

A Software Tool for Efficient Agricultural Logistics

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Abstract. The Internet of Things (IoT) revolution enables the integration of advanced automation techniques to the intra-logistic agricultural activities. Sensors and actuators seamlessly communicate in order to accomplish complex everyday tasks. From a logistics perspective, Automated Guided Vehicles (AGVs) pave the way to sustainable agriculture; working 24/7 with minimum labor costs and high safety standards while optimizing energy consumption and providing effective and efficient solutions for everyday activities. This article proposes a software tool for daily field level agricultural activities. The tool provides a cyber-physical interface to the physical entities (field boundaries, loads and vehicles) located at field level. Map services are integrated at our tool in order to provide the field layout, the absolute coordinates of the entities and a real time monitoring tool. Sophisticated algorithms can be used for navigation at simulation level while the absolute coordinates are sent to the vehicle for the physical navigation.

Keywords: Software tool, Automated Guided Vehicles, Navigation mechanism, Simulation tool, Agricultural Logistics.

1 Introduction

In this article, we develop a software tool that allows farmers to monitor agricultural fields' state and to effectively navigate an autonomous Inter-Agricultural Logistics (IAL) system. The provided software tool provides a cyber-physical interface to locate physical entities (e.g. field boundaries, loads and vehicles) and simulate a desired navigation pathway for the actual tractor to accomplish specific tasks.

The Internet of Things enables integration of sophisticated software applications and advanced automations to the cloud computing interface (Sarangi, 2016), hence unleashing sustainable growth opportunities for the agricultural sector (Ruiz-Canales and Ferrández-Villena, 2015). More specifically, Automated Guided Vehicles (AGVs) with embedded sensors and actuators are used in IAL to inspect soil quality, provide weed control by spaying pesticides, fertilize the field or automatically load and transfer harvested goods at pick-up points for transportation. Agricultural AGVs

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are usually free range vehicles and navigate on the field with the either individual or combined use of optical devices like cameras and LiDAR sensors, absolute Global Positioning System (GPS) enabled controllers (Gomez-gil et al., 2011), inertial guidance sensors like accelerometers and gyroscopes, and teleoperation techniques.

Despite the advances in robotic solutions for agricultural field operations (Bechar and Vigneault, 2016), their actual application is limited (Xiang, 2014) due to the increased modelling requirements' complexity stemming from the natural components of the unstructured and dynamic fields' environment (Bechar and Vigneault, 2017). Such components include varied shape, size, fruits which are characterized by high variability that affects robot behavior, many of which cannot be determined a-priori. Fully-autonomous AGV system could tackle the abovementioned challenge further promoting sustainable agriculture (Bechtsis et al., 2017), but the main limiting factors in their adoption lies in production inefficiencies and the lack of economic feasibility over the very short period of AGVs' potential utilization each year (Bechar and Vigneault, 2016).

In this regard, the present study proposes a software tool for daily field level agricultural activities. More specifically, the tool provides a cyber-physical interface to the physical entities (e.g. field boundaries, loads and vehicles) located at the field level. The Google Maps service is integrated at our tool in order to provide the field layout, the absolute coordinates of the entities and a real-time monitoring tool. Sophisticated algorithms can be used for navigation at simulation level while the absolute coordinates are sent to the vehicle for the physical navigation.

The remainder of the manuscript is organized as follows. In Section 2 we describe the system's architecture, along with the required input and operational data, and the field monitoring process. In Section 3, we discuss the key findings of the simulation tool application in a conceptual field. Finally, in Section 4 we wrap-up with conclusions and limitations.

2 Software Tool Design Architecture

In this paper we propose a stepwise simulation tool that combines GPS guidance techniques, enabled by the Google Maps service, with routing algorithms used to navigate an AGV on a field. The architecture of the system is demonstrated in Figure 1.

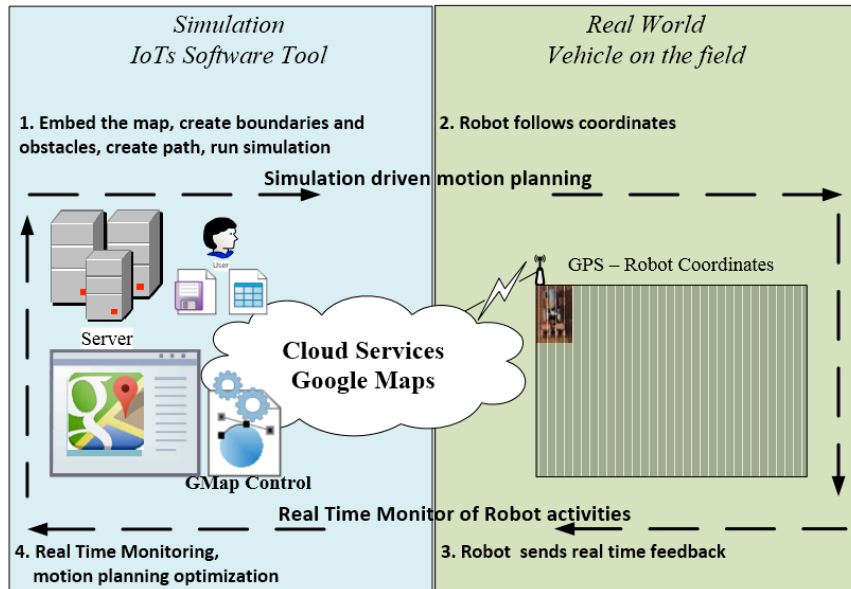


Fig. 1. System's architecture.

The system's architecture involves both the simulation and the real world as the real world coordinates are imported into the simulation environment; the motion planning algorithms are tested at simulation level and can be transferred to the robot; the robot can exchange information (coordinates, sensor information, robot's state) with the simulation environment and inform about its current state. The proposed software application is built with the C# framework using the Microsoft Visual Studio 2013 platform. The software enables the import of specific entities into the simulation environment (vehicle, obstacles and loads) in a grid layout. Each entity that enters the grid is an object of a developed class in the object oriented programming environment and is located on a specific cell of the grid. The software tool embeds maps using the GreatMaps open source project (GMap.NET) that belongs to the CodePlex hosting site supported by Microsoft. The GMap acts as a middleware in order to promote the use of specific map providers (Google, ArcGIS, Bing, OpenStreetMap, Yahoo and many more) and map types (political maps, terrain maps, transportation maps, satellite maps) in windows applications. For working with agricultural logistics it is necessary to implement satellite maps into the software tool in order to select the appropriate provider and embed the map to the application. Cell coordinates are calculated from the GMap middleware and create a direct link to the real world providing predefined coordinates for each cell in the grid. Finally routing algorithms are used at simulation level in order to navigate the vehicle at the field. At each step of the simulation process the X,Y coordinates of the cell are stored at the system's log. This log file can be provided as an input to the real world vehicle in order to provide the navigation path in means of GPS coordinates.

3 Computational Study

3.1 Field Specification

Firstly, the provider's map is embedded to the developed simulation tool to implement an absolute position oriented guidance system. It is worth mentioning that the GMap.NET acts a middleware in order to promote maps from different providers to windows applications. It enables the use of routing, geocoding, map directions and map previews to developers. As a next step the GMapControl tool was incorporated to the Toolbox for providing a handler to the MainForm of the application which links the form to the map's service provider using the proper libraries. Inside the form the GMap's menu is implemented in order to handle the maps properties and the user can select the presentation details of the map. Furthermore the selection "Mark Rectangle" provides an event handler for the creation of a dedicated form that embeds the region of interest and metadata information to the application. The region's coordinates and the map's scale are considered critical for the software tool. The user manually locates the region of interest (Figure 2).



Fig. 2. The user locates the region of interest using the Google Maps Service.

Secondly, the user locates the specific agricultural field of interest (Figure 3) and imports the captured field image into the simulation tool for further processing. The absolute latitude and longitude coordinates of the selected area's vertices are then exported from GMap and are imported in the tool. The operator can save the region with the required metadata for later use. As each field can have certain restrictions (complex boundaries, areas with obstacles, water covered areas that alter the fields landscape vary from year to year) the operator can capture a wider area of the map

and at a later stage set the exact boundaries of the field. The region of interest is fully functional at application level for providing efficient inter-agricultural logistics.

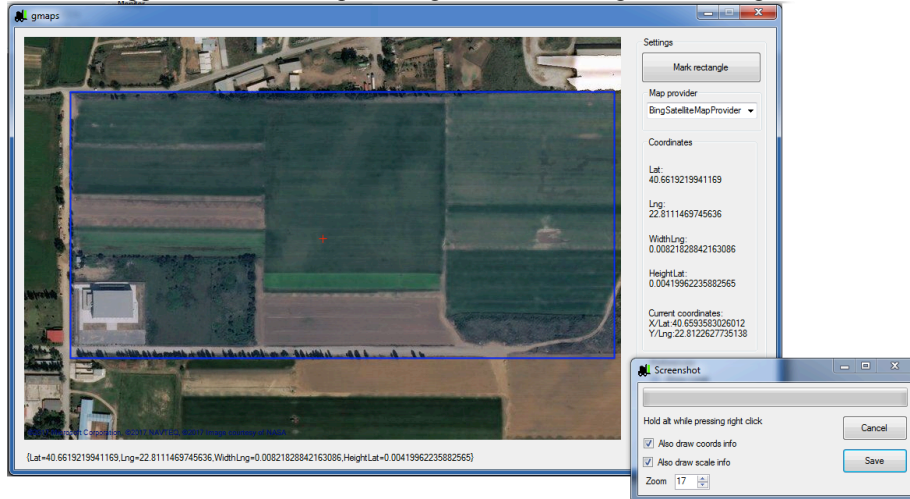


Fig. 3. The user selects the specific agricultural field of interest.

Following that, the user provides feedback and interoperates with the system by marking grid cells in the tool's embedded layer applied on top of the retrieved agricultural field's image. The selected grid cells indicate the field's boundaries, mark the position of any obstacles in the field, specify exact location of goods that should be transferred and point the start and exit positions of the AGV (Figure 4).



Fig. 4. The user defines the agricultural field's characteristics.

Each grid cell can have different properties that describe the objects of the physical world (e.g. barrier object for the outline of the field, obstacle object for obstacles inside the field, start and final position object of the AGV). Furthermore, at each grid cell correspond specific latitude and longitude coordinates formed by the original absolute coordinates. This projection enables the absolute positioning of all grid cells and provides an absolute localization mechanism for the AGV within the field. Using these entities, the user creates a map of the field's layout and establishes the active operational zone for the AGV. Finally, the AGV is able to navigate within the active zone following the motion planning algorithms that are implemented. The proposed application can find the shortest path between two cells in the active zone for either loading the vehicle or navigating to the exit point using the A* algorithm. The A* algorithm can calculate the shortest path after examining all the possible routes in the grid based environment while simultaneously avoiding all the possible obstacles (other loads, boundaries etc). The program also offers a visualization of the vehicle's movement in the field. Finally, for the evaluation of specific agrilogistics tasks, desired operations and sustainability performance metrics (scheduled tasks, vehicle state, direct and indirect emissions, etc.) can be reported from the software.

3.2 Exemplar Demonstrator

A common scenario is examined in the present paper as exemplar demonstrator. An in-field transfer of goods is simulated. The load is allocated to specific cells at the active field area and makes a transfer request to the AGV. The AGV begins from the starting position and finds an optimum pathway using the A* algorithm for reaching the user-specified goods. The AGV loads the goods and then transfers them to the exit position (Figure 5).



Fig. 5. Simulation.

Users monitor the movement of the AGV while the absolute coordinates of the grid cells are stored in a list to guide a corresponding physical AGV. The location of the AGV can be monitored in real-time by the proposed software tool.

4 Conclusions

This paper contributes to the operations research field by allowing the application of simulated results direct to the guidance of a physical vehicle. Unlike existing sophisticated tools, the developed navigation mechanism is user-friendly and highly customizable at outdoor navigation.

The tool provides a real time interface to the Google Maps engine in order to handle the field's boundaries, to map the obstacles' coordinates and to exclude specific areas from the vehicle's path. Real time positioning of the vehicle is used for monitoring the vehicle's status and providing real time feedback to the motion planning algorithm (Edwards et al., 2016; Zhe et al., 2015).

The proposed tool could lead to a commercial navigation system for agricultural machines providing a friendly user interface and sophisticated algorithms for motion planning while taking into consideration all the appropriate agronomical constraints.

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