POLITECNICO DI TORINO

Master's Degree in Mechatronic engineering

Navigation Algorithms for Unmanned Ground Vehicles in Precision Agriculture Applications

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Abstract. Robotics for agriculture can be considered a very recent application of one of the most ancient and important sectors, where the latest and most advanced innovations have been brought.
Over the years, thanks to continous improvement in mechanization and automation, crop output has extremely increased, enabling a large growth in population and enhancing the quality of life around the world. Both these factors, as a consequence, are leading to a higher demand for agriculture and forestry output.
Precision agriculture defined as the correct management of crops for increasing its productivity and maximizing harvest, is considered the answer to this issue. As a matter of fact, thanks to the development of portable sensors, the availability of satellite images and the use of drones, the collection of data is allowing a vast development in this field.
This thesis adresses in general robotics for agriculture in the form of a solution to be applied in order to improve robot mobility, in particular automated path planning in agricultural fields, by proposing a method to classify different parcels of which they are composed and to assign a precise task to the terrestrial unmanned robot.

1. General framework and objective

Since the end of the second industrial revolution, robotics and automation have lead to significant improvements on agriculture with particular attention to:

- Precision agriculture, defined as the management of crops heterogeneity both at time and spatial scale in order to enhance the efficiency of agricultural inputs to increase yield, quality and sustainability of production
- Auto-guidance on field crop machinery, which today can drive down a field with an accuracy unattainable by human drivers
- Machines that harvest fruits and vegetables for processing (e.g., tomato paste and orange juice).

In order to ensure an increase in productivity, scientific researches have now drawn their attention to the development of the next generation of sensing, mobility and manipulation technologies.

For long time the interests of agricultural research have been to follow well-defined traffic lanes with the purpose of minimizing damages on soil and plant growth. The introduction of automation and control technology has facilitated agricultural machine systems to follow paths spatially and temporally, especially by exploiting automated path planning to further optimize field work.

When robots have to achieve tasks that are too difficult to indicate the proper actions for all possible cases, it is necessary that they can perform themselves the most suitable solution to accomplish the task. In order to perform their action line adequately, robots require to think about the actions they are planning on executing, their future consequences and the side effects, whether they can be performed taking into account the different circumstances that may occur, and other situations. This requires that robots have an explicit representation of aspects of their environment to reason about. As a consequence it is necessary to know where the representation comes from, namely the generation and maintenance in real time of the environment, or at least some part of it based on past information collected by sensors, is an important aspect to take into account.

To design a planning system it is necessary to reach some targets by finding a solution to three main questions:

- World representation
- Actions representation
- Plan search process guidance

To answer these questions, the planning system should face the constraints imposed by the real world considering at the same time all the issues above-mentioned.

Therefore, the work developed here aims to find a possible solution able to link the recognition of the environment with the path plan which the UGV will use to explore it and eventually to interact with it.

2. Adopted approach

In order to correctly design a navigation algorithm, the objectives in the flowchart in Figure 1 are fixed. The first part focuses its attention on the development of a path planning algorithm that can be integrated in every environment: it combines the A^* search algorithm and path smoothing by exploiting the *Gradient Descent* algorithm.

The second part discusses how to generate a canopy segmentation from the mask obtained by processing images taken from unmanned aerial vehicles (UAVs). The developed algorithm is based on multiple steps: a first clustering of the mask is performed to identify each row, then the *Ordinary Least Squares* regression is applied in order to be used in the following clustering step to detect each parcel which composes the map by means of the *Dirichlet Process.* Finally a recombination of the rows is carried out for the purpose of avoiding the problem of missing plants and defective rows.

The last part addresses the issue of applying the path generation in order to cover the desired parcel with the cooperation of both path planning and clustering.

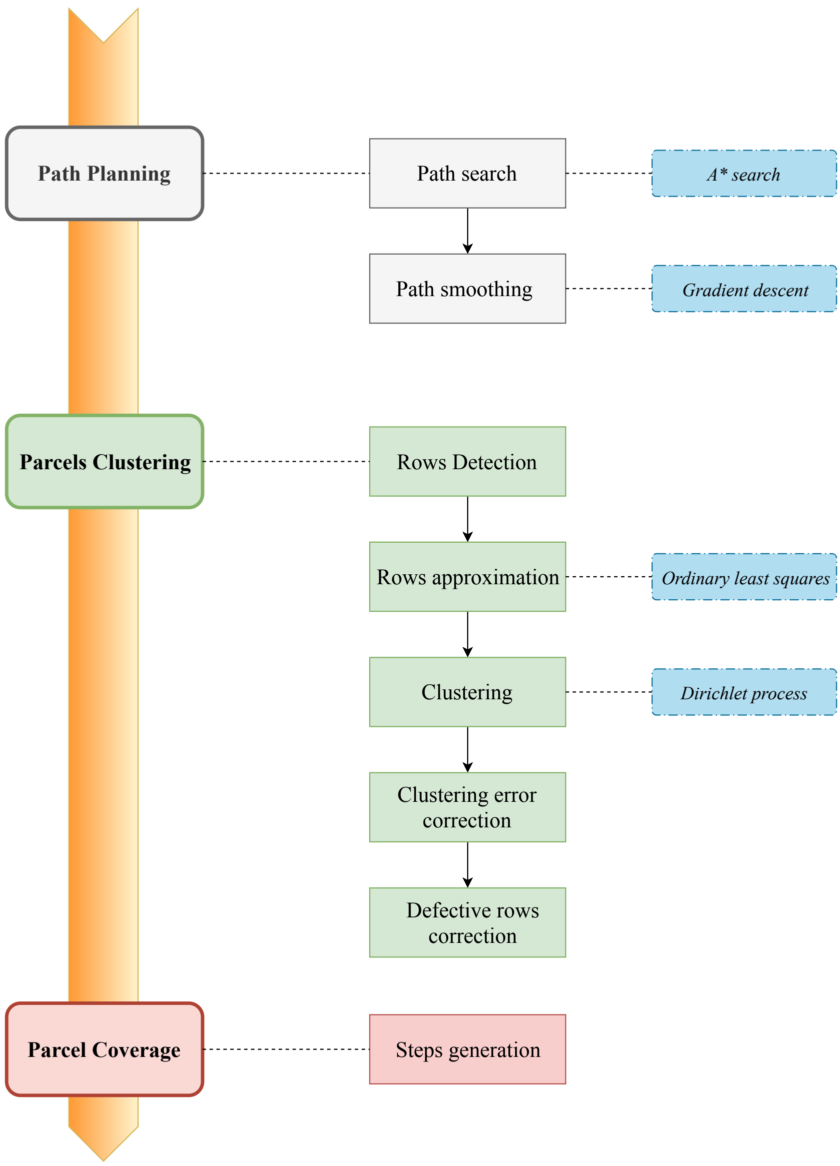

Figure 1.

3. Achieved results

The experimental results show that the work as a whole presents some weaknesses when dealing with environments that deviate significantly from the ones used in the development phase, which can be considered ideal cases where imperfections in parcels are due mainly to the presence of small areas where plants miss or defects in the image reconstruction.

For this reason the work developed can be considered a good starting point for further researches, trying to understand how to remove the errors that come out when important environmental changes occur in the map.

Besides, it is of great importance, once all the path plan has been defined, to deploy these information in the robot in such a way that it can cover the desired environment. To do this, the future work has already been defined, consisting predominantly of developing all motion controls which will allow to obtain a *Motion Plan*, and equally important being able to localize the robot in the environment in order to apply the just mentioned motion commands.