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# STRUCTURIZED ECOLOGICAL CULTIVATION WITH AUTONOMOUS ROBOTS IN INDOOR AGRICULTURE

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# *Future of indoor agriculture*


LABOR  INTENSIVE

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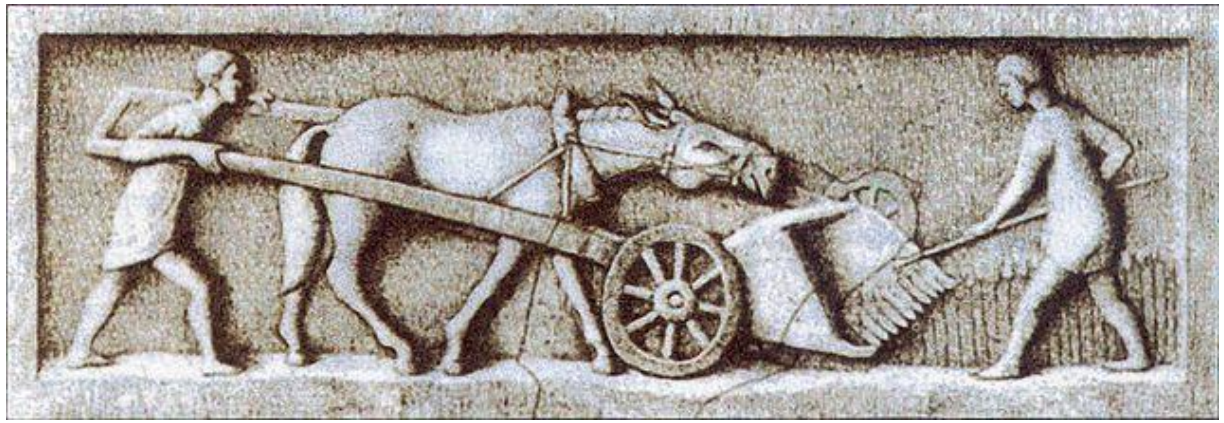
# Emperor Tiberius (42 BC–37 AD)

Although glassmaking still wasn't advanced enough to produce sheets large enough for use in a greenhouse, that didn't stop Roman Emperor Tiberius's insistence that his gardeners find a way to cultivate cucumbers year round. Their best efforts yielded the Specularium : a south facing heated cold frame made with pieces of semi transparent mica.



Imperial gardeners made sure that Tiberius had cucumbers every day of the year, even though they ripen naturally only in the summer. By taking the beds in which the cucumbers were planted and mounting them on wheels (imagine a kind of wheelbarrow), the gardeners could keep moving them around to follow the sun. During the cold months, they covered the cucumber beds with sheets of mica, a transparent stone (sheet glass had not yet been invented).

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# Heterogeneous robotic systems

- multi-robot systems, where robots work (move) together to accomplish tasks that would be otherwise unachievable by a single robot.
- We study a symbiotic UAV-UGV robotic system
- UGV can provide a UAV with a safe landing area and transport it across large distances,
- UAV can provide an additional degree of freedom for the UGV, enabling it to negotiate obstacles.
- We propose an overall system control framework that includes high-accuracy motion planning for each individual robot and mission planning for complex missions.

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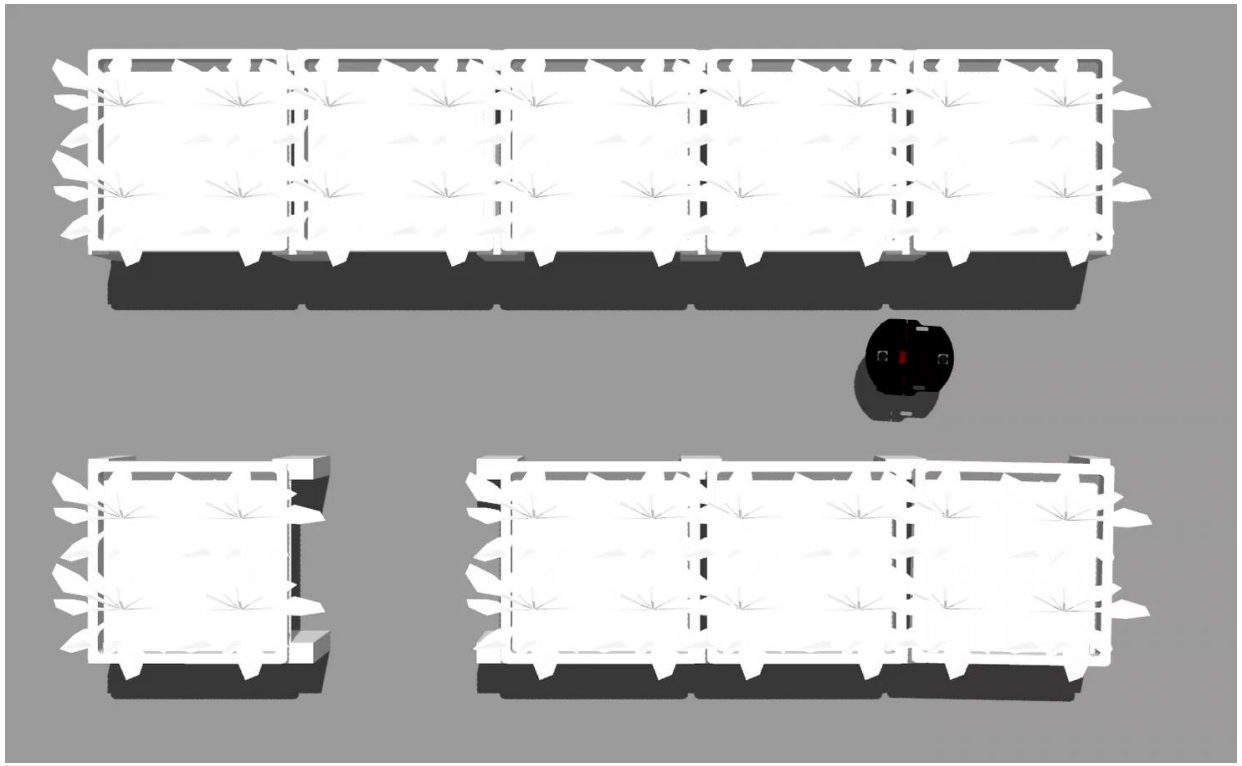
# Unmanned ground robot (UGV)

This robot is equipped with a mechanism allowing it to transport growth unit containers. These containers, are the smallest organization unit within the farm consisting of a single or variety of plants, that are used in the structured greenhouse environment, designed to suit the robot aided farming paradigm.



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# Farm optimization


## *Crop rotation*

- *Middle Ages open field system*
- *Norfolk four-course rotation*

- We want to grow different plant cultures
- Plants require different conditions
- We need to be able to reach every plant
- We want the optimal yield

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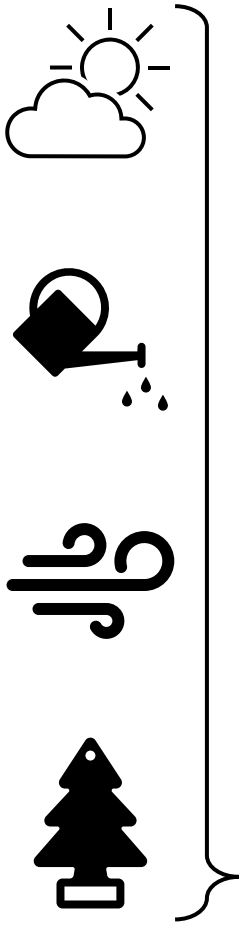
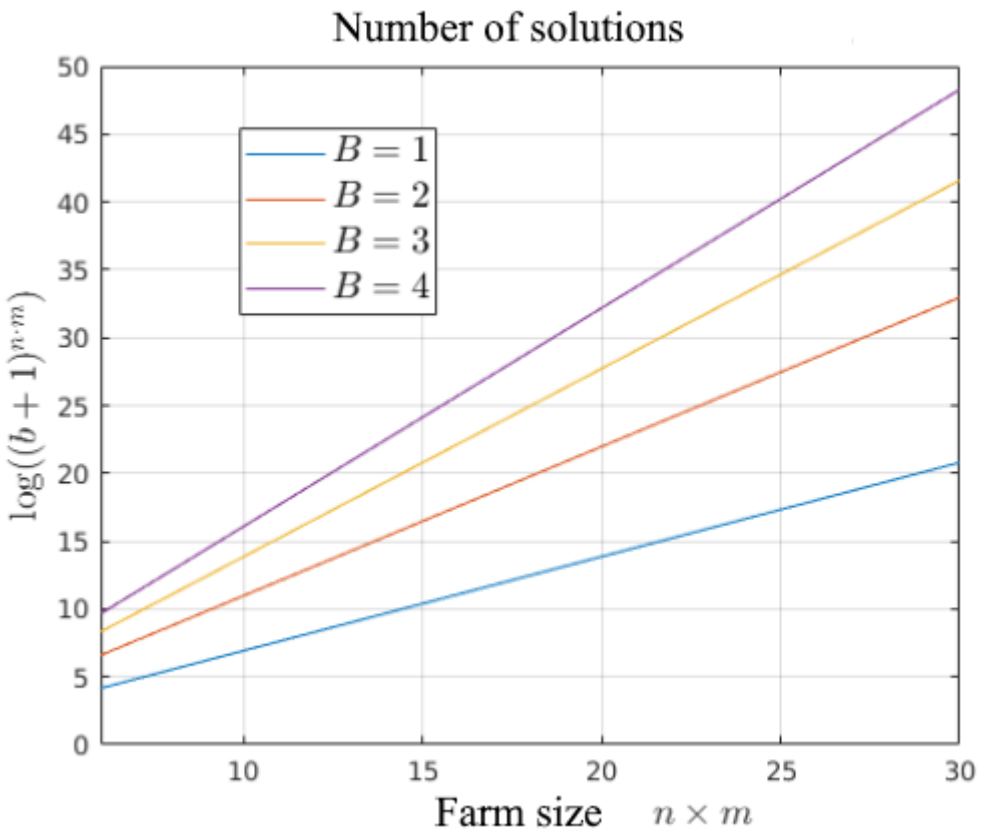
# Farm optimization






- All possible combinations

$$(B+1)^{n \cdot m}$$

*B* – plant cultures; *n,m* – farm size

- Farm map $M = \begin{bmatrix} 1 & 1 & 3 \\ 0 & 2 & 0 \\ 0 & 2 & 0 \end{bmatrix}.$

- Cost function $f(M)$

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*Compliant Plant Exploration for Agricultural Procedures With a Collaborative Robot* *M Polic, M Car, F Petric, M Orsag*
*IEEE Robotics and Automation Letters 6 (2), 2768-2774*

# Compliant multi degree of freedom manipulator

The key issue in dealing with sensitive plants is to ensure the necessary compliance from the manipulator motion. This will ensure the robot can execute certain tasks, and at the same time make sure that the plant is not harmed. This requirement also fits within the Soft robotics paradigm, that focuses researchers to build better sensing machines, capable of dexterous human like motion. Testing the robots on such a challenging application, represents an interesting research opportunity that will certainly lead to new results in a rapidly expanding field of research.

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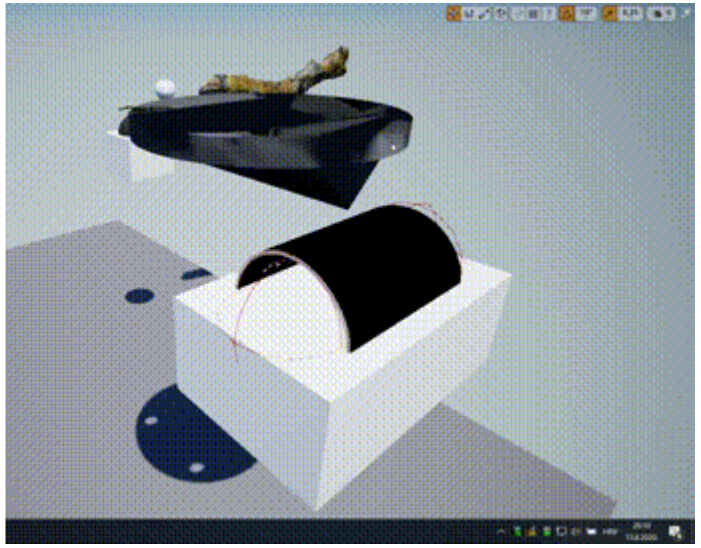
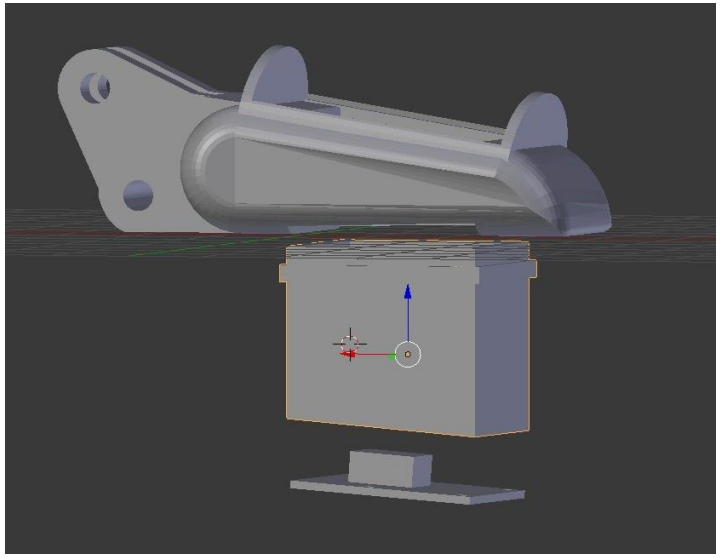
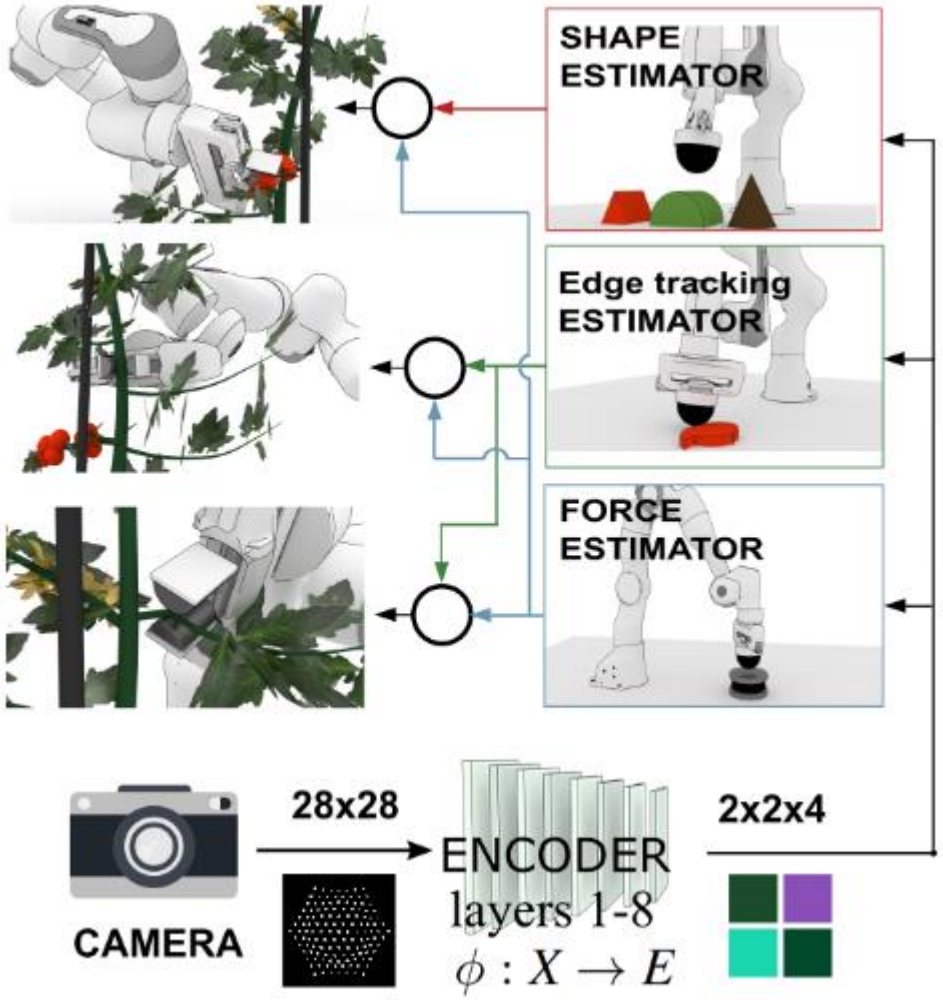
# Soft sensing



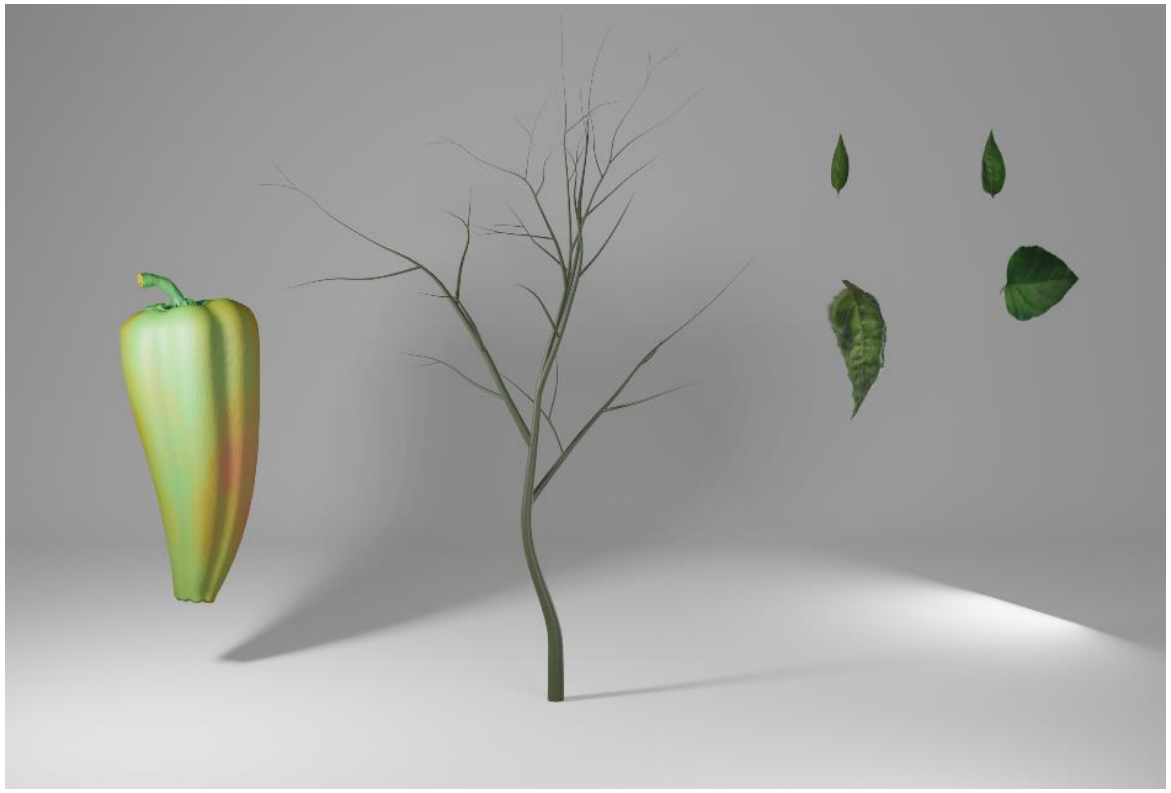





*Convolutional autoencoder for feature extraction in tactile sensing* M Polic, I Krajacic, N Lepora, M Orsag
IEEE Robotics and Automation Letters 4 (4), 3671-3678

This work has been supported in part by Croatian Science Foundation under the project UIP-2017-05-4042

# Artificial dataset generation



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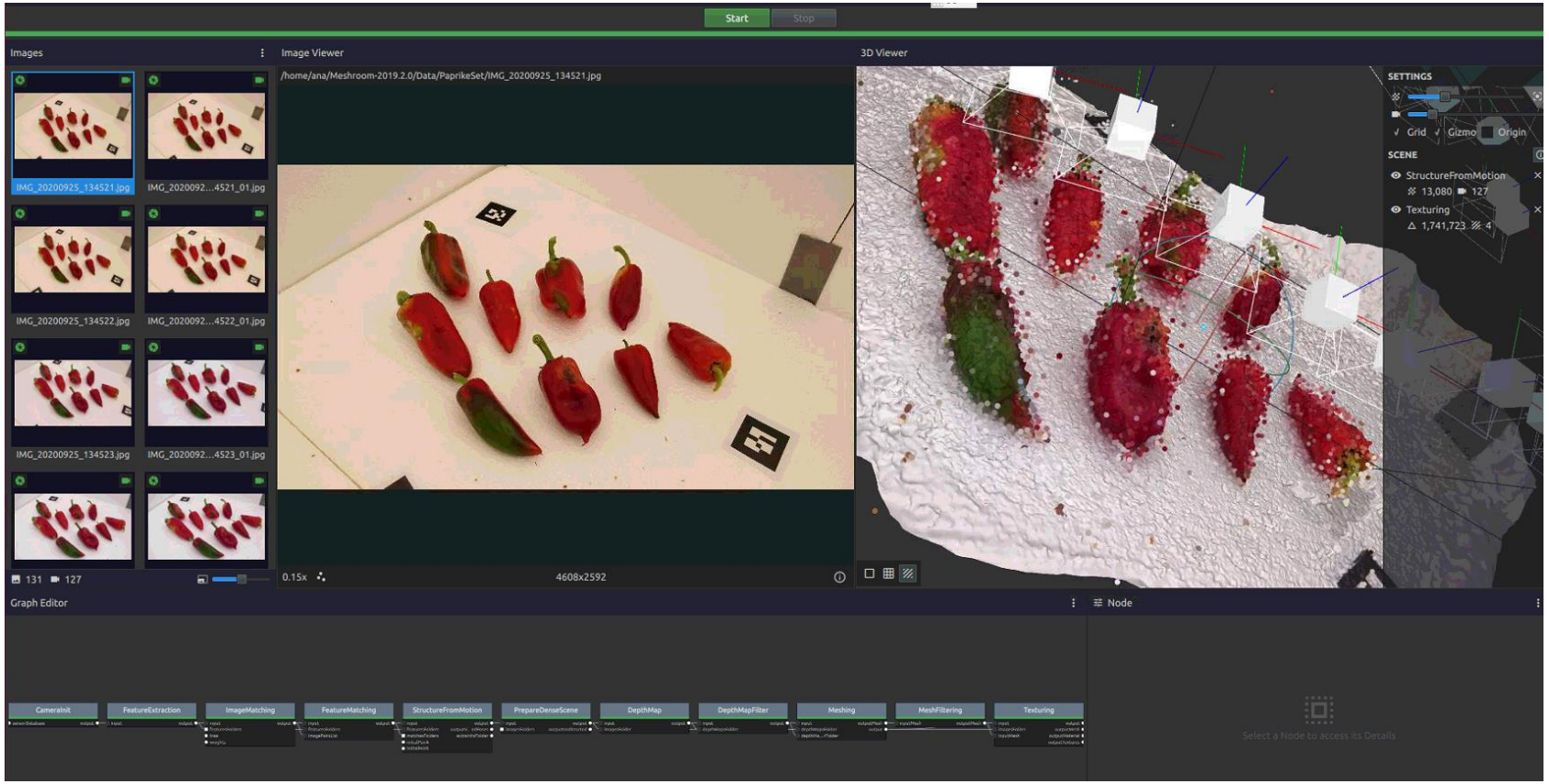


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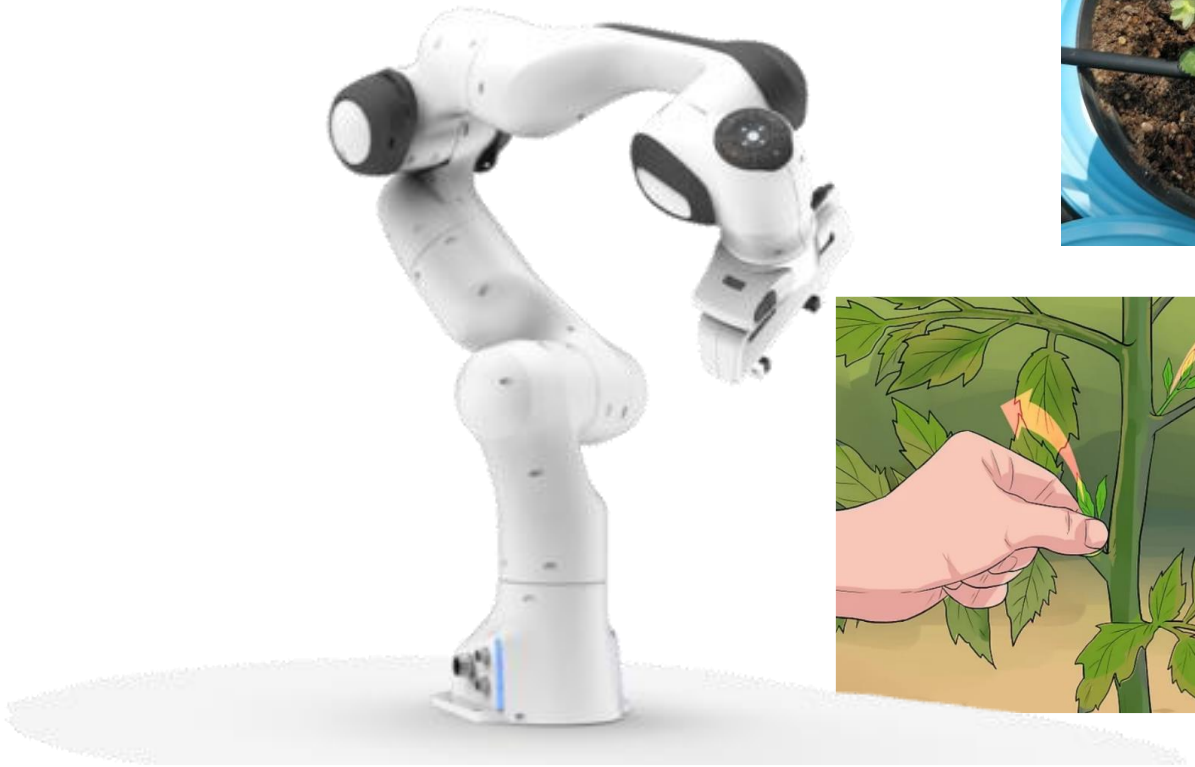

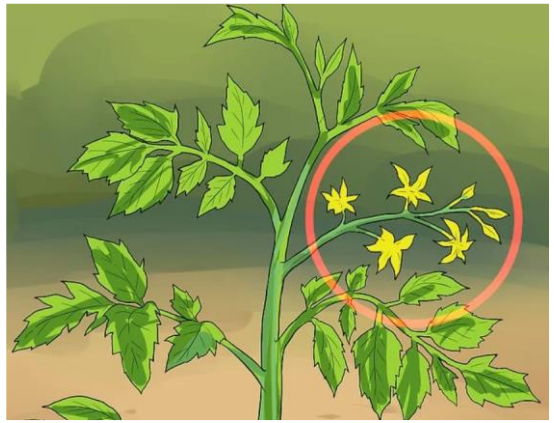

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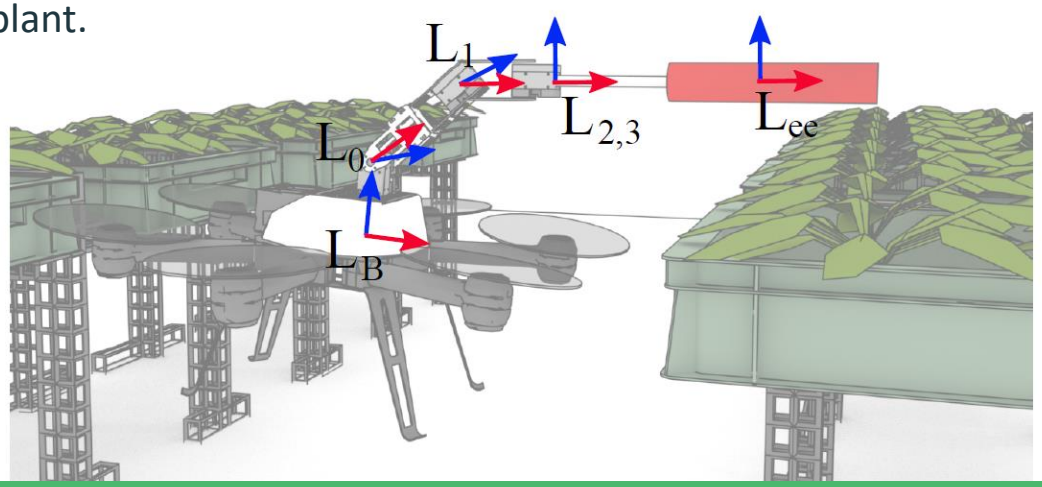
# Unmanned aerial robot (UAV)

Our UAV is equipped with a multi degree of freedom manipulator carrying sensors for plant surveillance. The multi degree of freedom manipulator enables the robot to fly outside the danger area, where its prop wash wind gust can damage the plant.





*Exploiting Null Space in Aerial Manipulation through Model-In-The-Loop Motion Planning* A Ivanovic, M Car, M Orsag, S Bogdan
*2020 International Conference on Unmanned Aircraft Systems (ICUAS), 686-693*

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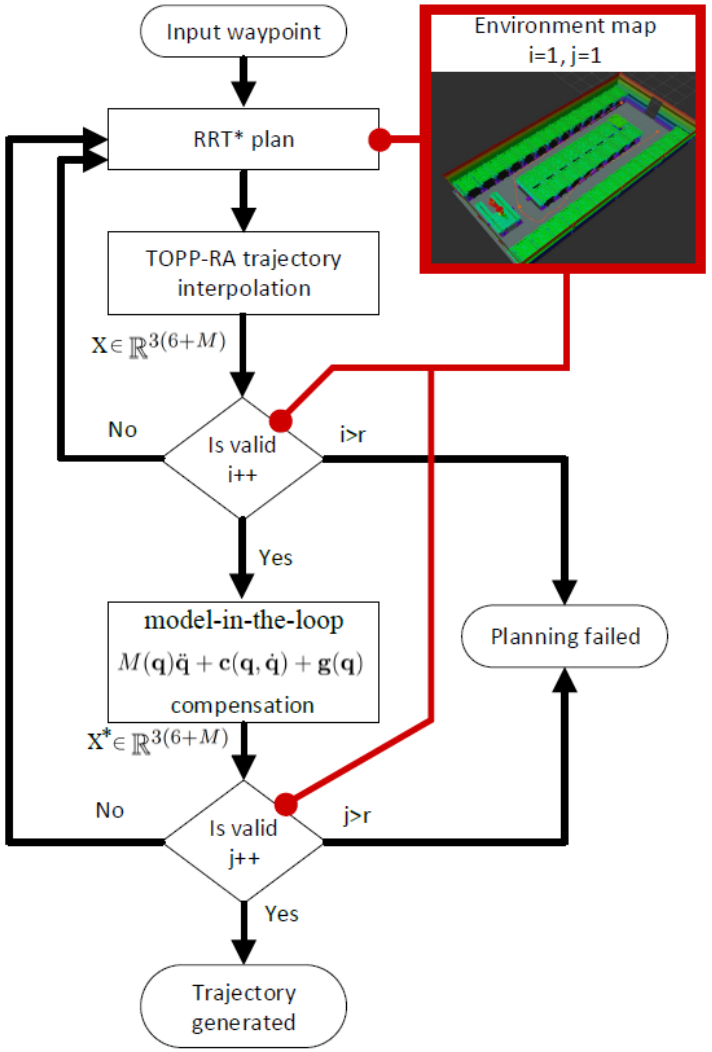


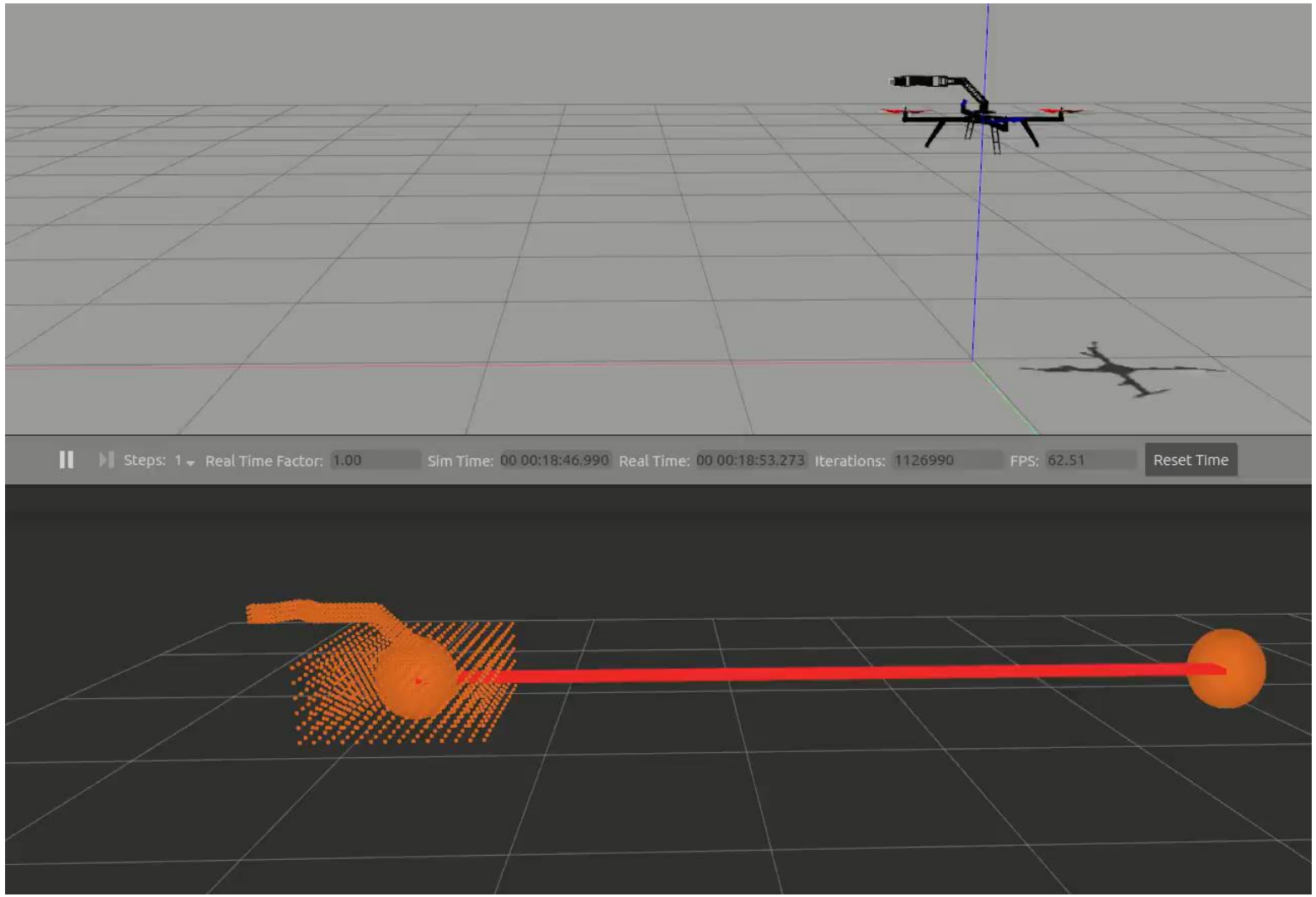


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# Robot Cooperation vs Mobile Manipulation: a Case Study on Indoor Agriculture Application

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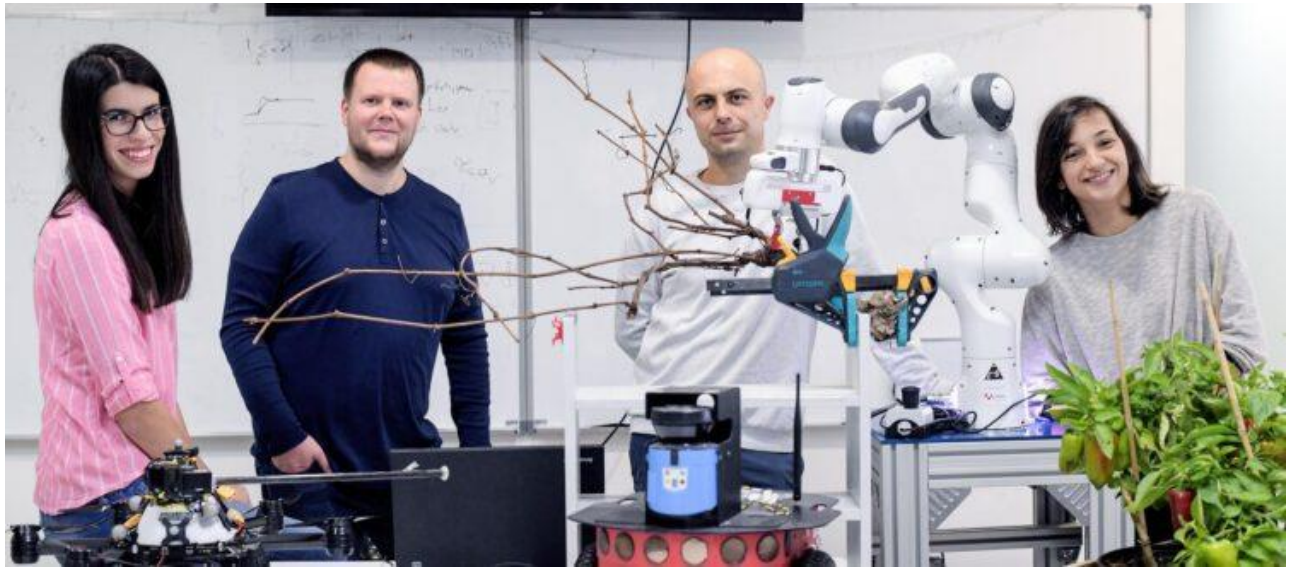

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CREATING LONG TERM VALUE

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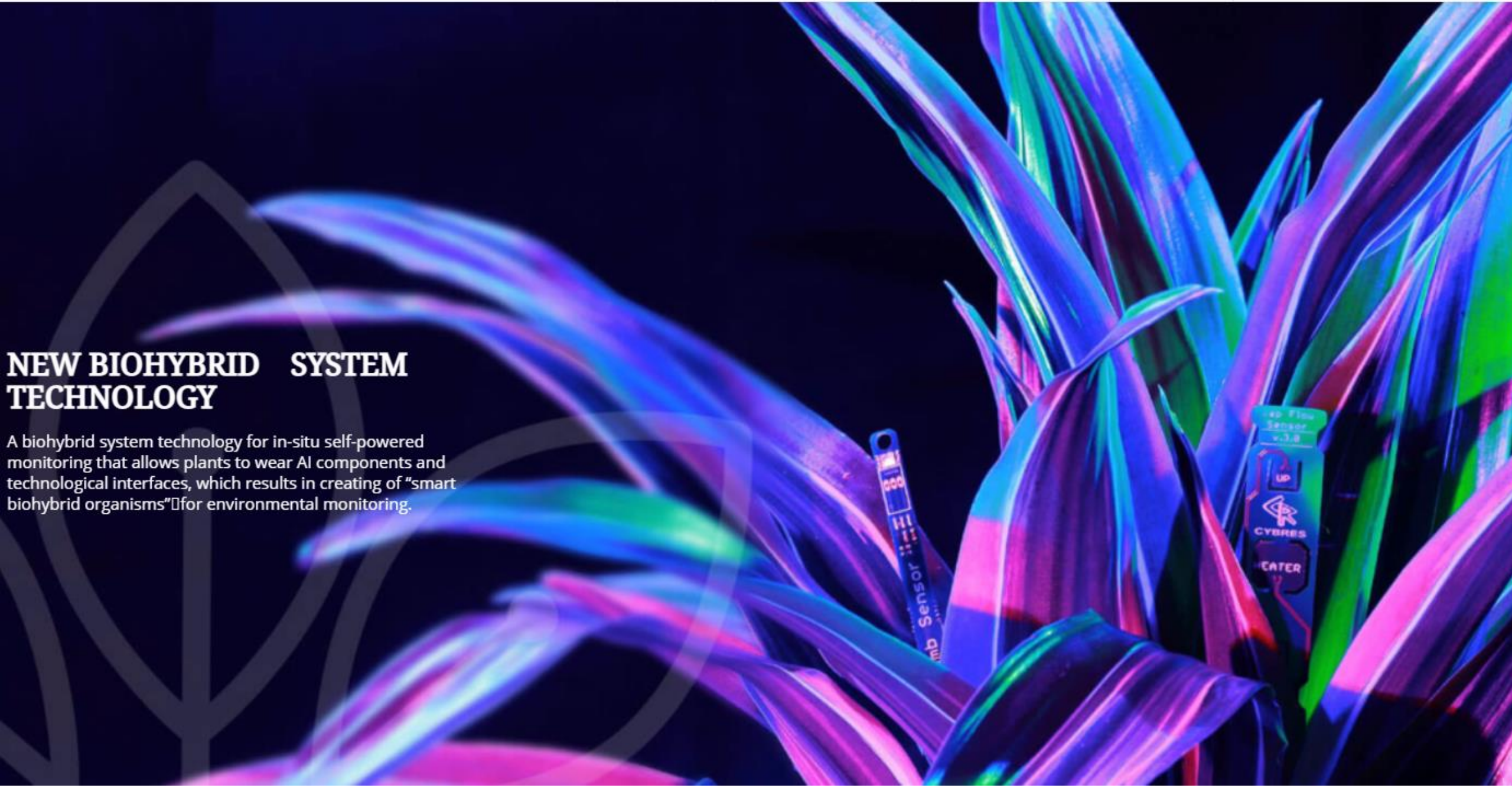


# NEW BIOHYBRID SYSTEM TECHNOLOGY

A biohybrid system technology for in-situ self-powered monitoring that allows plants to wear AI components and technological interfaces, which results in creating of "smart biohybrid organisms" for environmental monitoring.