Algorithms for mobile robots: perception, planning, control

Konstantin Yakolev https://www.hse.ru/staff/yakovlev-ks

Overview

Robotics is one of the areas of modern science and technology that experiences a substantial rapid growth nowadays. Such robotic devices as automated vacuum cleaners, filming drones, driverless cars, etc. are becoming a part of our everyday's life. The key feature of almost all such devices is the mobility, i.e. the ability to move from one location of the environment to the other. One of the key challenges researchers and engineers are now facing is automating such movements in a long-term horizon by creating state-of-the art controlling software based on the methods and models of artificial intelligence, automated control theory, computer vision etc.

In this course we will investigate the problems (and methods tailored to solve them) that arise in the context of intelligent robotics, such as:

- Perception (object detection, semantic segmentation, object tracking, mapping etc.)
- Planning (task planning, path/motion planning etc.)
- Control (machine learning for controlling the robots)

The main activities within the course are i) reading, analyzing and presenting papers ii) taking part in the discussion iii) preparing texts containing either overview of the methods for some specific problem or description of the empirical evaluation conducted by the student on its own.

Grading System and Requirements

Final grade is computed as follows:

$$O = 0{,}3*Opp + 0{,}5*Od + 0{,}2*Ot,$$

где:

Opp – paper presentation;

Od – discussion;

Ot – text (either an overview of the methods for a specific problems or description of the empirical evaluation of a specific algorithm).

Paper presentation

Each student has to present a paper that fall in the broad scope of 'intelligent robotics'.

The time of the presentation will be fixed by the instructor. You should be ready to present as early as Sep 28^{th}.

Student chooses paper on its own among the influential papers in the fields (from major conferences (rated A/A* by Core), journals (rated Q1/Q2)).

Student has to explicitly present an argument for choosing this exact paper for presentation (why among dozens of other papers this one was chosen).

Presentation time is limited to 20 minutes. Discussion for 10 minutes.

The presentation should contain:

- Motivation (why this research topic is impactful and actual, how the research is tied with the real world problems or other fundamental scientific problems)
- Problem Statement (formal description of the problem, what is the input, what is the output, how the cost objective is defined)
- Suggested Approach (overall idea + technical details)
- Evaluation results (how the approach was evaluated and compared to other methods in the field)
- Conclusions and Future Work.

Students who deliver a presentation on the 28th of September, 2020 are qualified for an additional +1 score to the Opp grade.

Students who deliver a presentation on the 12th of October, 2020 are qualified for an additional +0.5 score to the Opp grade.

Discussion

Each student has to participate in the discussion of the presented papers.

The main way you can participate – ask meaningful questions on the presentation.

For taking an active participation in a discussion of a single paper you earn one score.

Earned scores are summed up and form Od grade.

Max. Od grade is 10 (even if the total number of discussion scores is greater than 10).

Text (Overview)

Text should be formatted according to the IEEE template.

An overview should be given to a specific problem rather a broad area (e.g. not “machine learning in computer vision” but “depth estimation from monocular video”).

At least 20 related works should be discussed in the overview.

No copy-paste is allowed.

An overview should end up with a proper conclusion (which parts of the problems are not solved yet, what are the major challenges, what approaches seem perspective to overcome those challenges).

One may submit a text describing empirical evaluation (see below) instead of an overview text.

Text (empirical evaluation)

Empirical evaluation should be conducted by a student on its own. I.e. ther should exists an author’s repo containing all the needed components to reproduce experiment (code, instructions how to build/run the code, all the needed datasets (or links to them) etc.)

Text should be formatted according to the IEEE template.

Text must contain a link to the repository used for the evaluation.

Text should contain the description of the experimental setup and methodology (how the data was collected, which metrics were tracked, how the results were averaged etc.).

The text should be original (no copy-paste from the existing papers).

Tentative schedule

7 Sep 2020 – Intro

7 Sep 2020 – 10 Sep 2020 – students choose track.

14 Sep 2020 – Intelligent robotics: brief overview. An example of paper presentation by the instructor.

14.09.2020 – 21.09.2020 – assigning dates for paper presentations.

28 Sep 2020 – Where to find good papers? Paper presentations (4 studs.). *Students who present this date +1 score to the Opp.*

12 Oct 2020 – How to write an Overview (Related Works section)? Paper presentations (4 studs.). *Students who present this date +0.5 score to the Opp.*

26 Oct 2020 – How to conduct experiments and present results? Paper presentations (4 studs.).

09 Nov 2020 – Paper presentations (4-5 studs.).

23 Nov 2020 – Paper presentations (4-5 studs.).

07 Dec 2020 – Deadline for text submission. Paper presentations (4-5 studs.).

21 Dec 2020 – Wrapping up.

Sample papers for presentation

During the course each student has to present a papers which falls in the broad scope of intelligent robotics. The paper must be chosen among the most impactful papers in the field (e.g. from a top conference/journal). Some examples of such papers are listed below.

1. Koenig, S., & Likhachev, M. (2002). D* Lite. https://www.aaai.org/Papers/AAAI/2002/AAAI02-072.pdf
2. Harabor, D. D., Grastien, A., Öz, D., & Aksakalli, V. (2016). Optimal any-angle pathfinding in practice. *Journal of Artificial Intelligence Research*, 56, 89-118. https://www.jair.org/index.php/jair/article/download/11004/26163
3. Phillips, M., & Likhachev, M. (2011). Sipp: Safe interval path planning for dynamic environments. In *ICRA 2011*. pp. 5628-5635. http://www.cs.cmu.edu/~maxim/files/sipp_icra11.pdf
4. Wang, K. H. C., & Botea, A. (2011). MAPP: a scalable multi-agent path planning algorithm with tractability and completeness guarantees. *Journal of Artificial Intelligence Research*, 42, 55-90. https://www.jair.org/index.php/jair/article/download/10722/25615/
5. Sharon, G., Stern, R., Felner, A., & Sturtevant, N. R. (2015). Conflict-based search for optimal multi-agent pathfinding. *Artificial Intelligence*, 219, 40-66. https://www.cs.utexas.edu/~guni/Papers/CBS-AIJ15.pdf
6. Tamar, A., Wu, Y., Thomas, G., Levine, S. and Abbeel, P., 2016. Value iteration networks. In *NIPS 2016*. pp. 2154-2162. http://papers.nips.cc/paper/6046-value-iteration-networks.pdf
    a. Lee, L., Parisotto, E., Chaplot, D.S., Xing, E. and Salakhutdinov, R., 2018. Gated path planning networks. In *ICML 2018*. https://arxiv.org/pdf/1806.06408.pdf
    b. Schleich, D., Klamt, T. and Behnke, S., 2019. Value Iteration Networks on Multiple Levels of Abstraction. In *RSS 2019*. http://www.roboticsproceedings.org/rss15/p14.pdf
7. Takahashi, T., Sun, H., Tian, D. and Wang, Y., 2019, July. Learning Heuristic Functions for Mobile Robot Path Planning Using Deep Neural Networks. In *ICAPS 2019*. pp. 764-772. https://wvvw.aaai.org/ojs/index.php/ICAPS/article/view/3545/3413
8. Gupta, S., Davidson, J., Levine, S., Sukthankar, R. and Malik, J., 2017. Cognitive mapping and planning for visual navigation. In *CVPR* 2017. pp. 2616-2625. http://openaccess.thecvf.com/content_cvpr_2017/papers/Gupta_Cognitive_Mapping_and_CVPR_2017_paper.pdf
9. I. Laina, C. Rupprecht, V. Belagiannis, F. Tombari and N. Navab, Deeper Depth Prediction with Fully Convolutional Residual Networks. In *3DV - 2016*, pp. 239-248. https://arxiv.org/pdf/1606.00373.pdf
10. Zhou, T., Brown, M., Snavely, N. and Lowe, D.G., 2017. Unsupervised learning of depth and ego-motion from video. In *CVPR 2017*. pp. 1851-1858.

http://openaccess.thecvf.com/content_cvpr_2017/papers/Zhou_Unsupervised_Learning_of_CVPR_2017_paper.pdf

11. Li, Z. and Snavely, N., 2018. Megadepth: Learning single-view depth prediction from internet photos. In *CVPR 2018*. pp. 2041-2050. http://openaccess.thecvf.com/content_cvpr_2018/papers/Li_MegaDepth_Learning_Single-View_CVPR_2018_paper.pdf
12. Spek, A., Dharmasiri, T. and Drummond, T.. CReaM: Condensed Real-time Models for Depth Prediction using Convolutional Neural Networks. In *IROS 2018*. pp. 540-547. https://arxiv.org/pdf/1807.08931
13. Durasov, N., Romanov, M., Bubnova, V. and Konushin, A., 2018. Double Refinement Network for Efficient Indoor Monocular Depth Estimation. In IROS 2019. https://arxiv.org/pdf/1811.08466.pdf