Digital twin of rice as a decision-making service for precise farming, based on environmental datasets from the fields

P. Skobelev[1], A. Tabachinskiy[1], E. Simonova[2], T.-R. Lee[3], A. Zhilyaev[1], V. Laryukhin[1]

[1]*Samara State Technical University, Molodogvardeyskaya st. 244, Samara, Russia, 443100*
[2]*Samara National Research University, Moskovskoye shosse 34a, Samara, Russia, 443086*
[2]*National Chung Hsing University, Xingda Road 145, South District, Taichung, 402 Taiwan*

Abstract

In this paper a ready-to-use software component, which simulates real state of rice crop in the field and called "Digital Twin of rice" (DT), is studied. DT uses ontology-based knowledge base of plant cultivation to execute the rules of plant growth. The software provides real-time data collection from the fields and distributed decision making to find the optimum solution in planning process of rice growth stages.

Rice DT is developed as an autonomous service and can be integrated to any existing digital agricultural platform. A pilot integration with cyber-physical system (CPS) for precise farming is described in the paper. The CPS has a number of services to provide digital transformation in plant cultivation enterprises and big farms. The system performs adaptive scheduling of resources, such as fertilizers, protection agents, vehicles, personnel and finance.

Results of DT implementation shows adequate decision-making of the service compared to experiments on the pilot farms. So, DT of plant could be a next step in digital transformation of agriculture, providing improvement of ROI from precision farming, automate decision-making processes for farmers and service companies and make their business smarter, more flexible, and more cost-efficient, providing better productivity of plant cultivation and sustainability of agriculture under global climate changes.

Keywords

multi-agent technologies, precise farming, digital twin, knowledge base, ontology, plants cultivation, distributed decision making

1. Introduction

AI technologies penetrates basically all fields of economy and enhances decision making in responsible elements of technological process. Agriculture is a field, which requires significant implementation of smart technologies – optimal decision-making is able to reduce carbon impact, improve cost-efficiency and yield productivity. Smart agriculture market is expected to reach $22 bln. in 2025, and value of smart agriculture services increases as well.

To solve the problem of plant growth prediction, ontology-driven multi-agent service was developed. The smart service estimates parameters of plant growth, based on expert rules from rice cultivation and data from the fields, therefore it is called Digital Twin of rice (DT). For each growth stage of rice DT creates an agent with defined parameters and requirements, and provides a multi-agent environment to perform negotiations between the agents.

2. Rice digital twin implementation

Based on environmental data, rice DT calculates duration for each rice growth stages and estimates yield losses for this state. Environmental data includes instant temperatures, solar radiation, precipitation, humidity of air and soil, water density and water level, chemical content of soil. Field operations of the crop cultivation are also considered through change in environmental parameters. Rice DT establishes "ideal" growth process for each crop for particular specie, place and season, led by

transition rules in knowledge base, when yield estimation to the harvest is maximized. For any variation of input data rice DT recalculates the duration and parameters of growth stages, and deviation of parameters from the "ideal" process causes yield losses. To make the growth process closer to "ideal" and improve the yield, rice DT offers recommendations for precise field operation, for example, to fertilize with particular dozing. Rice DT also has simulation mode, when all the input data is modelled by user to watch the crop reaction to any environmental variation. This mode could help farmers to plan their field works and predict the effect of agricultural measures.

3. Conclusion

Integration of rice DT with smart cyber-physical system (CPS) is described. Integration allows to collect data from various weather services and sensors, and return results of rice growth calculation to the system. CPS with rice digital twin is able to schedule resources of a farm, which is supported by recommendations of DT regarding the optimal fertilizing and field operating. Calculated stage durations and yield estimations of DT with historical data of 2020 shows reliable results – thus, maximum difference between factual and calculated date of growth stage for six macrostages of rice was no more than 5 days.

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