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Enhance agent-based model AgriPoliS with individual decision model FarmDyn through deep learning surrogate model FarmLin

AgriPoliS, developed at the Leibniz Institute of Agricultural Development in Transition Economies (IAMO) over more than two decades, is an agent-based model for simulating the development of agricultural regions under changing economical, ecological and societal conditions. Individual farms, modeled as agents in AgriPoliS, make their decisions independently but interact with each other through different markets, especially land market. FarmDyn , developed at the University of Bonn since 2013, is an extensively detailed individual farm decision model designed to simulate farms' responses to various conditions, such as changing prices or policy instruments. In addition to economic indicators, FarmDyn encompasses a diverse set of environmental metrics.

Both models have been successfully applied in various research projects in different countries and exhibit distinct strengths and limitations. FarmDyn, focusing on individual farms, offers a higher level of detail in decision-making compared to AgriPoliS. Conversely, AgriPoliS, by considering inter-farm interactions, enables the exploration of dynamic and emergent phenomena.

The objective of this project entails integrating these two models to leverage their respective strengths and mitigate their weaknesses, thereby enhancing the overall modeling framework. Essentially, our aim is to integrate FarmDyn within AgriPoliS and thus link the detailed decisions at farm level with the interactions between the farms.

Given the autonomous evolution of both models across diverse institutions and locations, their independent development has led to conceptual and technical disparities, presenting unique methodological challenges in achieving alignment. Directly embedding FarmDyn into AgriPoliS encounters several complexities. For instance, the models operate in different programming languages—FarmDyn employs GAMS (Java), while AgriPoliS is built in C++. Further, FarmDyn's reliance on GAMS necessitates a license for the mixed linear programming solver CPLEX, potentially limiting simulation environments upon direct integration. Moreover, the intricate model complexity of FarmDyn poses critical considerations regarding computational efficiency of the integrated model.

To bridge these differences, our approach first involves the conceptual alignment of the models and the standardization of input and output formats. To do this, we define an interface with detailed descriptions of input and output variables that include names, definitions, data types and permitted data ranges. This standardized interface facilitates FarmDyn's customized contributions to the AgriPoliS environment. To technically facilitate the alignment, our approach involves the utilization of a surrogate model named FarmLin —a deep neural network-based surrogate implemented in Python using TensorFlow. FarmDyn generates extensive datasets used to train FarmLin, which, upon integration, bolsters the alignment between FarmDyn and AgriPoliS, overcoming inherent disparities and enhancing the overall modeling framework.

The integrated model was tested for the "Rheinisches Revier" agricultural region in Germany. The methodology has proven to be successful as it allows a comprehensive analysis of the structural development of the region, considering the interactions between farms. At the same time, it enabled the dynamic assessment of environmental indicators that were modeled exclusively in FarmDyn. This holistic approach enables a nuanced understanding of the region's development, encompassing both inter-farm dynamics and environmental changes.

Slot length

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