Robot performance
SWEEPER results

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Growing system

- SWEEPER robot was designed for a single row cropping system and pick from both sides of the plant.
Growing system at “De Tuindershoek & PSKW”

- V-system, double row, 3 stems per sweet-pepper plant
Growing system during experiments

- There was no single row system available for the performance experiments.
- However, we can also evaluate single row results by only taking into account the fruits growing on the front side of the stems.
Crop modifications

- Removal of fruit clusters
- Removal of leaves that largely occlude fruits
Results harvesting experiments

- For single row growing system (when only fruits on front side of stem are evaluated) *
  - 29% of ripe fruit were harvested in commercial crop.
  - 61% of ripe fruit were harvested in modified crop.

- For current double row growing system *
  - 18% of ripe fruit were harvested in commercial crop.
  - 49% of ripe fruit were harvested in modified crop.

* Pleased note that these numbers have been corrected in October 2018 after finalizing the data analysis.

In the earlier version of this document it was stated:

- For single row growing system (when only fruits on front side of stem are evaluated)
  - 30% of ripe fruit were harvested in commercial crop.
  - 62% of ripe fruit were harvested in modified crop.

- For commercial/current growing system
  - 20% of ripe fruit were harvested in commercial crop.
  - 49% of ripe fruit were harvested in modified crop.
Robot speed

- Average time to harvest 1 fruit: **24 seconds** (18 to 25s)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Average Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform movement</td>
<td>4.73</td>
</tr>
<tr>
<td>Fruit localization</td>
<td>3.71</td>
</tr>
<tr>
<td>Obstacle localization</td>
<td>3.02</td>
</tr>
<tr>
<td>Visual servoing</td>
<td>4.03</td>
</tr>
<tr>
<td>Detach fruit</td>
<td>2.22</td>
</tr>
<tr>
<td>Put fruit in container</td>
<td>7.77</td>
</tr>
</tbody>
</table>

*for one harvest attempt*
For safety reasons the robot was not operated at full speed during experiments.

Laboratory experiments showed that it is possible to harvest one fruit in less than 15 seconds*.

* Excluding platform movement
Lessons learned in the 3.75 years project

■ We made a big step!
  ▪ 61% Success rate* and 4 times faster than CROPS
  ▪ Market introductions requires higher performance

■ We know of the major bottlenecks and further steps:
  ▪ **Technology:** improving detection, reaching, cutting, catching, post-harvest logistics.
  ▪ **Cropping system:** Single-row. Adopted growing system will increase success rate (e.g. fruit and leave pruning)
  ▪ **Sweet pepper variety:** less clusters, better visibility (breeding)

- Pleased note that these numbers have been corrected in October 2018 after finalizing the data analysis.
  In the earlier version of this document it was stated: 62% Success rate
Direct (re)useable technologies and tools

- ROS-Software
  - Control of the robotic arm (path-planning)
  - Robot simulation tools
- 3D Vision detection system
- Obstacle detection (deep-learning)
- Fruit cutting mechanism (patent pending)
- Crop management practices for robotic harvesting
- Economic evaluation tool
- Integration in greenhouse logistic systems
- Use for other crops and applications
Future research topics

- Further technical improvements
  - cycle time, harvest success rate, fruit damage
- Deep-learning
  - Increase detection (also green peppers)
  - To support navigation in unstructured environments
- Human-robot collaboration
  - Robot-assisted human work, safety issues
- Combine robotics with plant breeding expertise
- Crop monitoring (added value)
  - Early detection of diseases/pests and crop quality/yield
www.sweeper-robot.eu

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Live demonstration

- Challenge to do so for a large audience.
- In the crop there is no space and a bad visibility.
- Because of safety issues – not close to robot
- We will show operating robot also live on screens.
Guidelines for going into the greenhouse

- Machine Safety Guidelines
  - A robot can make sudden and quick movements and it has an end-effector for cutting
  - Keep safe distance from a working robot
  - Only trained people may operate the robot

- Stay on the concrete path (NOT INTO CROP ROWS)

- No food/drinks!

- Follow up instructions of personnel
Program

Info market in the main hall and live demonstrations

16:15 Group 1 live demo
   (invited press only)
16:45 Group 2 live demo
17:00 Group 3 live demo

17:15 Discussion in the main hall
17:30 Food and drinks
18:00 Closure