Manufacturing Education and Training resorting to a new mobile robot competition

J. Gonçalves[13][1], J. Lima[13], P. Costa[23], and A. Moreira[23]

[1]Polytechnic Institute of Bragança, Department of Electrical Engineering, Bragança, Portugal

[2]Faculty of Engineering of University of Porto, Department of Electrical Engineering and Computers, Porto, Portugal

[3]Robotics and Intelligent Systems Research Group, INESC-TEC, Porto, Portugal

Abstract

In this paper it is discussed the educational, research and development outcomes that are expected to achieve from a new robot competition, proposed and conceived by the authors, that was recently included in Robotica (the main Robotics Portuguese Competition). The robot competition takes place in an emulated factory plant, where Automatic Guided Vehicles (AGVs) must cooperate to perform tasks. To accomplish their goals the AGVs must deal with localization, navigation, scheduling and cooperation problems, that must be solved autonomously. The presented robot competition can play an important role in education due to the inherent multi-disciplinary concepts that are involved, motivating students to technological areas. It also plays an important role in research and development, because it is expected that the outcomes that will emerge here, will later be transfered to other application areas, such as service robots and manufacturing.

1 Introduction

Robotic competitions are an excellent way to foster research and to attract students to technological areas [1]. The robotic competitions present standard problems that can be used as a benchmark, in order to evaluate and to compare the performances of different approaches. Although there are many robotic competitions [2] [3] [4] [5] , there is the need to create new ones, in order to solve new challenges. The factory environment is a prime candidate to use robots in a variety of tasks. A competition where mobile robots are tackling transportation problems in the shop floor is a challenge that can foster new advances in service robots and manufacturing [6][7]. This new robot competition presents problems that occur when using mobile robots to perform transportation tasks. The robots must be able to navigate, cooperate and to self-localize in an emulated factory plant, to transport and handle materials in an efficient way.

The authors have previous experience in robotic competitions, they participated in all senior competitions of the main Robotics Portuguese Competition, as well as in several leagues in the Robocup. This participations included several roles, such as being part of technical committees, competing with teams and also as event organizers. The goals of each competition are defined having in mind the outcomes that are expected. The outcomes could be technical, in order to obtain better hardware and software performances, in research, promoting advances in some areas of knowledge and in education, depending on what students can learn and practice while they are involved in the competitions.

The paper is organized as follows: After a brief introduction the contest description where robots hardware, dimensions, materials and localization requisites and different difficulty levels are described. Then the official competition robot simulator is described, allowing competitors to test their approaches without accessing to real hardware. It are also discussed, as case study,5 the authors feedback received from the first official competition that was held in Lisbon at the Robotica 2011 Festival. Finally, some conclusions and future work are pointed out.

2 Robotic competition description

In this section it is presented the competition description and the rules that teams must follow in order to qualify for participation and to compete. This competition was recently included as an official competition of Robotica 2011, the Main Robotics Portuguese Competition, being expected to be motivating for robotics researchers and enthusiasts.

[1] Corresponding author : Tel. : (+351) 273-3068 ; Fax : (+351) 313-051 ; E-mail : goncalves@ipb.pt

Although the competition requires real robots, competitors can use a simulator in order to test their approaches, before and during the competition. The official competition simulator is SimTwo, described in section 3, being a tool for the development and validation of robot software that can be freely downloaded [8].

2.1 Robot dimensions

Each robot must fit within a cuboid of 35 x 35 x 30 cm. The robot must be completely autonomous and cannot establish any kind of communication with external systems that are not explicitly provided by the organization.

2.2 Competition arena

The competition arena, shown in Figure 1, emulates a factory shop floor where there are warehouses and machinery. A real robot in the competition arena is also shown in Figure 2. The dimensions of this area is 3.5 x 2.5 m. There are eight machines available and two warehouses. One of them is used as a raw material storage and the other one is used as a destination.

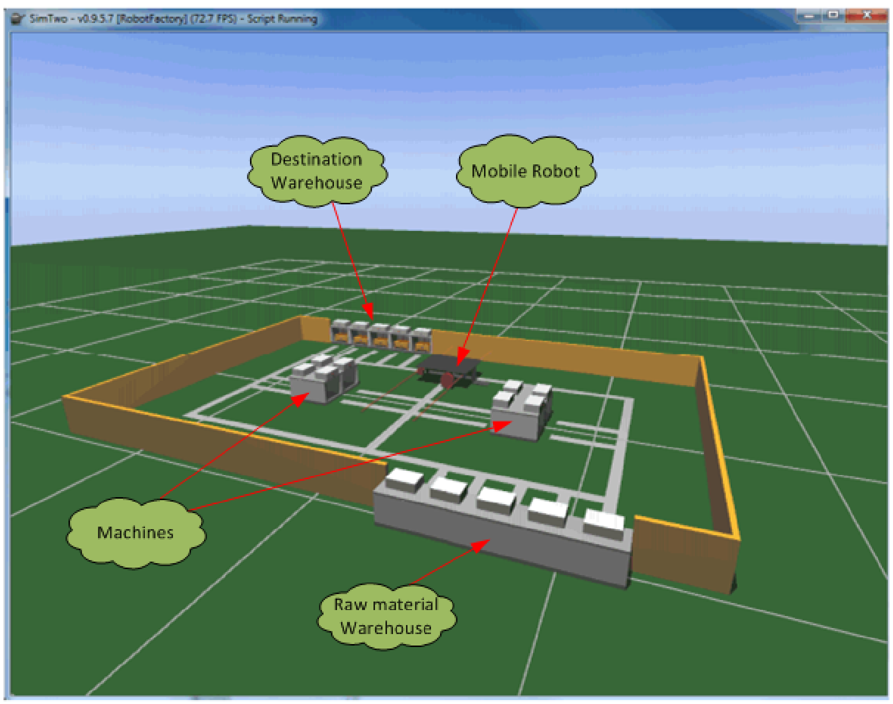

Figure 1: Competition arena modeled in the SimTwo.

2.3 Machinery and warehouses description

Each machine provides an area where the pieces should be placed in order to be processed by the machine. The robot must pick and place the material parts from the machine. While the part is placed in the machine it is processed and should not be removed. An RGB LED indicates that the machine is able to accept parts (light green), the machine is processing a part (yellow light), the part in this machine is already processed (white light) or that the machine is broken (blink red light).

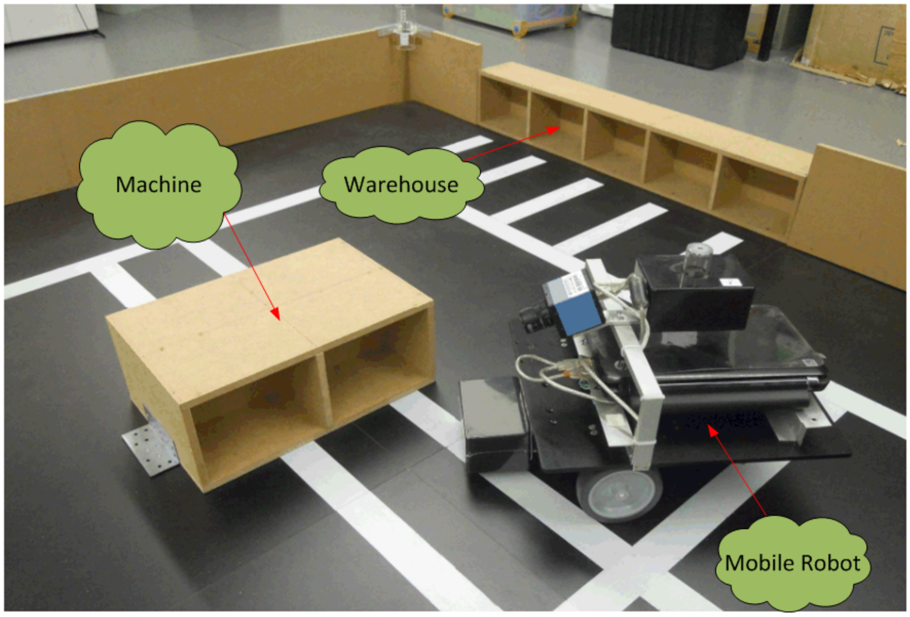

Figure 2: Robot in the competition arena.

2.3.1 The part materials

The materials to be transported by the robots should respect standard dimensions, width and length corresponding to an Europallete 80 x 120 mm (1:10 scale), the height should have a value between 30 mm and 50 mm. Each piece has an LED issuing an RGB color that identifies the type of material. When a part arrives to a machine, it can be processed and its color is changed in order to illustrate a different type of part.

2.4 Solving problems in the competition

Team responsible can access the robot up to four times, if one of the robots is not expected to be able to recover. While robot comes out from the arena the time scheduling continues unchangeable.

2.5 Competition starting

The robots must be placed in the park closed one hour before the start of each competition. Teams should not to have access to the robot until about 10 minutes before the start of their competition. There, the referees indicate the teams that should prepare the robot to start their competition.

2.6 Competition rounds

Since this is a competition that can accept participants with different background, it must be differentiated in three rounds. Event organization can provide, for some rounds, an external localization system for robots. This system will identify the robots using a pattern that must be placed on top of each robot and can provide the position and orientation of the robot.

2.6.1 First round

The main purpose of the first round is to collect the pieces of the raw material warehouse and transport them to the end warehouse. The robot should transport the most parts it can from the warehouses.

2.6.2 Second round

The main purpose of the second round is to process some parts of the raw material. The raw material should be transported from the initial warehouse to the machinery, in order to be processed. When the processing task is ended, the parts should be transported to the final warehouse.

2.6.3 Third round

The main purpose of the third round is to sequentially distribute the parts through several machinery. Some parts collected from the raw material warehouse should be placed sequentially in more than one machine to process. Only after the completion of this operation the parts should be transported to the final warehouse. There will be three types of parts in operation. During this round some tracks may be partially or totally blocked. In this round teams are authorized to use two robot at the same time, the used robots must cooperate to perform its tasks.

3 SimTwo - The Competition official simulator

SimTwo is a realistic simulation system that can support several types of robots. Its main purpose is the simulation of mobile robots that can have wheels or legs, although industrial robots, conveyor belts and lighter-than-air vehicles can also be defined. Basically any type of terrestrial robot definable with rotative joints and/or wheels can be simulated in this software. Figure 3 shows the software with all its main windows.

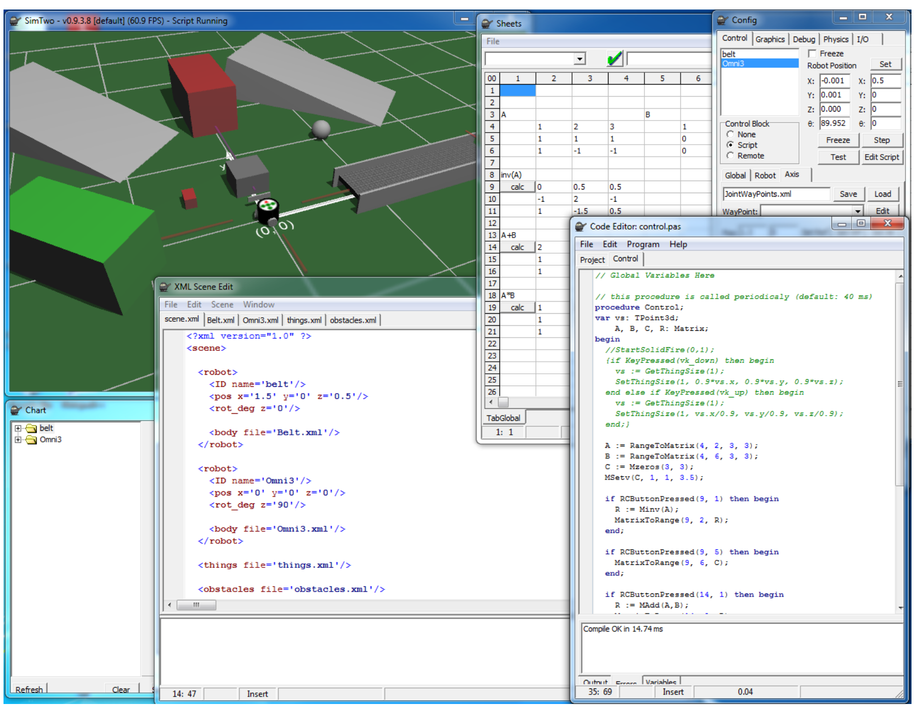

Figure 3: SimTwo software. Application windows clockwise from top left corner: world view, spreadsheet, configuration, code editor, scene editor and chart.

The dynamics realism in SimTwo is obtained by decomposing a robot to rigid bodies and electric motors. Each body behaviour is numerically simulated using its physical characteristics: shape, mass and moments of inertia, surface friction and elasticity. It is also possible to define standard joints such as universal, hinge and slider which can be coupled with an actuator or a sensor.

SimTwo is an application with a *multiple document interface* (MDI) where all windows are under the "world view" window control, shown in Figure 3, exiting the simulator is done by closing this window. The "configuration" window offers control over several elements of the virtual scene. It is possible to define the controller timestamp and to configure the 3D world view (camera position, shadow visibility, etc.). Robots information is also displayed in this window, like its position and speed.

The "code editor" offers an *integrated development environment* (IDE) for high-level programming based in Pascal language, this is the main tool in this simulator. The control algorithms are directly compiled in this window and a message appears in the bottom of the page informing of a successful compilation or the existence of coding errors. The control script is started from this window where the resulting robot movement is visible in the main window and any changes to the control script requires this to be stopped and recompiled.

Debugging the control algorithm is possible using the "chart" and the "spreadsheet" window. In the "chart" it is possible to plot all variables available for every robot, such as its position, motors speed and current, etc. In the "spreadsheet" window it is possible to define "edit cells" as well as "button cells" for specific operations. This window becomes a customizable form window, this is the equivalent to a graphic application.

The scene implementation is done by editing several XML format files, these files are definable in the "scene editor" window. A scene in SimTwo can have "robots", "obstacles" and "things", as shown in Figure 4.

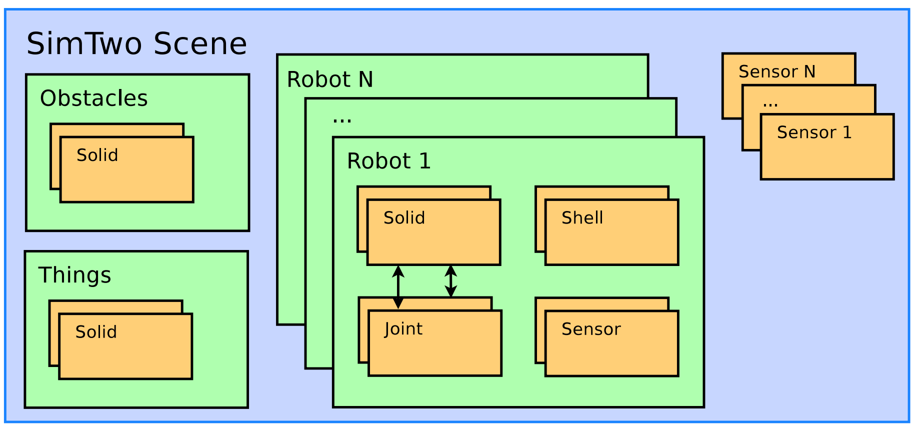

Figure 4: SimTwo Scene structure

A main scene file (scene.xml) defines the robots in use and their specific construction file. Each robot is defined by various solids (cuboid, cylinder and sphere) connected through joints (slider, socket and hinge). The shell elements are solids without mass, these do not modified the robot physical properties but are an essential part for collision simulation. A robot can also have sensors, these provide information from the environment surrounding the robot.

The scene objects are the "obstacles" and "things", these are very similar in definition (both are defined solely by solids) but while the "obstacles" are imovable in case of collision the "things" are not. If a robot collides with a "thing" these will react accordingly to their mass definition. A scene can also have sensors, these are static relative to the world as opposed to a robot sensor which gives information relative to its corresponding robot.

In Figure 5 it is presented the flux of information of a SimTwo controller. The controller has different levels that are updated at different rates, being presented its default values. The presented default values can be changed by the user depending on the application that is being simulated. The artificial intelligence (AI) controller is updated by default at 40 ms, being a common rate to accomplish real time requisites in mobile robotics challenges. The motor controller is updated by default at a 10 ms rate and its model output is updated by default at 1 ms rate. The default values are typical values that were chosen having in mind the dynamics of the world and motor models in mobile robotics, although user can change this values depending on the specific dynamics and real time requisites of its simulation.

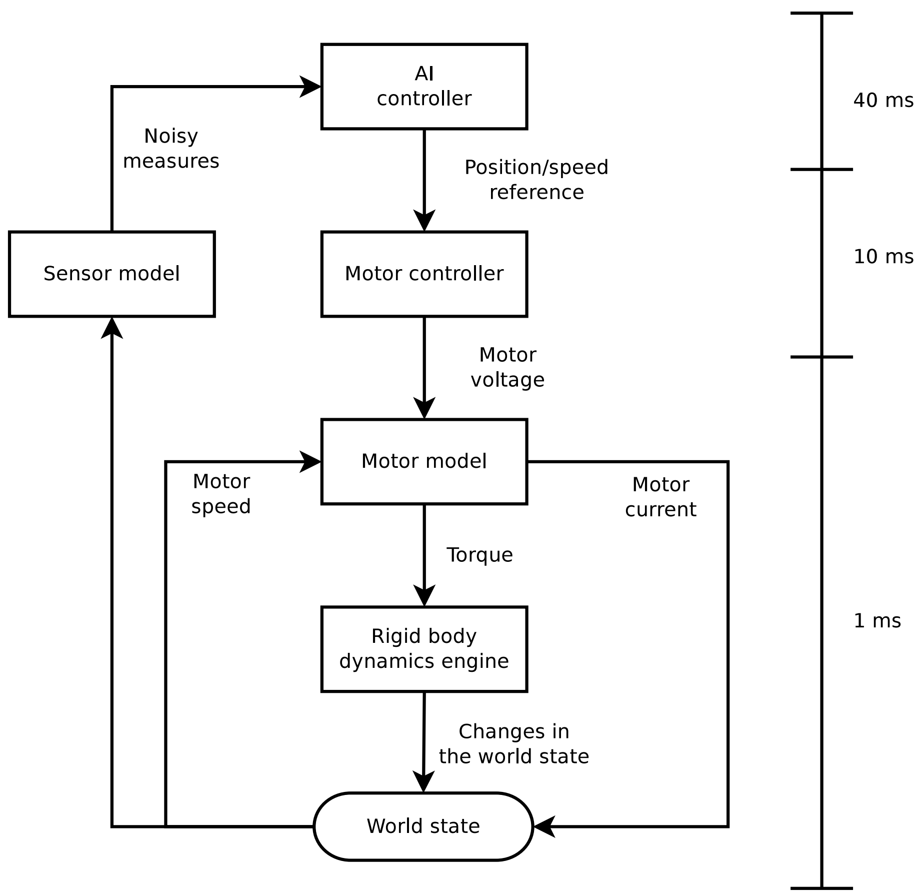

Figure 5: SimTwo controller cycle

The artificial intelligence level is provided with sensor information extracted from the world state. After some decisions and calculations related with control, localization and navigation the controller provides to the motor controller its inputs. The motor model provides the torque information, forcing the Rigid Dynamics Engine to react and consequently forcing the World state (Sensor, obstacles and robot positions) to change.

4 Case Study: First official competition

The first official competition was held in Lisbon at Robotica 2011, the Main Robotics Competition. Although there was a lot of uncertainty associated with this new contest, mainly due to the lack of information, five teams participated in the first event. Four teams made the scheduled attempts of material transportation between warehouses. The Robot@Factory competition environment is shown in Figure 6.

Figure 6: Robot@Factory competition environment

The contest was very competitive during the several rounds, which made it very interesting for the teams and for the audience. The authors received feedback from the first participants in order to evolve the rules of the competition to a more mature state, having in mind what students can learn and practice while they are involved in the competition and also to obtain new technical and research advances. It it is expected that the research and technical outcomes that will emerge here, will later be transfered to other application areas, such as service robots and manufacturing.

5 Conclusions and future work

In this paper it is presented a new robot competition that was included in the main Robotics Portuguese Competition. The robot competition takes place in an emulated factory plant, where Automatic Guided Vehicles (AGVs) must cooperate to perform tasks. To accomplish its goals the AGVs must deal with localization, navigation, scheduling and cooperation problems, that must solved autonomously.

While competitors do not have contact with physical arena and hardware, competitors can freely download the official competition simulator to test their controllers.

One educational aspect, other than the natural motivating factor, is the availability of a challenge that is harder than some entry level competitions but still reachable for teams with some experience on those tasks. Also, it is expected that the problem scales well to more complex approaches. This means that more complex robot, thus a harder robot to build, will also be able to perform better. This can be a excellent motivation for teams to learn and use more advanced robots and algorithms.

By presenting a scaled down factory shop, this competition creates a benchmark that can be used to compare different approaches to the problems that arise on this kind of environments. Also, the ability, in some restricted areas, alter the environment, can promote the test and evaluation of different localization mechanisms. Something that is usually, more restricted in most other competitions. That opens this area to be explored and benchmarked.

The participating teams of the first official competition contributed to this challenge in a very positive way, becoming clear that the chosen configuration was well chosen, being possible for teams to participate with simple approaches (from the technological and scientific point of view), without compromising the use of more complex approaches that provide a better performance. The competition evolution is now in the hands of the participants; its future depends on their enthusiasm, creativity, knowledge and effort.

6 Acknowledgment

This work is funded by the ERDF through the Programme COMPETE and by the Portuguese Government through FCT-Foundation for Science and Technology.

References

[1] Almeida, L., Azevedo, J., Cardeira, C., Costa, P., Fonseca,P., Lima, P., Ribeiro, F., and Santos, V.: "Fostering advances in research, development and education in robotics", Proceedings of the 4th Portuguese conference in Automatic Control, 2000.

[2] Browning, B., Bruce, J., Bowling, M., and Veloso, M.: "Ustp: Skills, tactics and plays for multi-robot control in adversarial environments", IEEE Journal of Control and Systems Engineering., 2005.

[3] Lund, H. and Pagliarinis, L.: " Robocup jr. with lego mindstorms ", International Conference on Robotics and Automation, San Francisco, CA, IEEE, 2000.

[4] Nakanishi, R., Bruce, J., Murakami, K., Naruse, T., and Veloso, M.: " Cooperative 3-robot passing and shooting in the robocup small size league. ", In Proceedings of the RoboCup Symposium, Bremen, Germany, 2006.

[5] Ribeiro, F., Moutinho, I., Silva, P., Fraga, C., and Pereira, N.: " Controlling omni-directional wheels of a robocup msl autonomous mobile robot ", In Scientific Meeting of the Portuguese Robotics Open, 2004.

[6] Yuta, S., Asama, H., Thrun, S., Prassler, E., and Tsubouchi, T.: " Field and Service Robotics, Recent Advances in research and Applications. ", volume 24 of Springer Tracts in Advanced Robotics, Lake Yamanaka, Japan, 14-16 July 2003.

[7] Arun N. Nambiar: " Challenges in Sustainable Manufacturing. ", Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management, Dhaka, Bangladesh, January 9-10, 2010.

[8] Costa, P., Gonçalves, J., Lima, J., and Malheiros, P.: " Simtwo realistic simulator: A tool for the development and validation of robot software ", International Journal of Theory and Applications of Mathematics Computer Science, 2010.