Master's research internship subject

Impact of megafires on the equilibrium of forest ecosystems: simulation and study of a numerical model

Supervisors: Benoît Delahaye, Guillaume Cantin, Adam Ali
Host laboratory: Laboratoire des Sciences du Numérique de Nantes, UMR 6004
Research team: VELO (Vérification pour l'Environnement et le LOgiciel)

Context

In an international context characterized by a significant increase in extreme climatic events, the preservation of terrestrial and oceanic ecosystems is a major societal challenge. The scientific community is being called upon to produce a better understanding of the complex mechanisms that threaten their equilibrium, notably to help implement mitigation and adaptation solutions. In particular, tropical, temperate and boreal forest ecosystems are highly impacted by megafires. These events destabilize forest ecosystems, which represent a biodiversity reserve, a carbon sink, and an economic resource.

The TOUNDRA research project (*Mathematical modeling and analysis of boreal forests vulnerability to climate change: a hybrid approach*), founded by the National Research Agency, proposes to study the stability of boreal forest ecosystems in response to climate change, using a hybrid modeling approach aimed at reproducing the biological dynamics of forests disturbed by megafires. The project therefore revolves around a mathematical model obtained by coupling a system of differential equations describing forest dynamics, with a discrete probabilistic process modeling the impact of megafires. The details of the model are given in the following articles: [CDF23], [CDF21] and [KABA94]. This Master's internship is fully in line with this research project.

Objectives of the internship

The main objective of this Master's internship is to study the properties of the hybrid forest dynamics model built by the team of researchers involved in the TOUNDRA project. This model has an innovative character that makes known mathematical methods difficult to apply. Nevertheless, this model can easily be simulated numerically. The first task will therefore be to appropriate the model, its parameters, and to carry out numerical simulations. A new visualization software will be developed to facilitate the interpretation of the numerical simulations. The second task will be to study the dynamical properties of the model, in order to guarantee its ability to reproduce the observations of the boreal forest ecosystem by the forest ecologists involved in the TOUNDRA project, who have produced a unique paleoecological database (see notably [AAL+08]). To carry out this study, the candidate will rely on recent methods for verifying hybrid dynamical models, as presented in [Tab09].

Depending on the quality of the results obtained during the internship, a thesis may be considered, provided an appropriate funding is obtained.

Profile of the candidate

To carry out this research work, the candidate must have solid skills in computer science, both computational (numerical simulation, supercomputing) and theoretical (formal model checking

methods). The candidate should also have an interest in environmental sciences. Experience in studying forest ecology models will be highly appreciated. Finally, the candidate should have good writing skills and an aptitude for teamwork.

Contract

- Status : paid internship under contract.
- Domains : computer science, modeling, forest ecology.
- Duration of contract: 6 months.
- Preferred starting date : January, 2025.

Application procedure

- Application deadline: December 1st, 2024.
- Send cover letter and CV to `guillaume.cantin@univ-nantes.fr`, `benoit.delahaye@univ-nantes.fr` and `ahmed-adam.ali@umontpellier.fr`.

References

[AAL+08] Adam A Ali, Hugo Asselin, Alayn C Larouche, Yves Bergeron, Christopher Carcaillet, and Pierre JH Richard. Changes in fire regime explain the Holocene rise and fall of Abies balsamea in the coniferous forests of western Québec, Canada. *The Holocene*, 18(5):693–703, 2008.

[CDF21] Guillaume Cantin, Arnaud Ducrot, and Beatriz M Funatsu. Mathematical modeling of forest ecosystems by a reaction–diffusion–advection system: impacts of climate change and deforestation. *Journal of Mathematical Biology*, 83(6):66, 2021.

[CDF23] Guillaume Cantin, Benoît Delahaye, and Beatriz M Funatsu. On the degradation of forest ecosystems by extreme events: Statistical model checking of a hybrid model. *Ecological Complexity*, 53:101039, 2023.

[KABA94] Yu A Kuznetsov, M Ya Antonovsky, VN Biktashev, and EA Aponina. A cross-diffusion model of forest boundary dynamics. *Journal of Mathematical Biology*, 32:219–232, 1994.

[Tab09] Paulo Tabuada. *Verification and control of hybrid systems: a symbolic approach*. Springer Science & Business Media, 2009.