Robot performance
SWEEPER results

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Growing system

- **SWEEPER** robot was designed for a single stem-row cropping system and pick on both sides of the crop.
Growing system at “De Tuindershoek”

- V-system, 3 stems per sweet-pepper plant
- 65% of all fruits grow on the front side (-90° to +90°)
Growing system at “De Tuindershoek”

- We only harvest peppers on the front sides
Crop modifications

- Removal of fruit clusters
- Removal of leaves that largely occlude fruits

Commercial crop

Modified crop
Results harvesting experiments (preliminary)

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

■ For commercial/current growing system *
  ▪ 49% of ripe fruit were harvested in modified crop.
  ▪ 18% of ripe fruit were harvested in commercial 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)
  62% of ripe fruit were harvested in modified crop.
  31% of ripe fruit were harvested in commercial crop.

• For commercial/current growing system
  49% of ripe fruit were harvested in modified crop.
  20% of ripe fruit were harvested in commercial crop.
Robot speed (preliminary results)

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

<table>
<thead>
<tr>
<th>Activity</th>
<th>Average time per fruit [seconds]</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
Robot speed (preliminary results)

- 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
Suggestions for improvement

- Conveyor belt + harvest trolley AGV
- Fingers to catch fruit may push plant away: a redesign is recommended.
- Certain sequences of arm movement can be easily speeded up.
- Adopted growing system will increase success rate (e.g. fruit and leaf pruning, special variety).
Lessons learned in the 3.75 years project

- We made a big step!
  - 61% Success rate* and 4 times faster than CROPS

- We know of the major bottlenecks and further steps:
  - **Technology**: improving detection, reaching, cutting, catching
  - **Cropping system**: Single stem-row
  - **Sweet pepper variety**: less clusters, better visibility (breeding)

- Dissemination
  - Many scientific and other public reports
  - PhD (3x)

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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

- Combine robotic developments with plant breeding expertise
- Human-robot collaboration
  - Robot-assisted human work, safety issues
- Deep-learning
  - Increase detection
  - To support navigation in unstructured environments
- Crop monitoring (added value)
  - Early detection of diseases/pests and crop quality/yield
Thanks

www.sweeper-robot.eu

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