PhD Position open on 2024 **Montpellier, France**

Real-time control of aroma synthesis in oenological fermentation

Context

Agri-food bioprocesses are still largely unoptimized. However, they must meet increasingly stringent requirements in terms of productivity, robustness and product quality. In the current context of climate change, energy sobriety and rising energy costs, it is also essential to minimize the environmental impact of these practices. In order to achieve production targets while meeting the numerous constraints of the process, the use of **control** becomes essential. Control theory has been extensively used in bioprocesses, but has been scarcely applied to alcoholic fermentation for wine production. Wine fermentation is a bioprocess carried out in a fermentor, where yeasts convert grape sugar into ethanol and CO2, and the synthesis of other metabolites (glycerol, organic acids, aroma compounds, etc.) that constitute the aromatic profile of the final product. The latter includes esters—and, to a lesser extent, higher alcohols—that contribute directly to the fruity aroma of wines. Until now, industrial practices have been essentially dictated by practical considerations of cellar management. The aim is generally to speed up fermentation, i.e. to accelerate the conversion of residual sugar, which is slower at the end of fermentation (when ethanolic stress is at its highest for the yeasts). To achieve this objective, two practices are commonly used: 1) the addition of nitrogen at the start or during fermentation, and 2) anisothermal fermentation management, which generally consists of raising the temperature at the end of the process. In recent works, it has been shown that these practices also influence the final aroma content of the wine, with very different impacts depending on each aroma compound. By regulating the amount and timing of nitrogen addition, and adjusting temperature in real time, it is possible to **control aroma synthesis** during alcoholic fermentation and achieve a predefined aroma and energy target.

Objectives of the PhD project

The aim of this PhD project is to **control the synthesis of aromas in wine by developing innovative real-time control strategies for the alcoholic fermentation process based on predictive mathematical models**. These strategies will also have to take into account numerous constraints related to the control scheme, and the energy consumption of the fermentation, which must remain sufficiently low. In previous works, a dynamic model of wine alcoholic fermentation was developed, which represents the main kinetics, the synthesis of the main aromas, and the energy consumption of the process. Using this model, a simple MPC (Model Predictive Control) loop has been designed and tested on the real process, which constitutes a proof of concept of the approach. Depending on the background and interests of the PhD candidate, multiple research questions are open to explore:

- **Biological modelling**: development of mechanistic control-oriented models representing the production of multiple aroma compounds, and calibration using experimental data. Various system identification methods could be considered and proposed here. Additionally, model-reduction techniques can be tested, in particular based on a decomposition of slow/fast dynamics (considering the difference in speeds between the nitrogen and glucose metabolic pathways).

- **Real-time control**: design of novel control laws, taking into consideration aspects such as performance and robustness to model uncertainty. The range of methods can vary from nonlinear and possibly adaptive feedback control laws for systems with input constraints, to optimality-based control algorithms (like MPC loops). Observability issues are also of interest for online state estimation in real-time implementations.

The project will involve theoretical investigation of the mathematical problem, numerical simulations and experimental validation of control laws to be applied and tested on the real process located at the Pech Rouge Experimental Unit in Gruissan.

Keywords

Control theory, wine fermentation, aroma synthesis, biological models, dynamical system

Required skills

We are looking for a background in **biological modelling**, **automatic control** or **applied mathematics** with a taste for applications. Knowledge of biological processes or systems is not required, but recommended. Good programming skills are required (Python and/or Matlab and/or R).

About the research center

The PhD candidate will be based at the UMR MISTEA (Mathématiques Informatique et Statistiques pour l'Environnement et l'Agronomie), on the Gaillarde campus of Montpellier SupAgro. The internship will be supervised by Agustin Yabo and Céline Casenave, both researchers at INRAE (Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement) working in the field of modeling and control of biological systems. The project will be held in collaboration with UMR SPO (Sciences pour l'ŒEnologie), the INRAE Pech Rouge Experimental Unit, and potentially private partners.

General information

Duration: 36 months
Location: Montpellier, France
Gross salary per month: 2100€ (1st year), 2200€ (2nd year) and 2300€ (3rd year)[1]
Starting date: Between September and December 2024
Benefits: reduced canteen rate, free public transport[2], social security, paid leave, flexible working hours

Contacts

Agustin G. Yabo	agustin.yabo@inrae.fr	www.agustinyabo.com.ar
Céline Casenave	celine.casenave@inrae.fr	celinecasenavefr.wordpress.com

References

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[1] https://www.enseignementsup-recherche.gouv.fr/fr/le-financement-doctoral-46472
[2] https://www.montpellier3m.fr/connaitre-grands-projets/gratuite-des-transports-en-commun