Jedermann, R.: Modelling for digital twin in horticulture: How to process live sensor data for real-time prediction**. VII International Symposium on Applications of Modelling as an Innovative Technology in the Horticultural Supply Chain**, Leibniz Institute for Agricultural Engineering and Bio-economy (ATB), Potsdam, Germany, June 11-14, 2023. Keynote, https://model-it2023.atb-potsdam.de/en/home

Modelling for digital twin in horticulture: How to process live sensor data for real-time prediction

Reiner Jedermann, University Bremen, Institute for Microsensors, -Actuators and –Systems (IMSAS), University of Bremen (IMSAS)

Several models have been developed in agriculture, including shelf-life, heat transfer in containers, packings, and inside fruit, supported by models for condensation/evaporation and resulting mass loss. Most models were tested in offline simulation with recorded data. We discuss the necessary steps for converting and combining such offline models into a system for processing of 'live' or real-time sensor data during cooling and storage. The system immediately analyses deviating conditions and updates predictions after each sensor measurement.

Problem

It has to be asked which models can be converted into an updatable form. Most models use an integral relation to describe a gradual quality loss, or a set of ODEs (Ordinary Differential Equations) for the dynamic relation between sensor inputs and fruit properties.

Parameter identification can mostly be formulated as incremental algorithm, e.g., to estimate a coefficient for heat transfer between ambient cooling air and fruit temperature inside the packing.

Some further fruit properties, which cannot directly be measured, are estimated by state observers based on the ODE system description.

However, the application of CFD models for real-time processing of sensor data is mostly limited to time-varying inlet or cooling air temperature as boundary condition. The inclusion of live sensor measurement from within the predicted 3D space leads to the problem of data assimilation, requiring highly complex optimization.

The description of the time-varying properties for agricultural products mostly consists of different sub-models, provided in several software formats. Moreover, models are only valid in specific life-cycle phases.

Solution

Digital twin (DT) platforms turned out to be a very useful tool for linking such inhomogeneous sets of models. We developed a set of wrapper functions to convert models into DT plug-ins. The models send their measurements and predictions as events to a streaming platform. Messages are transmitted in the programming-language independent JSON format. Routing of messages is handled by the DT platform. The platform provides graphic output and long-time storage as additional services.

Example

This approach was demonstrated for the transport and processing chain of bananas. A temperature model estimated a coefficient for heat transfer and subsequently predicts future temperature changes. The heat production during ripening can be estimated as unknown system state. Measured and predicted temperatures were fed into a green life model for quality estimation.