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UAV-assisted topological mapping for AGV navigation in vineyards

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INTRODUCTION

Topological maps have proven to be an effective representation to be used for outdoor robot navigation. These typically consist of a set of nodes that represent physical locations of the environment and a set of edges representing the robot's ability to move between these locations. They allow planning to be more efficient and to easily define different robot navigation behaviours depending on the location [1].

In the literature, the topological maps are sometimes manually created in an 2d occupancy map previously built by a robot [2], but this is not very practical or scalable when it has to be done in a 50ha vineyard with hundreds of rows. Other works focus on the vine rows classification using mainly Color Vegetation indices [3], however this assumes there is a green canopy which is not always the case depending on the time of the year. Focusing only on the rows also leaves other non-traversable structures such as fences, buildings and poles unmapped [4].

CONTRIBUTION

To overcome the aforementioned limitations, we propose a **pipeline to use UAV imagery as an input to create a topological map of the vineyard** where an AGV has to be deployed. The pipeline proposed to achieve such task contains three main steps:

i) Obtain a non-traversable map of the environment using the pointcloud generated from all the UAV images.

ii) Classification step to separate vine rows from other structures in order to define specific node placement and navigation behaviour according to the different areas.

iii) Compute the topological nodes and edges in the vine corridors and the remaining open space incorporating the semantic information from the previous step.

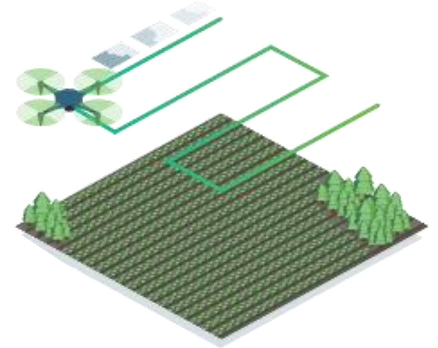
REFERENCES

[1] Hawes, Nick, et al. "The strands project: Long-term autonomy in everyday environments." IEEE Robotics & Automation Magazine 24.3 (2017): 146-156.
[2] Hiller, Markus, et al. "Learning topometric semantic maps from occupancy grids." 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).
[3] Cinat, Paolo, et al. "Comparison of unsupervised algorithms for Vineyard Canopy segmentation from UAV multispectral images." Remote Sensing 11.9 (2019): 1023.
[4] Santos, Luís Carlos, et al. "Occupancy grid and topological maps extraction from satellite images for path planning in agricultural robots." Robotics 9.4 (2020): 77.
[5] OpenDroneMap Authors ODM – A command line toolkit to generate maps, point clouds, 3D models and DEMs from drone, balloon or kite images.
[6] Zhang W, et al. An Easy-to-Use Airborne LiDAR Data Filtering Method Based on Cloth Simulation. Remote Sensing. 2016; 8(6):501.
[7] https://github.com/LCAS/topological_navigation

TOPOLOGICAL MAPPING PIPELINE

1 OBTAIN A NON-TRAVERSABLE MAP

Obtain UAV images

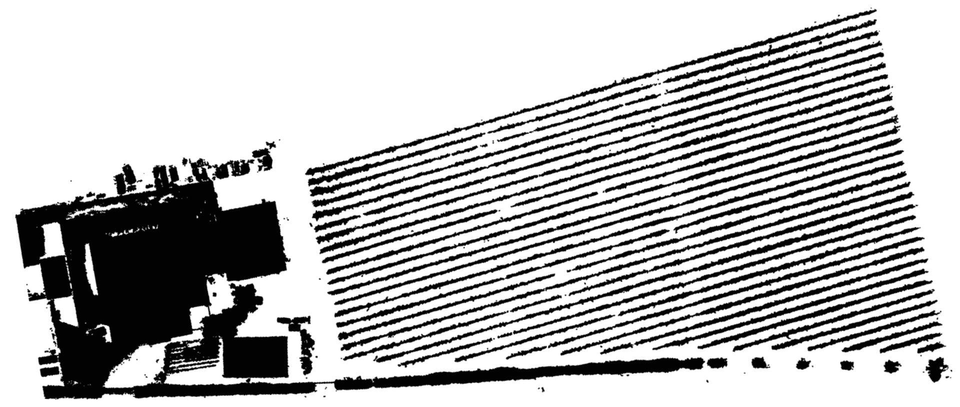


Take aerial 2d images covering the area where the AGV needs to be deployed.

Generate Pointcloud

Generate a 3d pointcloud using photogrammetry (Open Drone Map [5]) with all the aerial images. Example captured in Ktima Gerovassiliu vineyard (Greece).

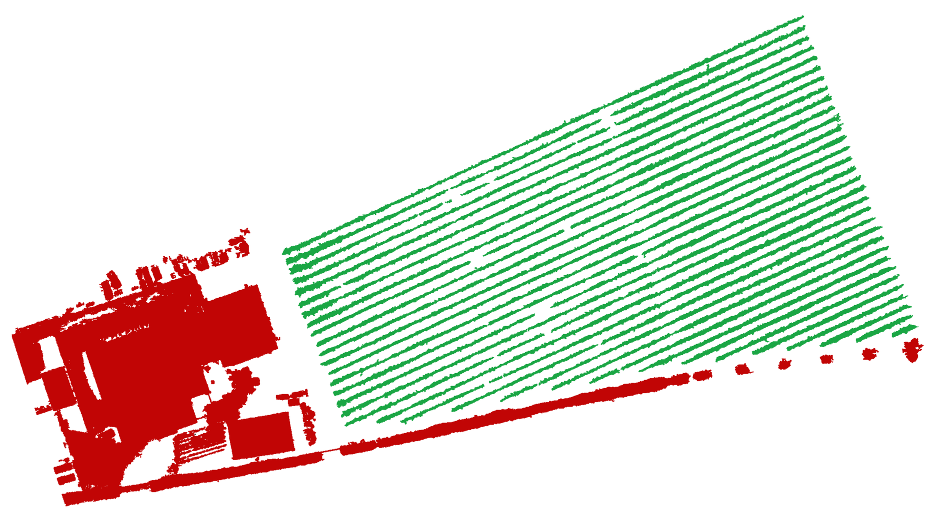
Compute non-traversable map



A cloth simulation filter [6] is applied to extract the non-ground points. These are then transformed into a height map that is later binarized.

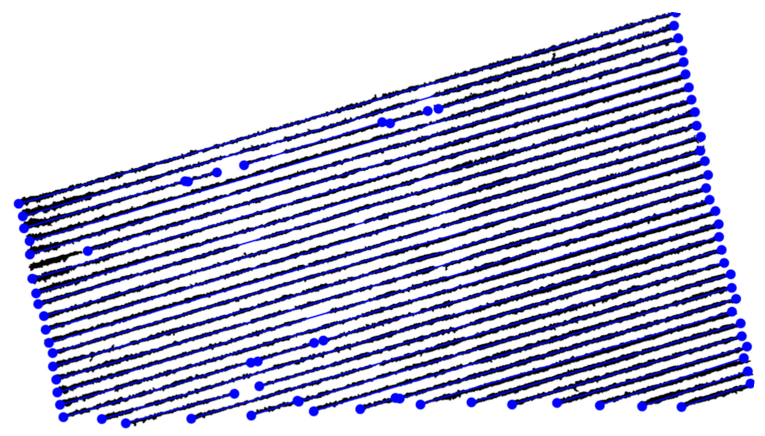
2 DETECT THE VINE ROWS

Cluster classification



Each cluster in the binary image is classified as row/non-row using Principal Component analysis.

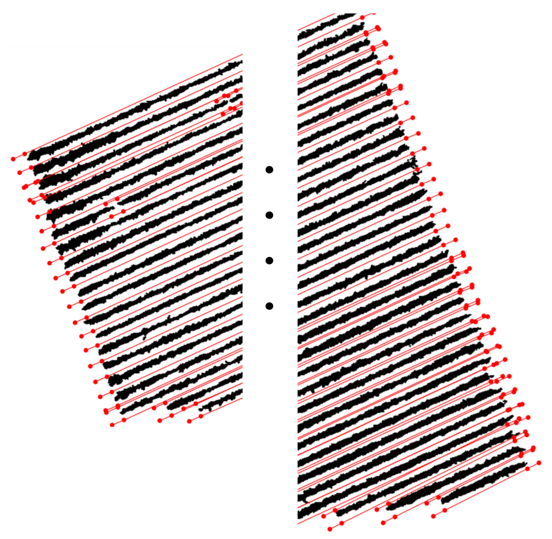
Compute row lines



Each cluster detected as a row is fitted with a line using the Hough transform. Consecutive lines are merged.

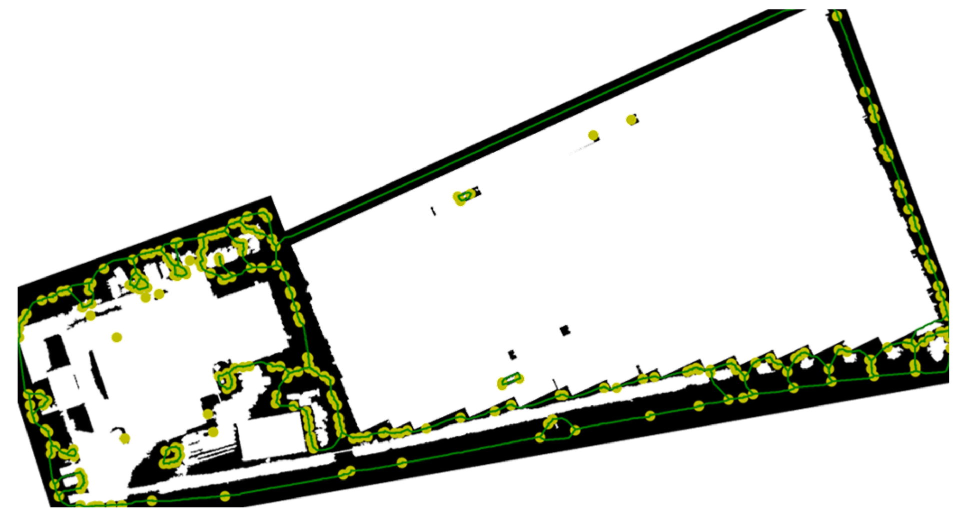
3 COMPUTE TOPOLOGICAL NODES

Corridor nodes



Using the row lines obtained, a set of topological nodes are computed for the corridors on both sides of the vine row.

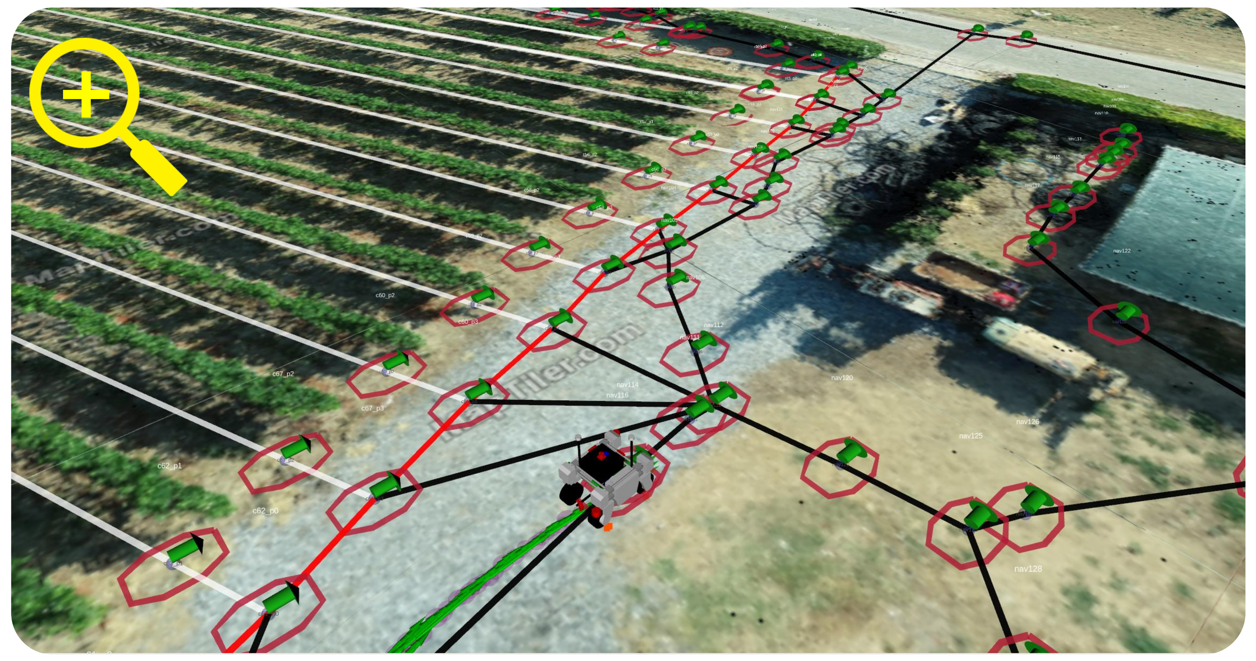
Open space nodes



All rows are masked using the lines and a skeletonization process is applied to the remaining free space. The skeleton is then transformed into a graph in which the nodes are used as topological nodes.

RESULT

All the nodes are transformed into map coordinates (red circles) and the edges between node pairs are computed. White edges represent corridor traversal behaviours, red edges define a corridor change and black edges define the use of *ROS* navigation stack. The final result is a topological representation that can be exploited by the AGV to operate in the environment using topological navigation [7].



Future work is aimed at refining the topological representation using the feedback from the AGV sensors as it navigates around the environment after deployment.

ACKNOWLEDGEMENT

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