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Use of Global Positioning System in mine landscaping and visual impact assessment: A case study

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ABSTRACT

The satellite-based Global Positioning System (GPS) needs a clear view of sky for determining a geodetic position and hence it is particularly suitable in overall projects of open-pit recovery and landscape restoration. The purpose of such measurements is to make highly accurate topographic maps thus forming the backbone of a project. In the work presented here geodetic measurements are combined with advanced visualisation techniques and GIS applications in a possible recovery plan of the abandoned excavations of Bonucoro in the mining district of Orani, central Sardinia, Italy. Considering the naturalistic and geographic settings of the mining area and its surroundings, a few proposals concerning the re-utilisation of these excavations are presented. The preparatory work consisted of the area characterisation by carrying out a topographic survey followed by a geodetic control network establishment by the GPS to describe the morphological features of the landscape and for the subsequent three-dimensional analysis and geoprocessing. The final step involved the use of VueInfinite, a computer program capable to integrate graphical data with geological and morphological attributes. It was also able to create a virtual 3D scene of a present, past, or future landscape required for visual impact assessment.

INTRODUCTION

Global Positioning System (GPS) is a tool which can determine its own position without any relation to the topography or other factors. It is a satellite-based system designed to operate 24 hours in all weather for the position determination on the earth with global coverage. The GPS receiver, which tracks the satellites, can be mounted on a tripod and centred on the exact point whose location is required; it decodes the satellite signals and computes the position in respect of latitude, longitude, and altitude. The receiver data can be transferred to a computer to calculate the positions and heights of points using post-processing transformation software. A clear view of sky is needed for working with GPS and hence it is particularly suitable in opencast projects for estimating the excavated volumes in overall projects of open-pit recovery, modelling, and landscape restoration (Sudhir et al. 2002). The aim of such geodetic measurements is to make highly accurate maps, involving topographic maps and the maps of present locations of historic buildings on the ground, thus forming the backbone of a recovery project. Nowadays with more advances in computer hardware and software, it has become possible for the remediation and restoration workers to produce three-dimensional virtual models and to interact with geographical and geological data. The aim of this work was to combine geodetic, conventional, and satellite measurements with advanced 3D modelling and visualisation techniques in conjunction with the GIS in landscaping of an abandoned excavation in the talc-chlorite-feldspar mining district of Orani, central Sardinia, Italy, where several mining sites have long been exploited. Most of these are open-pit excavations, which at times cover several hectares, especially in talc mining where the ratio of overburden to talc frequently reaches a value of 35. The abandoned excavations have not been recovered as yet. There is a possibility of recovering the open-pit of Bonucoro (in the district of Orani) considering its morphology and the presence of abundant water (from aquifers drained through faults crossed by mining works). Considering the naturalistic and geographic settings of the mining area and its surroundings, a few proposals concerning the reutilisation of these excavations, through stabilisation and remediation interventions, are here presented using the conventional aerial photo interpretation techniques and new techniques such as GPS, Computer-Aided Design (CAD), and Geographic Information System (GIS). This integrated method enables computer-aided image analysis to generate three-dimensional perspective views.

GEOLOGICAL SETTING AND SITE CHARACTERISATION

The Orani mining district is situated in the granite batholith of Central Sardinia still covered by extensive roof-pendants of Palaeozoic metasedimentary rocks, which in the study area include micaschists, marbles, and gneisses. These rocks are partially overlain by Tertiary volcanic rocks to the west. Almost all of the Palaeozoic succession hosts several

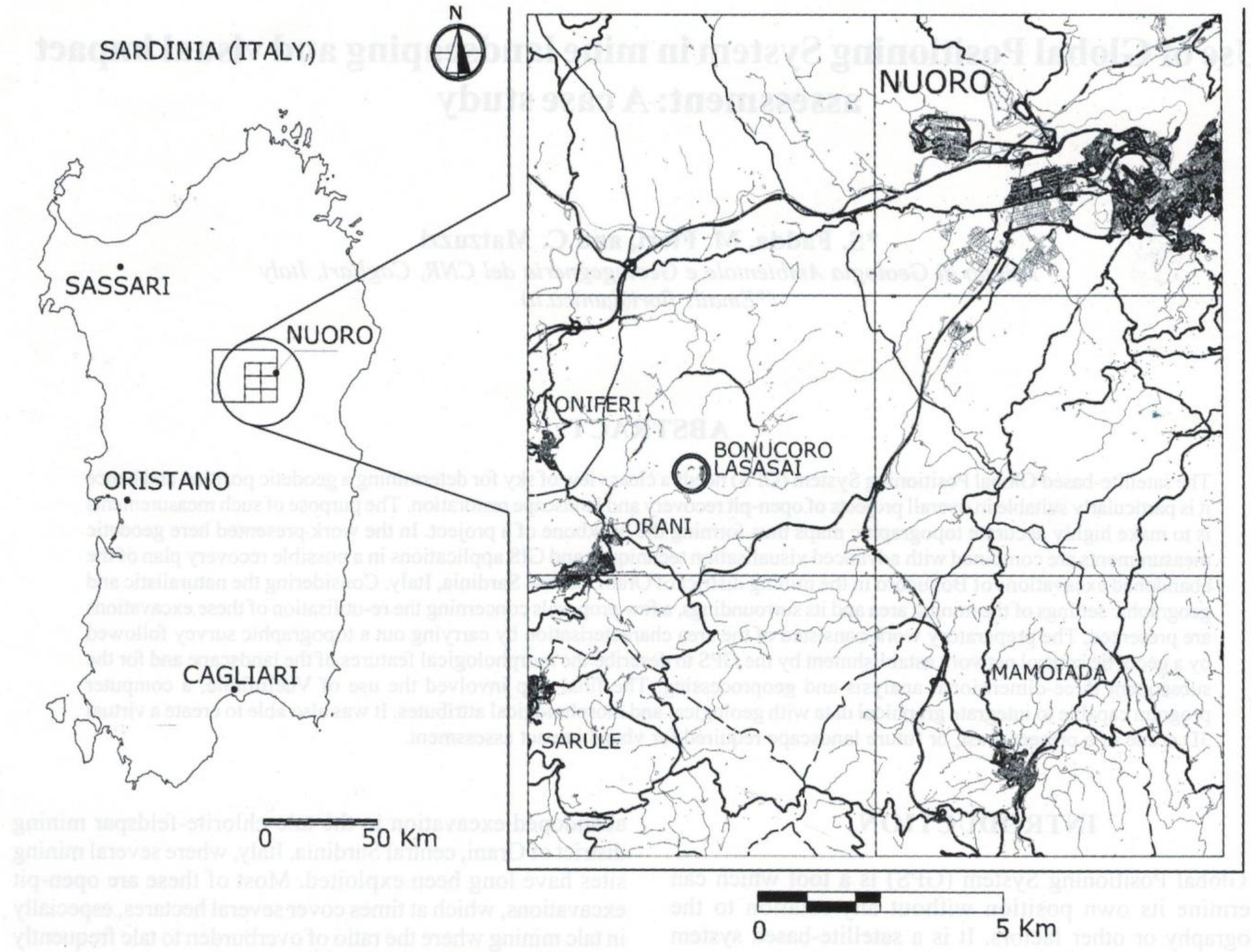


Fig. 1: Topographic sketch map of the mining district of Orani

occurrences of albite-chlorite, talc, and Mg-chlorite bodies. These bodies are of economic size in the district of Orani; the talc mine of Sa Matta and the feldspar mine of Is Paduleddas are currently in operation.

The old talc mine of Lasasai-Bonucoro is situated about 3 km northeast of Orani (Fig. 1). All the talc and chlorite open-pits excavations were dug between the mid fifties and the mid seventies of the past century. Since the exploitation reached a high overburden to ore ratio of about 35, with the deepening of the works, especially in the Bonucoro pit, the excavation resulted in a large and wide cavity. Both the Bonucoro pit and another minor but important one of Lasasai are now occupied by two pools (Fig. 2). The elongated form of the pool is related to the lenticular shape of the talc-chlorite bodies, controlled by fractures. The Bonucoro lens occurs between two N–S-striking faults; the eastern one dips 60º–70º E and marks the talc-granite contact; the western one dips 45º N and marks the talc-micaschist contact.

The Lasasai lens follows a fault with 50º–60º trend and 40º E dip, which locally marks the granite–micaschist contact. A detailed mapping has revealed the main structural features of the granite on the eastern side of the Bonucoro pit. Besides the main N–S fracture system, several other fault systems occur, and among them those striking 60º, 130º, 30º, 155º, and 90º are the most important ones. This results in a highly fractured sector, and many of these fractures are open, and only seldom filled with talc and (or) chlorite and calcite. This fracture system also accounts for the occurrence of a possibly deep aquifer in otherwise impermeable rocks, given its apparently constant flow. The footwall of this fault is inferred to be made up of less fractured metamorphic rocks. Indeed, even after pumping a great deal of irrigation water to surrounding farms during a long and severe drought the Bonucoro pool lowered only by about 1 m, while the minor Lasasai pool, which was not subjected to water pumping, did not lower at all.

These two pools came into existence after mine termination when water from the surrounding region began to accumulate in the two pits. The water level in the Bonucoro pool is at a 698 m altitude. It has a maximum surface area of

Fig. 2: Topographic map of Bonucoro area

about 11,000 m^2, and a maximum depth of about 14 m; whereas the recorded minimum surface area is 10,000 m^2 with a corresponding depth of 13 m. The minor pool of Lasasai also formed after the end of the exploitation, but it is only a few metres deep. Its surface area is about 2,000 m^2 and water level is at an altitude of 685 m. In both pools the still water looks quite clear. This apparent purity was also confirmed by analyses performed on the Bonucoro water, which was classified as the oligo- (with low-ion-content) mineral water.

Besides the possible water use as a commodity, the pools themselves and their surroundings may represent a resource. Despite its mean altitude approaching 700 m, it has a landscape of rolling hills with widely spaced level grounds – especially to NE of the Lasasai pit. The small downstream valley N of Lasasai also displays a broad bottom and gentle flanks. There is a dense forest both in the above valley and around the pits. The exploitation benches of the excavations are often broad and can be variously utilised (Fiori et al. 1997, 2004).

PROJECT WORK PLAN

The rehabilitation activities of this area include: 1) levelling and re-modelling (by balancing cut and fill) of uneven landscapes such as mine dumps; 2) restoration of the lost soil cover and rehabilitation of the waste disposal sites applying such re-vegetation techniques as grass turfing, hydroseeding, and sprinkling; 3) re-vegetation of the cut slopes and poorly vegetated areas (e.g. benches).

Preparatory work

To reach these aims the preparatory works consisted of: 1) the preparation of a detailed plan of the mine workings by carrying out a topographic survey integrated with a photogrammetric examination, in order to define the levels of the different benches, quarry tops, and surroundings; 2) geo-referencing of the existing road network; 3) geological survey especially around the contacts of formations; 4) finding of historical photographs illustrating the evolution of mine workings for evaluating the landscape changes brought about by mining; 5) complete visual analysis of the area by taking suitable photographs and preparation of a photo mosaic for photogrammetric survey in order to characterise all the hydrogeological, morphological, and landscape features; 6) preparation of a detailed topographic map of the area and modelling of the present situation as well as of that foreseen after the proposed environmental rehabilitation using triangulated irregular network (TIN) and digital elevation model (DEM) (Borraccini et al. 2003).

Geodetic measurements

The accuracy of a GPS survey depends upon many factors such as receiver quality and receiving duration, amount and quality of data acquired, signal strength and continuity, atmospheric conditions, site obstructions, and satellite geometry.

A good quality hand-held TOPCON RTK GPS real-time receiver with a multi-parallel channel unit was utilised throughout the work for collecting field data (Fig. 3). A data cable connected to the GPS unit was used to export the waypoints to a PC equipped with commercial software to download and export data from the unit. The GPS settings and operating procedure are given in Table 1.

A geodetic control network was first established covering the entire study area. In order to describe the morphological features of the landscape, the altitudes of selected points were recorded. Traverse points were set up for densification of the network as needed including hard break-line information to avoid smooth interpolation across these lines. Three local permanent markers were established to serve as main control points and georeferenced in the World Geodetic System 1984 (WGS84) co-ordinate system. The GPS measurements were then exported for subsequent three-dimensional analysis and geoprocessing using commercial GIS, CAD, or VueInfinite software.

Post-processing of data in GIS or CAD environment

With the aim to generate a realistic virtual representation of the rehabilitated area it was necessary to develop a graphic interface which facilitates the interaction with GPS topographic data. A DTM in TIN format of the site and its environs was produced in the CAD environment with the '.dwg' format using AutoCAD Civil Design Release 5.0 which allows interoperating among other software solutions and connection with GIS. The generated application is capable

Fig. 3: Photo of the TOPCON RTK GPS System

of handling topographic data as DEM in raster '.grid' format for surface reconstruction (Fig. 4). The final step is represented by the use of e-onsoftware's VueInfinite (scenery generator) that, combined with DEMs, is capable to integrate graphical data with geological and morphological attributes, to create essential topologies, to perform spatial analysis, and finally to produce thematic maps generating virtual 3D landscape environments (Fig. 5). In addition, the frequently used software program VueInfinite which supports a wide range of surface definition parameters and image-rendering enhancements, was employed to give an imagination of past, present (Fig. 6), or future landscapes (Fig. 7), so that the anthropogenic or natural changes can be modelled through consecutive images using different overlays for understanding the landscape development process and to carry out the visual impact assessment.

DISCUSSION AND CONCLUSIONS

The remodelling and restoration or improvement scheme for the Bonucoro site has been designed taking into account the strongly changed local topography in order to enhance the ecological value of the area. A detailed landscape reconstruction and assessment of potential visual impact was then required, since the site has economic, recreational,

Table 1: GPS configuration settings and operating procedure

Type	Topcon GPS: RTK (Real Time)
Antenna	Legant GGD: Centre of phase zero
Receiver	Legacy: H GD 40 L1 GPS
Datum	WGS 84
Units	Metric
Coordinate system	Geographic UTM: WGS 84
Antenna base	Height: Hb 1,2,3 = 1.40 m; Hb3 = 1.45 m
Antenna rover	Height: Hr = 2 m
3d-manual mode	Minimum 5 satellites: Maximum 9 satellites
Signal strength	Minimum level of 6
Satellite elevation	15 degree angle of visibility

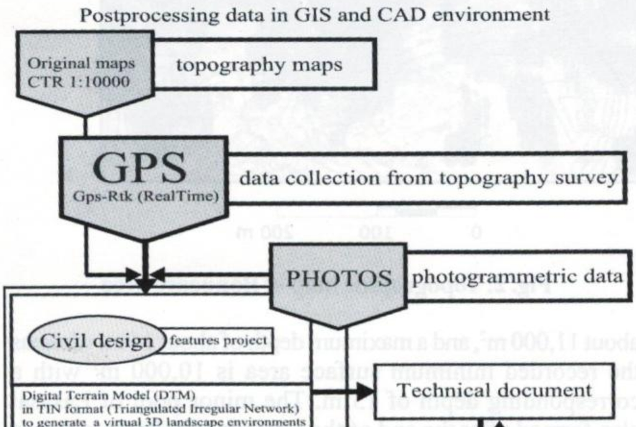
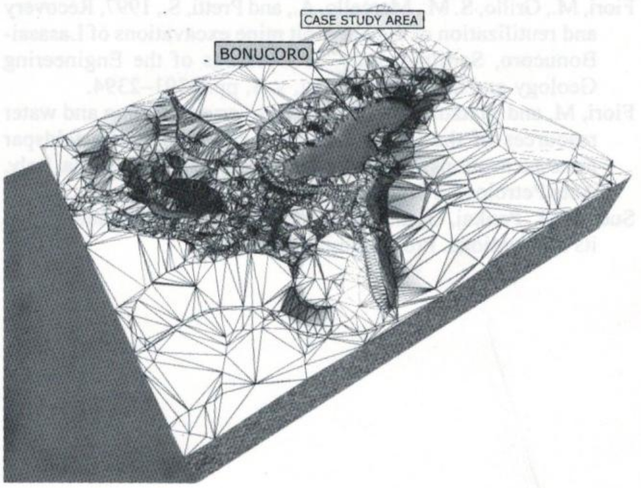


Fig. 4: Flowchart showing the post-processing of all data by computer software

and touristic opportunities. However the site improvement should be centred on the already existing large water body. Structural consolidation and anti-erosion works on the pool banks, the consolidation and stabilisation of the slopes, restoration and (or) improvement of soil characteristics would be designed to blend into the existing hills that form the slopes of the landfill void. A detailed, computer-based model of the restoration scheme for the site is a formidable aid to illustrate the proposed changes and the merging of the final restored landform into the existing, adjacent landscape. Planning and modelling (which involve the monitoring of landscapes by surveying and mapping) for

5a



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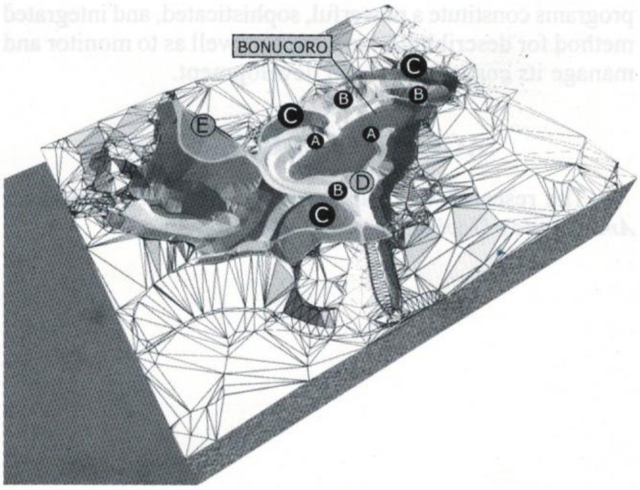

Fig. 5a: TIN models of Bonucoro area showing: a) present site model comprising the area under study; b) post-project site model depicting the rehabilitated zones as follows: A: Structural consolidation and anti-erosion works on the pool banks; B: Consolidation and stabilisation of the slopes C: Remodelling and (or) improvement of soil characteristics; D, E: Preliminary works to recover the existing structures for recreational, educational, and naturalistic activities

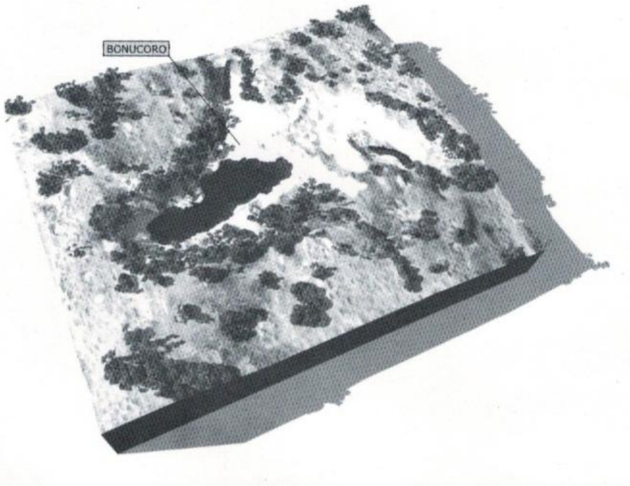

Fig. 6: Present environmental model of Bonucoro area with geomorphology, soils, and vegetation maps as rendered by VueInfinite software

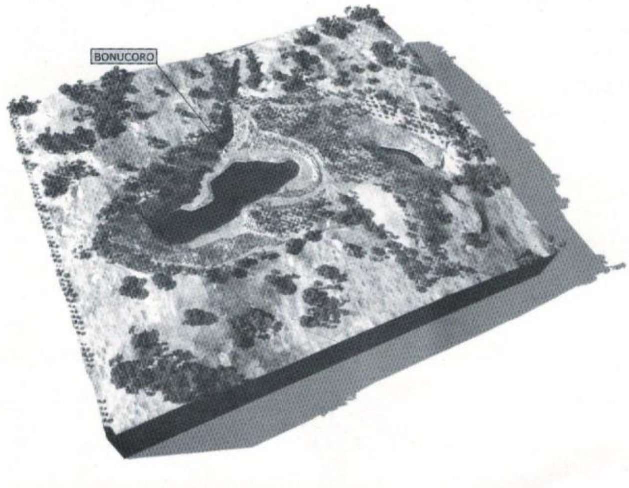

Fig. 7: Rehabilitation works proposed at Bonucoro and its vicinity

future development of the abandoned quarry sites require high costs, and hence they are often neglected. With modern surveying and advanced visualisation techniques, landscape documentation and visualisation have become affordable and rewarding. Especially when combined with GIS, complete 3D digital reconstruction and rendering programs constitute a powerful, sophisticated, and integrated method for describing a landscape as well as to monitor and manage its conservation and development.

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