PhD Project: Modelling adoption of agricultural phenotyping robotics and its impacts using Machine Learning surrogates

Phenotyping robotics have huge potential in transforming current agriculture into a more sustainable production system. In order to model farmers’ technology adoption and its economic, social and environmental impacts, two questions must be answered: 1) what are the factors that influencing farmers’ adoption decision of phenotyping robotics? 2) how do we overcome the computational constraints of large-scale ABM (Agent-based Modeling) for simulation of technology adoption and its impacts?

This PhD project firstly conceptualize the analysis of adoption and diffusion of phenotyping robotics over space and time. By reviewing determinants of farmers’ adoption decision of precision farming technologies, digital farming technologies, and agricultural robotics, this research will disentangle the complex interaction between determinants on individual level (e.g. the farmer’s characteristics and farm characteristics) and system level (effects of market, role of technology supplier, policy-makers, financial institutions, and so on). By extending the theory of planned behavior, factors on individual level and system levels will be connected. This step will be fundamental for the second step: modeling technology adoption and its impacts.

As we know it is computationally very costly in large-scale ABM to model farmers’ complex technology adoption decision and production decision, a cheaper surrogate model must be needed to overcome this constraint. The surrogate model should be able to capture the relationships between inputs and outputs sufficiently, but computationally it is much cheaper to run. Machine Learning (ML) approach, especially artificial neural networks (ANNs), is compelling due to its high accuracy of prediction and the ability to handle multi-outputs models. Convolutional Neural Networks (CNN) and Recursive Neural Networks (RNN) even have strength of dealing with sequential or spatial data and to reflect model dynamics, which offer huge opportunity to this research.

The second step of this PhD project is to develop ML surrogates for complex farm decision models to increase computational feasibility of ABM for testing, validation and application at regional scale. Data for the training ML models will be generated in FarmDyn, a highly flexible farm-level decision model with detailed information with regard to farm planning and technological specification. One of the challenges that ML surrogate modelling aims to conquer is to capture corner solutions and kinks using domain knowledge. In some special cases of constraint output maximization and profit maximization, first-order conditions cannot be satisfied, thus optimal solution does not locate at tangency. Still optimal solutions can be found in corners, referred to as “corner solutions”. In some other cases, objective functions are not smooth, and optimal solutions can only be found at kinks. Corner solutions and kinks make it difficult to find good solutions from different initial parameters. Since it is already a challenge for optimization models, as its surrogate, ML is also facing the same problem.

This PhD project will have both theoretical and methodological innovations.