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 interacting elements that exhibit emerging phenomena.

The main objective of naXys is to study such complex systems by means of the analysis of real-world data, their modeling through mathematics and numerical simulations, and their control and optimization. Our belief is that a proper understanding of systems requires a modeling 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 modeling, analysis and simulations are essential.

naXys is divided into 6 research poles:

1. Mathematical Biology (BIO)

The main objective of this research pole is to provide mathematical models to describe complex biological mechanisms. The latter 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 modeling (statistical and dynamic), and inference of biological mechanisms through model-data comparison.

2. Optical Engineering & Quantum Optics (OPTICS)

This research pole deals with the engineering of optical devices whose numerical modeling is computationally expensive. For this purpose, are developed bio-inspired optimization techniques (genetic algorithms, particle swarm optimization, etc), which account for the specificities of optical systems and eventually provide globally optimal solutions. Moreover, this research pole explores foundational issues in quantum mechanics and quantum optics, both theoretically and experimentally, in particular using the concept of weak measurements. It also develops advanced spectroscopies which are based on weak measurements, or that exploit the quantum nature of light and the special properties of entangled photons.

3. Socio-Economic Complexity (ECO)

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 goal of this research pole is to identify mechanisms driving the future evolution of the systems, from systemic risk in financial networks to information diffusion in social networks. Moreover, this pole has a recognized expertise in network models, traffic studies, and behavioral analysis including activity-based approaches.

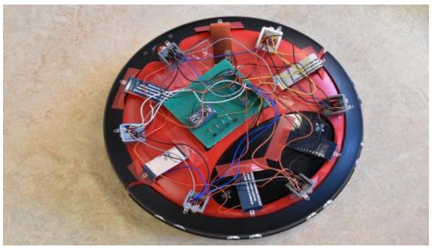
4. Dynamical Astronomy, Cosmology & Astrobiology (SPACE)

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

5. Stability & Robustness (ROBUST)

This research pole deals with the concept of stability and robustness in various fields of research, with the aim of identifying its key structural determinants. In many situations such as ecology and in financial networks, catastrophic changes in the overall state of a system can ultimately derive from how it is organized — from feedback mechanisms within it, and from linkages that are latent and often unrecognized. This change can be mitigated by designing control methods, which also make the system more robust to external factors.

6. Optimization Algorithms, Artificial Intelligence & Robotics (AI)



This research pole aims at developing evolutionary algorithms to address large-scale computationally expensive optimization problems, which are based on natural selection strategies and take advantage of the computational resources of high-performance computing systems. Machine-learning algorithms are also developed for the analysis, classification or visualization of high-dimensional data, in order to achieve a better understanding of the roots of their functioning. Moreover, research activity in the domain of Evolutionary and Swarm Robotics is also carried out in our lab equipped with Kilobots, E-pucks and other robotic platforms. Evolutionary computation techniques and other bio-inspired control algorithms are used to design neurocontrollers for robots required to cooperate and execute tasks that are beyond the capabilities of single agents.

STRONG POINTS

The naXys research Institute has now been active for 10 years. It has a strong international recognition and has attracted funding for numerous projects from the Walloon region, F.R.S.-FNRS, Belspo, FWB and Europe. The Institute also enjoys strong international appeal, as evidenced by the list of speakers of the naXys seminars and the broad audience of the conferences organized by naXys.

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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