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Extending the intelligence of the Pioneer 2AT mobile robot. *Michael A. Rudy¹, Eugene V. Chepin¹ and Alexander A. Gridnev¹ (michaelrudy95@gmail.com).*

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ABSTRACT

This paper describes the process of expanding the intellectual capabilities of a Pioneer 2AT skid-steer mobile robot by developing a module that allows using the ROS (Robotic Operating System) and its capabilities. This software and hardware system allow to quickly expand the capabilities of an outdated mobile robot, giving it access to modern algorithms e.g. SLAM. It also granted the support for various attachments - lidars, stereo cameras, etc, autonomous navigation algorithms, data collection for training CNNs, as well as simulating the operation of these algorithms in the Gazebo. The module consists of two parts, the first is launched on the Arduino board, to which the wheelbase with the associated sensors is connected, the second part is the ROS node, which translates all the data coming from the Arduino into a format corresponding to the ROS interface.

INTRODUCTION

The main goal of the project was to upgrade the hardware of the Pioneer 2AT mobile robot. The upgrade of this robot in many years of operation was carried out twice. The purpose of those modifications was, in fact, the installation of a up-to-date on-board computer. The objectives of this upgrade are wider:

- Replacing an outdated on-board computer with a modern PC;
- Replacement of the burnt control board as a result of natural wear and its unreliability, by developing its Arduino-analogue while maintaining the speed and motors specifications of the robot;
- Orientation to support the ROS interface.

In fact, it was necessary to develop a new version of the mobile robot, which could provide a significant improvement in the development and application of intelligent algorithms and software:

- Support a modern common in the industry framework - ROS;
- Support SLAM algorithms, in particular: Gmapping, Rtabmap, as well as autonomous navigation algorithms;
- Widespread implementation of data collection for training for, in particular, the use of convolutional neural networks (CNNs);
- Support simulations in the Gazebo;
- Provide with a ROS-compatible interface all installed sensors, as well as additional equipment that was not previously on board the robot.

METHODS

The hardware upgrade made it possible to fundamentally change the situation using modern software technologies. First of all, this concerns the possibility of using the ROS framework, and therefore the entire arsenal that it possesses namely SLAM algorithms that were originally built into the system, such as: gmapping, hectormap, rtabmap and in-built autonomous navigation algorithms. Secondly, due to the unified interface between ROS nodes, now there is no need to develop protocols for various tasks - this is standardized at the system level by message types.

Next, we will take a look at the tasks that were solved by upgrading and go directly to the developed software and hardware system. That module allows to quickly connect and configure the wheel base of robot to the on-board computer with ROS, thereby expanding its intellectual functionality.

One of the main goals of the project was to support modern SLAM algorithms. SLAM is one of the most important areas of modern robotics, which, however, is considered resolved at the theoretical and conceptual level [1]. The undoubted advantage of SLAM is the provision of a built and globally harmonized environmental map using both robot motion measurements and loop closure, without loop closure, SLAM is reduced to odometry [2].

Each year, new implementations and papers appear in this area, so you can not do any research without access to the already proven algorithms, new developments, as well as independent research in this area. In modern SLAM, two different approaches are most often used - methods based on filtering and based on key frames. [3]. Since the modeling of the environment by the robot depends both on its complexity and on the limitations of the sensors [4].

FINDING #1

The developed intelligent control software system is divided into two independently executable modules: the first works on the Arduino board, the second is the ROS node. Two modes of functioning of the system are possible. In this work, for the Pioneer 2AT, an implementation is used in which the modules use the speeds in ticks of the encoder per second (tick / s) when communicating with each other. It allows to reduce the delay and reduce the number of computational operations on the Arduino board, without losing accuracy by using integer calculations. In an alternative implementation, the speed between the modules is transmitted in m / s, in this case the modules can be used separately and for various tasks, for example, only for processing data from the wheelbase or only for converting odometry coming from the signal processing board of the wheelbase to a format, corresponding ROS.

To implement the developed software solution into a specific mobile robot model, you need to know the following robot specifications: the radius of the robot wheels, the distance between the wheel centers, the number of ticks of the encoder with a full wheel turn, the minimum and maximum speed of the robot, the maximum current for motors. Additional equipment is connected using the appropriate ROS nodes.

Results #1

To test the intelligence of mobile robot, a fairly well-known, widely used in practice problem was chosen: SLAM. Testing was carried out in two stages. At the first stage, the gmapping, hectormap, rtabmap algorithms were launched in the Gazebo simulation environment on a model that corresponds to the specifications of the Pioneer 2 AT mobile robot. In the course of robot testing, it was necessary to create a room map, having passed the path from point A to B, for each experiment this path was the same.

At first, the algorithms were tested for working with lidar (see Fig. 1). In this case, all the algorithms provided fairly high-quality maps, according to which further autonomous navigation is possible. Next, tests were carried out with a stereo camera (see Fig. 2), and if rtabmap was originally designed to work with a stereo camera, then for two other algorithms it was necessary to convert a cloud of 3D points from a disparity map into a two-dimensional contour emulating the behavior of a lidar. This transformation imposed some significant limitations: a low scanning range, a small viewing angle, low frequency, point drift, in general, all those properties that, in general, a real lidar does not have.

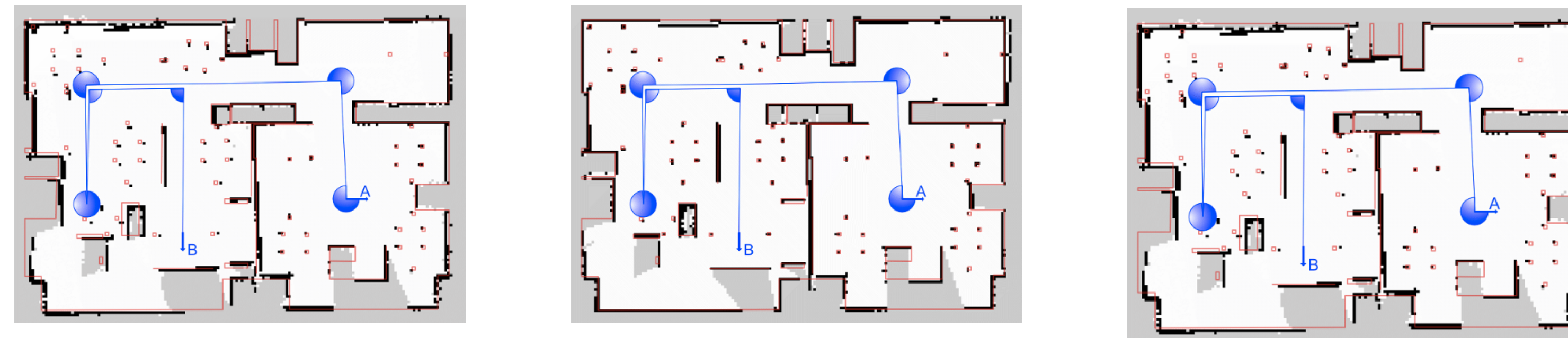


Fig. 1. SLAM results with lidar a) gmapping b) hectormap c) rtabmap

When constructing a map using gmapping, satisfactory results were achieved only with a halving of the speed of movement of the robot model (linear speed 0.09m / s, angular 0.19 rad / s) and a long selection of internal parameters. Hectormap failed to achieve adequate results. At the same time, rtabmap, which was initially launched with a stereo camera, produced a map of comparable quality, giving an undeniable bonus as a three-dimensional display of the surrounding space, despite the fact that the speed of model did not change from tests conducted with lidar (linear speed 0.19 m / s, angular 0.39 rad / s).

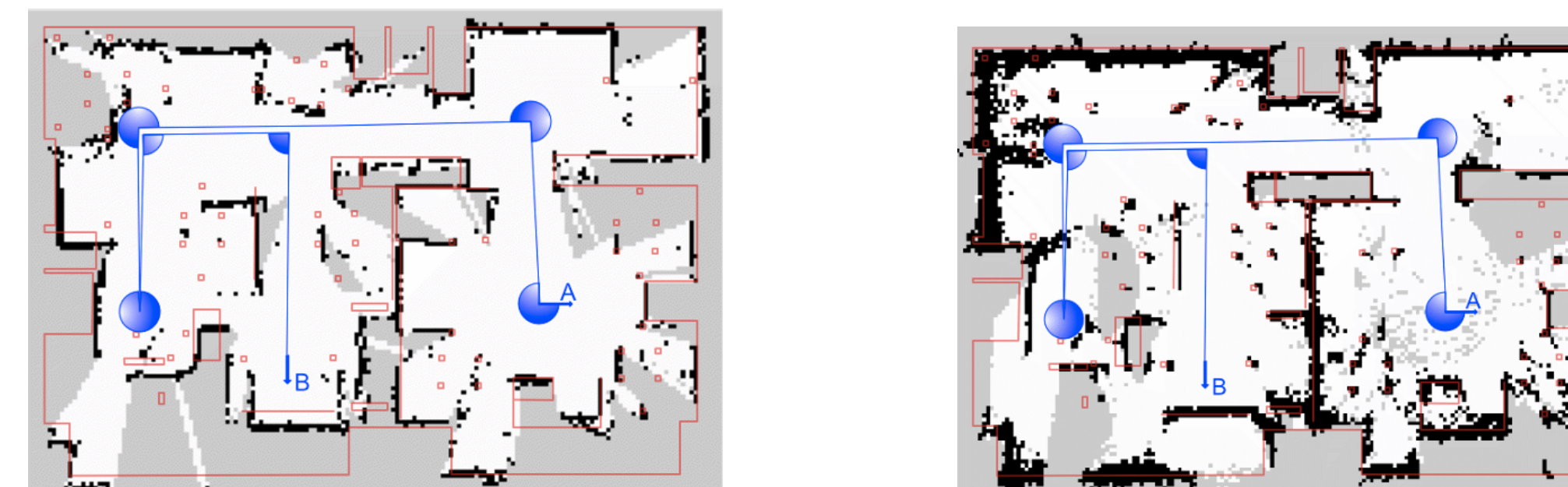


Fig. 2. SLAM results with stereo camera: a) gmapping b) rtabmap

Results #2

The second stage of testing was planned to be carried out on a real Pioneer 2 AT robot, and it would consist in repeating the experiments conducted on the model, in the room according to which a room model was created from the experiments of the first stage. Unfortunately, the circumstances surrounding the pandemic did not allow a full-fledged final experiment on the real mobile robot, so only the results obtained in the simulation are given below.

CONCLUSIONS

The results presented in this article allow us to state that if the mechatronic base of the wheeled mobile robot is well preserved, it is possible, due to the relatively simple hardware and software upgrade of the on-board electronics and computer equipment, in some cases only software upgrade, to bring the robot to the modern level its intellectual properties. The article describes in detail the process of such an upgrade for mobile robot Pioneer 2AT. A similar technique can be applied to a wide range of robots of this type.

ACKNOWLEDGMENTS & REFERENCES

- 1.H. Durrant-Whyte, T. Bailey: Simultaneous Localization and Mapping: Part I in IEEE Robotics & Automation Magazine (Volume: 13, Issue: 2, June 2006) (2006), doi: 10.1109/MRA.2006.1638022
- 2.C. Cadena, L. Carlone, H. Carrillo (eds): Past, Present, and Future of Simultaneous Localization and Mapping: Toward the Robust-Perception Age in IEEE Transactions on Robotics (Volume: 32, Issue: 6, Dec. 2016) (2016), doi: 10.1109/TRO.2016.2624754
3. S. Perera, N. Barnes, A. Zelinsky: Exploration: Simultaneous Localization and Mapping (SLAM) in Computer Vision, pp.268-275, (2014), doi: 10.1007/978-0-387-31439-6_280
- 4.T. Bailey, H. Durrant-Whyte: Simultaneous Localization and Mapping (SLAM): Part II in IEEE Robotics & Automation Magazine (Volume: 13, Issue: 3, Sept. 2006), (2006), doi: 10.1109/MRA.2006.1678144
- 5.G. Grisetti, C. Stachniss, W. Burgard: Improved Techniques for Grid Mapping With Rao-Blackwellized Particle Filters in IEEE Transactions on Robotics (Volume: 23, Issue: 1, Feb. 2007), (2007), doi: 10.1109/TRO.2006.889486
- 6.S. Kohlbrecher, O. von Stryk, J. Meyer, U. Klingauf: A Flexible and Scalable SLAM System with Full 3D Motion Estimation in 2011 IEEE International Symposium on Safety, Security, and Rescue Robotics, (2011), doi: 10.1109/SSRR.2011.6106777
- 7.M. Labbe, F. Michaud: RTAB-Map as an open-source lidar and visual simultaneous localization and mapping library for large-scale and long-term online operation in Journal of Field Robotics 36(3), (2018), doi: 10.1002/rob.21851
- 8.Verbitsky N.S., Chepin E.V., Gridnev A.A. Study on the Possibility of Detecting Objects in Real Time on a Mobile Robot. In: Misayun S., Arkelian V., Avetisyan A. (eds) Advanced Technologies in Robotics and Intelligent Systems. Mechanisms and Machine Science, vol 80. Springer, Cham, (2020)
- 9.S. D. Kulik, A. N. Shtanko: Experiments with Neural Net Object Detection System YOLO on Small Training Datasets for Intelligent Robotics. Published: 2020 by Springer Science and Business Media LLC in Modeling and Control of a Tracked Mobile Robot for Pipeline Inspection pp 157-162 (2020), doi:10.1007/978-3-030-33491-8_19
- 10.Yazdi M., Bouwmans T.: New trends in moving object detection in video images captured by a moving camera: A survey Computer Science Review. – T. 28. – C. 157-177. (2018)
- 11.Steven M. LaValle: PLANNING ALGORITHMS Cambridge University Press Pages: 727-730 (2006)
- 12.L. Abdolreza Yekini, A. Dan-Isa: Fuzzy Logic Control of Goal-Seeking 2-Wheel Differential Mobile Robot Using Unicycle Approach IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS 2019), (2019), doi: 10.1109/I2CACIS.2019.8825082
- 13.L. Caracciolo, A. De Luca, S. Iannitti: Trajectory tracking control of a four-wheel differentially driven mobile robot in IEEE International Conference on Robotics & Automation (1999), doi: 10.1109/ROBOT.1999.773994
- 14.W. Domszki, A. Misur: Slippage Influence in Skid-Steering Platform Trajectory Tracking Quality with Unicycle Approximation In 24th International Conference on Methods and Models in Automation and Robotics (MMAR), (2019), doi: 10.1109/MMAR.2019.8864720
- 15.Z. Jian, W. Shuang-shuang, L. Hua, Li Bin: The Sliding Mode Control Based on Extended State Observer for Skid Steering of 4-Wheel-Drive Electric Vehicle In 2nd International Conference on Consumer Electronics, Communications and Networks (CECCNet), (2012), doi: 10.1109/CECCNet.2012.6201445
- 16.Gao Shuang, Norbert C.Cheung, K.W. Eric Cheng, Dong Lei Liao Xiaozhong In 7th International Conference on Power Electronics and Drive Systems (2007), doi:10.1109/PEDS.2007.4487913
- 17.Pentzer J., Brennan S., Reichard K.: The Use of Unicycle Robot Control Strategies for Skid-Steer Robots Through the ICR Kinematic Mapping in 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2014) (2014), doi: 10.1109/IROS.2014.6943006
- 18.T. Wang, Y. Wu, J. Liang, C. Han, J. Chen, Q. Zhao: Analysis and Experimental Kinematics of a Skid-Steering Wheeled Robot Based on a Laser Scanner Sensor Sensors 2015, 15, 9681-9702 (2015), doi: 10.3390/s150509681
- 19.T. Hallstrom: Kinematics Equations for Differential Drive and Articulated Steering 2011-08-28 Umeå University (2011)
- 20.O. Barrero, S. Tilagay, Y. M. Nova: Outdoors Trajectory Tracking Control for a Four Wheel Skid-Steering Vehicle IEEE 2nd Colombian Conference on Robotics and Automation (CCRA) (2018), doi: 10.1109/CCRA.2018.8588153
- 21.K. Kozłowski, D. Pądzierski: Modeling and control of a 4-wheel skid-steering mobile robot 2014 Int. J. Appl. Math. Comput. Sci., Vol. 14, No. 4, 477-496 (2004)
- 22.D. Pądzierski, K. Kozłowski, T. Gawron: A unified motion control and low level planning algorithm for a wheeled skid-steering robot in IEEE 20th Conference on Emerging Technologies & Factory Automation (ETFA) (2015), doi: 10.1109/ETFA.2015.7301490
- 23.O. Barrero, H. F. Murcia: Modeling and parameter estimation of a 4-wheel Mobile Robot (2016) https://www.researchgate.net/publication/314011229_Modeling_and_parameter_estimation_of_a_4-wheel_Mobile_Robot..., last accessed 2020/04/15
- 24.A. Allon, A. Costic, I. Zohar, A. Rodic: Control for teams of kinematic unicycle-like and skid-steering mobile robots with restricted inputs: analysis and applications 15th International Conference on Advanced Robotics (ICAR) (2011), doi: 10.1109/ICAR.2011.6088541
- 25.LabVIEW Robotics Programming Study Guide - Kansas State University – Polytechnic