ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

Scientific Report

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Nationality	Spanish
Name of the *Host Organisation*	Norwegian University of Science and Technology
First Name / family name of the *Scientific Coordinator*	Gunnar Tufte
Period of the fellowship	01/04/2019 to 31/03/2021

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

My research activity at NTNU (Trondheim, Norway) has been focused on the study of the complexity of systems neuron cultures, artificial spin ice and cellular automata. The aim is to compare these systems in terms of computational power and to improve the existing methods to analyse their behaviour.

flatspin has being developed as a large-scale simulator for artificial spin ice models (it has been developed in the SOCRATES project, which I have been part of). From this, the process of experimentation has improved in terms of time and money inverted, since no real devices must be implemented for each experiment, but only the most critical ones. With this software, some experiments are being carried out, trying to gather information about the capabilities of these systems to store information (long and short time memory) and perform information processing. It is being also used to produce artificial spin ice samples for synchrotron experiments.

In summary, the main contributions of my scientific activity during my ERCIM fellowship are:

1. Analysis of the complexity of elementary cellular automata, using topological data analysis. In this sense, several differentiations among different classes of automata with respect with their topological properties have been defined, using the simplicial complexes of the data in order to understand their nature. The first parameter that is being studied is the Betti number of the different cellular automata, and it seems reasonable to think from the results that each of the four classes (uniform, stable, chaotic and complex) define different topological spaces. This new approach to the analysis of elementary cellular automata seems promising to study their underlying complexity, and it could be generalised to other types of cellular automata, even with different connectivity patterns.
2. I have been using data analysis techniques in order to find patterns in the behaviour of neuron cultures, getting some interesting information in a visual manner. In this sense, a virtual tool for experimentation has been developed, capable of introducing new algorithms *on the fly* for being applied to the existing data. This visual tool will be published in a near future.
3. I am creating models of Membrane Computing (the research field of my PhD) to both neuron cultures and artificial spin ice designs. More precisely, I am modelling them in this framework to both make it easier to stablish a relationship between the three models and to have a powerful tool to study the behaviour of both types of machines in terms of the rules used to describe each one.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Since I had to switch my research line at NTNU, while using some similar methods than in my previous work, but updating the models used, the main results are being developed now and they will probably be published in the next months.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I have attended the Caleidoscope: Complexity as a Kaleidoscope Research school in computational complexity in Paris (France), in June 2019. I have also attended the 18th Brainstorming Week on Membrane Computing in Seville (Spain), in February 2020. I have also attended the seminars “Topological Data Analysis and Machine Learning” and “Shaping the future of AI in Industry” in Seville (Spain), in November 2019 and October 2020, respectively.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I visited Simula in Oslo (Norway) from February 17th to 21st, under the supervision of Stefano Nichele. During the REP, I was able to exchange ideas with the research team about some ways to evolve cellular automata for making them fault tolerant. Specifically, using the EvoDynamic framework that Sidney Pontes-Filho have developed, we have obtained interesting results about the ability of these systems to self-correct their behaviour. I also gave a seminar entitled “Computation inspired by nature: From Physics and Biology to Computing and back”, in which I explained some research lines where we are working on.