Autonomous Guided Vehicles Applied to Industrial Engineering and Management Studies

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***Abstract*—This article presents a framework to an Industrial Engineering and Management Science course from School of Management and Industrial Studies using Autonomous Ground Vehicles (AGV) to supply materials to a production line as an experimental setup for the students to acquire knowledge in the production robotics area.**

The students must be capable to understand and put into good use several concepts that will be of utmost importance in their professional life such as critical decisions regarding the study, development and implementation of a production line.

The main focus is a production line using AGVs, where the students are required to address several topics such as: sensors actuators, controllers and an high level management and optimization software.

The presented framework brings to the robotics teaching community methodologies that allow students from different backgrounds, that normally don't experiment with the robotics concepts in practice due to the big gap between theory and practice, to go straight to "making" robotics. Our aim was to suppress the minimum start point level thus allowing any student to fully experience robotics with little background knowledge.

I. INTRODUCTION

Simulation environments achieve great success in robotics learning especially when the students are at the beginning of their studies. Simulation is very useful for several reasons: students are just starting to learn robotics, the hardware is not ready, the operations place is very far away or inaccessible (e.g. other planets), the setup is often not operational (and to make it operational it can be difficult and time consuming), or even when the developers only want to test some small things and don't want to wait all the time needed for starting up the robots.

When students are just beginning to learn robotics, dealing with the hardware is complicated and simulation can teach the basics of robotics without having to deal with hardware problems.

The input focus of this framework was an Industrial Engineering and Management Science course in which students are required to learn how a production line works as well as everything around it. The students need to study production lines using robotics transporters. The aim is to use Autonomous Ground Vehicles to supply materials to a production line as an experimental setup for the students to acquire knowledge in the production robotics area. Students are expected not just to know the necessary concepts of industrial management but to understand how to apply them to a real-life problem/challenge.

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The main objective is stock management in a production line using AGVs, where the students are required to address several topics such as: sensors, actuators, controllers and an high level management and optimization software.

Introducing the students to robotics requiring almost no prior knowledge on the subject was a challenge, therefore a two step approach was used: a simulation one and a practical one. There are several works presenting the simulation of a production line using AGVs [1], [2], and several presenting studies about the dynamics of AGVs [3], [4] but the solution presented allows the student to learn about the flow of materials in the production line, electronics and AGVs dynamics.

The paper is organized as follows: Section II describes the proposed architecture. Section III describes the experimental setup, developed to support the previous assumptions by having a two step approach: a simulation one and a practical one. Section IV provides some conclusions and discusses future work.

II. PROPOSED ARCHITECTURE

The proposed architecture main objective was to develop a framework capable of managing the automated transport of materials in any given production line. In this framework it was necessary to keep in mind that first year industrial management engineering students have no prior knowledge of robotics and little knowledge in electronics, therefore, the proposed architecture had to be easy to interact with.

The main architecture of our framework can be seen in Fig. 1.

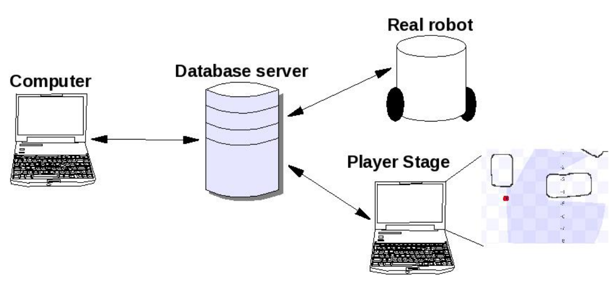

Fig. 1. Global architecture

The typical interaction used in the industry to manage the production is an Enterprise Resource Planning (ERP) which uses a backend database. Our approach was to use a database to interact with both the simulation environment and the application developed by the students. In this approach the students are expected to develop an application that interacts with the database according to their industrial management scenario.

The industrial management scenario is an industrial plant with physical representation of the stock area (both of raw materials and finished products) and the number of existing production lines. All the supply and collect points are marked and tagged.

The idea is that the students, using this scenario, would develop an application that determines the stock quantity of raw materials, the production rhythm (the maximum production rate of the production line is given), the stock quantity of finished products and controls the supply of materials to and from the production lines. The supply of materials is done using AGVs. Therefore, the students need to take into account the AGV dynamics since it adds time restrains to the supply of materials which can lead to lower production rates. The control of the AGV dynamics and route planning and optimization is not an objective for these first year students. Moreover, the simulation platform was chose so that these features could be added in future work to be used by more advanced students.

All the location points where the materials are collected or supplied are marked in the scenario. This is done by adding tags in a database. This database is given to the students and has tags for every supply or collect point and the initial quantity of materials in each point.

The students application interacts with this database to implement their supply management strategies.

This application uses a known open source tool from robotics community: Player project [6] (formerly know as Player/Stage).

This framework is composed by 3 layers:

- Player Project
- Database
- Application Program

A. Player project

The Player project [6] [5] is a multirobotic simulator (see Fig. 2) that uses a client/server model to manage the robot interface. It is possible to interact with a simple sensor or with an entire robot. There are several robots, devices and algorithms predefined in the original source but, if needed, new ones can be created.

The Player is capable to perform tasks by dealing with sensors and actuators interfaces (drivers) being simulated or from a real robot.

The Stage is a multirobot simulator in a two dimensional world. This software package integrates already a vast list of sensors models that can be easily modified and new sensors can be added. The Stage can talk with the Player allowing robot simulation if there isn't any real robot available.

The use of Player project allows the students and developers to avoid the time consuming task of developing the physics simulator and is a project with constant development, well

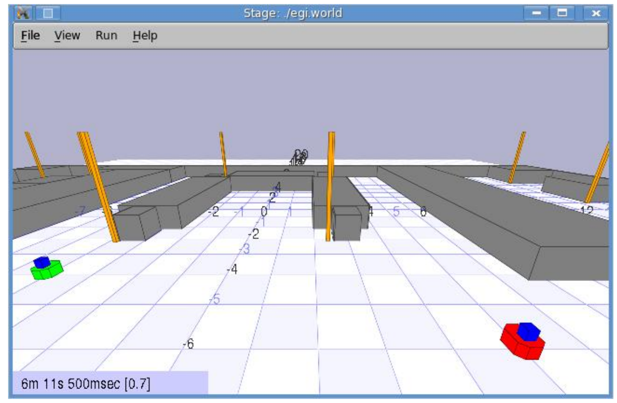

Fig. 2. The simulation scenario with two production lines in Player Project

established and flexible enough to add new robots such as AGV or robotic arms. Using a powerful tool such as Player project enables the further development of this framework, allowing the students to edit the industrial plant, adjust the number of production lines and AGVs, control the AGV dynamics and perform route planning and optimization tasks.

B. Database

In a typical simulation environment such as the proposed Player project, the interaction with the simulator is made by using a UDP socket communication. This communication layer requires knowledge that is beyond the scope of the course in which this framework was implemented. Therefore, a database was developed in an open-source platform, MySQL, that will be used as the information layer, allowing the simulation environment to interact with the students applications.

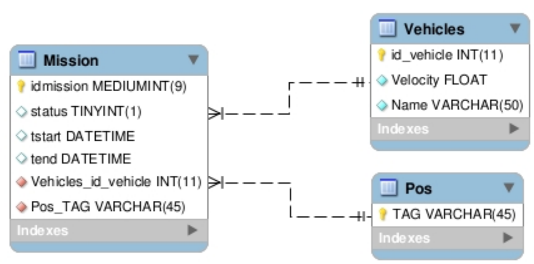

Fig. 3. Normalized implemented database

The database is composed by three tables (see Fig.3), two of them are associated with the simulation environment (*Vehicles* and *Pos*) and the third to the dynamic of the vehicles in the product line (*Mission*). The tables associated to the simulation environment are loaded with information regarding the AGVs available in each scenario and the supply/lifting end product positions in the warehouse. The database also allows the interaction with standard platforms or hardware solutions designed by the students without having to extend their knowledge on wireless networks or other type of communications.

C. Application program

The application program developed in GTK+ [8] is an interface that allows the student to initiate their simulation work (see Fig. 4). The GTK+ toolkit was chose because it is open-source and cross-platform which is important considering the different operating systems that students use.

Fig. 4. Management Software

This application was developed to be user friendly, having only two main controls responsible for starting and stopping the simulation, encapsulating all the hard work that is needed by the simulation environment. It is responsible for managing the requests from the database and interact with the simulator producing all the data logs required. Some data logs are showed in real time, so students can understand what is happening in the simulator window, and other logs are output to a file as being final results from the simulation itself.

In order to manage more than one robot a multi-threaded application is used by allocating a thread to each AGV present in the simulation scenario. Each thread is responsible to access the database requesting the mission for the assigned robot and then providing the path to execute the mission. The next mission will only be executed after the last one is completed and all timestamps from the mission are recorded in the database.

III. Experimental Setup

The proposed architecture was made available to the students allowing them to optimize the production line by controlling the AGV's dynamics without any prior knowledge on robotics. This approach allows the students to develop management applications that are able not only to study the AGVs dynamics but also other important themes such as stock and supply chain management which are areas of interest in industrial engineering and management sciences.

Using knowledge acquired in the programming, algorithm and data structuring course, the students develop graphic applications that can parametrize both the missions and the AGVs by interacting with the proposed database available in the framework.

The students' application interacts with the database by sending tags with the information regarding the location where the AGV needs to pick up material or where it needs to deliver the material. This information is read from the database and fed to the simulation environment where the students can visualize the AGV's movement but also obtain other useful information. The architecture allows the user to configure its' scenario by stipulating the maximum load and speed to the AGV's but also by introducing unique physical characteristics of the AGV (like wheel diameter, etc) and adjust the AGV's reaction based on a physical model.

A. Simulation Environment

The first step is simulation, allowing the students to validate the AGV dynamics relatively to the material supplying. In this phase it is possible to extract important information about the whole system which includes: supply times, route optimization and inventory management.

After starting the simulation environment, that consist of the definition of the layout that is already available (given by the teacher), and the application program installed in a class room, the students are now able to interact with the database.

The layout that is developed by the teacher has a challenge for each student that consists in a representation of all stages of the supply chain process(raw materials, production line and finished product). The black dots presented in the Fig. 5 are the tags where each AGV has to move. The example illustrates four spots (tags), two of them representing the supply materials (MP1_0002, MP1_0003) and the other two the production line supply points (LP1_0001, LP1_0002).

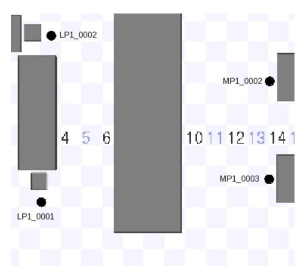

Fig. 5. A small layout example with tags. These tags are locations where the AGV has to move. The grey zones are areas where the AGV cannot pass through.

These events (or tags) have to be generated according to the students previous stock management planning and it can also serve as testing ground for different strategies. With this information, the students start to define the mission in the database. If the objective is to supply the production line LP1_0001, (Fig.5) from the supply warehouse tagged MP1_0001 the students perform the following SQL command:

>>MYSQL_CONNECT(IP_MACHINE, USERNAME, PASSWORD)

>>INSERT INTO mission (Pos_Tag_id, Vehicles_id_vehicle) VALUES(MP1_0001, 1)

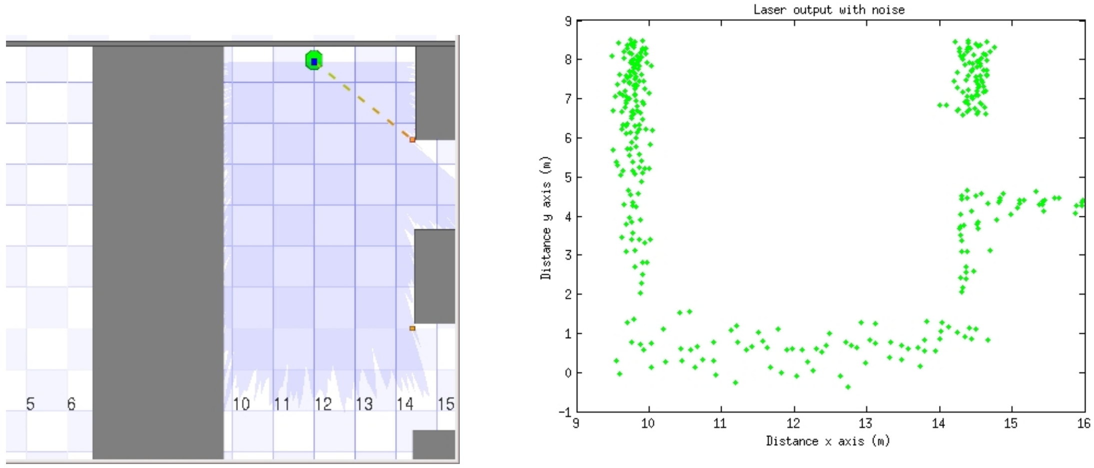

Fig. 6. AGV navigation with laser sensor (left). Environment mapping from AGV laser sensor (right).

>>INSERT INTO mission(Pos_Tag_id, Vehicles_id_vehicle) VALUES(LP1_0001, 1)

>>MYSQL_CLOSE(sock)

The AGV loading, travel and unloading times are managed by the application program defined in the layout setup. Besides this results the students can also learn several robotic topics such as path planning and sensor navigation (see Fig. 6 and Fig. 7).

A major advantage from this simulator is the capacity to evaluate different type of sensors considering the proposed scenarios. Figure 6 represents a sensor behavior with its own characteristic measurement noise. Students without in depth knowledge in electronics can choose different sensors for different scenarios by testing them, analysing their advantages and disadvantages from a practical point of view.

In figure 7 the AGV path and localization process that was simulated by the students can be observed. This is important because they can analyze the results and be able to evaluate different locomotion and navigation methods [7].

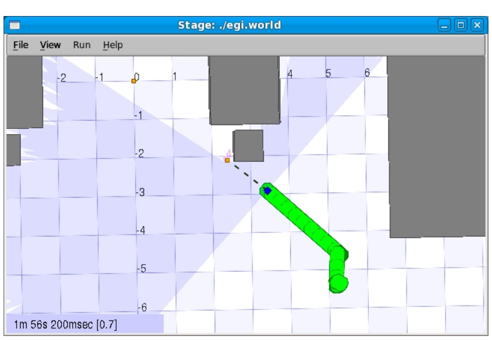

Fig. 7. This is an exemple of an AGV moving to LP1_0001 tag after receiving a command. The AGV path is also represented.

B. *Robotic platform*

The second step is the implementation of a small scale robotic platform to be used by the students and that have identical physical characteristics to the simulation step.

This allows the evaluation of the software developed by the students in a practical case as well learning the behavior of sensors, actuators and controllers in a real scenario. Each robot has a wireless communication system allowing the execution of the same instructions used in the simulation step.

The students can program the robots events the same way they did in the first step, therefore, this step adds no extra difficulty.

Since first year industrial management students don't have the necessary knowledge to implement the robots this step is intended only as a physical simulator of their production line stock management strategies. However it is an important stage to stimulate the students in achieving the best strategies and also to get them to take an interest in robotics.

The implementation of the robotic platforms is intended to be done by the students in the following years.

IV. Conclusions and Future Work

This article presents a framework for the students to acquire knowledge in the production robotics area using Automated Guided Vehicles.

This work allows the students to acquire skills in robotics area and supply chain management. The students are able to experiment with several practical scenarios and the presented simulation environment gives them an opportunity to see the results of their implementation.

This approach proved to be a good strategy to motivate the students to learn robotics and lead them to want to know more about this area.

Considering the impact of the proposed solution, we would like, in the future, to integrate the simulation environment with an e-learning platform so that it can be accessible by all students at school and at home. Also, the teacher/supervisor could easily add/change scenarios.

Further development of this framework to allow the students to have more control on the variables of industrial production planning was an initial idea and will be done in future work. The concepts necessary to take advantage of these new features are beyond the scope of first year students but this has great potential for more advanced students.

In another line of work, the students can develop their own small scale robot platform to interact with the present framework.

Currently we are working in the integration of Gazebo (a 3D multirobot simulator provided by Player project) in order to achieve more realistic feeling in the simulation output.

V. Acknowledgments

The authors would like to thank the School of Management and Industrial Studies and Porto Polytechnic. This work is sponsored by ESEIG and IPP. We would also like to acknowledge the support from Autonomous System Laboratory, LSA/ISEP/IPP.

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