The Amazon Picking Challenge 2015

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The first Amazon Picking Challenge (APC) was held at the 2015 IEEE International Conference on Robotics and Automation (ICRA) in Seattle, Washington, 26–27 May. The objective of the competition was to provide a challenge problem to the robotics research community that involved integrating the state of the art in object perception, motion planning, grasp planning, and task planning to manipulate real-world items in industrial settings. To that end,

> **Amazon provided US$26,000 in prize money for the winning teams.**

we posed a simplified version of the task that many humans face in warehouses all over the world, i.e., picking items from shelves and putting them into containers. In this case, the shelves were prototypical pods from Kiva Systems, and the picker had to be a fully autonomous robot.

The items were a preselected set of 24 products that were commonly sold on Amazon.com and that we expected would pose varying degrees of difficulty for the contestants. On the easier end were simple cuboids like a box of straws or a spark plug. Some items were chosen because they were easy to damage, like the two soft-cover books or the package of crushable Oreo cookies. Others were harder to perceive and grasp, like the unpackaged dog toys or

the black mesh pencil holder. The box of Cheez-Its posed a challenge because it could not be removed from the bin without twisting it sideways.

Each pod had 12 bins, and the 25 products were distributed among the bins in such a way that each competitor had the same challenges. Each bin had one target item to be picked, with a base score of ten, 15, or 20 points depending on how many other items were in the bin. In addition, some items that were projected to be more difficult to pick were given one to three bonus points. Damaging an item incurred a five-point penalty, while picking the wrong item incurred a 12-point penalty. Each competitor had 20 min to pick as many of the 12 target items as possible and could score as many as 190 points.

The competition was announced 1 October 2014. Through a series of video submissions, the organizers selected 25 teams to receive equipment grants (sample pods and products) and travel grants to help defray the costs of travel to the venue. In addition, Amazon provided US$26,000 in prize money for the winning teams.

Representing 11 different countries, 26 teams made the trip to Seattle to try their robot's hand at picking out of Kiva pods. The success of the teams was mixed, but the enthusiasm and excitement was contagious. The competition was won by RBO from the Technical University of Berlin, Germany. Its device, with a Barrett arm, a Nomadic Technologies mobile platform, and a suction cup attached to a commercial vacuum cleaner, was able to successfully pick ten of 12 correct items in under 20 min. Their score of 148 points put them well into the lead. The Massachusetts Institute of Technology (MIT) team placed second, with seven items picked and 88 points (Figure 1). The MIT entry used
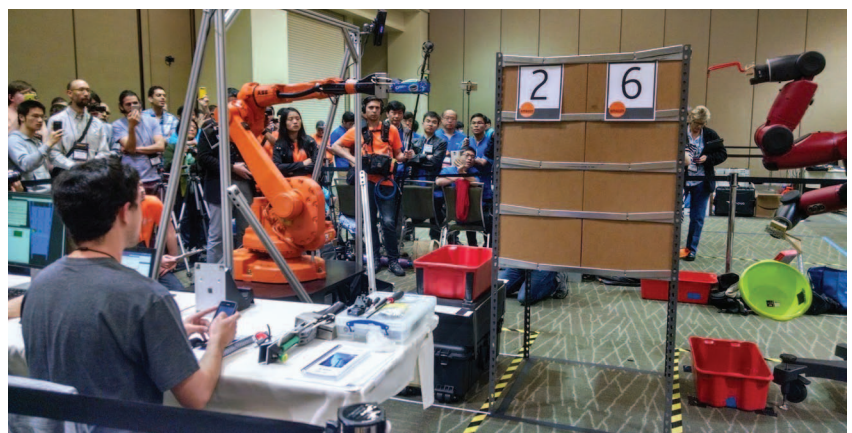
Figure 1. A crowd gathers to watch Team MIT's entry. MIT's robot placed second after picking seven items in 20 min. (Photo courtesy of Joseph Romano.)

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Table 1. The final scores of the APC 2015.

Team	Affiliation	Items Picked	Score
RBO	Technical University of Berlin	10	148
Team MIT	MIT	7	88
Grizzly	DataSpeed and Oakland University	3	35
NUS Smart Hand	National University of Singapore	2	32
Z.U.N.	Zhejiang University, University of Technology–Sydney, and Nanjiang Robotics Co.	1	23
C^2M	Chubu University, Chukyo University, and Mitsubishi Electric Corporation	2	21
R U Pracsys	Rutgers University	1	17
Team K	JSK, University of Tokyo	4	15
Nanyang	Nanyang Technological University	1	11
A.R.	The Netherlands	1	11
Team Georgia Tech	Georgia Tech	1	10
Team Duke	Duke University	1	10
CVAP	KTH (Sweden)	2	9

Figure 2. The APC judges perform one final check before Team A.R. begins its trial. (Photo courtesy of Peter Wurman.)

Figure 3. The audience watches as a gripper reaches out to pick an item.

an industrial ABB arm and a scooper end effector that could be flipped over to alternatively use a small suction cup. In third place was Team Grizzly from Dataspeed Inc. and Oakland University, with 35 points. Their solution used a Baxter robot attached to a custom mobile base.

The final scores are shown in Table 1. Many teams demonstrated successful picking in their warm-ups but, for various reasons, failed in their official 20-min attempt. The reasons for failure varied widely and included last-minute code changes, failure to model how a vacuum hose would twist around the arm in certain poses, and grippers that were so big that they could not figure out how to get in the bin. However, even the systems that failed to pick any items demonstrated interesting robots, end effectors, and technical approaches. Overall, 36 correct and seven incorrect items were picked.

Other teams competing included Worcester Polytechnic, the University of Texas at Austin, the University of Texas at Arlington, the University of Washington, the University of Alberta, Robological PTY LTD, Universitat Jaume I, the University of Colorado at Boulder, Colorado the School of Mines, the University of Pisa, the University of California at Berkeley, Dorabot and the University of Hong Kong, and St. Francis Institute of Technology in India. The teams were supported by several hardware vendors, including Rethink Robotics, Barrett Technologies, Yaskawa, Olympus Controls, and Clearpath Robotics.

The first APC was very successful, drawing a large number of competitors from around the world and demonstrating the state of the art in both the software and the hardware required for robotic manipulation. Despite being scattered over 16 testing bays in the ICRA competition area and spread over two days, every team drew a large crowd of spectators eager to see how the robots would perform (Figures 2 and 3).

For more information, see http://amazonpickingchallenge.org.