ALPS – AI-based Learning for Physical Simulation

Computer simulations are massively used in scientific research and in the industry for the analysis, design and optimization of physical systems. Over the last decades, Artificial Intelligence (AI) and Machine Learning (ML) methods have successfully entered science and engineering workflows to match the growing demands for fast and accurate physical models, thanks to a combination of improvements in the algorithms, computational power and data assimilation techniques. For example, AI and ML have contributed to advance weather prediction and the simulation of complex fluid flows. However, limitations of purely data-driven methods have emerged as concerns their *generalization* capabilities and their *intelligibility*.

To overcome these limitations, ALPS (ERC Starting Grant, duration: 5 years – 2022-2027, funding: 1.3 M€) proposes an original approach combining ML methods and mathematical modeling for the development of new algorithms that are able to automatically learn models of physical systems from experimental data, especially in *small-data scenarios*, where deep learning is not the solution. The system will also incorporate novel *human-inspired strategies* for *knowledge distillation*, *accumulation* and *reuse*, which are missing in state-of-the-art physical model learning algorithms. To efficiently handle the computational cost associated with the proposed methods, the algorithms will be implemented in a new software platform that seamlessly integrates *automated model learning* and *high-performance simulation*.

The methods proposed in this project will be applied to address scientific challenges in *human health*, *sustainable energy science and technology*, and *soft robotics*. In particular, we envision new scientific discoveries in the problem of tumor growth, where accurate mathematical models are still elusive and could provide the basis for new treatment strategies. Further, we will use the algorithms to derive effective reduced-order models for *model-based control* in soft robotics and to tackle *design, optimization and control* problems in engineering for sustainable energy technology, in collaboration with industries.

The successful candidate will work on: 1) the definition of a mathematical framework for model learning and simulation of physical systems; 2) the implementation of the algorithms and their application to the aforementioned scientific challenges. The focus on each of these research topics will be adjusted according to the background and interests of the candidate.

Research on this project will be carried out within the Mathematical and Computational Modeling Area at the BioRobotics Institute, in collaboration with groups working on soft robotics (collaborations will also be assessed based on the background and interests of the candidate). Candidates interested in this scholarship, should select “ALPS” as research topic and Prof. Alessandro Lucantonio (alessandro.lucantonio@santannapisa.it) as supervisor.