Teaching Intelligent Robotics with a Low-Cost Mobile Robot Platform

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***Abstract*—In this short paper we present the requirements and implementation of a mobile robot platform to be used for teaching intelligent robotic classes. We report our experience of using the platform in university courses and various extracurricular activities.**

I. Introduction

Selection of a suitable robot platform plays a crucial role when teaching advanced intelligent robotics classes. It is very desirable that the students are able to build upon solid theoretical foundations on one hand, and get a direct hands-on experience on the other hand. The robot platform that is used in a such pedagogical process should therefore preferably fulfill the following requirements. (1) It should be robust, durable and non-fragile, enabling students to work with it on a daily basis. (2) It should be accurate and reliably controllable; the actions should be sufficiently repetitive. (3) The sensors should be sufficiently rich, and the computational power should enable demanding computations; the system should be scalable and upgradeable in terms of software and hardware to enable extensions for tackling more advanced tasks. (4) The price should be reasonable to enable the purchase of a larger number of robots for small groups of students. (5) It should enable transfer of learned knowledge to other more expensive robots that are used in the practice.

In the past decade a lot of different robot platforms designed for educational use have been presented [1]. When starting a new course on development of intelligent system, however, we tried to find a solution based on the requirements mentioned above. The requirement (4) clearly rules out powerful yet expensive robotic platforms that are usually used in research. The requirements (3) and (5) mostly rule out the use of Lego Mindstorms, Thymio robots or similar educational platforms. The requirements (1) and (2) discouraged us of using some other hobby robotic platforms. We brought a decision to build our robot on top of the low-cost iRobot Roomba vacuum cleaner and to extend it to meet all the requirements mentioned above. Since at that time, in late 2011, the TurtleBot platform based on the related iRobot Create platform became available, we decided to make use of it; to extend it and to adapt it to our needs. In this paper we describe these modifications and report our three year experience of using the platform in university courses and various extracurricular activities.

II. The robot

In the design of our robot platform we have largely followed the TurtleBot concept, but made some changes and improvements in terms of robustness and hardware maintenance. The robot system is composed of the robot base, a processing unit, a depth sensor and a camera, and a framework connecting all the components in a unified device. A schematic overview of our platform is shown in Figure 1.

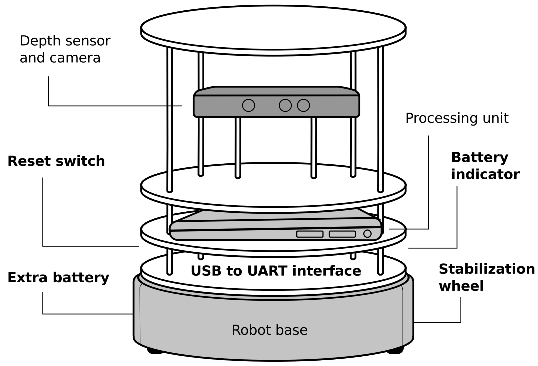

Fig. 1. An overview of our robot platform. Our modifications of the original TurtleBot concept are written in bold.

A. Robot base

Due to unavailability of iRobot Create in Europe at the time, we have opted for a modified version of iRobot Roomba 531, a commodity autonomous vacuum cleaner robot. By default this robot is equipped with a front bumper sensor, an IR cliff sensor, IR proximity sensors, and an odometry sensor. The internal battery suffices for around 3 hours of work. We have removed the vacuum unit and replaced it with an *extra battery* for the depth and color camera. Since it turned out that shaking of the original robot base in case of rapid accelerations decreased the navigation capability, we have added a *rear wheel* to increase the stability of the robot. The robot base is controlled by a laptop computer using a *custom USB to UART interface* that is also able to turn the base on when the communication is started. The base is also equipped with a *hardware restart button* that enables fast reset.

B. RGBD camera

As a primary sensor we use the first generation of Microsoft Kinect (released in 2010, a year before the start of our course) as a depth sensor and a color camera. Immediately after its release Kinect became extremely widely utilized in robotics community [2]. Unfortunately the sensor needs additional external power, which is supplied by the extra battery in the robot base that suffices for around 2 hours of work. We have also included an external battery status indicator so that users know when to charge the battery.

C. Processing unit

The central processing device of the robot is an Asus X301A laptop with Ubuntu operating system and Robot Operating System (ROS) [3] middleware. The usage of a laptop for controlling the robot base offers a great deal of flexibility: it can be used directly or it can be accessed over the WiFi network. Similarly, all the computations can be performed on-board, or they can be distributed over several computers using the WiFi network and ROS distributed computing environment. Being able to use ROS modular architecture and numerous available packages is also a great advantage. The laptop contains Intel i3 processor, 4GB of RAM and was upgraded with a 120GB SSD drive that is more resilient towards vibrations and rapid accelerations. The laptop only has two USB slots, which suffices for the basic use, however, we also added a USB hub to allow for the use of additional devices (e.g. an additional camera, external speakers, etc.). The integrated battery offers around 4 hours of autonomy (depending on the computational load).

III. Teaching robotics

The robot platform was used during the practical part of the course Development of Intelligent Systems. The students worked in small groups and had to program the mobile robot to accomplish a given task that involved robot navigation, object recognition and localization, dialogue, and planning. The examples of the tasks were a slalom ride, object search, and mini Cluedo. In the latter task the robot had to autonomously detect and recognize persons' faces, approach them, and in a dialogue with them found out where they had hidden which object; then the robot had to find and show these places. The tasks could therefore be quite challenging involving different functionalities that the students have to develop and/or integrate. The assessment was organized in the form of competitions, which enabled the students to compare their solutions in a competitive manner. The students accepted such form of work and assessment very well and were highly motivated for the work.

Keen students also use our robot platform for their diploma and master thesis projects. Several functionalities and systems have been developed, such as people following, autonomous exploration of space, autonomous object search, autonomous building of 3D model of an object, a mobile landing platform for a quadrocopter, etc. It turned out that the robotic platform is very suitable for such work that definitively increases the interest of students as well as provides a very important set of skills for the prospective students that are willing to continue their work in the field of intelligent robotics, either in research or industry.

Our robot platform is also used to promote robotics among children. To make the robot more approachable we have created an external shell that resembles the famous R2-D2 robot from Star wars movies. The shell is equipped with a USB camera, a microphone and speakers. At the events the robot was quickly recognized by children who then easily interacted with it.

IV. Conclusion

The robot described in Section II fulfills the requirements presented in Introduction. (1) A very robust and durable domestic robot is used, which turns to be (2) sufficiently accurate and reliably controllable. (3) Since it is controlled by on-board computer running ROS, the system is very scalable and enables the usage of numerous ROS packages implementing various functionalities, as well as it enables the usage of different sensors; the RGBD camera Kinect suffices for our purpose. (4) Since the system is composed of off-the-shelf consumer products, the price is kept relatively low (below 1.500 EUR). (5) However, since most of the software used is portable to almost any ROS-enabled mobile platform, the knowledge learned is fully transferable to significantly more expensive and widely used robotic platforms.

By using this platform for educational purposes for three years we also identified several problems and found adequate solutions. A robot platform that is used for teaching mobile intelligent robotics has to be robust and composed of easily replaceable components as frequent use by many users that are less familiar with the system wears down the hardware. Having a lot of user shifts on the same robot in a short period of time also requires a lot of coordination. Users have to take care of status of multiple batteries in one system which is hard to achieve when students have a deadline. Using multiple robots at the same location (in a class) can also be problematic when using WiFi networks to monitor the status. Image or point cloud transfers can cause a lot of traffic and even clog most commodity-level wireless routers.

Our future work will include additional modifications to the platform to increase its robustness. We plan to unify the charging mechanism so that all devices will be charged at once. We have been already testing the dual-band wireless networking for higher network throughput. With these additional improvements we will create a very robust and efficient platform for teaching intelligent robotics classes.

References

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