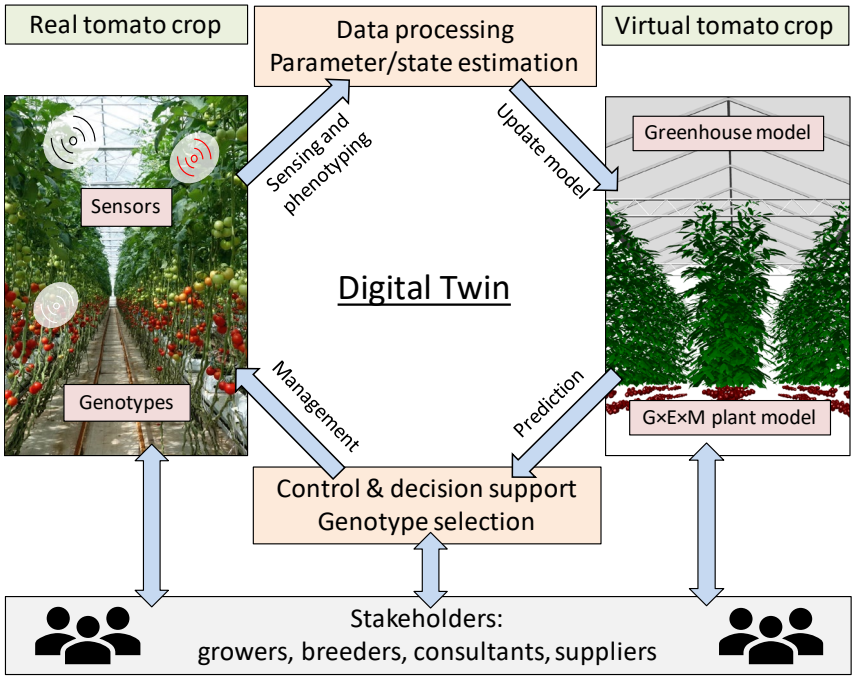
Title: The Digital Twin project Virtual Tomato Crops (VTC)

The Digital twin project 'Virtual Tomato Crops (VTC)'is a 3-year project within Wageningen University & Research, and one of the three investment themes of the WUR Strategic Plan 2019-2022. The VTC project aims to develop a simulation model that predicts tomato plant growth in 3D. The model simulates crop yield, CO_2 uptake, and use of nutrients, energy and water, as well as profit and environmental impact. Simulations are based on real-time measurements of tomato plants and their growing conditions. Based on the model predictions, crop management strategy can be adjusted, and improved plant traits can be identified.

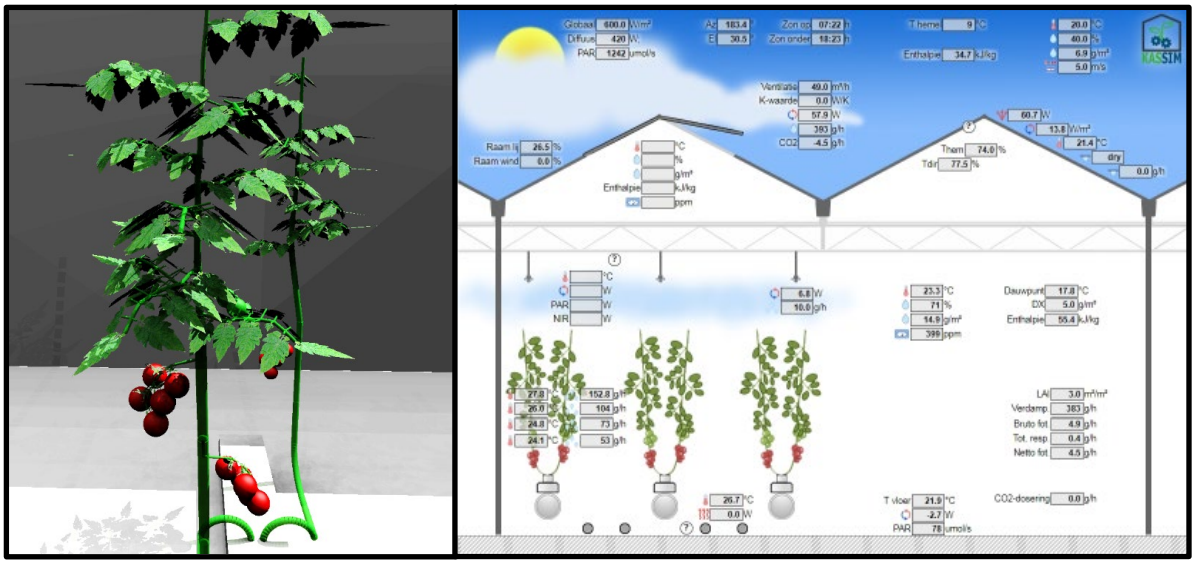


Concept map of the Virtual Tomato Crops digital twin. (G×E×M = interaction between genotype, environment and management)

Development and testing of the VTC will be done in regular contact with stakeholders. The ultimate goal of this digital twin is to increase resource use efficiency of greenhouse tomato systems, resulting in lower dependence on external energy inputs, a further reduction in CO_2 emissions and optimization of water use and fertigation. This will reduce costs and reliance on inputs, making tomato growing more cost-effective. The VTC will work towards production of greenhouse tomatoes with a minimum of resources as well as demand driven by consumer preferences, and thus will realise a feasible cultivation and production system. The VTC is the first step towards this ambitious goal.

Approach

The core of the VTC is based on the concepts of functional-structural plant (FSP) modelling, which simulates individual plants and their functioning (such as leaf photosynthesis) as well as their 3D architectural development. The crucial property of FSP models is that growth and development of the plants feed back on the resources driving that growth, in terms of increased shading and depletion of nutrients and water. Crop behaviour is thus the result of individual plants using shared resources. The environmental variables driving plant growth and development will be simulated by a greenhouse module based on the Kaspro model.



Left: example of a functional-structural tomato plant (P.H.B. de Visser) and right: the interface of greenhouse climate model Kaspro (G.J. Swinkels).

The VTC will be continuously updated with data from the real twin; a tomato crop growing in the greenhouse. In real time, data on plant growth and growing conditions will be captured using the NPEC greenhouse facilities (www.npec.nl). Data from several sensors in the NPEC facilities, such as the multi-spectral 3D laser scanner, chlorophyll fluorescence camera, thermal camera and climate sensors, will be processed to estimate plant traits and climate conditions. The climate sensors measure the desired quantities directly. The focus is therefore on estimating plant traits from raw sensor data. Building on previous work, we will use and develop deep-learning methods to obtain morphological, reflectance, and physiological traits (such as photosynthesis, transpiration, pigmentation).

The output of the model, which is updated as the crop grows and develops, will be used for automatic control of greenhouse climate settings, following a model predictive control strategy. Research questions to be answered concern effects of model granularity on climate control advice, and the effect of daily crop status update on control performance in terms of light use efficiency. Furthermore, the digital twin can be used to virtually explore leaf pruning strategies, to test different greenhouse cover types, and to select superior crop traits.

The VTC is evaluated from an integrated and practical perspective and based on its technical and economic performance. Testing will be conducted at the lab or greenhouse scale, either at WUR or at sites of producer organisations.

Participants and contact
Stakeholder communication throughout the project will be done by Marc Ruijs (Wageningen Economic Research). Contact person for development of phenotyping protocols and estimation of model parameters is Gert Kootstra (Farm Technology). Jochem Evers (Centre for Crop Systems Analysis) is the contact person for development and integration of the tomato plant model, and Simon van Mourik (Farm Technology) will lead efforts on model application on short- and longer-term decision support. Communication on the use of the NPEC facilities within the project goes through Rick van de Zedde (Agro Food Robotics).

Postdocs assigned to this project are Bolai Xin (Farm Technology) and Katarina Streit (Centre for Crop Systems Analysis). An additional postdoc will be assigned by the end of 2020.

Essential further expertise is contributed by:

- Daniela Bustos Korts and Maikel Verouden at Biometris
- Pieter de Visser, Gert-Jan Swinkels, and Nastassia Vilfan at Greenhouse Horticulture
- Elias Kaiser at Horticulture and Product Physiology
- Mark Aarts and Peter Roos at the Laboratory of Genetics
- Harm Bartholomeus at the Laboratory of Geo-information Science and Remote Sensing
- Patrick Hendrickx at Plant Breeding