RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

INRAE

DTWIN4FRUITTREES

EXPLORATORY PROJECT

2024-2025

Towards the development of digital twins for fruit trees

Coordination
Evelynes Costes
AGAP Institute
evelyne.costes@inrae.fr

Key words
FSPM
Phenotyping
Plant architecture
Digital twins
Fruit trees

INRAE units involved
AGAP Institute
GAFL
Arboricole Diascope
A2M
Arboricole Bordeaux
Horti Angers
CAPTE
PSH

Partnerships
CIRAD
Hiphen
AgroCampus Ouest - University of Angers

Functional-structural (FS) models, developed in several INRAE units, provide dynamic 3D representations of plants. Their detailed representations of a plant's development and of the competitive relationships that emerge, both within the plant and with the environment, make them an ideal tool for understanding and predicting how trees function in an orchard population.

Context and challenges

Model parametrization represents a significant hurdle for FS modelling, currently acting as a brake on its use as a decision-making tool for orchard management. The parametrization process calls for large quantities of data that are both complex and time-consuming to acquire manually, especially for large populations of individuals.

To overcome this hurdle, the DTwin4FruitTrees project will explore the possibility of parametrizing FS models by making use of imaging data from high-throughput phenotyping.

The project will therefore set out to forge closer links between different scientific communities, building connections between groups working on the development of FSPM models for fruit trees and those whose interest lies in the acquisition and analysis of high-throughput phenotyping data, establishing a two-way exchange between the two approaches.

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Goals

This project will combine emerging phenotyping methods that use LiDAR and imaging data with methods for the creation and parametrization of FS models. The work will be organised into 4 stages:

1. Literature review of traits that can be accessed through phenotyping to feed the models.
2. Assimilation methods for branching rules: machine learning of meristem development and branching rules using Lidar data.
3. Inference of tree shape and organ geometry: optimisation of FSPM outputs from photogrammetric data, down to the shape and distribution of the organs.
4. Exploration of morphospaces: development of an FSPM prototype for apricot and use of apple and apricot FSPMs to explore the 'morphospaces' created by different genotypes.

This project will open up novel opportunities for the optimisation of orchard management and could enable the development of virtual teaching tools. Its ultimate purpose is to apply the concept of digital twins to the study of fruit trees.

Research units involved and partnerships

INRAE scientific division	INRAE research units	Expertises
Plant Biology and Breeding	AGAP Institute	Quantitative and evolutionary genetics, phenotyping and modelling
	GAFL	Quantitative genetics, phenotyping, phenomic prediction
	Arboricole Diascope	Digital phenotyping
	A2M	Digital phenotyping
	Arboricole Bordeaux	Digital phenotyping
	Horti Angers	Digital phenotyping
Agroecosystems	CAPTE	Digital phenotyping, algorithms
	PSH	Ecophysiology, modelling, phenotyping
External partners		**Expertises**
CIRAD	AGAP	Plant modelling, algorithms, OpenAlea platform, optimisation, deep learning
	AMAP	Statistics, Markov and generalised linear models
	Hortys	Agronomy, mango FSPM modelling
Hiphen		Algorithms, signal analysis, digital phenotyping, branching analysis
AgroCampus Ouest - University of Angers	IRHS	Algorithms, signal analysis, FSPM, GroIMP platform