PATH PLANNING FOR AGRICULTURAL VEHICLES BASED ON GENERATED PERCEPTION MAPS

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ABSTRACT

Agricultural field operations, such as spraying, harvesting and seeding, can potentially be automated and executed either by conventional machinery equipped with automation systems, or by autonomous machines. An automated operation must be planned and organized in a manner that, on one hand reduces risk and failure potential and, on the other hand, optimizes productivity and efficiency. However, the diversity of the natural out-door environment and the huge amount of diversified in type data required to picture the operational environment, comprise the hardest challenges for the deployment of fully automated agricultural operations.

In the context of this paper an algorithmic approach was developed aiming at solving one of the various problems encountered in the autonomous agricultural operations. Specifically, the problem addressed is the navigation in the semi-structured environment of orchards. The navigation process consists of seeking a valid path connecting two predefined points in the field enabling the vehicle to travel between them. This is also a core functional component for robotic vehicles in agricultural operations.

The developed software receives as input pre-processed data, a geotagged depiction of an orchard farm, which is obtained by an unmanned aerial vehicle. The pre-processing formats the coordinates which define the field's tracks. Based on this data, the software creates a grid-based map related to the accessible areas, utilized by a graph-based algorithm that produces the topological path planning solution. Subsequently, the solution is translated as a sequence of coordinates which define the produced optimal path.

The software was executed, and its functionality validated in routing applications in an orchard using an autonomous farming vehicle.

Keywords: path planning, UGV, routing, graph based

1. INTRODUCTION

In precision agriculture, an automated operation should be programmed and scheduled resulting an increased productivity and efficiency while risk factors are being avoided. In the other hand, dynamically changed environments, alongside with the required data that describes the respective field, consists in the most serious challenge that must be achieved in order to accomplish a fully automated and unmanned in-field navigation. The exploitation of such technologies requires the

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review of the traditional techniques that takes place into the field. Oksanen (2007) introduced two path planning algorithms, one is separating a complicated field area to smaller and simpler areas while the other one is using prediction methods. Sørensen et al. (2004) are using a method which compiles a combinational optimization on the planning patterns, based on combined field's, vehicle's and implement's characteristics. In many cases, new solutions provided a more efficient result comparing with the traditional ones (Hameed et al., 2011). As suggested by Bochtis et al. (2012) an optimized vehicle path planning offers a plenty of advantages such as reduced required initial data for an operation, cleaner and healthier production method, decreased environmental impact and a better product maintenance. At recent years, the implementation and optimization of unmanned automated vehicles have triggered the interest about the robotics and path planning (Keicher and Seufert, 2000) . Research on this area has focused on solving problems such as minimizing vehicle maneuvers in the field by reducing its complexity and fragmenting fields into smaller areas to create simple patterns (Jin and Tang, 2006). Still in research, Cariou et al. (2010) is studying to find optimal maneuver patterns when changing a crop line. In this paper, the approach of the problem in relation to the speed and the maneuvers of the vehicle is examined. Then there are various kinds of changes when turning the vehicle. A research which is also remarkable is Jensen et al. (2012) in which it is planned to design a path of unit supporters within a field (within the crop lines, on the headland) as well as outside the field (rural roads, field entrances). At work Ali et al. (2009) a complete approach is developed in which a continuous coverage of crop lines is presented. While the study focuses mainly on harvesting, it can also be applied to feed applications as it covers the case of moving off-road vehicles for landing purposes. The Han (2019) approach is also remarkable. In this work, a path-finding implementation has been carried out in three dimensions. This problem has more challenges than finding a path in the two-dimensional world. In this approach, a method has been developed where a subset of obstacles translates into terms of significance within the path.

In the context of this paper an algorithmic approach was developed aiming at solving one of the various problems encountered in the autonomous agricultural operations. The developed software receives as input pre-processed data, a geotagged depiction of an orchard farm, which is obtained by an unmanned aerial vehicle. Based on this data, the software creates a grid-based map related to the accessible areas, utilized by a graph-based algorithm that produces the topological path planning solution. Subsequently, the solution is translated as a sequence of coordinates which define the produced optimal path.

The software was executed, and its functionality validated in routing applications in an orchard using an autonomous farming vehicle.

2. METHODOLOGY

2.1 Analysis and assumptions

In this work, linear crops are examined, with the common feature of the impossibility of moving vehicles perpendicular to the lines. Given this limitation and the inherent structure of the system it is possible to create a topological grid that fully describes the field. To solve the problem, it was necessary to make some assumptions. Initially, it was assumed that there would be no mechanical failure or malfunction in the vehicles. Then, in the context of optimization, the motion of the main and secondary vehicles was calculated simultaneously and cooperatively. In addition, dynamic obstacle avoidance is not part of the path design as this operation is performed using lower level hardware and sensors. Finally, the algorithm can be applied to either convex or non-convex fields, provided that the crop lines are parallel curves.

2.2 Review

The field is presented as a topological grid where there are nodes in it. Each node can represent the following states, Reserved point / obstacle, Free point, Starting point of the path and Endpoint of the path. Each node is associated with four (4) movements within the space: Up, Down, Right, Left.

Also, for every adjacent node to which traffic is allowed, there is a direct connection (**Figure** 1). Required input data for the algorithm is the number of cultivation lines. Under these circumstances, the problem goes back to the problem of finding the shortest path in a grid that joins the original to the final node. In the case where more than one path is found, the elongated distance of each one is calculated, and ultimately it is chosen with the lowest cost.

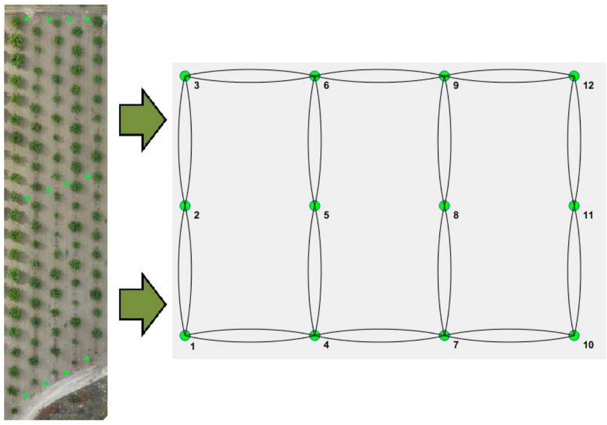

Figure 1. Map to topological grid

2.3 Representative topological grid of the field

A field can be represented as a topological grid contains points that can be characterized by a state (Reserved point / obstacle, free point, starting point, end point).

Reserved point / obstacle: Any actual obstacle or still working vehicle. Considered to be immobilized

Free point: Any point of the topological grid where the vehicle can reach.

Starting point: The starting point of the path
End point: The endpoint of the path

3. IMPLEMENTATION

The implementation of the solution is divided into the following steps: The software reads and edits the data from the UAV. A grid-based map is produced using that data and, in addition, the optimal path is created using the algorithmic approach that is presented is this paper. Furthermore, a KML (Keyhole Markable Language) which describes the produced path, is created. Finally, the KML file is imported to an unmanned ground vehicle in order to be parsed and execute the respective operation (**Figure** 2).

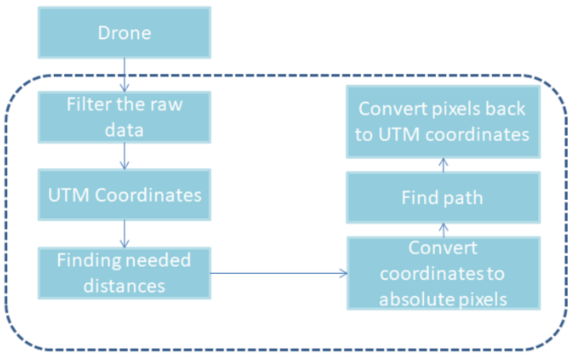

Figure 2. Raw data as algorithm's input

The input data consists of UTM (Universal Transverse Mercator) coordinates that form the crop lines as well as the corresponding pixels of the coordinates on the images (**Figure** 3).

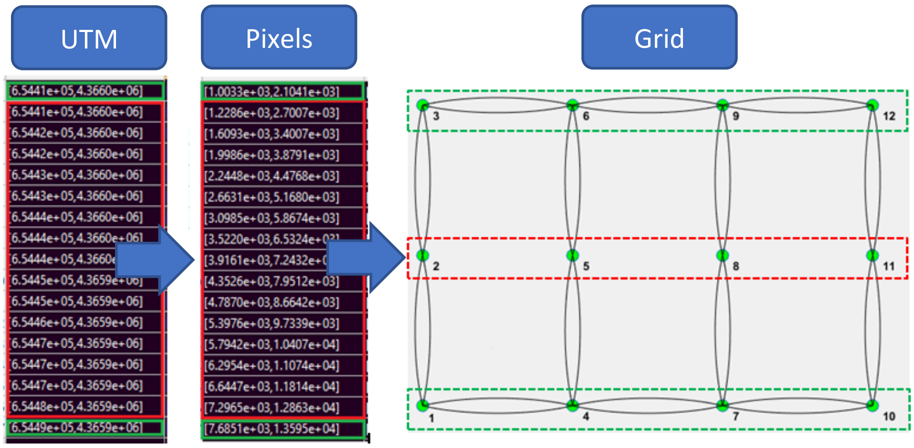

Figure 3. UTM coordinates to topological map

A routine is responsible for the integrity of the data while it cleans out any faulty coordinate or empty entity. After that, 3 class objects are created describing the grid-based map and the lines of the field. The obstacle declaration is done by the user, stating the location of the entity (actual obstacle, parked machinery or implement, working labor). Considering the existing topology map, the nodes belonging to the path are colored in blue while obstacle is colored in red. When all nodes are designed, a dashed blue line joins these points (Figure 4) producing two (2) results. The graph of the nodes and the planned path in the real field.

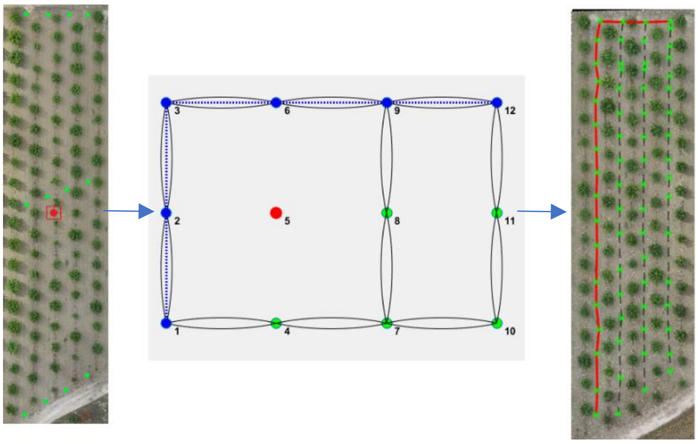

Figure 4. The produced result

4. CASE STUDIES

The algorithm was tested in two (2) different usage scenarios presented below (**Figure** 5 and **Figure** 6). In all cases, the scope was the same field. Differentiation lies in the different points that are placed as the starting point and the end point. The results produced by the software are as follows: Stamping the path to the image of the mosaic, mapping the path to the topological map, create a graph describing the path based on the pointers of its points and create a KML file and present the path using the Google Earth software.

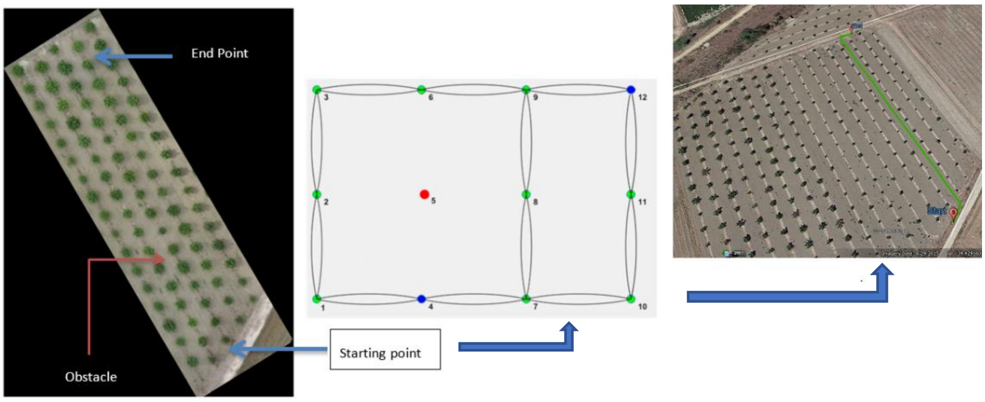

Figure 5. Usecase 1 with 1 obstacle

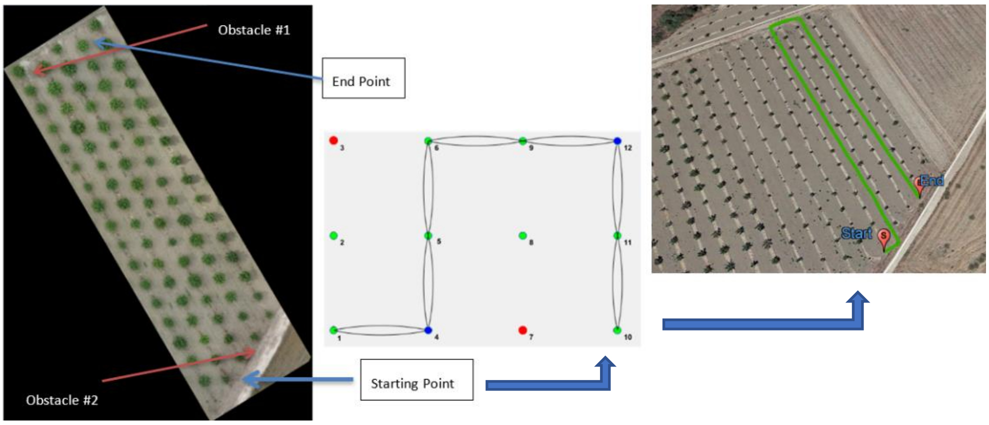

Figure 6. Usecase 2 with 2 obstacles

The produced KML files created by the software can be used for various purposes with different media. Some forms of use include tracing a path with a handheld GPS receiver or importing the file into a robotic vehicle. In this paper, a robotic ground vehicle was used to trace the path that is produced by the software (**Figure** 7). The robotic vehicle fitted a GPS receiver, parses the KML file, and finally, using the integrated computer, the UGV is moving corresponding to the KML's coordinates.

Figure 7. UGV traces the generated path

5. Conclusions and Future Steps

This work solves a part of the problems that exist when trying to navigate autonomously within the field. The next steps that will be studied increase the expectations for further development of this sector. One goal consists of the software ability to produce within the KML file new entities that will represent the obstacles. Further options and arrangements will be added for the vehicle morphology and obstacles. Appropriate sensors will then be attached to the stand-alone vehicle in order to dynamically avoid obstacles. A laser sensor and a. A depth camera are suitable for applications requiring object recognition when moving the vehicle into space (Fu et al., 2015). Finally, the objective is the interaction of the UAV with the UGV in real time will allow it to solve even more complicated and complicated problems (Sivaneri and Gross, 2018).

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