscopic environments. In this project we will explore different aspects of the thermodynamic description of small systems and their link with information theory, including microscopic models of Maxwell’s demon though experiment and the use of gambling strategies for stopping a process at particularly selected times [2].

[1] J. M. R. Parrondo, J. M. Horowitz, and T. Sagawa, *Thermodynamics of information*, Nature Physics 11, 131–139 (2015).
[2] G. Manzano, D. Subero, O. Maillet, R. Fazio, J. P. Pekola, and É. Roldán, *Thermodynamics of Gambling Demons*, Physical Review Letters 126, 080603 (2021).

3. Power grid stability in scenarios of large renewable penetration
Advisors: Pere Colet and Damià Gomila

The power grid is, arguably, the largest socio-technical system in the world. Stable operation requires the synchronization of the power plants and a precise balance between generation and consumption. The balance is not easy to achieve due to the random character of (part of) the load and the increasing use of renewable sources which are subject to uncontrollable factors, such as wind or sunlight. In this project we will study the synchronization and stability of a prototypical power grid when a large

fraction of the generation comes from renewable sources, as well as the effect of including battery storage systems.

4. Analysis of biodiversity in Posidonia meadows with satellite images through machine learning
Advisor: Manuel A. Matías

The goal is to process satellite multispectral images with machine learning (ML) to extract information about the relative abundance of different macrophyte species (like Posidonia oceanica, Cymodocea nodosa and several macroalgae) in the coast of Mallorca. The analysis will be carried out using ML, that specially through Deep Learning is making major advances in solving problems that have resisted the best attempts of the artificial intelligence community for many years. The labels for the ML training will be available georeferenced data on the presence of the different macrophyte species in the coast of Mallorca obtained through sonar surveys. They will be used to train ML models (MLMs) based on information from multispectral satellite images, namely the differential absorption of different spectral bands. The project requires programming abilities with Python and working with datasets. Prior knowledge of MLMs, like ANNs, RNNs, SVM, etc. through standard libraries like TensorFlow or PyTorch will be welcome.

5. Entropy for systems with memory
Advisors: David Sánchez

Daily precipitation series or ranked linguistic data are two paradigmatic examples of complex systems described with random variables. These systems can be modeled with the Markovian approach that considers that the future state of the system only depends on its present state. While in some cases this is enough to predict the system evolution, in other cases it is necessary to also take into account the past states. In this project, we will investigate the block entropy as a reliable method to determine the memory of the system which in turn informs us on its correlation strength.

6. Interferometry with topological insulator nanowires
Advisor: Llorenç Serra

A topological insulator (TI) material has the properties of a conventional insulator in the bulk but hosts topologically protected metallic states on the surface. The surface states have the peculiarity of behaving as massless Dirac fermions with a linear dispersion relation and a unique spin polarization that is tied to the momentum. The nontrivial topology of these TI materials is caused by strong spin–orbit coupling and a band inversion that lead to robust time-reversal symmetry protection of these surface states emerging within the bulk gap. In this SURF project the student will get a first contact with the properties of TI materials and their interest towards applications in the so-called second quantum revolution (like robust and efficient devices or quantum computation). In addition, the project may include specific calculations of inteferometry in TI nanowires containing gated sections or magnetization textures known as Skyrmions.