Namur Institute for Complex Systems (NAXYS)

What do the human brain, social networks, financial systems, the universe, optical systems, metabolism or a genome have in common?

They are classical examples of **complex systems**, i.e., systems composed of a large number of simple elements in interaction and exhibiting emerging phenomena.

The main objective of naXys is the study of such **complex systems**, by means of the analysis of real-world data, their modelling through mathematics and numerical simulations, and their control and optimization. Our belief is that a proper understanding of systems requires a modelling step, which allows to identify causal relationships between various parameters and to identify the mechanisms by which they operate. This abstraction must be based on empirical validation, but the mining of data alone is neither sufficient nor satisfactory. For this reason, a knowledge of the specific domain and the use of adequate tools in modelling, analysis and simulations are essential.

naXys is divided into 5 research clusters:

1. Mathematical Biology

The main objective of this centre is to mathematically describe complex biological mechanisms. These mechanisms may be located at any level of biological organization (from genes to ecosystems), and cover any temporal or spatial scale (from local short-term events to the global evolutionary history of life). Adopted techniques include mining of big data and machine-learning approaches, various types of modelling (from statistical and phenomenological to mechanistic dynamic modelling), and inference of biological mechanisms through model-data comparison.

2. Bio-inspired Evolution Strategies & Quantum Optics

This centre deals with the optimisation of optical devices and spectroscopies by advanced optimisation techniques and by exploiting the quantum nature of light and entangled photons. Different types of heuristics and optimisation strategies, including Genetic Algorithms and Derivative Free Optimisation, are developed. Genetic algorithms are also used here for studying the evolution of biological systems.

3. Socio-Economic Complexity

The increasing availability of large-electronic databases on a variety of socio-economic systems has opened, in recent years, new scientific perspectives and potential applications. The main purpose of this centre will be to identify mechanisms driving the future evolution of the systems, from systemic risk in financial networks to information diffusion in social networks, price dynamics in the sharing economy and mobility.

4. Dynamical astronomy, cosmology and astrobiology

This research pole deals with the modelling of the Universe, on different scales: space debris, Solar System, extrasolar systems, up to the large-scale structures of the Universe. We will focus on the non-linear interactions and chaotic dynamics of these physical and mathematical objects, sharing the tools of celestial mechanics, cosmology, general relativity and modified gravity.

5. Stability and robustness

This centre will deal with the concept of stability and robustness in various fields of research, aiming to identify its key structural determinants. In ecology as in financial networks, catastrophic changes in the overall state of a system can ultimately derive from how it is organised — from feedback mechanisms within it, and from linkages that are latent and often unrecognised. The change may be initiated by external factors, but is more usually triggered endogenously.

STRONG POINTS

naXys has a strong international presence, with the development of exchange programs, for example with the University of Kyoto, frequent seminars from international experts, organisation of conferences (e.g. Complex Planetary Systems in 2014) and participation in workshops, editorial boards and research networks (e.g. the Complex Systems Society).

naXys has the experience to run projects with the Walloon region (eg ShareABike, VirtualBelgium in Health, PIT Big Data, etc.), FNRS (fellowships, PDR, FRIA and MIS), Belspo (PAI), FWB and Europe (FP7).

Its research has found a significant echo in the mass-media, in Belgium (Le Vif, etc.) and abroad (Guardian, MIT Technology Review, etc.).

As complexity becomes more and more central in our modern society, naXys is a pioneer with no equivalent in Belgium, thanks to its integration between different disciplines, including finance, urban studies, biology and physics, at the interface of applied sciences and basic sciences.

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