

Road Cadastre an Innovative System to Update Information, from Big Data Elaboration

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Abstract. The proposed research activity is based on the study and development of advanced monitoring techniques for the inspection and mapping of road infrastructures. Data detection (initial and periodic) is one of the most important phases of the process to be followed for the knowledge of the current state of road infrastructure and this is fundamental for the design and intervention choices. This operation can be done both through traditional (such as GNSS receivers, total motorized station and 3D laser scanner) and innovative tools (such as remote sensing, mobile mapping systems vehicles or road drones and APAs). Recently, technological development has offered the possibility to use tools that allow continuous detection of the object to be investigated, and there is the possibility to have multiple sensors at the same time that allow to make high-performance surveys. The aim of the research will be the design and implementation of an innovative measurement and component sensor system to be equipped on technological systems for data acquisition. The research also consists on the implementation of dedicated algorithms for the management of the amount of georeferenced data obtained and their representation on GIS (Geographic Information System) platforms as "open and updatable" thematic cartography. In this context, the establishment and update of the Road Cadastre is also included, intended (in our application) as a computer tool for storing, querying, managing and visualizating of all the data that the owner/manager acquired on its road network. In it will be possible to represent the elements inherent geometric characteristics elements of the roads and their relevance, as well as the permanent installations and services related to the needs of the circulation; in this way we can obtain a continuos updated database that allow rapid selective searches for topics.

Keywords: Road Cadastre · UAV · Big data

1 Introduction

For some decades now, the introduction of electronic computers has led to a substantial revolution in the capacity of analytics and data collection, trhough the latest technological advances in the digital age.

Pratically, what was once acquired in the field manually with timely surveys and consequently with relatively high time and cost it can now be acquired through a

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growing number of devices such as sensors, actuators and cameras, characterized by ever-increasing automation (also in terms of the possibility of a subsequent integrated and dynamic analysis of the data) and increasingly reduced costs.

Among the many types of sensors that can be used in the infrastructure examples of hardware systems aimed at quantifying virtually real-time, or almost, traffic flows, noise, flooring status, geometric (for example, point clouds by laser scanning, etc.), are already today consolidated.

It will be possible to carry out visual inspections of the state of an infrastructure continuously and automatically via drones, land and aircraft, using artificial intelligence for the analysis of the collected data (in the form of instrumental measurements, but also images), so exceeding in this the intrinsic limits of a human operator in terms of fallibility and the ability to compare a large amount of data varying over the time.

The very first effect of this evolution is the increase in mobility-related information that can be stored in databases, whose availability and number for stakeholders grows at an exponential rate, also introducing the new aspect of the dynamism of the data over time; At the same time, even traditional systems for analysis and management are insufficient to process such a large amount of big data.

By focusing on the operation of transport infrastructures, a Management Authority therefore has available not only the data collected by sensors distributed on the network, such as data related to the monitoring of structures, traffic data and videos collected along the roadways, but also demographic and environmental information.

The archives also contain the register of works, the history of maintenance work with the related costs and all information related to the security of the infrastructure.

One of the main elements of the management of the road network thus becomes the system (of timely and forecasting interrogation and analysis) used to manage the database in order to arrive at informed decisions about the interventions to be carried out, also implementing decisions in time as real as possible.

Although the amount of data can be considered a distinctive character, the heterogeneity and the information structure strongly characterize this type of data and it becomes essential to be able to rely on effective methods and as much as possible automated. This characterization enhances the information useful for analysis, discarding unnecessary information to avoid a burden of the system, without the risk to incurre on excessive errors' simplifications or their amplification.

The biggest challenge of managing big data is precisely in developing methods that can predict future observations, optimize the information available, and at the same time find correlations between the information collected.

In this regard (management and use of the large amount of data acquired for infrastructure monitoring), the application reported in this note can be particularly useful.

In fact, the aim of the research will be the design and implementation of an innovative measurement and component sensor system to be equipped on technological systems for data acquisition. The research also consists of the implementation of algorithms dedicated to the management of the amount of georeferenced data obtained and their representation on GIS (Geographic Information System) platforms as "open and updatable" thematic cartography. This developed system is therefore an open GIS

to be considered as a valid tool also for updating the Road Cadastre; once completed and implemented it can be proposed to the Authorities responsible for its use.

2 Materials and Methods

2.1 Study Area

To test the methodology, it was decided to identify an area with a low level of traffic, and with all the necessary elements to be examined within the experiment.

The operations were tested in a road with low traffic in the territory of the city of Melito di Porto Salvo (RC), South Italy, on a low density and traffic area (Figs. 1 and 2).

It is an interurban road that connects the city center with a hamlet that develops along the bank of a river. The road reports deteriorations in some stretches, and failures, as well as stretches in which the horizontal signs are covered with brushwood of various kinds and there is also present a good number of vertical signals.



Fig. 1. Study area in Reggio Calabria South Italy

The study area can be reached through a 5-arch bridge, which crosses the Tuccio stream. It was built in 1924 during fascism and is the identifying symbol of the country of Prunella. In the first arch of the bridge, there is a concrete plaque, which recalls the construction data and the lives of the numerous workers sacrificed to build this majestic work.



Fig. 2. Case study: road and bridge in Reggio Calabria South Italy

2.2 Road Cadastre and Proposed Automatic Update Methodology

The road Cadastre represents the inventory of all public roads present in the national territory and has as its first objective the definition of the consistency of the national road network in a way compatible and integrated with the Land and Buildings [1].

Usually, the Road Cadastre must contain certain elements relating to the geometric characteristics of the roads and their relevance, as well as the permanent installations and services related to the needs of the traffic.

The segmented attributes of road elements could be grouped into homogeneous entities. Among these, the most significant are: (1) Road Element Section; (2) Road paving; (3) Road body; (4) Bridges, viaducts and underpasses; (5) Tunnel and subways; (6) Margins, gutters; (7) Road body protection; (8) Protection of the surrounding environment; (9) Lighting systems; (10) Parking pitches; (11) Retention devices; (12) Service relevance; (13) Works of hydraulic continuity; (14) Accesses; (15) Mileage signals.

For the survey of the quantities necessary for the construction of the Road Cadastre, the so-called Mobile Mapping System (MMS) [2] i.e. high-performance detector vehicles (VARs) are usually used to determine its position on time and acquire data from other different on-board sensors related to each other [3–5]. In this case, instead, an innovative procedure was tested which contemplate the use of a properly designed fleet of drones, which, proceeding from point *a* to point *b,* allows to acquire the images of the object of study. Subsequently, images are processed by suitable automated finalized algorithms to the identification of potholes, road signs, traffic lights, manholes and their subsequent visualization and updating of a basic cartography on the GIS system.

The captured data is therefore high-resolution images with high spatial sampling rates.

In this research, we focused specifically on the analysis of some of the attributes in the Database. In particular, we focalized the attention to the elements that can be identified through the classification and segmentation of the images acquired by the proposed system: the presence of deterioration of the road surface, the presence and maintenance status of the horizontal signs, vertical traffic lights and the presence of manholes.

2.3 Innovative Measurement System

We have used a fleet of automated drones connected to the cloud (or a local network) that are automatically recharged through special charging stations located in pre-established points. With the integration of the cloud platform, a real-time data feed is obtained from the drone fleet; this dataset is subsequently processed by our proposed algorithms for the selection of the images. The drones used are DJI Mavic 2 Pro, equipped with omnidirectional vision sensors and infrared sensors, DJI-branded technologies, such as obstacle detection system, intelligent features such as Hyperlapse and ability to set the flight fly points.

The data capture system planned the installation of two platforms along the path to be detected. These platforms are necessary to allow the charging of the drone battery and the transfer of data necessary for the next processing.

In this research we realized a mini light-weight unattended drone system, including a C500 charging pad, a charging landing gear, a tailored Mavic 2 Pro battery, a canopy, an OC(Embedded AI-computer), a LS (local server), an CS (internet server), a T3 (HDMI camera monitoring), a Loudspeaker and a DJI Mavic 2 10 parts.

Using this solution, we can control a fleet of automated drones connected to the cloud.

In particular, the process of this research is divided into three automated phases, schematized in the flowchart of Fig. 3 and that provide:

1. Definition of flight plan, in terms of GSD (Ground Sampling Distance), image overlay and waypoint route [6]
2. Image analysis: pre-elaboration – segmentation –classification. In order to improve the quality and precision of the images, the use of different ad hoc algorithms that involve the combination of various methodologies has been experimented (segmentation; Edge detector; Canny filter; Gaussian filter; Support Vector Machine - SVM).
3. Geo-localization data on the GIS platform in order to associate each element of the GIS with coordinates relative to the data implemented in the database [7, 8].

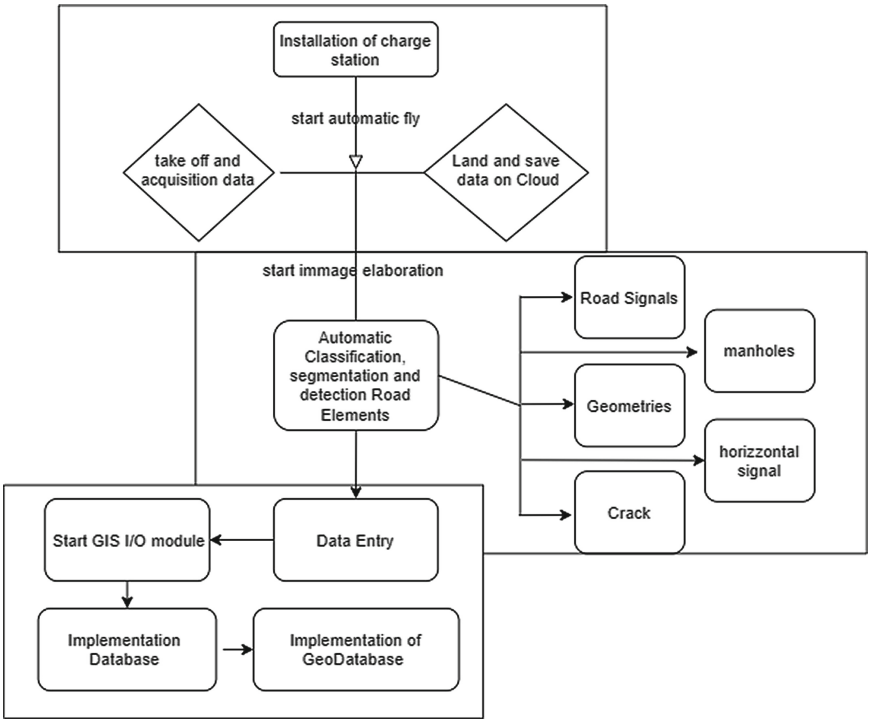


Fig. 3. Workflow automatic system Gis integration

3 Result and Discussion

3.1 Image Acquisition and Processing

In order to populate the database, we appropriately processed the images acquired through the described acquisition system, extracting the geometric characteristics of the infrastructures, the presence of deterioration of the road surface, the presence and maintenance status of the horizontal and vertical signs and the presence of manholes.

To better explain the procedure, we present the methodology applied to the classification of only a typology of crack (Fig. 4).

The acquired images (Fig. 4a) were automatically subjected to a pre-processing and enhancement process (Sobel and Prewit operator) (Fig. 4b–d), then they were segmented (edge detector, Canny filter, Gaussian filter) and classified (Segmentation and Classification (SVM)) (Fig. 4c and e) in order to be able to extrapolate the information we need (cracks, signal horizontal and vertical, light signal.. etc…).

In particular, the SVM classification was carried out in two phases [9, 10].

1) SVM Training.
2) Performance testing.

In the first phase, the geometric characteristics of the linked components assigned for SVM training were initially calculated [11–13]. Then, these features were normalized to a range. Kernel with radial base function (RBF) was chosen as a kernel trick, because the number of instances (connected regions) was not very large and the size of the space transformed with RBF is infinite.

The optimal training parameters for the SVM were found using grid search. During this operation, triple cross-validation was performed to correctly learn the different types of cracks. In this triple cross-validation, the training set was divided into 3 equal subsets. To ensure proper learning, a subset was tested using the trained classifier on the remaining two subsets. The goal was to identify good parameters in a such way that the classifier can predict exactly data test. After learning that the parameters had been determined, SVM was trained with the "One Against All" approach using the MATLAB LIBSVM library [14].

In the second phase, connected regions that were not used during SVM training were tested.

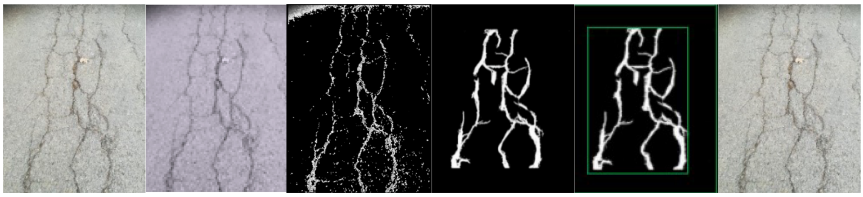


Fig. 4. (a) Input Images, (b) Enhancement, (c) Segmentation, (d) Post Processing and Image Enhancement, (e) Classification and Detected Crack Candidates, (f) Crack detection.

3.2 Database and Geodatabase

As is well known, the data in a Geographic Information System are traditionally divided into "graphs" and "attribute". The first are organized in vector or raster structures while the attribute data are made up of tables connected to the graphical data and connectable to each other through the rules of the relational databases (through the application of SQL commands on the table structures appropriately). Vector graphic structures are those that mostly use SQL commands for the connection between attribute tables ("select" and "join" commands). Generally, in this way the thematic cartography is produced, often as integral part of extensive and in-depth territorial studies. In these studies, the term "database" is sometimes used improperly, the set of tables connected to graphic layers defined as a database, often not connected to each other. A relational database, on the other hand, is a completely different thing of an archive of integrated and shared digital data, cause the relationships created by the various keys in the fields of the tables. In fact, storing a multitude of tables connected to graphic layers on hard disk does not mean building a relational database.

We can define a database as a digital data store. Generally, a software called DBMS (Database Management System) manages databases. The management of a database

consists of a whole series of operations (data storage, deletion, display access to the database, updating, processing). Similar to the data, these operations are stored only through tables (generally non-square matrices made up of columns (fields) and rows (records). The data of a database must be integrated and shared. This feature is of fundamental importance for the correct and efficient functioning of the database.

As mentioned above, integration means avoiding the duplication of a data item in the archive. Integration ensures that information is managed efficiently (for example, updates are faster) and is a good premise to avoid errors within the archive. Data integration is achieved by relating the different tables that populate the database. Relationships are achieved through the equality of common fields ("key" fields).

If geometric components are also stored in the database tables, we can speak of spatial databases or geodatabases. In this way, the database structure acquires additional potential, linked to the spatial analyses (often also very advanced) made available. So, the management software becomes a "Spatial DBMS" able to perform spatial queries and geographical elaborations of the data obtained from them.

Specifically, in our appliction the database was built with:

- the trajectory graphic subsystem (in ASCII format containing trajectory information) Table 1
- photo capture units of the drone (JPEG image folders related to photographic capture, and ASCII files containing the connection information between the trajectory data and the images,) Table 2
- the connection with the elaborations of the acquired data and the information of the database what was indicated in the previous paragraph what was (JPEG image folders related to elaboration, ASCII files containing the connection information between the trajectory data and the elaborated images).

Since there are a multitude of these elements, it is necessary to put them in connection each other by populating for each of elements a table also containing a reference to an element of the upper level [15, 16].

Therefore, the data structure used consists of a set of integrated relational table, some auxiliary tables that contain the source data and the information processed in progress.

Table 1. Trajectories table

Trajectories (contains survey data and association with photograms)
Id (primary key)
Id Session (unique identifier assigned to the survey session, and the name of folders containing the image files)
Time (numeric, instant of the measure)
Distance (numeric, odometric distance detected)
Latitude (numeric, latitude)
Longitude (numeric, longitude)
Altitude (numeric)
Heading (numeric)
Frame (string, measure associated file name)

Table 2. Table frame.

Frame (contains the pixel observations performed on the frames, the flat coordinates of the points in the map system and the classification of observations)
Id (primary key)
Id Session (foreign key to the Trajectories table)
Photogram (foreign key to the Trajectories table)
Typology (main classification numeric code)
Collocation (bin code to the axis [+ , −, NULL])
Segmentation (Segment end marking [Start, End, NULL])
Element (numeric, elements road code)

In order to relate the data described previously, an initial processing is carried out, that consists of the population of the table, using with the grids and defining the placement of the images within folders with the same name assigned to the measurement session. Moreover copies of the trajectories table, exported in XML format, and the folders containing the images are then delivered to operators to make frame observations on frames [17]. For the construction of the Geodatabase, we proceeded by creating and naming the database on pgAdmin and inside it, the PostGIS spatial extension was inserted. A connection to the database was built on QGIS in pgAdmin and through the "DB manager" plugin, PostGIS was chosen among the available spatial extensions (thus ensuring the connection between the database and the layers); thus it was created the database tables with spatial component [18]. The experimental system, using the aforementioned automations, was tested on the reference area by acquiring a number 180 frames, transferred to the cloud and processed. In the post-processing phase, the entities detected automatically were georeferenced and shown on the screen (see Fig. 5). In particular, 14 manholes, 52 between vertical and horizontal signals, and 96 cracks were detected.

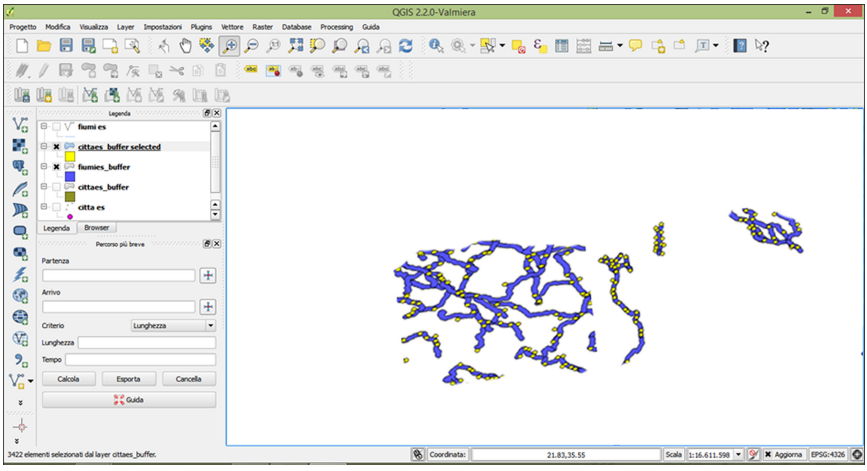


Fig. 5. Gis elaboration

We realized a first updated map showing the road network updated by the data collected by the proposed experimental system (Fig. 6). The roads are clearly visible from the images and both the presence of signs or artefacts and the conditions of the road surface can be determined. The images acquired by drone clearly show the details of the roads, and the data can be acquired regularly, without the aid of operators, thus facilitating operations and reducing costs and times.

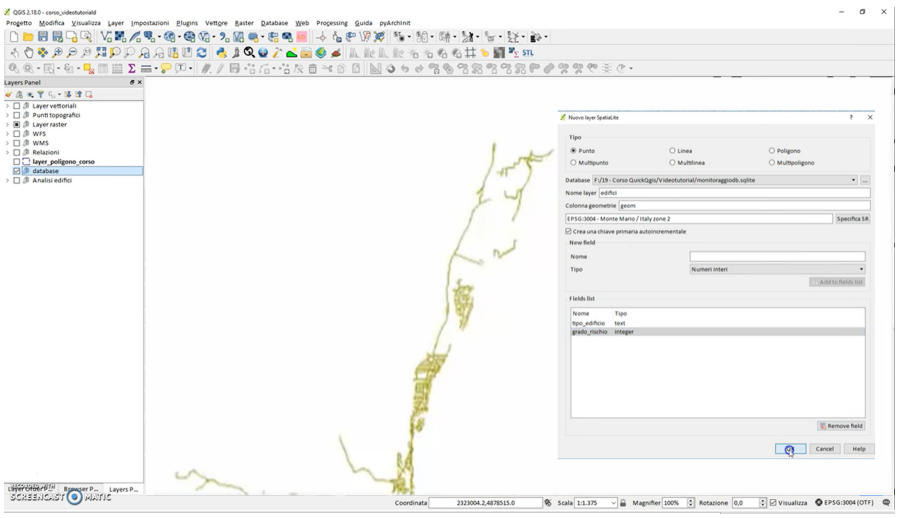


Fig. 6. Example of Gis results.

Thanks to the proposed system, through the creation of road network geodatabases the roads can then be monitored and consequently facilitate the scheduled maintenance process. The database shows the names of the streets identified in the study area, their types and conditions, etc.

In addition, we are still working to develop how to make the system usable in accordance with the new EASA regulations.

Moreover, other implementations and therefore additional information can be inserted into the Road Cadastre. To propose to the municipality of Reggio Calabria the Information System that we are implementing, we have populated the dataset with other additional information (census of the segmented attributes of road arcs, traffic flow data, air quality monitoring and noise pollution data); in order to highlight the regions within the study area, that are more distressed from this point of view and propose the most appropriate interventions to solve the problem (inserting noise barriers or traffic diversion interventions for example), in addition a basic function has been implemented for the planning of maintenance of various aspects such as road pavement, horizontal and vertical signage, works of art related to the streets and the complementary works.

For this purpose, in addition to the geometric and identifying information of the censused elements, the conservative and functional state must also be indicated, in this way it's possible to integrate the information entered in the Gis Cadastre.

4 Conclusion

In the representation of the roads Cadastre, clearly not all the roads have the same characteristics and for this they cannot be described in the same way; according to the context where they are (urban or suburban) some information are more or less useful.

From an economic point of view the construction of the Road Cadastre is very expensive; however, if implemented with road body maintenance functions, this can be a great tool for the management agencies, that can then schedule maintenance based on GIS indications.

In fact, even if the Roads Cadastre was born with the aim of surveying the existing road heritage and therefore has fundamental cognitive purposes, however, relying on the acquired data, we could extend the knowledge to elements more aimed at planning maintenance activities. Databases have been therefore enriched with a number of possible additional information that are useful for this purpose and that are not provided by the legislation. We therefore decided to analyze how to implement the Road Cadastre in order to be able to use it for planning the maintenance of horizontal road signs, through the implementation of a an Innovative System to Update Information on Road Cadastre from Big Data Elaboration.

Future developments aimed to the implementation of functions allow the planning of maintenance of additional elements such as road pavement, vertical signage and works of art related to roads.

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