

CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Electrical Engineering

MASTER'S THESIS



Zdeněk Rozsypálek

Brick Detection for MBZIRC Competition

Department of Control Engineering

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Prohlášení autora práce

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- [1] Himmelsbach, Michael, et al. "LIDAR-based 3D object perception." Proceedings of 1st international workshop on cognition for technical systems. Vol. 1. 2008.
- [2] Dou M., Guan L., Frahm JM., Fuchs H. (2013) Exploring High-Level Plane Primitives for Indoor 3D Reconstruction with a Hand-held RGB-D Camera. In: Park JL., Kim J. (eds) Computer Vision - ACCV 2012 Workshops. ACCV 2012. Lecture Notes in Computer Science, vol 7729. Springer, Berlin, Heidelberg
- [3] Ma, L., Kerl, C., Stückler, J., & Cremers, D. (2016, May). CPA-SLAM: Consistent plane-model alignment for direct RGB-D SLAM. In 2016 IEEE International Conference on Robotics and Automation (ICRA) (pp. 1285-1291). IEEE.

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III. PŘEVZETÍ ZADÁNÍ

Diplomant bere na vědomí, že je povinen vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací.
Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v diplomové práci.

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Abstract

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Abstrakt

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Keywords: Keywords

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1 Introduction

Multirobot, autonomous, motivation, BLAH BLAH BLAH

2 MBZIRC Contest

The contest took place in March in Abu Dhabi. Whole competition consisted of three challenges and the grand challenge which connected all challenges together. The first challenge was the only one which was focused solely on UAVs. The goal of the first challenge was to pop multiple big color balloons and to catch small ball carried by the organizer's drone. The other two challenges was designed for both UGVs and UAVs. The second challenge was about building a wall using the robots. Multiple polystyrene bricks were placed in the arena and the robots should have move these bricks to the destination area and stack them on top of each other to build the wall. Lastly the third challenge was to extinguish fire on the surface of the building model. This task was motivated by inability of firefighters to extinguish fire inside high-rise buildings in UAE. UAVs and UGVs carried tanks full of water and squirt it into the fire dummy. Every team had three rehearsals in before the contest and then two competition attempts for each one of three challenges. Only the best teams from all three challenges was nominated into the grand challenge which was limited to just one attempt.

2.1 Second challenge

This thesis is focused on the second challenge and more specifically on the ground robot section of the second challenge, so that we provide more detailed description of this challenge. Each team is given thirty minutes to explore the arena (40×60 meters), localize all interest areas and build the wall. There are four types of the bricks with different colors. All bricks must be very light to enable the UAVs to pick them up. The dimension and colors of the bricks can be seen in the figure 1. Team obtains points for every placed brick. Bricks with different colors are rewarded by the different number of points. Placing bigger bricks means higher rewards. In addition the UAV bricks are rewarded by twice as many points as the UGV bricks.

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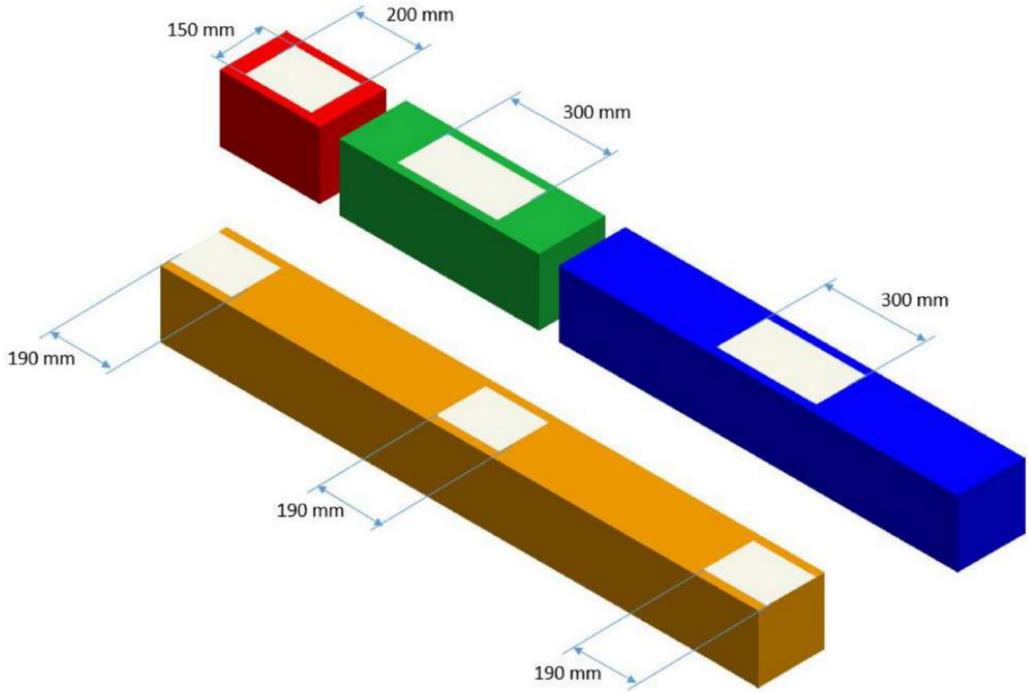


Figure 1: Colors and dimensions of the bricks provided by the organizer.

Each brick has thin metal plate on top of it, so that the robots are able to pick them up using electromagnets. In the beginning of challenge are all bricks placed at beforehand unknown position. Initial position of bricks is unknown but there is predefined pattern in which are the bricks put together. There are different patterns for the UGV piles of bricks and the UAV piles. The UGV bricks are stacked into the multiple height levels whereas the UAV bricks are stacked into the width and all are put on the ground. Due to the low weight of the bricks it is necessary to put UAV bricks into the rails, otherwise the bricks can be easily blown away by the propellers of the drones. Since the UAV bricks are all on the ground level (in purely horizontal pattern), it is much easier to detect them with the UAV bottom camera than using the lidar. That is why we are further concerned only about UGV bricks. These bricks are stacked in the positions displayed in the figure 4.

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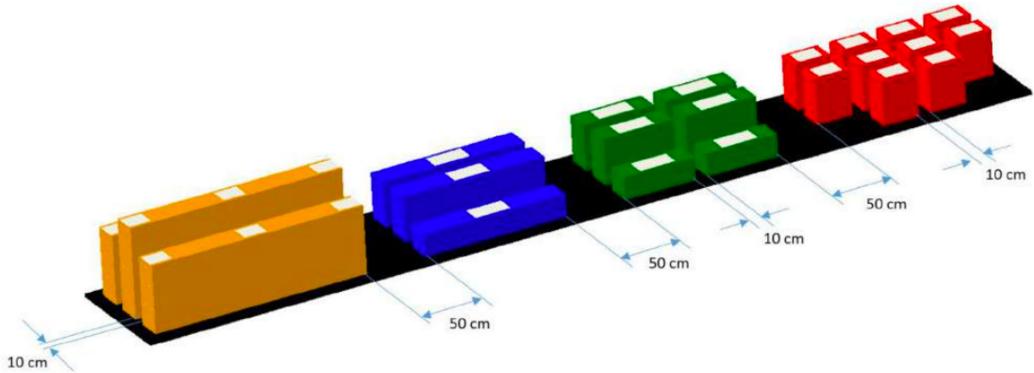


Figure 2: The positions of the bricks at the beginning of the second challenge.

Another objects of interest are destinations where the bricks should be placed. The robots must during the exploration look for them too. UGV bricks destination is marked by checker pattern. It is necessary to mention that the form of the pattern was not known till the second rehearsal. The final form of the pattern is shown in the figure 3a. Although we are not concerned about the UAV bricks, the destination of the UAV bricks is a vertical object, so it is much easier to detect it from the ground using the lidar. The UAV brick destination is basically a wall as can be seen in the picture 3b. Bricks should be placed on top of this wall. The metal plates on top of each brick shift the center of mass to the top and make the brick very susceptible to rolling. That is why are on the top of UAV destination auxiliary handles to help place the bricks properly. At the beginning of the challenge is each team given the instructions which describe how the wall should look like at the end. When the built wall does not fit the instructions, the team gets penalty and gains less points for inaccurately placed bricks.

INTRODUCTION

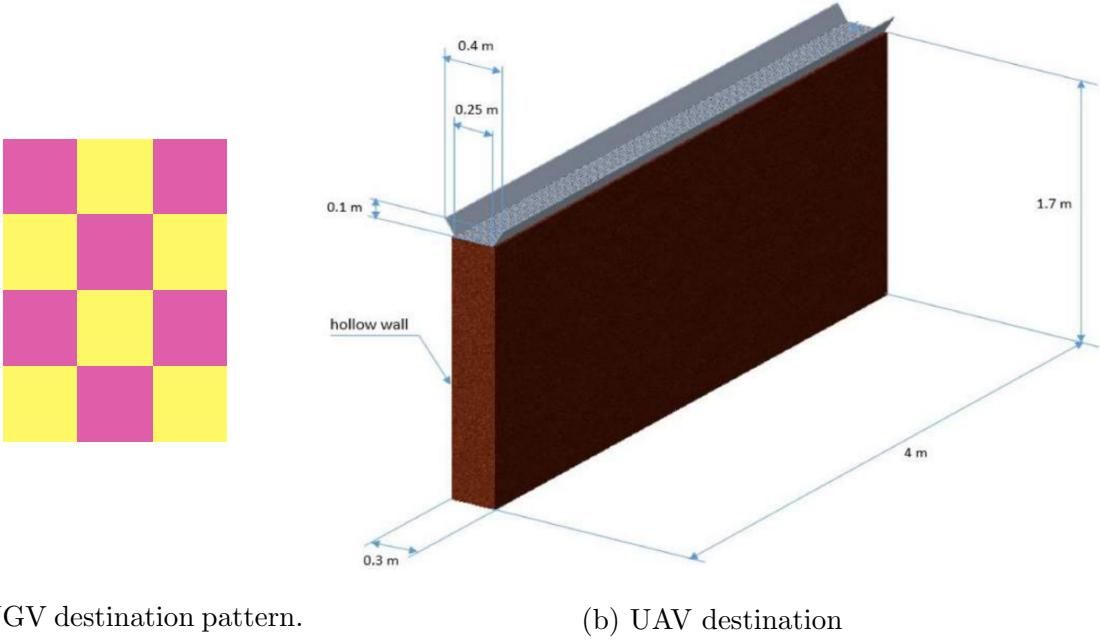


Figure 3: Description of target places for UAVs and UGVs. Each square on the UGV pattern has 10cm. Pattern consists of two 4×0.4 meter segments which are connected into the L shape. Whole UAV destination consists of five similar segments arranged into the M shape with right angles.

3 Equipment

For the sake of completeness is necessary to describe what exact equipment was available. We used **Clearpath Husky A200** which is wheeled robot designed for outside robotics. The robot is equipped with many additional devices. As a computer running all code on robot is used **Intel NUC**. To manipulate the bricks we mounted **Kinova robotic arm** on top of the Husky robot. Two **12V electromagnets** are attached to the end-effector to enable the arm to grip the bricks. It would be very hard to grip the bricks without any feedback loop to the hand. For visual servoing and proper gripping we placed **Intel Realsense** camera close to the end of the arm. It is also possible to obtain feedback from electromagnets thanks to hall effect sensors and decide whether the brick is gripped correctly. For the localization, collision avoidance and detection is used **Velodyne VLP-16** lidar sensor. Lastly for the moving the bricks around the arena we created a handmade cargo area which can contain up to six bricks and attached it to the rear bumper. Whole setup is captured in the figure ??.

INTRODUCTION

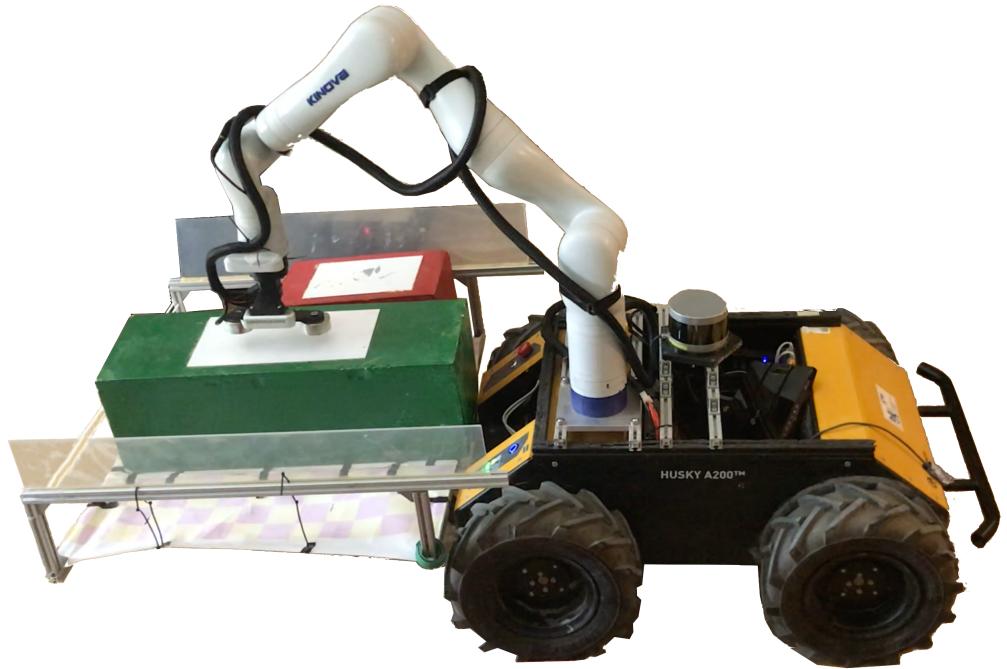


Figure 4: Clearpath Husky A200 adjusted for the second challenge.

3.1 Velodyne VLP-16

4 Algorithms

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EXPERIMENT

5 Experiment

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6 Conclusion

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6.1 Future work

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LIST OF REFERENCES

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APPENDIX

Appendix A CD Content

In Table 1 are listed names of all root directories on CD.

Directory name	Description
thesis	the thesis in pdf format
ctu_thesis	latex source codes
lidar-gym	OpenAI gym environment

Table 1: CD Content

Appendix B List of abbreviations

In Table 2 are listed abbreviations used in this thesis.

Abbreviation	Meaning
CNN	Convolutional neural network
DDPG	Deep deterministic policy gradients
DQN	Deep Q-learning
MDP	Markov decision process
RL	Reinforcement learning
ReLU	Rectified linear unit
TD	Temporal difference

Table 2: Lists of abbreviations

APPENDIX
