BRIDGE

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5th Call

for BRIDGE Discovery proposals

Letter of intent (LOI)

Title: Sustainability Discovery in Eco-Evolutionary Diversification-Inspired Federated Networks

Short description

In the last decade, we have experienced an exponential growth in the capacity to generate and store data of diverse nature, thanks in part to the electronic devices connected to the Internet, and in the capacity to analyze them with Big Data analytics and Artificial Intelligence techniques. Yet, the complex and global challenges humans are facing in our digitalized societies show how vulnerable we are. Nature has been adapting and evolving in its struggle for survival with other species and the environment. Biological interactions and traits diversify across multiple scales of biological organization, from neurons to populations, maintaining a complex ecological balance. This endless eco-evolutionary arms race inspires a new Artificial Intelligence approach for a sustainable knowledge-based global society. The signs of identity of our project are evolution, interaction and change and are substantiated by federated networks, that is, networks with heterogeneous nodal structure, in which many different groups of species, humans and technologies coexist to exploit resources. Our aim is to lay the foundations of a technology facing the challenges of global sustainability. We validate our approach with a case study focusing on the sustainability of the Oceans, the largest ecosystem on the planet and a major player in the climate balance and ecological stability. We will develop a user-inspired open platform -- one that is easy to download and use -- to explore sustainability scenarios in aquatic ecosystems containing many distinct datasets (i.e., Sustainability of the Oceans data, Global fishing data, etc). Sustainability scenarios will be represented each throughout a network of causal effects. By modifying the network of causal effects the user can play and explore the consequences on the ecosystem like the discovery of novel paths to increase or decrease resource exploitation, collapse and sustainability in species-rich diversifying ecosystems.

Description of the project

Ecosystems' collapse around the globe is calling for technologies to discover novel ways of sustainable exploitation. In this regard, computational sustainability is rapidly evolving to help solving global sustainability challenges by connecting data-driven intelligent machines to knowledge-based societies. Yet, connecting diversification patterns of biological systems to computational sustainability to build technology around novel sustainable paths in complex ecosystems is at a very incipient stage. Currently, diversifying traits in species-rich networks have been observed in overexploited ecosystems but the computational implications of diversification have not been used for sustainability discovery.

Biological systems are characterized by feedbacks between the ecology and evolution of interacting traits, the eco-evolutionary feedbacks, to produce novel traits with new functions and information content. In computational systems, novel traits result in new computational properties, like new cooperation and competition strategies and/or information processing capabilities that change the properties of the system. Diversification usually occurs in heterogeneous ecosystems with limited

resources where many distinct groups of species need to develop specialized traits and strategies to coexist with other strategies. The outcome is the formation of consortia composed of phylogenetically and ecologically distinct groups.

Conventional Artificial Intelligence (AI) is rapidly moving towards explainable pattern inference but often fails of accounting for diversification of the networks under study for exploring new computing capabilities. The same situation occurs for artificial neural networks that make limited use of novel computing capabilities as a consequence of diversifying interactions and traits. **The goal of this project is to implement eco-evolutionary diversification-inspired solutions to find novel computational sustainability paths based on rapidly diversifying traits and interactions in large and complex ecosystems. The exploitation of emerging interactions, strategies and traits will allow us to create novel discovery solutions for natural ecosystems facing sustainability challenges like overexploitation of the oceans and inland waters, where harvesting renewable resources are beyond the diminishing returns for many species and ecosystem resources.**

Why should we go deeper into diversifying networks for computational sustainability? With connections and traits represented in a spatially distributed network, as found in natural ecosystems, diversification is an avenue to harvest renewable resources because most innovations in ecosystems are connected to new sensing and information processing cues to detect and exploit resources. **This allows considering not only evolutionary processes changing traits and agents (i.e., plasticity and other sources of variation as in many classical studies in deep learning networks), but the formation of new entities to quantify new scenarios for sustainability that substantially deviate from evolutionary computation considering only plastic changes and not diversification of traits and interactions.** This approach will allow representing real-time solutions for ever-changing renewable resources, which is a key problem in many digital and natural ecosystems. To show the capabilities of the our approach, we will address automation, visualization, and reporting to make the technology fully reproducible. Overall, the impact of our approach is to provide a new technology to improve ecosystem sustainability relevant to community-rich digital and natural ecosystems.

We will implement a eco-evolutionary diversification-inspired technology to find sustainability paths along the whole life cycle of the project contrasting the approach with different datasets. The central goals of our project are:

1. To extend existing theories of eco-evolutionary diversification and AI-inspired solutions to decipher the factors driving sustainability discovery in federated networks.
2. To investigate how spatiotemporal evolutionary diversification and AI-inspired networks mimic the empirical patterns of natural and socio-technological ecosystems when human groups, technologies, and species-rich ecosystems coexist.
3. To develop fast, reproducible and automated eco-evolutionary diversification-inspired sustainability discovery technology for real-time information processing tasks.
4. To obtain principles of sustainability discovery for prediction in federated networks when diversification in interactions and traits occurs in a large and heterogeneous set of species, technologies and human groups.