Robotic harvesting of fruit vegetables

Jan Bontsema, Jochen Hemming

Wageningen University and Research Centre, Greenhouse Horticulture

Eldert van Henten

Wageningen University, Farm Technology

2015

Global Technologies in Horticulture Seminar

June 25th, 2015

WAGENINGEN UR
For quality of life

Funding

The research received (and is receiving) funding from

- The Dutch Ministry of Economical Affairs
- The European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 246252
- The Dutch Horticultural Product Board
- The European Union's Horizon 2020 research and innovation programme under grant agreement n° 644313.

Contents

- Introduction
- Cucumber harvesting robot: CUPID
- Sweet pepper harvesting robot 1: CROPS
- Sweet pepper harvesting robot 2: SWEEPER

Why robotic harvesting?

- Maintaining a sophisticated greenhouse sector (in Europe)
- Lower labour costs
- More sustainable labour (low skilled labour replaced by high skilled labour)
- Better guaranteed food safety (cf. EHEC scandal 2011)
- Higher quality (selective harvesting)
- Higher yield (by changing climate into a for humans unacceptable climate)

30 years of robotic harvesting research:

Harvesting Robots for High-value Crops: State-of-the-art Review and Challenges Ahead

C. Wouter Bac and Eldert J. van Henten
Farm Technology Group & Wageningen UR Greenhouse Horticulture, Wageningen University and Research Centre, Droevendaalsesteeg 1, 6708 PB, Wageningen, The Netherlands
e-mail: wouter.bac@wur.nl, eldert.vanhenten@wur.nl
Jochen Hemming
Wageningen UR Greenhouse Horticulture, Wageningen University and Research Centre, Droevendaalsesteeg 1, 6708 PB, Wageningen, The Netherlands
e-mail: jochen.hemming@wur.nl
Yael Edan
Department of Industrial Engineering and Management, Ben-Gurion University of the Negev, P.O. Box 653, 84105, Beer-Sheva, Israel
e-mail: yael@bgu.ac.il

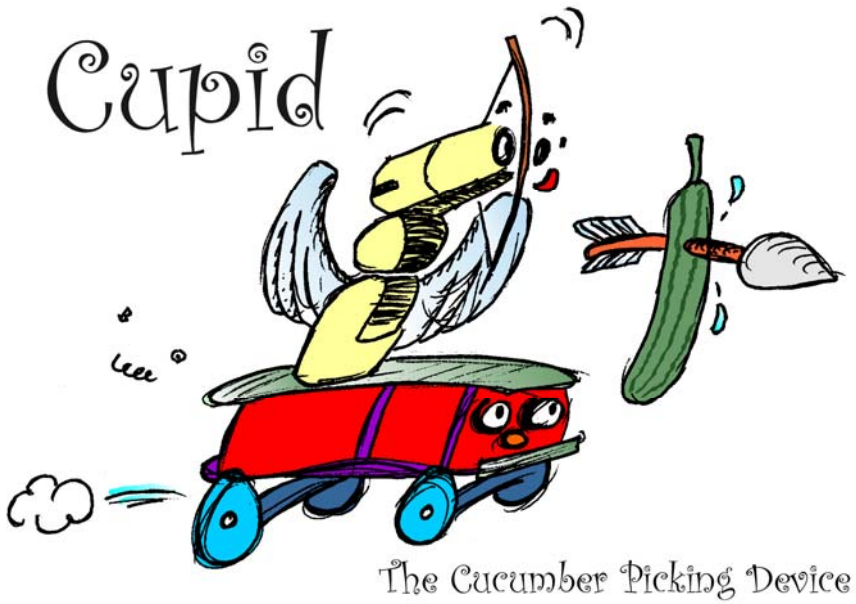
Received 19 November 2013; accepted 9 April 2014

Journal of Field Robotics 31(6), 888–911 (2014)
View this article online at wileyonlinelibrary.com • DOI: 10.1002/rob.21525

WAGENINGEN UR
For quality of life

Cucumber harvesting robot

- Project running from 1996 – 2002
- Funded by the Dutch Ministry of Economical Affairs (actually at that time by the Ministry of Agriculture)



WAGENINGEN UR
For quality of life

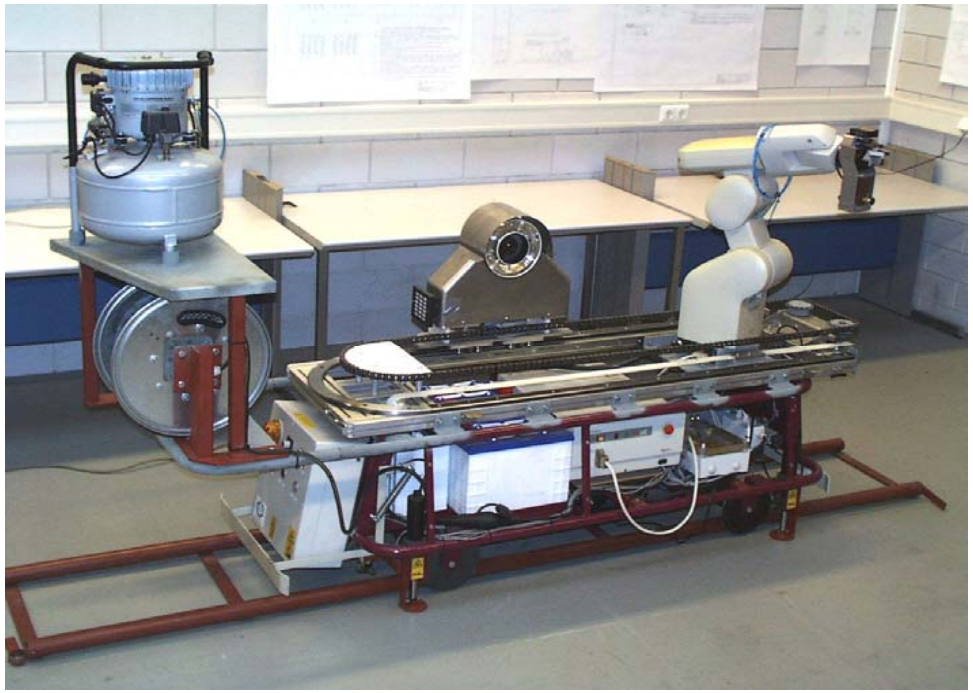
Cultivation system cucumbers

Traditional

High wire

High wire, leaves removed before harvesting

The cucumber harvesting robot

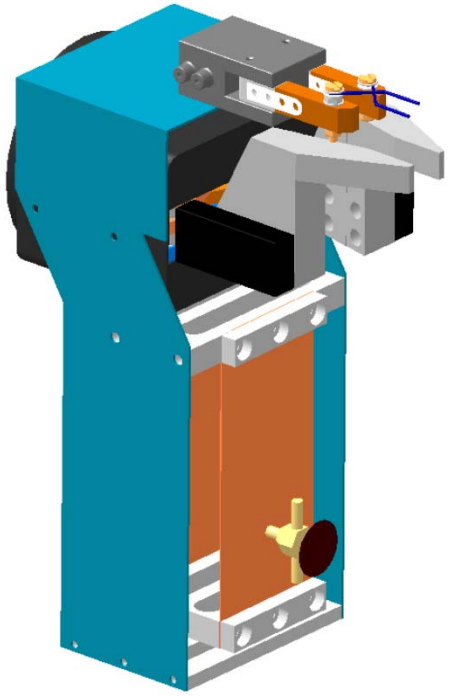


Prototype in laboratory

Prototype in greenhouse

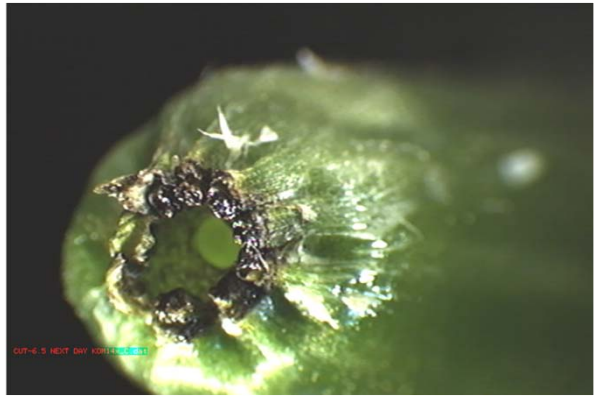
WAGENINGEN UR
For quality of life

End-effector

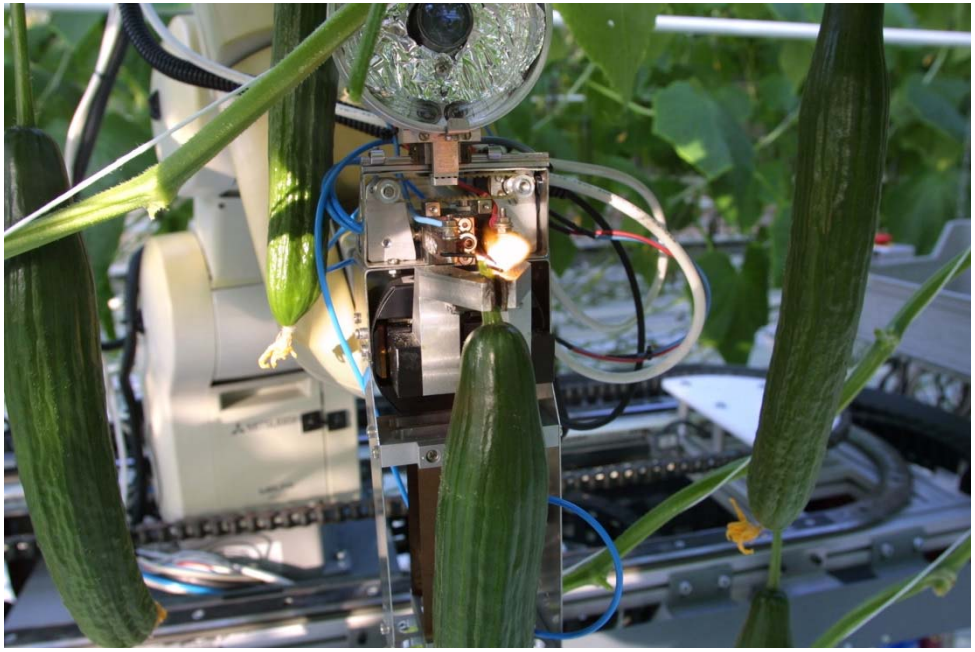


No virus transport

No mold on fruit or plant

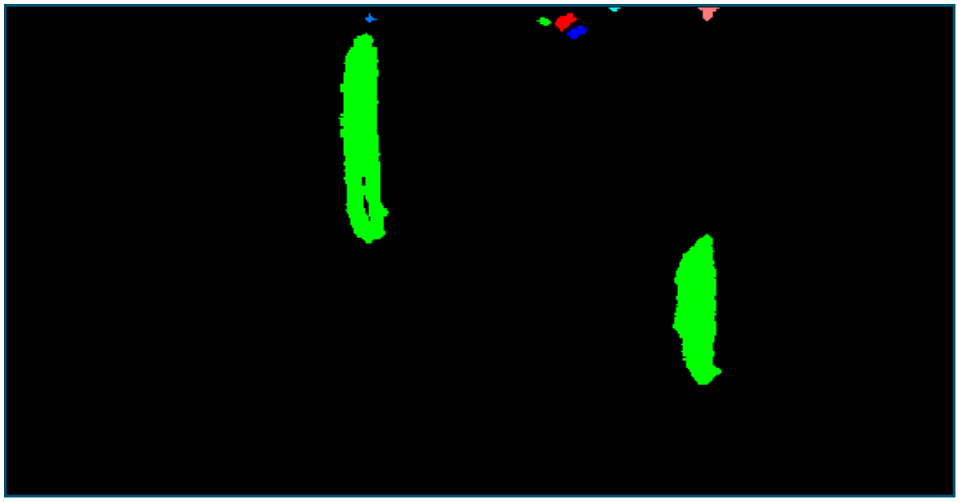


cf.: electro surgery



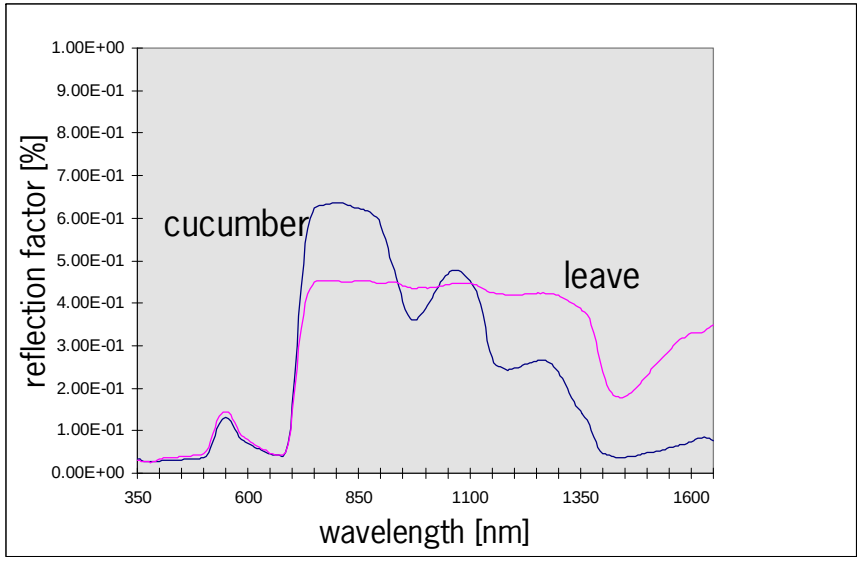
WAGENINGEN UR
For quality of life

Cucumber detection



2 cucumbers detected

NIR reflection: detecting water content



Reflection properties of fruit and leaves

Depth determination: stereo vision

WAGENINGEN UR
For quality of life

Cucumber harvesting robot in the greenhouse

Cucumber harvesting robot, results

- Detection: 95%
- Harvesting rate:74%
- Cycle time: 124 s

Website: www.wageningenur.nl/nl/show/Cucumber-harvesting-robot.htm

WAGENINGEN UR (http://www.wageningenur.nl)

Project

Cucumber harvesting robot

Today, labour is the largest cost factor of a modern greenhouse holding. More than 30% of the total production costs are spent on wages for the grower and his employees. Obviously, to cope with saturating market demands and increasing competition, the grower is looking for ways to improve the over-all efficiency of the production process. Manual labour in a greenhouse is demanding, especially under poor climatic conditions.

Because the robots reported in literature were not suited for the high productivity growing systems used in Dutch horticultural practice, in 1996, we began research on the development of an autonomous cucumber harvesting robot supported by the Dutch Ministry of Agriculture, Food and Fisheries. The task of designing robots for agricultural applications raises issues not encountered in other industries. The robot has to operate in a highly unstructured environment in which no two scenes are the same. Both crop and fruit are prone to mechanical damage and should be handled with care. The robot has to operate under adverse climatic conditions, such as high relative humidity and temperature as well as changing light conditions. Finally, to be cost effective, the robot needs to meet high performance characteristics in terms of speed and success rate of the picking operation.

This research project was finished in 2002.

Status: Afgerond
Start project: 1-jan-1996
Einde project: 31-dec-2002

Partners: Wageningen UR Greenhouse Horticulture (/en/Expertise-Services/Research-Institutes/Wageningen-UR-Greenhouse-Horticulture.htm)

Flyer

An autonomous harvesting machine for cucumbers (146,57 kb) (/upload_mm/5/5/7/c221711e-98da-4865-805a-8fc8531aa624_flyer_cucumber%20harvesting_robot_uk.pdf)

Cucumber harvesting robot

Key publications

- Van Henten, E.J., J. Hemming, B.A.J. van Tuijl, J.G. Kornet, J. Meuleman, J. Bontsema and E.A. van Os, (2002): An Autonomous Robot for Harvesting Cucumbers in Greenhouses. Journal on Autonomous Robots, 13, 241-258. (http://link.springer.com/article/10.1023%2FA%3A1020568125418)
- Henten, E.J. van., Hemming, J., Tuijl, B.A.J.van., Kornet, J.G. and Bontsema, J., (2003): Collision-free Motion Planning for a Cucumber Picking Robot. Biosystems Engineering, 86(2): 135-144.
- Henten E.J. van, Tuijl, B.A.J.van, Hemming, J., Kornet, J.G. and Bontsema, J., Os, E.A. van, (2003). Field Test of an Autonomous Cucumber Picking Robot. Biosystems Engineering, 86(3): 305-313.
- Henten, E.J. van; Schenk, E.J.J.; Willigenburg, L.G. van; Meuleman, J.; Barreiro, P. (2010): Collision-free inverse kinematics of the redundant seven link manipulator used in a cucumber harvesting robot. Biosystems Engineering 106 (2). - p. 112 - 124.
- Henten, E.J. van; Slot, D.A. van 't; Hol, C.W.J.; Willigenburg, L.G. van (2009): Optimal manipulator design for a cucumber harvesting robot. Computers and Electronics in Agriculture 65 (2). - p. 247 - 257

WAGENINGEN UR
For quality of life

Sweet pepper harvesting robot 1: CROPS

Intelligent sensing and manipulation for sustainable production and harvesting of high value crops.

SEVENTH FRAMEWORK PROGRAMME

CROPS

The partners

WAGENINGEN UR
For quality of life

KATHOLIEKE UNIVERSITEIT LEUVEN

UNIVERSITÀ DEGLI STUDI DI MILANO

CHILE
Potencia Alimentaria y Forestal

אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev

CSIC
Consejo Superior de Investigaciones Científicas

Force A
SEE TO ACT

Univerza v Ljubljani

Technische Universität München

FESTO

UMEÅ UNIVERSITET

CNH INDUSTRIAL

SLU
Swedish University of Agricultural Sciences

SEVENTH FRAMEWORK PROGRAMME

CROPBS

Some facts and figures

- FP7 EU project within Theme NMP: Nanotechnologies, Materials and new Production Technologies
- Start date: Oct. 1st 2010, end date: Sept. 30th 2014
- Budget: 10.2 million Euro
- EU financial contribution 7.6 million Euro for a period of 48 months
- 13 (was 14) partners from 10 countries

SEVENTH FRAMEWORK PROGRAMME

CROPBS

Applications (demonstrators)

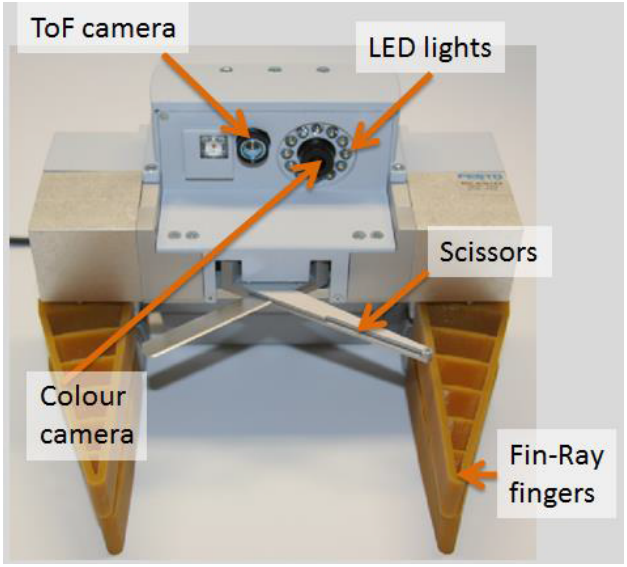
Sweet pepper, apples, grapes, precision spraying, obstacle avoidance in forestry

SEVENTH FRAMEWORK PROGRAMME

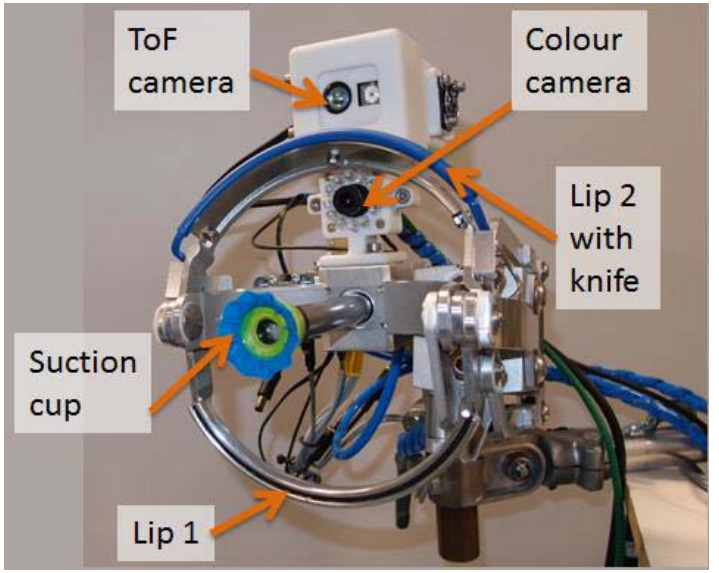
CROPBS

Sweet pepper harvesting robot

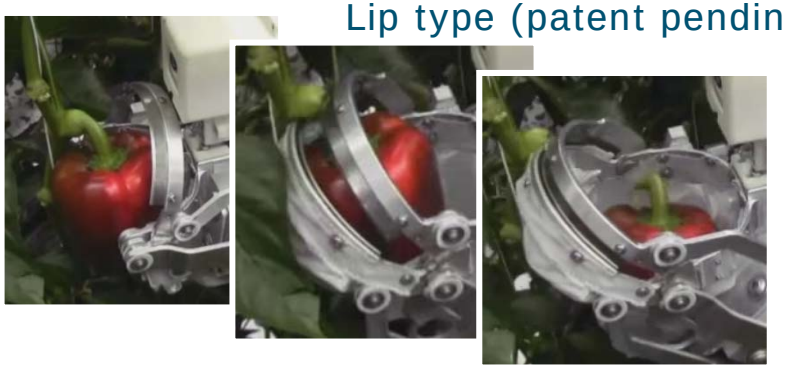
End-effectors for sweet pepper



Finray type



Lip type (patent pending)



Main partners:

FESTO

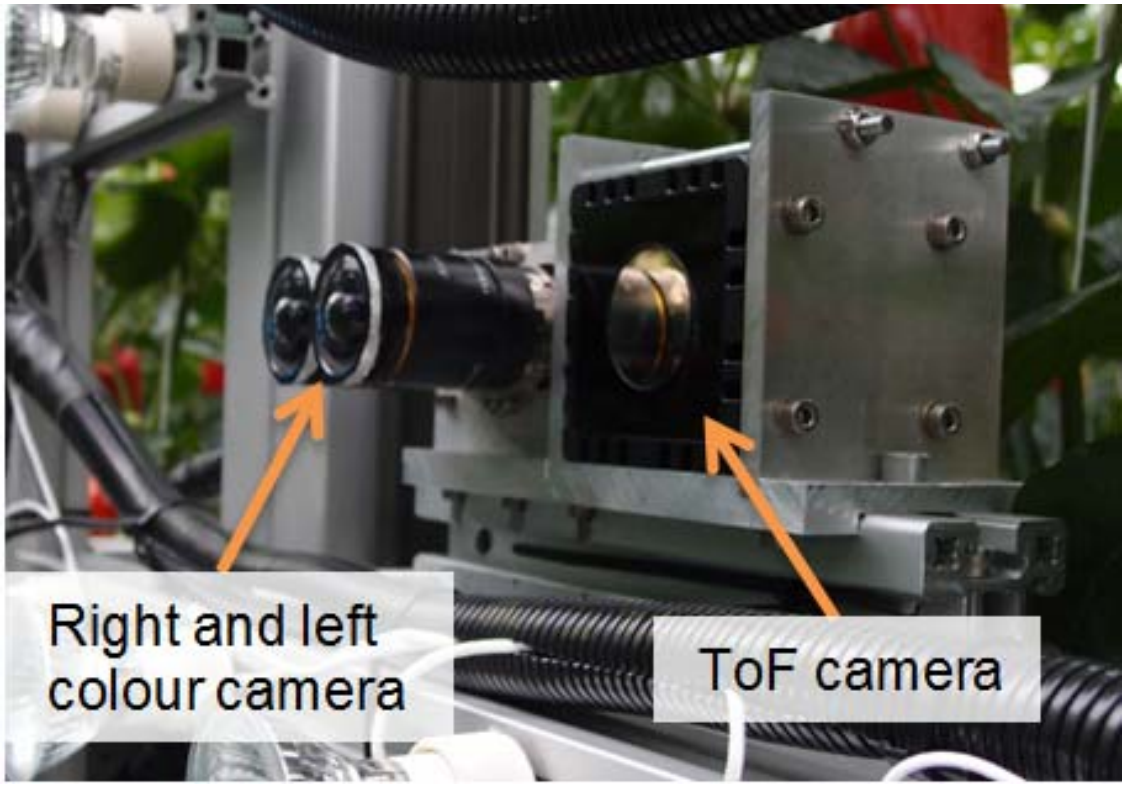
WAGENINGEN UR
For quality of life

CROPBS

SEVENTH FRAMEWORK PROGRAMME

Main sensors

- Combination Time of flight (ToF) and 1 colour camera for fruit localization
- Stereo vision for obstacle localization



Main partner CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

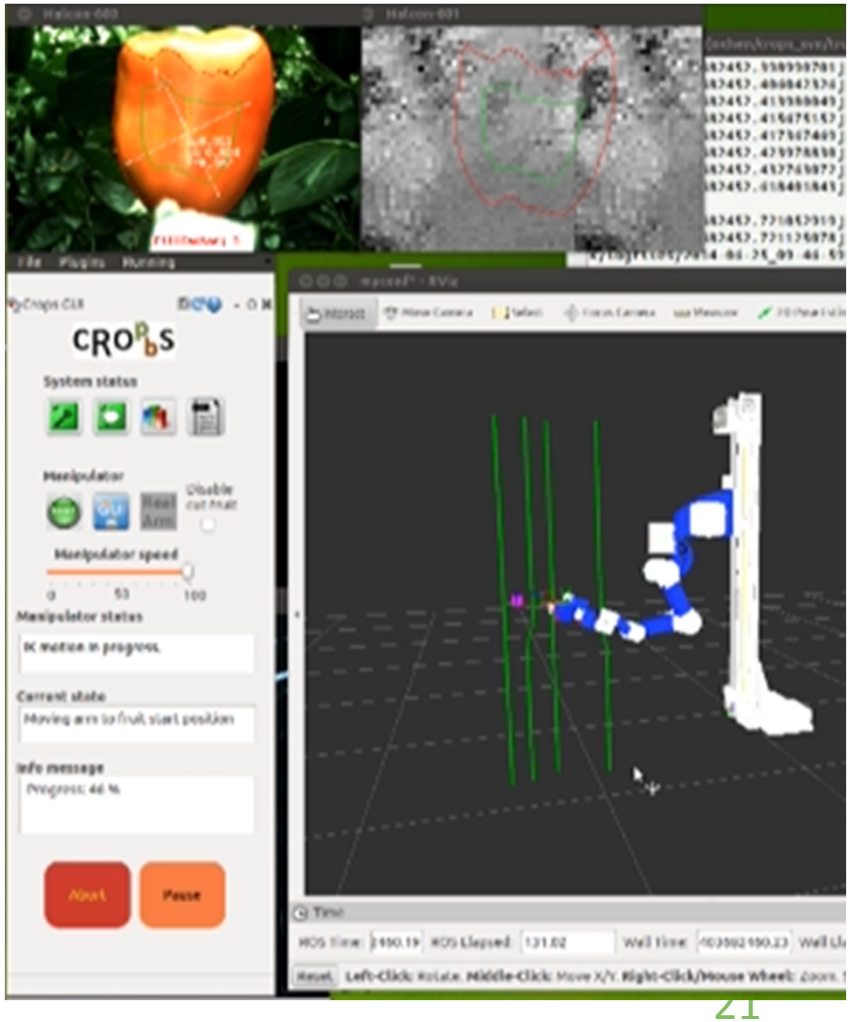
SEVENTH FRAMEWORK PROGRAMME

CROPBS

Software

ROS.org

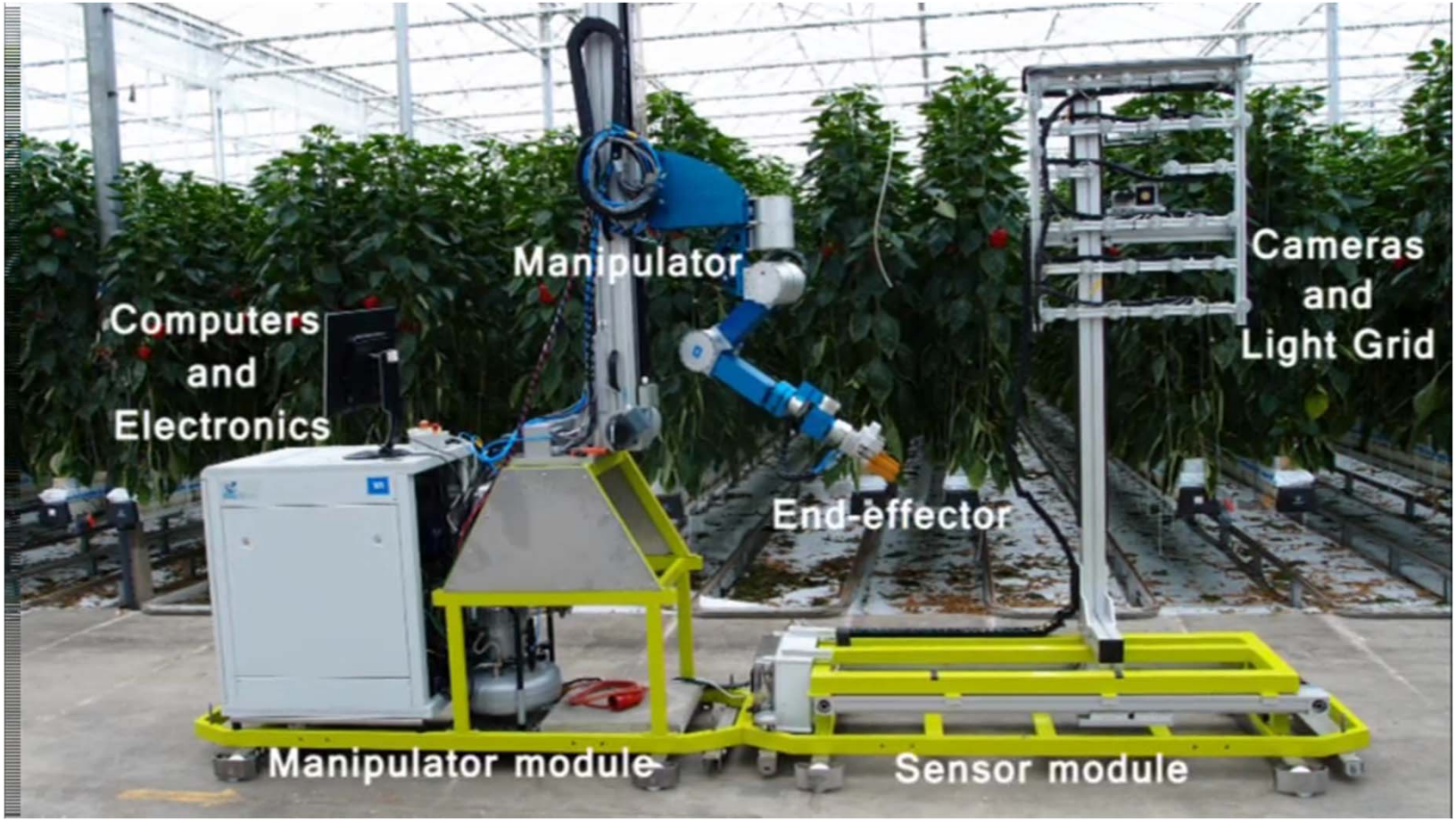
- Linux
- Robot Operating System (ROS)
- C++
- Simulation and visualisation environment
- Image processing done using OpenCV and Halcon (MVTec)
- Main partner:



SEVENTH FRAMEWORK PROGRAMME

CROPS

Sweet pepper harvester testing:



Sweet pepper harvesting robot, results

- Fruit detection and localization rate: 56%-86%
- Harvesting success: 33% (due to suction failure of end-effector)
- Cycle time: 94 s/fruit

Website: www.crops-robots.eu

SEVENTH FRAMEWORK PROGRAMME

CROPS

HORIZON 2020

The EU Framework Programme for Research and Innovation

Sweet Pepper Harvesting Robot

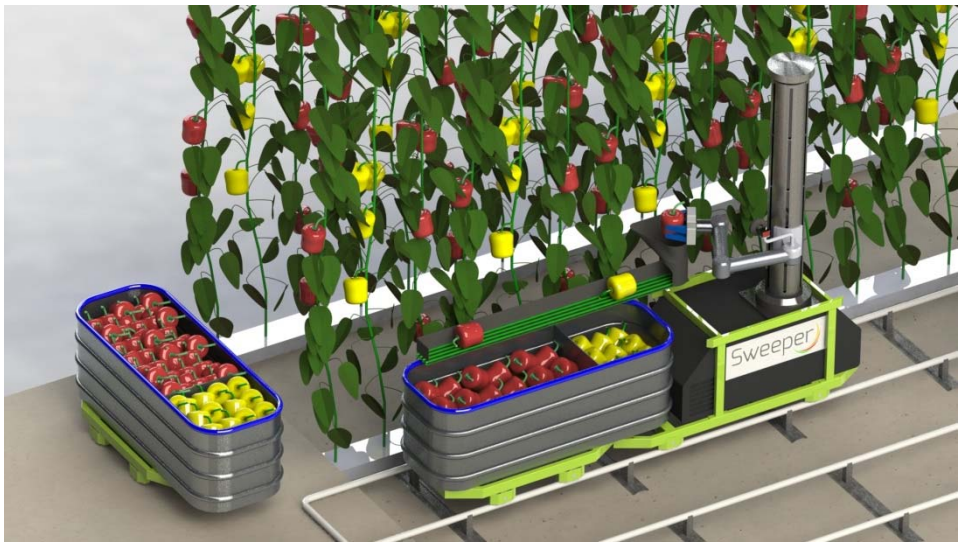
Jan Bontsema, coordinator

Partners:

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 644313

Sweeper

SWEEPER: sweet pepper harvesting robot

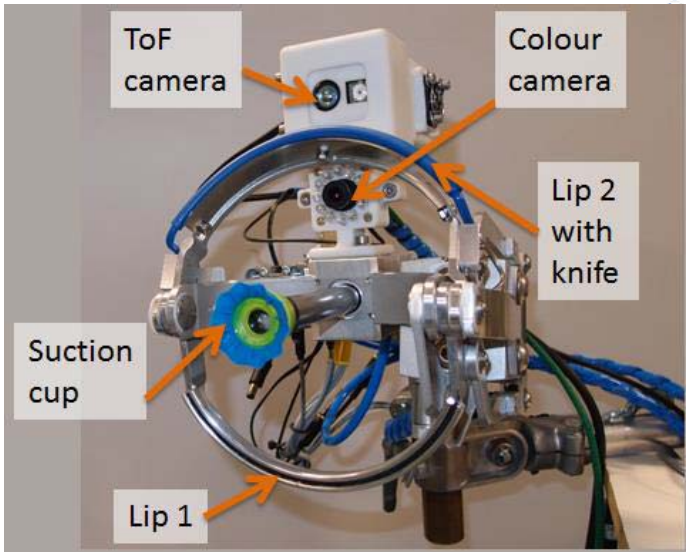


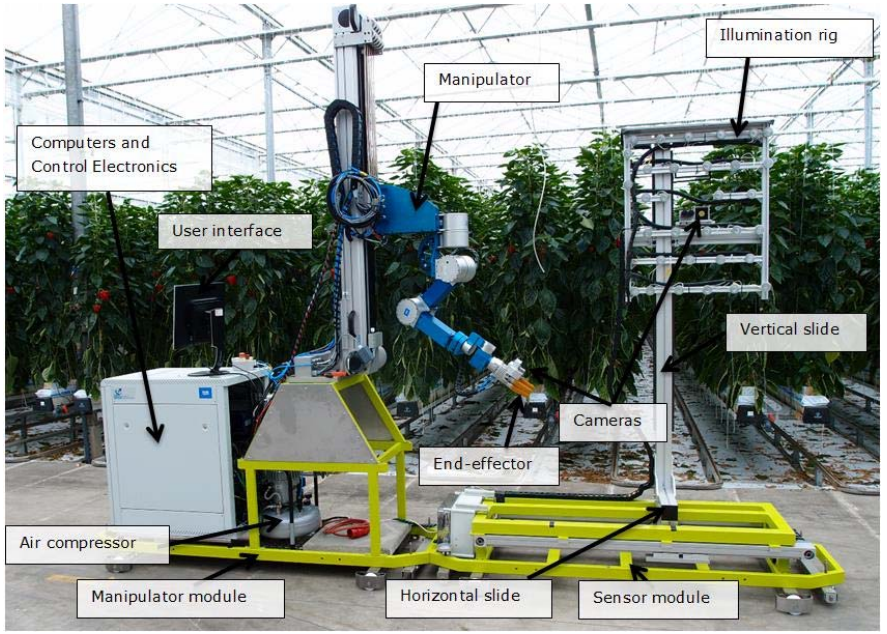
- Some facts:
- Budget: M€ 4.6
- EC-contribution M€ 4.0
- Period: Feb. 1st, 2015 – Jan. 31st, 2018
- H2020 EU project within the program Industrial Leadership, Information and Communication Technologies

European Commission

How? SWEEPER is a follow up of CROPS (FP7)

1. Using ROS
2. Using mechatronics (mechanics overcomes inaccuracies in detecting)
3. Visual servoing

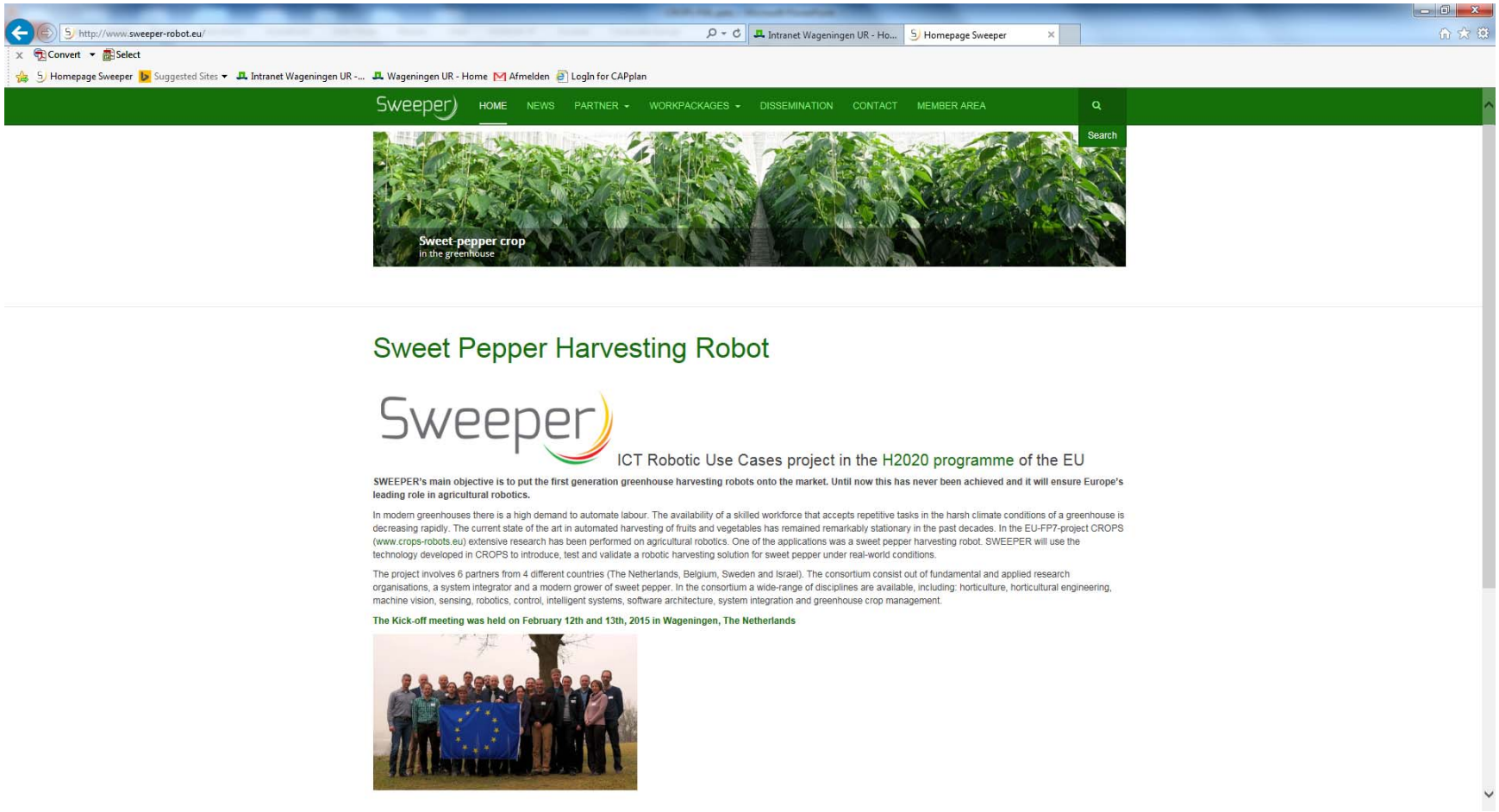




4. Crop adjustment
5. Involvement of horticultural research station
6. Grower as partner

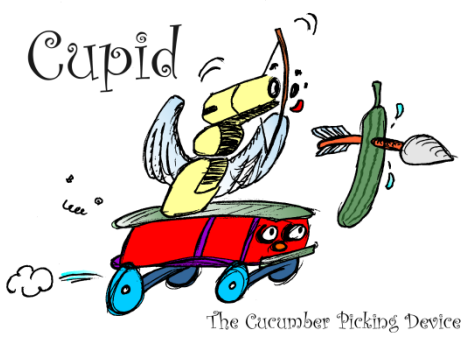
European Commission

Website: www.sweeper-robot.eu



European Commission

Thank you for your attention



CROPS Sweeper

Ministerie van Economische Zaken

European Commission

Productschap Tuinbouw

WAGENINGEN UR
For quality of life

Info: jan.bontsema@wur.nl

Is robotic harvesting economically feasible?

- For sweet pepper harvesting robot, with a cycle time of 6 sec, the investment space for the grower would be € 196.000 per robot
- New markets for robot suppliers (In NL only: 230 robots, 40 M€, for 30% of sweet pepper growers)