PhD PROPOSAL FOR THE DOCTORAL SCHOOL
« Végétal, Animal, Aliment, Mer, Environnement »

GENERAL INFORMATION

Thesis title: Towards a knowledge-based DIGItal Twin for a tOMato production system
Acronym of the project: DIGITOM
Disciplinary field 1: Computer sciences   **Disciplinary field 2:** Modelling
Three keywords: Digital twin, ontology, ecophysiology
Registration establishment : Institut-Agro Rennes-Angers
Research unit: UMR 1345 IRHS / UPSP EPHOR
Name of the thesis director HDR (Accreditation to supervise research) required: Gerhard Buck-Sorlin   **Email address of the thesis director:** gerhard.buck-sorlin@agrocampus-ouest.fr   **Name of the thesis co-supervisor 1:** Julie Bourbeillon   **Email address of the thesis co-supervisor 1:** julie.bourbeillon@agrocampus-ouest.fr   **Name of the thesis co-supervisor 2:** Etienne Chantoiseau   **Email address of the thesis co-supervisor 2:** etienne.chantoiseau@agrocampus-ouest.fr
Contact(s) (mailing address and E-mail):   L'Institut Agro Rennes-Angers, 2 rue André Le Nôtre, F-49045 Angers cedex 01   gerhard.buck-sorlin@agrocampus-ouest.fr,   julie.bourbeillon@agrocampus-ouest.fr,   etienne.chantoiseau@agrocampus-ouest.fr
☒   **Doctoral school contest**

SCIENTIFIC DESCRIPTION OF THE PhD PROJECT

Socio-economic and scientific context: (10 lines)

In the context of challenges such as climate change, scarcity of workforce, pressure from new pests and diseases, regulations concerning the use of pesticides, production of horticultural crops has become a difficult endeavour. There is a real need to develop new production systems, that overcome these problems. At the same time, enormous progress has been made recently at the frontiers of information science, artificial intelligence and sensor technology. 3D plant models representing plant architectural and physiological development in space and over time at different resolutions (scales) are now available, putting the creation of a horticultural digital twin within reach. Such a digital twin (i.e. a multi-scaled model able to update its parameters automatically) would be a powerful tool enabling us to rapidly optimize existing, and to propose novel, production systems *in silico*.

Assumptions and questions (8 lines)

A digital twin consists in multiscale models with a multitude of parameters. The mater is how best to interconnect these models, and to reason simplifications at the scale of the digital twin. We therefore need to automatize the exploration of these different scales. This can be achieved thanks to a formal representation of the multi-dimensional landscape of scales and parameters through an ontology. The aim of this thesis is to navigate the ontology to determine what is relevant by comparing simulated with real data. The challenge is to carry out such a comparison by developing a method for automatically moving from one scale to another, without losing essential information.

The main steps of the thesis and scientific procedure (10-12 lines)

1. Characterising the multidimensional landscape of scales and parameters: Inventory of photosynthesis and biomass production models (especially for tomato), characterize the key parameters to create an ontology describing the parameter landscape of each model.

2. Building the integration system: Define how to transfer data between ecophysiological models and scales, and represent them in the ontology for the tomato crop case. Exploit the information to describe how to use the output of one model in another.

3. Greenhouse trials: Define how to measure the environment and the plants at the desired level of detail for the model(s) under consideration, based on the results of the system (output from point 2).

4. Refining the integration system: Compare the experimental results with the integration system to improve the representation. A second set of experimental data may be used to validate the corrections made.

Methodological and technical approaches considered (4-6 lines)

The first step is a bibliographical comparison and an analysis of the code of various models, then proposing a (re)coding of the models (Functional-Structural Plant Model, Process-Based Model, or 3D model of the greenhouse) based on an ontology to be created. This work will be followed by sensitivity analysis, optimisation studies, simulation of scenarios and validation in GroIMP or/and R. Validation will be provided by experiments planned as part of Marie Simonin's (Emersys) ANR JCJC INHERSEED project (2024-2028).

Scientific and technical skills required by the candidate

The candidate should have sound skills in at least two of the following domains: bioinformatics, data sciences, computer science or plant sciences. The candidate must be at ease with programming (knowledge of the JAVA language would be a plus) and should have a strong interest in agronomy (or plant science) and be ready to carry out experiments in interaction with agronomists. Applications with both data science and plant sciences degree will be appreciated.

The working language of the Ph.D. is French or English. Though sufficient oral and writing English skills are mandatory for scientific communication, foreign candidates with at least a basic knowledge of the French language or the willingness to learn it would have an advantage.

THESIS SUPERVISION

Unit name:	**Team name:**
IRHS	ImHorPhen
Unit director name:	**Team director name:**
Marie-Agnès Jacques	David Rousseau
Mailing address of the unit director:	**Mailing address of the team director:**
marie-agnes.jacques@inrae.fr	david.rousseau@univ-angers.fr

Thesis director

Surname, first name: Buck-Sorlin Gerhard

Position: Professor

Obtained date of the HDR (Accreditation to supervise research): 11/06/2011

Employer: Institut Agro Rennes-Angers

Doctoral school affiliation: VAAME

Rate of thesis supervision in the present project (%): 40

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 0

Number of current thesis supervisions/co-supervisions: 0

Thesis co-supervisor 1

Surname, first name: Bourbeillon Julie

Position: Assistant professor

Accreditation to supervise research ☐ yes ☒ no   If yes, date diploma received:

Employer: Institut Agro Rennes-Angers

Doctoral school affiliation: VAAME

Rate of thesis supervision in the present project (%): 30

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions: 0

Thesis co-supervisor 2

Surname, first name: Chantoiseau Etienne

Position: Associate professor

Accreditation to supervise research ☐ yes ☒ no   If yes, date diploma received:

Employer: Institut Agro Rennes-Angers

Doctoral school affiliation: VAAME

Rate of thesis supervision in the present project (%): 20 %

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 30%

Number of current thesis supervisions/co-supervisions: 1

Professional status of previous PhD students supervised by both director and co-supervisors (from 5 years)

WANG Wuqian

Date of PhD beginning and PhD defence: 15.11.2017 – 25.2.2021

Thesis supervision: G. Buck-Sorlin, Etienne Bucher, François Laurens

Professional status and location: Researcher in genetics, Tongji University, Shanghai, P.R. China

Contract profile (post-doc, fixed-term, permanent): postdoctoral researcher

List of publications from the thesis work:

- Wang W, Celton JM, Buck-Sorlin G, Balzergue S, Bucher E, Laurens F. (2020). Skin Color in Apple Fruit (*Malus × domestica*): Genetic and Epigenetic Insights. Epigenomes. 4. 13. 10.3390/epigenomes4030013.

Ramananjatovo Toky:

- Thesis supervision: P. Cannavo, G. Buck-Sorlin, and E. Chantoiseau
- Ph.D. student between November 1st 2018 and March 15th 2022
- Permanent Business Developer at INRAE Transfert SAS (Paris-Saclay)
- Publications:
  - Ramananjatovo T., Chantoiseau E., Guillermin P., Guénon R., Delaire M., Buck-Sorlin G., Cannavo P. (2021). Growth of Vegetables in an Agroecological Garden-Orchard System: The Role of Spatiotemporal Variations of Microclimatic Conditions and Soil Properties. Agronomy, 11(9), 1888. https://doi.org/10.3390/agronomy11091888[7]
  - Ramananjatovo T., Peugeot J., Guillermin P., Chantoiseau E. Delaire M., Buck-Sorlin G., Guénon R., Cannavo P. (2023). Apple trees enhance soil organic matter and soil microbial activity in a garden-orchard system. Acta Horticulturae, 1375, 301–308. https://doi.org/10.17660/ActaHortic.2023.1375.39
  - Ramananjatovo T., Chantoiseau E., Buck-Sorlin G., Guillermin P., Guénon R., Delaire M., Cannavo P. (2021). Microclimatic conditions affect lettuce growth in apple tree-lettuce intercropping. Acta Horticulturae, 1327, 237–244. https://doi.org/10.17660/ActaHortic.2021.1327.31
  - Ramananjatovo T., Guenon R., Guillermin P., Chantoiseau, E., Delaire M., Buck-Sorlin G., Cannavo P. 2021. Dynamique de la matière organique du sol dans un système

verger-maraîcher. Comifer. Les Matières Organiques dans les Sols agricoles, Clermont-Ferrand.

Five main recent publications of the supervisors on thesis subject:

- Alix Pernet, Rayan Eid, Claudine Landès, Emmanuel Benoît, Pierre Santagostini, et al. Construction of a semantic distance for inferring structure of the variability between 19th century Rosa varieties. IHC 2022 31st International Horticultural Congress, Aug 2022, Angers, France.

- Rayan Eid, Claudine Landès, Alix Pernet, Emmanuel Benoît, Pierre Santagostini, et al. DIVIS: a semantic DIstance to improve the VISualisation of heterogeneous phenotypic datasets. BioData Mining, 2022, 15 (1), pp.10. ⟨10.1186/s13040-022-00293-y⟩.

- Stauffer, V., Leseur, T., Grisey, A., Colin de Verdière, P., Bournet, P.E., Chantoiseau, E., Julien, N., Boulard, T. and Darfeuille, B. (2020). Energy balance and climate control assessments in greenhouse projects using Hortinergy, a friendly scientifically based web tool. Acta Hortic. 1296, 41-48 DOI: 10.17660/ActaHortic.2020.1296.6

- Henke, M., & Buck-Sorlin, G. (2017). Using a full spectral raytracer for calculating light microclimate in functional-structural plant modelling. Computing and Informatics, 36(6), 1492-1522.

- Chen, T. W., Henke, M., de Visser, P. H., Buck-Sorlin, G., Wiechers, D., Kahlen, K., & Stützel, H. (2014). What is the most prominent factor limiting photosynthesis in different layers of a greenhouse cucumber canopy? Annals of botany, 114(4), 677-688.

THESIS FUNDING

Origin(s) of the thesis funding: CPER (Institut Agro Rennes-Angers / Région Pays de la Loire)
Gross monthly salary: 2100 € in 2024
Thesis funding state: Acquired
Funding beginning date/duration of the thesis funding: 01/10/2024 – 36 months

Date: 19/01/2024

Name, signature of unit director: Marie-Agnès Jacques

Name, signature of team director: David Rousseau

Name, signature of thesis project director: Gerhard Buck-Sorlin