Analysis of complex networks derived from interaction graphs for landscape dynamics analysis

The proposed PhD subject aims at the intersection of two main disciplines: complex networks analysis and spatial dynamics modeling. Spatial dynamics modeling is a preferred approach to study the complex processes of human-environment interaction that are central to land use systems.

In this context, a new approach based on the concept of interaction graph has been developed at CIRAD/UMR TETIS, with the objective of allowing a better coupling of modeling systems with GIS (Geographic Information System) and improving the modeling of mechanisms that are influenced by dynamic spatial structures. The interaction graph is a set of nodes connected by arcs, whose arcs can carry interaction functions. A system represented by interaction graphs can thus evolve when the interaction functions are activated and when they modify the connected entities. The elements present in a geographical space can then define spatial, functional, hierarchical and even social relationships. The implementation of this approach relies on the Ocelet modeling language, and its software development environment (http://www.ocelet.org).

The models developed with Ocelet are mainly used to simulate spatial dynamics in different complex territorial systems, e.g., to compare several land use scenarios. These models generally involve several interaction graphs, in structures that carry knowledge of the functioning and organization of the territory. Until now, when deploying such models, only the simulation results are analyzed while the graphs are not, even though they are a formal expression of very diverse processes that interact in the territory. These analyses would allow to clarify the links between the structure and functioning of the territory, in order to aim, in the long term, at the possibility of inferring knowledge of the processes from the exploration of spatial data, such as those from satellite images.

The overall objective of this PhD is the development of innovative methodologies, based on complex network analysis techniques, for the analysis of interaction graphs resulting from the modeling of landscape dynamics. This work will allow to exploit in an original way the spatial simulation models developed with the Ocelet approach, by allowing to create new knowledge from the modeled interaction graphs and its dynamics. Algorithms for ranking, clustering, information diffusion and link prediction specifically adapted to the context of diverse relationships (e.g., spatial, functional, hierarchical and social) between entities of a landscape system will be developed. This will represent a significant contribution to the field of network analysis and data science, as well as to the modeling and analysis of landscape dynamics.

The first step of the proposed research work will be to understand how the interaction graphs between the elements of a landscape observed on satellite images, and which express the functioning of the socio-ecosystem present in the landscape, can be translated into the network structure of these graphs. The second step will consist in developing and implementing complex network analysis methods specifically suitable for the models considered in response to the previous research question. The idea is to obtain a suite of analysis methods generalizable to different contexts, which can then be integrated into the Ocelet platform. To carry out this work, we will adopt a multidisciplinary approach, where the proposed methodological contributions will always be submitted to the opinions of experts in spatial modeling of landscape dynamics.

These two steps will be conducted first on a variety of study sites for which models have already been developed, or are under development (e.g., in Burkina Faso, Senegal, Mozambique, Reunion, Republic of Congo). In particular, this PhD will be supported by two projects in which

TETIS is strongly involved, and which will implement ambitious spatial models (AFD/LUCCIA project in Mozambique, to help assess the national REDD+ strategy, and the PUDT Congo project, to help optimize the wood-energy supply network of a large city). Then, a fieldwork in West Africa, in connection with the issue of food security, will be privileged. More contextualized analyses, more in line with the field, will be carried out with the aim of explaining the characteristics observed in the networks.

Hosting institution:

The PhD student will be hosted in the TETIS laboratory in Montpellier (France). The TETIS laboratory is a Joint Research Unit (UMR) between INRAE, CIRAD, AgroParisTech and CNRS.
The UMR TETIS conducts methodological research on spatial information management. An integrated approach of the spatial information chain is implemented, from acquisition to its use, through its processing and management.

Expected Skills of the Candidate:

- Strong background in computer science (complex network analysis and graph mining, data mining).
- Good programming skills (preferably Python) are expected.
- He or she should have completed (or be about to complete) a master's degree.
- Good level of written and spoken English.
- Interest and/or experience in applied sciences, especially in agronomy/environment/geography, and in the implementation of simulation models will be appreciated.

Supervisory team:

Roberto Interdonato (CIRAD, UMR TETIS, Montpellier, France)
Danny Lo Seen (CIRAD, UMR TETIS, La Réunion, France)
Pascal Degenne (CIRAD, UMR TETIS, Montpellier, France)
Mathieu Roche (CIRAD, UMR TETIS, Montpellier, France)

The candidates must send the following documents to roberto.interdonato@cirad.fr :

- A two-page CV.
- A one-page cover letter detailing skills, knowledge and experience relevant to the PhD thesis.
- Recent academic transcripts.
- Contact information for one or two referees; no letters from referees.

The deadline to apply is **November 25, 2022**.

Bibliographic references:

Pascal Degenne, Danny Lo Seen: Ocelet: Simulating processes of landscape changes using interaction graphs. SoftwareX 5: 89-95 (2016)

Roberto Interdonato, Matteo Magnani, Diego Perna, Andrea Tagarelli, Davide Vega: Multilayer network simplification: Approaches, models and methods. Computer Science Review 36: 100246 (2020)

Roberto Interdonato, Raffaele Gaetano, Danny Lo Seen, Mathieu Roche, Giuseppe Scarpa: Extracting multilayer networks from Sentinel-2 satellite image time series. Network Science 8(S1): S26-S42 (2020)

Matteo Magnani, Obaida Hanteer, Roberto Interdonato, Luca Rossi, Andrea Tagarelli: Community Detection in Multiplex Networks. ACM Computing Surveys 54(3): 48:1-48:35 (2021)