# NXTGEN Hightech
# Agrifood 19: Ecosysteem

## Evaluation Report Test Validation Demonstration

### Projecttitel

IImmersive Data Visualization

11-12-2025

# Inhoudsopgave

## Contact details

### Details of the problem owner

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### Details of other involved parties

| Organization | Name | Role in the implementation |
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| TomatoWorld | Jan Enthoven | Expert and test location |
| Hortivation | Harmen van Dam | Independent expert |
| Robocrops | Joeri van den Hoek | Knowledge dissemination |
| Erasmus Centre for Data Analytics (Erasmus Universiteit Rotterdam) | Marie Kegeleers | Knowledge expert |
| 360Fabriek | Jan Verwoerd | Technical developer |

## Public summary of the evaluation report

### Test and validation

**2025WP3_Plantfellow_002**
**Status: : Finished**

**Business case**
Minimal viable product analysis

**Problem owner:**
Plantfellow

**Involved:**
Hortivation, TomatoWorld, Erasmus Centre for Data Analytics, 360Fabriek, Robocrops / InnovationQuarter

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Glastuinbouw

# Immersive data visualization



REAL-TIME Nutreatics

**Broad knowledge question**
How can we effectively and user-friendly visualize the growing amount of greenhouse data, so that growers and other stakeholders can make optimal use of it for decision-making and the optimization of cultivation processes?

**Approach**
We used an iterative, practice-oriented methodology to apply the AR solution to the greenhouse context. Data from various sources was combined with location and time data to create a robust structure for real-time processing and visualization. The process included multiple sessions with industry experts, during which growers and other stakeholders provided feedback to improve the application's functionality and user-friendliness. Quality was ensured through the direct involvement of Erasmus University Rotterdam (EUR), which facilitated the project process and safeguarded methodological standards. Collaboration with an experienced developer enabled the technical implementation of a Minimum Viable Product (MVP), following best practices and standards in AR development.

**Objective**
1. Developing a working MVP for an Augmented Reality (AR) application that presents complex greenhouse data in an intuitive and visually accessible way. This MVP will combine data streams from various sensors with location and time data and visualize them in an AR interface, enabling users to gain real-time insights at plant level.
2. Gaining insights into how data integration, digital twins, and AR technology can be practically applied in greenhouse horticulture, as well as the user-friendliness and adoption potential of such technologies by greenhouse workers and growers.

**Results and reflection**
The GRAAG project delivered a functional prototype for real-time spatial data visualization in a greenhouse, focused on tomato cultivation. During a showcase at Tomatoworld, users experienced live temperature data through a mixed reality headset, which was well received. Feedback highlighted the value of on-site data visualization for training and quick decision-making. However, users indicated the need for more data types, lighter hardware, and customizable visualizations. Involving growers in future development was seen as key for broader adoption. These insights offer a strong foundation for scaling XR applications in horticulture.

## Broad knowledge question

How can the increasing volume of greenhouse data be visualized effectively and in a user-friendly way, enabling growers and other stakeholders to optimally use it for decision-making and crop optimization?

1. **Information failure:** The explosive growth of greenhouse data means traditional visualization methods are no longer sufficient. As a result, users struggle to properly interpret information, complicating decision-making.
2. **Infrastructure failur**e: There is no standardized infrastructure for processing and presenting greenhouse data, leading to fragmentation and inefficient data use.
3. **Network failure:** There is insufficient collaboration between different parties such as software developers, data providers, and growers to create integrated and usable visualization solutions.

For a successful transition toward future-proof greenhouse data visualization, the following transformative failures must also be addressed:

1. **Vision and direction failure:** There is no clear long-term vision on how greenhouse data should ideally be visualized. This preliminary research represents a crucial first step in developing such a vision.
2. **Market failure:** Commercial parties often develop their own dashboards and visualization tools, resulting in a lack of standardization and a fragmented market.
3. **Learning failure:** There is still insufficient joint knowledge development on innovative visualization techniques in greenhouse horticulture. This project contributes to a shared learning curve within the sector.

## Introduction

The greenhouse horticulture sector faces major challenges and opportunities due to the explosive growth of data generated by sensors, drones, and AI technologies. These data streams offer valuable insights but also create significant complexity. Traditional dashboards are no longer sufficient to make this data accessible. At the same time, the expertise of experienced growers – so-called green knowledge – is gradually disappearing.

This project focuses on developing an innovative Augmented Reality application that visualizes complex greenhouse data in an intuitive and immersive way. By using advanced technologies such as AR, Natural Language Processing, and real-time data analysis, the solution reduces data complexity while contributing to more efficient and sustainable greenhouse cultivation practices.

The project scope includes combining data from various sensors, both static and dynamic such as drones, with coordinates and timestamps in a real-world setting. The goal is to make this information accessible through a user-friendly AR interface that enables growers to gain insights easily and make better-informed decisions.

This approach contributes not only to the modernization of the sector but also to sustainability and the preservation of essential knowledge within greenhouse horticulture.

## Project description

The project aimed to develop an innovative Augmented Reality application to visualize complex greenhouse data in an intuitive way and support decision-making. It aligns with the future vision of greenhouse horticulture: an autonomous greenhouse in which plants are fully cared for by robots in the most efficient and effective manner. Although this vision may still seem futuristic, increasing numbers of data points are becoming available through sensors, drones, and advanced measuring equipment, while traditional green and technical knowledge is gradually disappearing.

The innovation focused on creating a digital representation of the greenhouse situation, a digital twin, in which real-time data is combined with agrotechnical expertise. Examples include sensors measuring nutrients in the substrate, probes monitoring plant processes, drones collecting visual data, and location data to precisely identify individual plants. The challenge was to combine, interpret, and visually present these diverse data streams in a way that is accessible to greenhouse employees. This project took the first step by visualizing greenhouse data using an AR application as a proof of concept.

The project was carried out in collaboration with TomatoWorld, where it was tested in a semi-practical environment, and with Erasmus University Rotterdam, which facilitated a design trajectory to create a user-friendly solution. The team also worked with external developer 360Fabriek, which developed a Minimum Viable Product based on insights from the design trajectory and existing technologies. This approach represents a fundamental step toward digital and autonomous greenhouse horticulture.

The proof of concept demonstrated how employees can use AR technology to directly view relevant information about individual plants, including necessary actions to improve efficiency and sustainability. It addressed the broader knowledge question of how data from various sources can be effectively integrated and visualized to support an autonomous greenhouse.

The project tackled systemic failures such as the lack of infrastructure for real-time data integration and interpretation, as well as transformative failures such as limited adoption of new technologies by growers. It delivered a concrete and scalable proof of concept that not only demonstrates technological innovation but also provides a practical pathway toward autonomous, data-driven, and future-proof greenhouse horticulture.

## Materials and methodology

The project applied an iterative and practice-oriented methodology to develop the AR application. Data from various sources such as sensors were combined with location and time data to create a structure suitable for real-time processing and visualization. The design process was supported by design sessions with sector experts, during which growers and other stakeholders provided feedback to optimize functionality and usability.

Design sessions included:
Design session 1 Empathize, understanding user needs
Design session 2 Define, defining challenges and opportunities
Design session 3 Ideate, working toward solutions
Design session 4 MVP development by 360Fabriek
Design session 5 Testing of the MVP

Quality assurance was ensured through the involvement of Erasmus University Rotterdam, which facilitated the design trajectory and safeguarded methodological quality. Collaboration with experienced developer 360Fabriek ensured best practices and standards for AR development.

Sensor data such as temperature and light from the TomatoWorld greenhouse were integrated via the Robocrops platform. A prototype AR/MR application was developed using the Apple Vision Pro headset. Sensor values were displayed on-site using semi-transparent cloud visualizations in heatmap colors. Interaction was enabled through hand gestures, and location calibration was achieved using QR codes. This approach ensured technical feasibility and continuous user feedback.

The planned hardware did not need to be purchased, as equipment was made available by 360Fabriek and Erasmus University Rotterdam. Testing and demonstration at TomatoWorld were therefore conducted without additional hardware costs.

## Results

### Realization

The project successfully delivered a proof of concept in the form of a working AR prototype. The application uses real-time data including temperature, humidity, and RTR score from the TomatoWorld greenhouse via the Robocrops platform. Through the Apple Vision Pro headset, this data is visualized on-site using colored clouds and spheres, making spatial differences directly observable. The application was tested and demonstrated in a semi-practical environment as planned. Software and hardware choices align with the ambition to move toward a digital twin and autonomous greenhouse.

## Interpretation

While the prototype functions technically and was well received, further development is necessary to fully realize the project ambition. Spatial visualization of greenhouse data is technically feasible but currently limited in functionality, interaction options, and data types. The project highlights both the potential of AR in greenhouse horticulture and remaining systemic challenges such as hardware complexity and limited standardization. Growers see potential, but adoption depends on improved usability, scalability, and active end-user involvement.

## Conclusions and future perspective

The project demonstrates that complex greenhouse data can be visualized on-site using Augmented and Mixed Reality. The prototype provides intuitive spatial insights for greenhouse staff and confirms technical feasibility in an operational setting. Users recognized value especially for training, monitoring, and rapid decision-making.

However, further development is required to move from prototype to practical application, including:
- Expansion of data types such as substrate measurements and growth predictions
- Improved lightweight and accessible AR hardware suitable for greenhouse use
- Enhanced interaction and personalization including time-based data navigation
- Active involvement of growers to increase adoption
- Scalability and standardized data infrastructure integration

The project offers both a technological starting point and a framework for further innovation toward autonomous, data-driven greenhouse horticulture.

## Disseminatie

Results were shared broadly and non-exclusively. A demonstration was held at TomatoWorld in October 2025 for growers, technology partners, and policymakers. Erasmus University Rotterdam produced a final report shared with partners and made available for broader sector dissemination. Communication about the research was also conducted via social media.

Software components developed by 360Fabriek are available for further development in new initiatives. Jointly developed results such as design guidelines and methodological insights are shared through public reporting and new projects. Agreements between partners ensure that jointly developed knowledge can be freely shared with the sector.

## Reflection

| Aspect | Reflection: what was good, what could be better |
|---|---|
| Received support | Support from Erasmus University Rotterdam and 360Fabriek was professional and substantive. EUR contributed expertise in design methodology and user experience, ensuring a structured design process. 360Fabriek provided technical AR/MR expertise not typically available within the sector, enabling realization of a working prototype. |
| Location facilities | The TomatoWorld test location proved highly suitable, supported by 5G infrastructure for stable data processing and visualization. Although the number of data types was limited, this was sufficient to convincingly demonstrate technological potential.<br><br>Overall, the project is considered a successful first step toward immersive technology in greenhouse horticulture, supported by strong collaboration and a solid foundation for further development. |