How Team Delft won the Amazon Picking Challenge 2016

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WHO
Team Delft
Team Delft

Robotics Institute

WHO
TU Delft Robotics Institute

Established in June 2012
6 faculties, 13 departments
140 staff and PhD

- Fundamental research
- BSc and MSc education
- Industrial collaboration

Robots that work

Interactive robots

Swarm robots
Team Delft

Made possible by:
WHAT
The Amazon Picking Challenge

• Robot **pick and place** in a warehouse:
  – Pick challenge
  – Stow challenge
The Amazon Picking Challenges

- **unstructured** environment
- **diversity** of products
  - 3D Vision
  - Motion planning
  - Grasping
  - Task planning
  - Robustness
WHY
Cost-effective robotization

integrating the manipulator and vision software
Challenge accepted!

(slide idea adapted from M. Bharatheesha)
Can we already solve it?

- Results 2015
  - simplified task
  - 2 teams > 50% picks
  - most robots 1/12 picks

"Andra Keay from Robohub even likened the event to "watching paint dry," as the machines moved at a glacial pace."

Mariella Moon, Engadget

https://youtu.be/UrpMfdj-Mpc
Team Delft robot

https://youtu.be/3KlzVWxomqs
Results 2016

Team Delft (1st)

11 /12 stowed
9 /12 picked
83% actions
30s avg.

<table>
<thead>
<tr>
<th>Stowing scores</th>
<th>Picking scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>214 Team Delft</td>
<td>105 Team Delft (0:30 first pick)</td>
</tr>
<tr>
<td>186 NimbRo Picking</td>
<td>105 PFN (1:07 first pick)</td>
</tr>
<tr>
<td>164 MIT</td>
<td>97 NimbRo Picking</td>
</tr>
<tr>
<td>161 PFN</td>
<td>67 MIT</td>
</tr>
</tbody>
</table>
HOW
Keys

• **Requirements** driven
  – Targeted: speed, robustness
  – Design for the requirements
    • Robot selection
    • Gripper and grasping optimized for competition objects

• Leverage team **strengths** to improve **weakness**
  - no compliant grasping, no force feedback
  + 3D vision, reliable gripper, optimized motion planning pipeline

• **Reuse:**
  – ROS + ROS-Industrial
Team Delft Robot

Robot arm

Tote camera

Shelf

Tote

Rail

Gripper
Pick task workflow

https://youtu.be/W_sFDpq_zvs
Robot selection

- Workspace analysis
- Motoman driver
Object recognition

• Deep Learning
  – Faster R-CNN
  – Object classification
  – Bounding box

< 150ms
> 99% reliable

Object recognition
Object Localization

- Based on PointCloud registration with objects CAD model
  - Super 4PCS + ICP

✧ To improve:
  ✧ make it smarter

Camera Calibration

- Ensenso calibration
  + ROS (MoveIt, RViz)
Grasping: gripper

- Lean development: 4 iterations
- 3D printing
Grasping: grasp planning

- Auto-grasp pose generation
- Selection process
  - Geometric occlusion
  - Visual occlusion
  - Collision occlusion
Motion Planning

- Offline motions
  - outside the shelf \textit{(known)}
  - trajectory database for relevant locations
  - free (joint) space motion planning with RRT-Connect

- Online cartesian path planning
  - manipulation inside the shelf \textit{(unknown)}
  - key waypoints - “approach”, “contact”, “lift”, “retreat”

- Stitching trajectories (RRT-Connect)

- Event-based I/O
Manipulation

- **redundancy** to deal with uncertainty
  - collision avoidance (FCL): PointCloud (octomap) + bin model

- To improve: **manipulation demands contact** (compliance, force-feedback)
Key ideas
6 weeks with the robot!
Development: integration + tools

Movelt!
RViz
ros-industrial / motoman
ros-industrial / industrial_robot_simulator
Smach, PCL ...
Robotics is now Software

> 12 components
> 230 files (+ 400 data files)
> 20 K LC
> 13 developers

2000 commits
Team

Software: those NOT in the circle
... and

> 12 components + dozens reused
> 230 files (+ 400 data files)
> 20K LC
  13 developers
> 100 contributors (ROS community)
  2000 commits
Thank you

questions?

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