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A GIS application for UAV flight planning

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Abstract: The flight planning for Unmanned Aerial Vehicles (UAVs) is extremely useful both in terms of planimetry and altimetry. Regarding the planimetry, it is needed to reach and operate on the region of interest, while for the altimetry, it is functional to plan the flight altitude as function of the obstacles along the navigation path. In this paper we propose an innovative approach for the construction of a georeferenced map of the obstacles based on Geographic Information Systems (GIS) technologies. In this way the path planning for the UAV navigation can be accurately managed by defining precise flight plans on a cartographic support where the obstacles are represented in a three-dimensional way. The employment of free and open source software only, makes the approach widely usable and customizable.

Keywords: Robotics, Navigation systems, GIS, UAV, DBMS.

1. INTRODUCTION

The planning of the flight and the management of the navigation of UAV is essential in order to identify the optimal route depending on the position and height of possible obstacles present in the operating zone [Niendorf et al., 2011, Muscato et al., 2012, Yu-Cheol et al., 2011]. Thus it is essential to trace a path in terms of planimetry and altimetry.

To this aim, the GIS environment is particularly useful to have a cartographic support that is accurate and precise for determining the route in planimetry, and to construct maps in which the altitude variation of the obstacles is represented and georeferenced.

Here we present a GIS approach to generate raster maps representing the obstacles present in a real urban environment. Our approach is based on the following main steps:

- Digitization of buildings as vector data shapefile(when a 3D numerical cartography is not available);
- Conversion of vector data to raster data using the GIS functionalities;
- Use of the "spline" algorithm to generate a raster that contains the spatial variation of the heights of the buildings;
- Definition of the possible path for the UAV in the GIS environment;
- Conversion of the path to waypoints successively stored in a text file made available to the UAV.

In this way each possible obstacle to the autonomous navigation of the UAV is perfectly localized and georeferenced in the urban environment.

This procedure has been tested on an urban environment where buildings are positioned as obstacles with different heights.

2. GIS OPEN SOURCE ARCHITECTURE TO MANAGE THE UAV NAVIGATION

The development of the GIS architecture for the autonomous navigation of the UAV is based only on free and open source software, since its source code is made available by the developers and therefore it is easily customizable.

In particular, the GIS architecture is composed by:

- A desktop GIS platform;
- A Web-GIS platform;
- A spatial database;

The desktop GIS platform (Figure 1) has been developed using QGIS 1.7.0-Wroclaw integrated with functionalities of Grass 6.4.

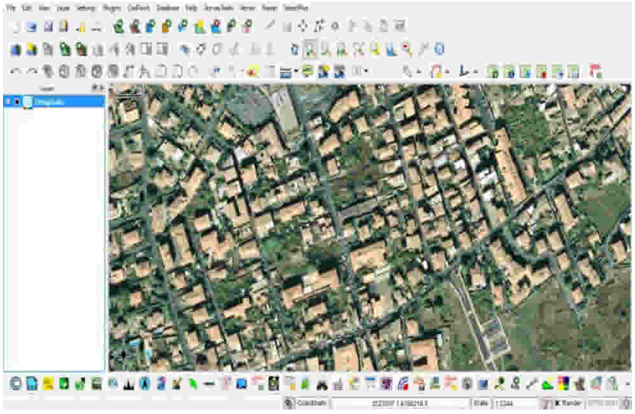

Fig. 1. Screenshot of the desktop GIS platform. On the left, the layer tree containing the legend of vectors and rasters. On the right, the area displaying the cartographic support that is a WGS84 orthophoto and the vector layer.

The Web-GIS [Daisuke et al., 2010; Mangiameli et al., 2013] has been developed with the free JavaScript library OpenLayers, available at the web link http://openlayers.org/.

The spatial database has been developed using PostgreSQL with the PostGIS geographic extension that allows the creation and management of geodatabase perfectly connectable to GIS platforms, both Desktop and Web side.

3. PROCEDURE FOR THE REPRESENTATION OF THE OBSTACLES IN THE GIS ENVIRONMENT

In order to develop the raster map of the spatial distribution of obstacles, we first load in the QGIS environment the cartographic support. The optimal support is a numerical cartography. If it is not available, other raster supports can be used, i.e. ortophoto or satellite imagery. For our tests, we used a orthophoto over which we defined a flight area.

Then we digitized the obstacles, e.g. buildings or trees, in the QGIS environment, associating a corresponding vector layer attribute table that contains an attribute for the height of obstacles [Scianna, 2011] (Figure 2).

Using the Grass functionalities in QGIS, the vector layer generated is converted into raster (with the tool "vector to raster") and finally a raster map is generated in which the altitude variation of the buildings is represented. We used the spline interpolation available among the GRASS functionalities for surface interpolation related to raster data (Figure 3).

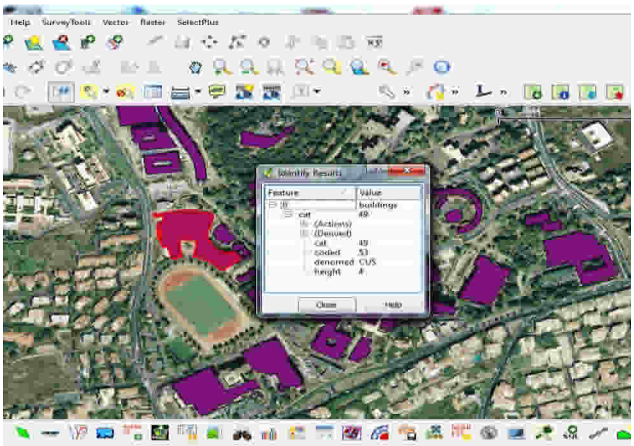

Fig. 2. Buildings in the area chosen for the UAV navigation, in QGIS software and associated to an attribute table that contains the heights.

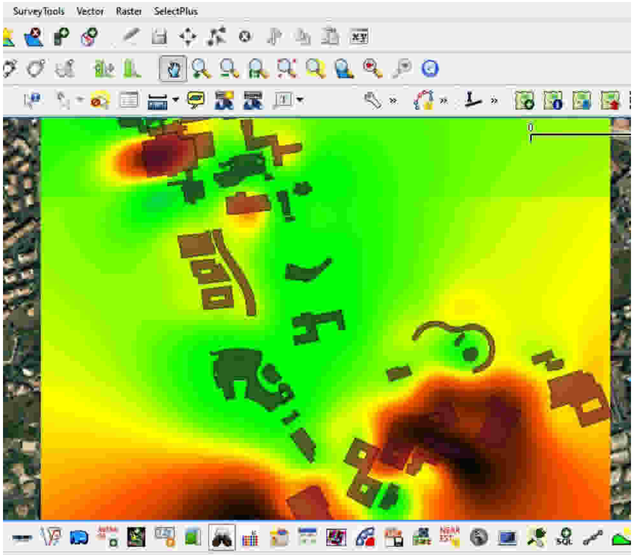

Fig. 3. Map in which the altitude variation of the buildings is represented in the area chosen for the UAV navigation.

The darkest areas of the raster map in Figure 3 represent buildings having the greatest heights. Using the properties of the raster layer in GIS environment, the complete legend can be displayed in which the color and the relative height associated to each building are indicated (Figure 4).

Obviously the raster map can be queried to obtain the height value associated with each pixel (Figure 5).

Using this approach, altitude limits can be easily displayed to manage the UAV navigation and to track the flight path.

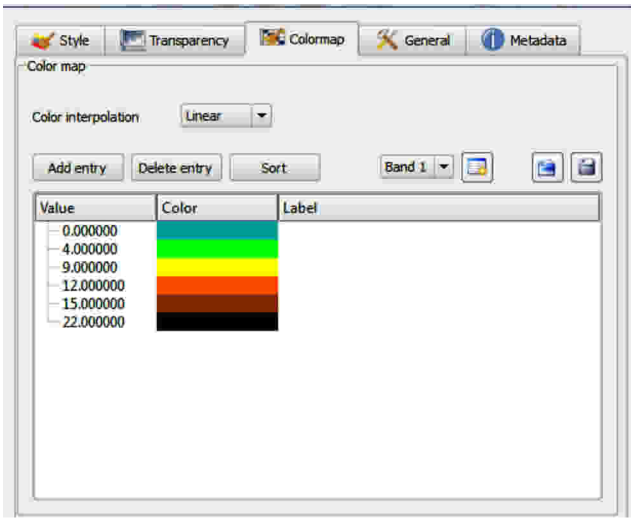

Fig. 4. The Legend shows the correspondence between colors and the values of heights.

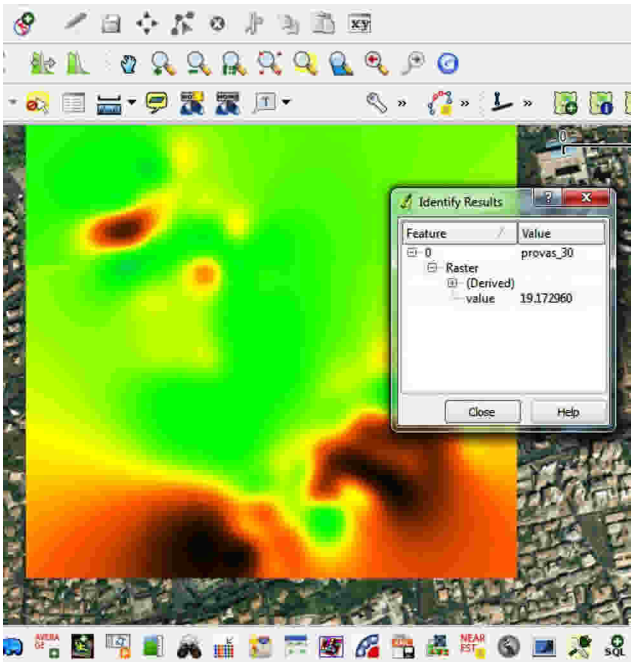

Fig. 5. Query of the map raster resulting in a pixel with a value of height

Using the raster map for the obstacle heights, we digitized the flight plan of the UAV as vectorial thematism in function of the actual navigation altitude (Figure 6).

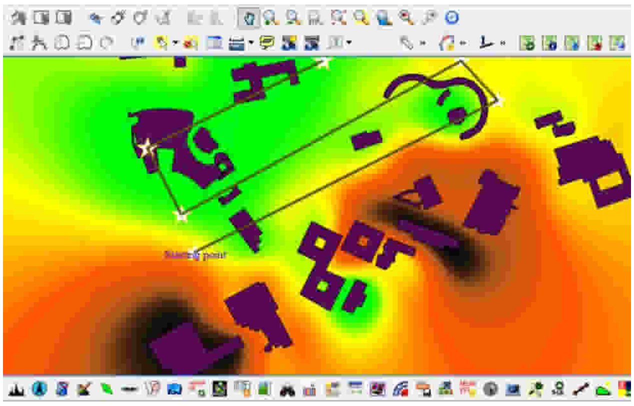

Fig. 6. Flight planning using the raster map of obstacle heights.

The flight plan is thus exported to the spatial database using SQL spatial queries [Mangiameli, 2013]. The format of the plan is an alphanumeric string exported to a row of a table of the spatial database. This string is then converted in a sequence of waypoints (stored in different rows of another table) from which the latitude and longitude coordinates are extracted and stored in two different columns (Figure 7).

The coordinates are finally standardized as a textual file format (csv, txt, ..) interpretable and directly usable by the navigation system of the UAV [Mangiameli et al., 2012].

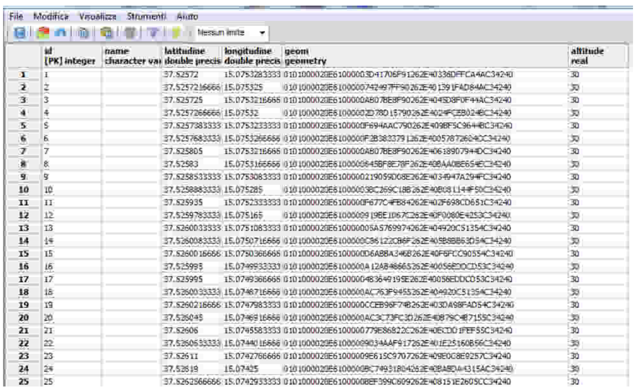

Fig. 7. The spatial table containing the data of the flight plan for the UAV

The raster maps developed in the Desktop GIS environment can be also loaded and used in the WebGIS to define a possible flight plan and monitor the UAV position in real time using the GPS mounted on board [Namie,2008]. All these activities can be performed thanks to a customization of the WebGIS platform [Daoxun et al., 2009; Mangiameli, 2013].

Fig. 8. The WebGIS platform in OpenLayer customized for the UAV navigation.

4. CONCLUSIONS

In recent years the use of flying robots, especially of UAVs, has become of huge interest due to their great reliability, to the reduction of costs and to the intrinsic characteristics of these flying platforms that often have very contained dimensions. Thanks to all these characteristics, UAVs have become ideal tools for monitoring the territory and hostile environments.

The variety of geo-mapping supports and of different reference systems available nowadays, makes it very useful, even necessary, to resort to the use of GIS environments for the correct interpretation of georeferencing and assigned flight plans actually covered.

The GIS allows to manage the UAV navigation on the bases of correctly georeferenced spatial data and to acquire any further information on the same reference system from the sensors installed aboard the UAV. The GIS technology can be very useful also for the management of the UAV navigation in external environments with the use of cartographic maps, orthophotos, satellite images and digital elevation models.

This paper describes two GIS platforms, a Desktop and a web, containing cartographic supports georeferenced with the accurate approaches of topography. Moreover a procedure for the management of the UAV autonomous navigation has been developed, in terms of both planimetry and altimetry by generating a georeferenced raster map that represents the variation in altitude of the obstacles. In this way, flight plans for the UAVs can be defined in real-time in relation to the possible obstacles present in the area.

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