

Improving interoperability between phenomics and modelling communities by designing a Plant Modelling Ontology (PMO)

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In recent years, plant phenomics has produced massive datasets involving millions of images in experiments performed in the field and in controlled conditions, concerning hundreds of genotypes at different phenological stages and scales (Tardieu et al., 2017). In the future, information extracted from these datasets will be used increasingly as variables or parameters of mathematical and computational models, thereby broadening the scope of information extracted from phenomics data (Muller and Martre, 2019). Feeding such data to structural plant models (SPMs), functional plant models (FPMs), functional-structural plant models (FSPMs) and process-based crop simulation models (CSMs) in ad hoc pipelines has the potential to derive high-throughput predictions of integrated (e.g. yield) or functional traits (e.g. root system architecture) across a wide range of target environments or management practices (Chen et al., 2019). Unfortunately, the connectivity between these two communities is greatly limited by the absence of a common semantic framework and harmonized vocabulary.

Currently, the terminology (e.g. objects, variables) used by these communities can be quite heterogeneous depending on the research discipline, scale and objective and even can differ between research groups. This limits the ability to accurately relate information within and across communities. A solution to facilitate the connection and the exchange of information is the use of a controlled and standardized vocabulary of common and internationally recognized descriptive terminology that can be connected and shared uniformly among the communities. The phenomics community has tackled these issues by reusing existing ontologies (e.g. Plant Ontology – PO or Plant Trait Ontology – TO), developing new standards (e.g. MIAPPE) as well as ontology-driven information systems (e.g. PHIS). Similarly, some initiatives have been developed within the crop modelling community such as the ICASA Master Variables List (ICASA-MVL) and the AgMIP data standards and data translator tools, the recent functional-structural root architecture modelling community or some open software platforms (e.g. OpenAlea). However, despite these recent developments no ontology describing the variable inputs, the variable outputs and the parameters of the plant models exists and can be used to facilitate exchange in and across communities. One solution to this problem involves the development of structured controlled vocabularies for the plant modelling community arranged in a new ontology (Plant Modelling Ontology – PMO).

The goal of the PMO is to produce structured controlled vocabularies of the variables and parameters used by mathematical and computational models (SPMs, FPMs, FSPMs and CPMs) with clear definitions and relations with the existing phenomics ontologies (e.g. description of the phenomics variables used in the parameter estimations). In addition of the benefit to find compatibilities between phenomics datasets and plant models using ontologies (Figure 1), the PMO facilitates the connexion between the models themselves, promoting the design of multiscale models (Christensen et al., 2018) or the intercomparisons of models (Athanasiadis et al., 2009). This new project, initiated and supported by the European infrastructure EMPHASIS, involves an interdisciplinary collaboration in order to:

- 1) **Inventory and define the vocabulary used by the plant models.** We compile a list of the variable inputs, variable outputs and parameters used by the plant models.
- 2) **Formalise terms and their relationships in a common ontology.** We formalise the terms and establish relations and properties within and between the different terms used in modelling and plant phenomics by using semantic web technologies (e.g. OWL).
- 3) **Develop a web application.** We design an interactive web companion for model developers and users to identify possible connections between plant models' variables and parameters and phenomics datasets. This application helps to design model-based data analysis pipelines.

Following the recent development of quantitative-plant.org (a website referencing plant and crop simulation models), we take advantage of this new network to engage the interest of the plant modelers in the development of a Plant Modelling Ontology. The design of this ontology aims to be a collaborative effort by defining the terms used by any group or researcher using or developing a plant model. One important aim of this activity is a joint publication and web services that show the proposed Plant Modelling Ontology as well as an overview of connections with the phenomics community. In the future, a long-term cooperation between the phenomics and modeling communities towards the development of common platforms could be designed to enable transparent data exchange from models to experiments and vice-versa.

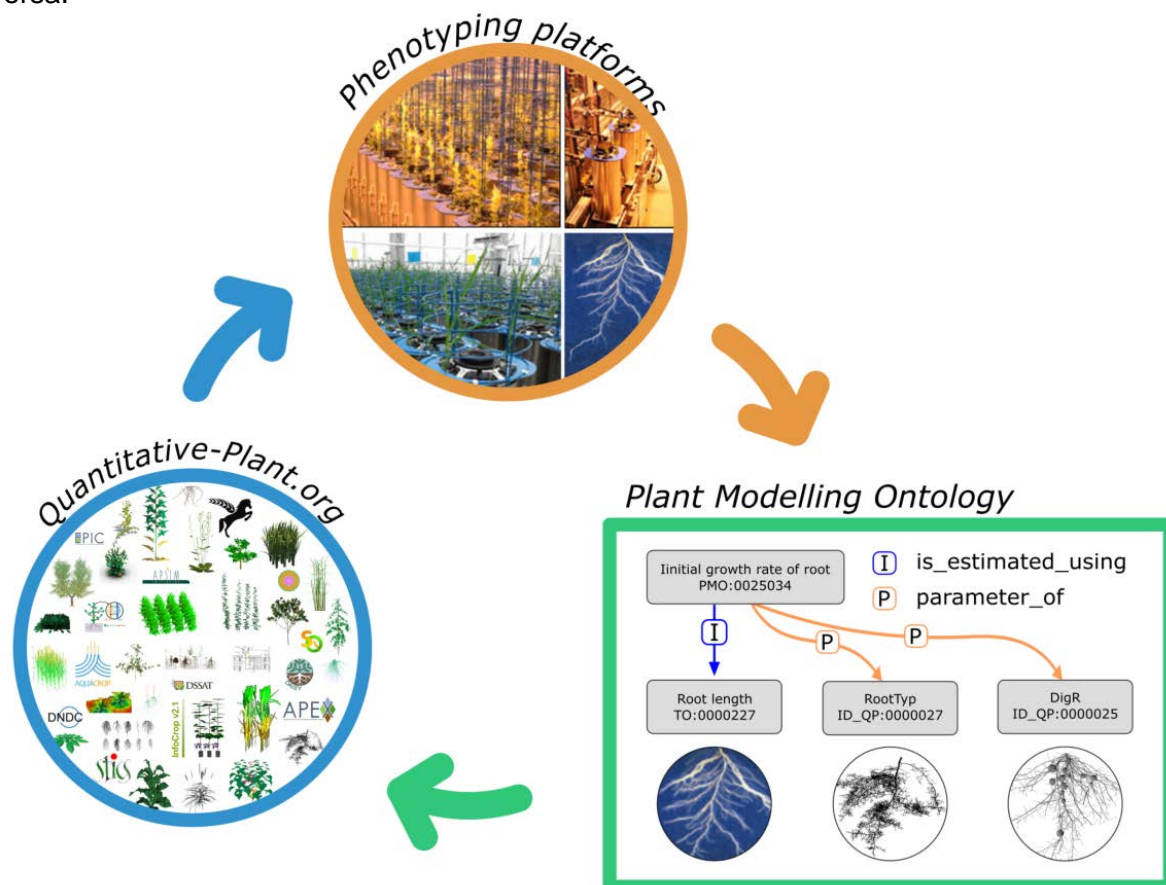


Figure 1: Schematic representation of the connexion between the phenomics and the modelling communities using a Plant Modelling Ontology (PMO)

References

- Athanasiadis et al., 2009, *Metadata and Semantic Research*, doi: 10.1007/978-3-642-04590-5_27
 Chen et al., 2019, *Journal of Experimental Botany* 70: 2523–2534, doi: 10.1093/jxb/ery309
 Christensen et al., 2018, *Nutrition Reviews* 76: 332–347, doi: 10.1093/nutrit/nux076
 Muller and Martre, 2019, *Journal of Experimental Botany* 70: 2339–2344, doi: 10.1093/jxb/erz175
 Tardieu et al., 2017, *Current Biology*, doi: 10.1016/j.cub.2017.05.055

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