A GIS FOR THE MONITORING OF THE HYDRAULIC SYSTEM OF THE ROYAL RACCONIGI PARK

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ABSTRACT

The importance of decision making tools is evident when managing properties with a territorial range; it becomes even more important when dealing with objects of historic and artistic value. The Architecture and Landscape Safeguard Office in Piedmont manages the Royal Caste and Park in Racconigi, a site mentioned in the UNESCO world heritage list. A restoration project of the hydraulic system of the Park has recently been started; the interventions were necessary to keep the system functioning: since it was first constructed, it has tended to fill with earth, and some canals have become completely obstructed. The aim of the works was to recreate the planimetric situation that was documented in an 1839 historic map, and to improve it by having the sections replanned by experts. These interventions required a correct knowledge of the whole Park morphology and the geometry of the canals and lakes; the works would also have led to great changes that should be properly documented and maintained in time. A cooperation between the Architecture and Landscape Safeguard Office and the Politecnico di Torino Geomatics research group was started. The goal was to develop a GIS that could help in the project, both in planning and in documenting the site changes. This GIS was also important to weigh the benefits offered by a GIS in the management of the entire site. The GIS project was an occasion to coordinate different activities: a survey campaign made it possible to create a reliable geometric base on which to overlay historical studies and hydraulic simulations. The tool also makes it possible to check the evolution of the works in the park, and to monitor the status of the hydraulic system. A specific tool was created for the easy management of the surveyed hydraulic sections; this tool makes it possible to quickly evaluate the need for maintenance interventions by estimating the volume of material that has to be moved.

1. INTRODUCTION

The town of Racconigi is located in the north west of Italy, about thirty kilometers South of Turin. The Royal Park and Castle are part of the so-called system of “corone di delizie” (crowns of delights), a group of royal residences that surrounds Turin, the former capital city of first the Savoia Kingdom and later then Italy. These residences have recently been included in the world heritage list by UNESCO (1999).

The Racconigi Park was not a simple place of pleasure for the king, it was also a productive centre. Evidence of this fact is the presence of a mill near the castle, and of a building called the ‘*Casino del Cacio*’ (‘cheese building’); there are also documents stating it was a farming centre, especially in the northern fields, near the farm called *la Margaria*. The role of the water and the hydraulic system in the Park has always been important. Besides the need of supplying the Park with water, it was very important to control the amount of water given to the surrounding area and the productive activities: the mills, and silk factories.

The great attention paid by the Racconigi masters to the hydraulic system of the Park was first of all due to economic reasons, and then to pleasure and landscape planning ones. Many famous architects worked in the Park; the historic evolution came to an end, during the reign of King Carlo Alberto, when the park assumed its present definitive form. After the last expansion, with the creation of the Great Lake, the system started to show a trend to be filled with earth, due to the very slow speed the water had and because of the slimmy water of the Maira stream. This fact, together with the lack of maintenance works in the period of the second world war and the difficult years that followed, led to the complete obstruction of some canals, and to a general decay of the whole hydraulic system and of the Park.

The Architecture and Landscape Safeguard Office in Piemonte, which manages the site, recently started a restoration project of the hydraulic system of the Park.

Figure 1. The hydraulic connection between the Park and its territorial context

The first problem encountered was the lack of knowledge of the geometries; a hydraulic replanning was also needed; last but not least, an instrument that was able to document the project choices and modifications and that could be used in the monitoring was also necessary.

2. THE GEOMETRY SURVEY

2.1 The Racconigi Castle Park Reference Network

At the beginning of the project, there was a complete lack of reliable knowledge on the geometries of the Park. There had never been a proper survey scheduling policy. It was therefore decided to first plan a permanent Reference Network, that would be maintained in time. The aim of such a choice was to create a group of stable groundpoints, suitably monographed, which could also limit the error propagation in the detail survey phase. These points were thought up in order to materialize a unique reference system on which to base the present and future survey works. In the planning of the network, there were different needs which had to be considered. First of all, the network had to be conceived to be useful for different scale surveys (from 1:500 up to1:50); considering the fact that the Park has an approximate area of 2 km^2 and the normal network density standard for high scale surveys, fifteen vertices were materialized. Eleven were placed uniformly inside the park, so that they could be easily reachable from any point in the park, and four were placed outside to circumscribe the area. The network vertices had to be easy to find, but well hidden, because of the intrinsic value of the site. In the end it was decided to measure the network using GPS, therefore a preliminary inspection campaign was carried out to check the satellite visibility.
The network was surveyed during a fast – static GPS campaign using Trimble receivers (3 double and 1 single frequency); in each survey phase, two receivers were kept idle on two reference vertices whereas the other two were moved to progressively occupy the remaining points.
The network was first calculated in a WGS84 geocentric system, then integrated in the national cartographic system (using IGM95 national network). The heights were derived from a high precision levelling campaign that included one IGM bench mark (IGM 0067 047).

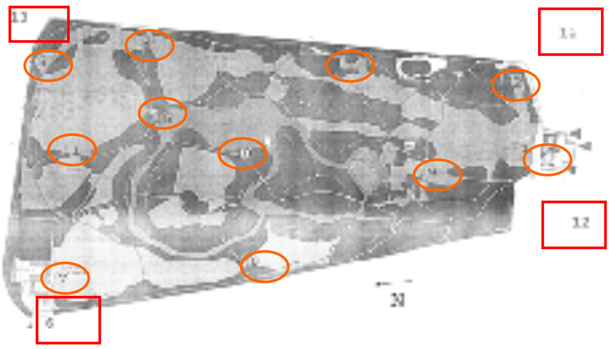

Figure 2. The Reference Network Planimetry of the Park

2.2 1:500 Map of the Park

Two aerial strips were taken on of the area (N-S direction); the twenty-four 1:3500 scale photograms have overlays higher than 60% and sidelays higher than 40%. Considering the commonly used standards, it was possible to create a 1:500 scale map.

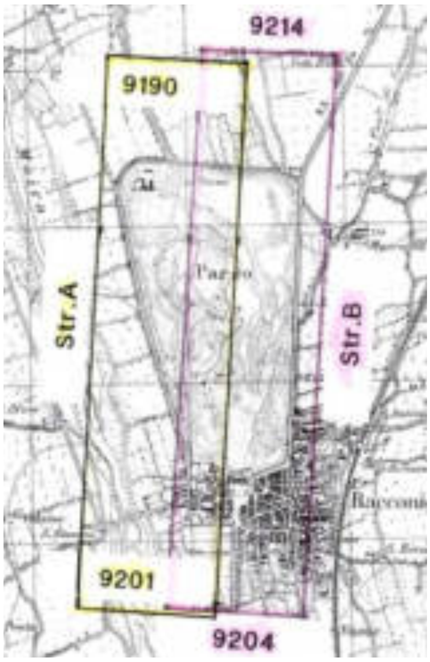

Figure 3. The aerophotogrammetry flight strips

First a triangulation phase was carried out, then the restitution of the elements of interest started.
The photogrammetric restitution was integrated with a terrestrial operation (tacheometry) linked to the reference network, as the highly vegetated nature of the park hid large areas. The terrestrial operation focused in particular on the hydraulic system of the park, surveying the canal banks and more than 80 canal sections to use in the hydraulic modelling.
All the terrestrial operations were conducted inside a refinement polygonal anchored to the reference network, in order to guarantee high precision. The two kinds of survey were overlapped to check the quality of both.

2.3 First True Orthophoto of the Park

As triangulated photograms and a photogrammetrically derived DEM were available, it was decided to produce an orthophoto of the Park. From this point of view, the park can be divided into two main zones: the first characterized by the presence of important buildings (the Castle and the *Margaria*, the farm of the royal residence), whereas the second has only natural land coverage. It was decided to make a true orthophoto on the first zone, to eliminate the errors due to the sharp discontinuity of the elevation model; starting from the mapping of the roof, a technique developed at the DITAG of the Politecnico di Torino was used to generate the true orthophoto.

Figure 4. Traditional (left) and True Orthophoto (right)

A traditional orhophoto was created on the other part of the park (zone 2) using commercial software. The two products were then put together, so the first 1:1000 scale orthophoto of the Racconigi Park was thus created.

Figure 5. Zone 1 covered by a True Orthophoto

3. THE GIS

The so far described operations made it possible to obtain a reliable geometric GIS base. A complete vision of the Park can be achieved with this tool, which offers the chance of overlaying different levels of information. The raw vector data obtained from terrestrial and photogrammetric surveys were edited (area reconstruction) and linked to the available information, for example, the sketches of the network vertices. The GIS environment was also supplied with products that are able to integrate the Park and its historical evolution description: the orthophoto, and the DEM.

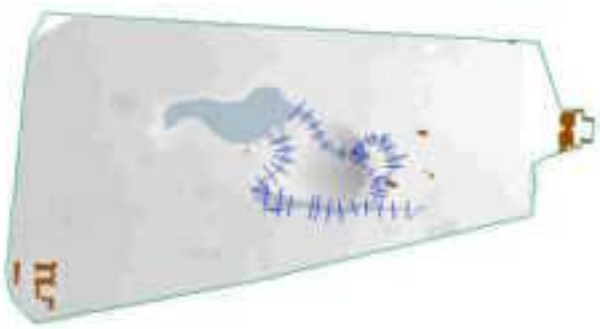

Figure 6. The TIN of the Park built in the GIS environment

3.1 The Georeferencing of the Historical 1839 map

The GIS environment was a useful aid in the historical research. In the hydraulic replanning of the park the Safeguard Office decided to reconstruct the historic situation represented in a 1839 map as faithfully as possible. Using a rational function deformation model, the different measurement units and the deformation of the map were considered according to the age and the digitalization process. The map was georeferenced by selecting homologous points on both cartographic supports, making the residual errors on the point less than 3.5 m; the main difficulty was to find elements stable in time. Most of the chosen points were fences and building edges and the main road intersection.

3.2 The hydraulic replanning

The hydraulic simulation was carried out by a specialist team at the Politecnico di Torino. The GIS environment was used to derive the geometric model of the hydraulic network from the survey supports. The canal edges were derived from the overlapping of the actual geometries on the georeferenced historic map in the GIS environment. It was attempted to change the actual situation as little as possible; when in doubt, e.g. for the width of the northern waterway that had to be chosen, the GIS potentiality was applied to historical document data. The archive research work in fact produced work reports about the creation of some canals: in particular the length, width, and depth of each part of the last expansion works. It was therefore possible to reconstruct the geometry of these canals from the document data: using the present northern waterway centre line information and the excavation data, the width data were placed on the actual map.

Figure 7. Matching of the photogrammetric vector layers on the georeferenced historical map

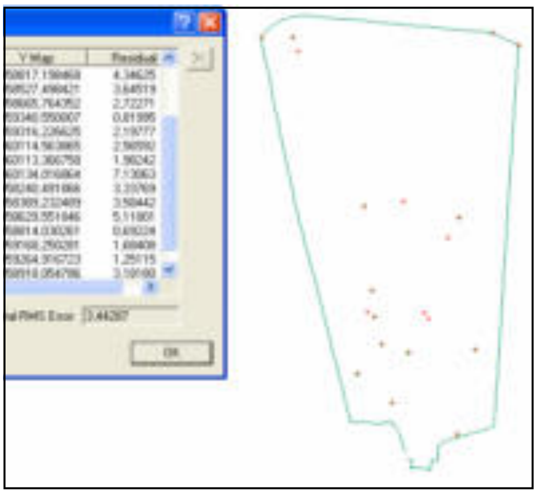

Figure 8. Map of the homologous points used in the georeferencing, and the RMS error.

A good matching was observed between the present day geometric information about the length of the northern waterway and the archived excavation documents. This interpretation work led to the design of today's restoration works done in that part of the park.

3.3 The evaluation of the volume that has to be moved

The GIS environment was also used to evaluate the volume of earth that has to be moved in the restoration works. The photogrammetric DEM information was first integrated with the canal section surveys; this operation was repeated using the canal section restoration projects. Two DTMs were obtained: one about the actual Park situation and one about the planned situation. Using raster calculator functionalities in the GIS environment, it was possible to map the DTM differences and to evaluate the excavation and filling volumes, and the consequent expected costs.

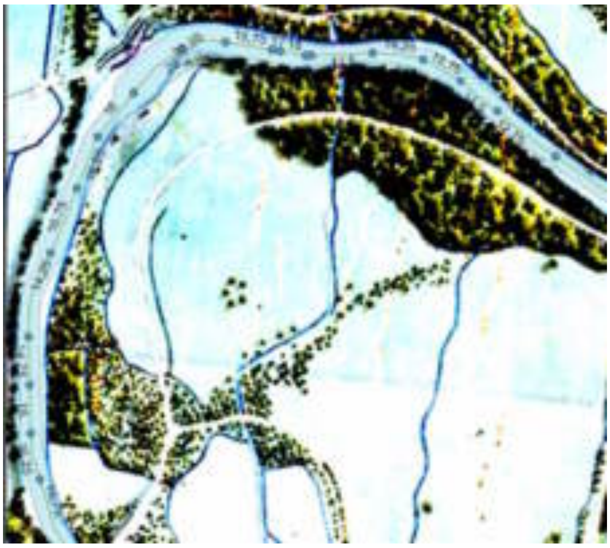

Figure 9. GIS aid in the historical analysis phase

Figure 10. Image of the differences between the two present and planned Park configuration DTMs.

3.4 The monitoring

A suitable database was set up to deal with the monitoring of the hydraulic system. It was planned to store the section drawings of the project and of the periodic control surveys. The control-sections were materialized and their planimetry inserted into the GIS. These sections were linked to the project and the monitoring data were stored in the database. By selecting the planimetric section it is possible to have access to all the available information on it, and therefore have access to the desired data.

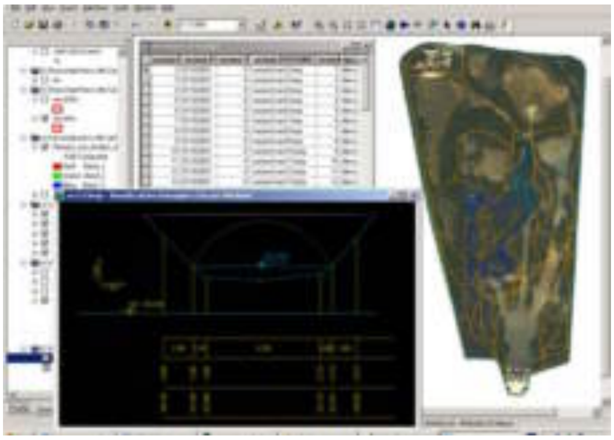

Figure 10. Monitoring of the hydraulic system in the GIS: a link between the planimetry of the control-sections and the surveys.

Beside the normal GIS tool, a personalized application of the software environment was developed for the monitoring. A specific toolbar was created for this application using Visual Basic when the GIS platform is ESRI ArcGIS. First of all it offers the user the chance to select a desired survey section and to calculate the area of that section, from a text file that contains the geometric information of the section. Then the area of the design-section is calculated and a comparison is made between the two situations: the user is supplied with the excavation and filling areas. In this way, it is easy to estimate the need for punctual interventions. This procedure can also be used to evaluate the amount of material that has to be moved: starting from the area of each section, the tool is able to automatically calculate the excavation/filling volume in the part of the canal between the chosen section and the following one (according to a predefined direction). The Torricelli formula is used for sections without sharp variations [1].

$$V = d * \frac{F_1 + F_2}{2} \quad [1]$$

where: F_1, F_2 are the two sections that limit the considered part of the canal

The tool can be applied in the most general cases where two sections have different excavation trends.

4. CONCLUSIONS

The cooperation between the Politecnico di Torino Geomatics Research group and the Architecture and Landscape Safeguard Office in Piedmont has led to the accurate knowledge of the geometries of the Royal Racconigi Park. A stable Reference Network has been created and surveyed, and will represent a base for all future surveys. This geometric knowledge concerns the Park map, orthophoto and DEM. The building of a GIS made it possible to create a valid management and analysis tool. This tool was used in the hydraulic planning of the interventions: it was useful to georeference a historical map and also to interpret data of the excavation documents. It was therefore possible to have a historically correct restoration plan. The GIS environment was also useful in the monitoring of the hydraulic system: both standard tools and personalized ones, made it possible to easily check the status of the network, the intervention needs and to make a first evaluation of the volume of materials that had to be moved and therefore of the estimated costs.

5. FUTURE EVOLUTION

It is planned to first improve the knowledge of the Park, surveying the buildings inside the park, and to insert them into the GIS project. It is then hoped to extend the hydraulic system database to structure the data concerning the monitoring of the secular plants. A cooperation with the Electronics Department of the Politecnico di Torino, which has started testing a sensor to monitor the stability of the trees, was started for this purpose: it is hoped to integrate these data with the planimetric sensor position in the Park.

Figure 11. True Orthophoto of the Castle i n the WebGIS environment.

As the Safeguard Office has offices throughout the region, it is hoped to extend the potentiality of this management tool on the Web. It is also planned to follow the government indications in favour of open-source software in public administrations.
A Web GIS project has already been started using the University of Minnesota Mapserver. It is also intended to extend the system to a management tool for the whole Park; Survey and document data about the park buildings will also be inserted into the system.

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