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New instrumentation for aerial gradiometric survey

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***Abstract* – The SAGAcE (*Sistema Avanzato di MonitoraGgio AmbiEntale*- ADVANCED ENVIRONMENTAL MONITORING SYSTEM) project which has as its main objective the environmental monitoring of water, air and soil. To know the state of the environment with objective data, it is advisable to create detection systems located throughout the territory, which periodically acquire a series of specific parameters for the main environmental matrices (air, water and soil), or which allow, if necessary, a punctual detection, through specific missions, of the quantity of pollutants in large areas and with low costs. With these systems it is possible to define the safety conditions of the areas in question, controlling and preventing the pollution factors in order to comply with current regulations. The state of the environment has an important influence on the state of conservation of archaeological and monumental assets. In this work some of the results of the project are presented.**

I. INTRODUCTION

The contribution of environmental pollution is estimated to be around 8-9% of the total in the developed world, both in terms of mortality and Disability-Adjusted Life Years. In addition to the problems related to acute poisoning, the cumulative impact of exposure to toxins and various chemical combinations can be a relevant factor in a number of health conditions and chronic diseases. Furthermore, monuments with great cultural and artistic interest are often located in areas where anthropic activity is non-negligible. Consequently, air and soil pollution exhausts from industrial plants, and public transport mainly contributes to the damage of building exteriors.

Atmospheric and soil pollution acts as a noticeable accelerating factor in the material deterioration of buildings

An original approach towards establishing the relation between monuments and pollution [1] was proposed for the quantitative sampling on the cement mortar surface of a modern sculpture, the Camerlata Fountain in Como, Italy. Chemical analysis of the stained-glass windows and characterization of the patinas developed at their surface are an unavoidable first step in the definition of the best restoration practices to be followed. For the preservation of stained-glass window in the Pedralbes Monastery, Barcelona, Spain, the combination of X-ray diffraction techniques and Fourier transform infrared spectroscopy techniques has demonstrated its potential for the determination of the degree of weathering via the characterization of their patinas [2]. The study of medieval-like model glasses, exposed to simulated atmospheric conditions, permitted the evaluation of the role of both the composition and the surrounding environment on potash–lime glass weathering [3]. This study also highlighted the differentiation to make between wet and dry deposition conditions in the weathering process.

Since monitoring is a fundamental activity for the protection of the environment. Is important, through monitoring solutions, to reduce the risks by detecting pollution alert situations that are involuntary or caused by offenses that, in the past, have been committed and which, as previously highlighted, even today they are still made. To improve the effectiveness and efficiency of monitoring activities, scientific-technical-management solutions are required. It is necessary to develop technologies capable of carrying out punctual monitoring with specific or continuous missions located throughout the territory, less invasive in their executive processes, at lower cost and rapid deployment. The new technologies will offer a fundamental contribution to end users (especially public ones) who with “reduced costs and innovative tools” will respond to the legislation. The SAGAcE project (www.sagace.eu) contributed to the realization of an advanced monitoring technological and methodological solution based on Radar, Magnetic, Optical and Chemical technologies that are (from the Latin Sagax) acute and insightful and (from the Latin Sagus) with a data processing capacity to the limit of premonition.

II. THE GRADIOMETER ON DRONE

One of the projected instrumentation in the SAGAcE project was the gradiometer on drone (italian patent 102020000020179 del 14/08/2020).

Despite the multiplicity of fields of application of the magnetic method, there are currently no portable magnetometric instruments that can be used, without the direct presence of the operator in the field, in environments that are little or not at all accessible, such as - for example - those in which the presence of strong of obstacles (vegetation, walls). The magnetic survey of superficial anomalies related to the presence of hidden structures, human burials, or, for example, of illegal dumps, in fact, needs to be carried out at a relatively small distance compared to the earth's surface. This has so far prevented the development of this application, due to the impossibility of having aircraft, which could perform flights at very low altitude. The solution to the problem was studied during the doctoral thesis period and is offered today by the spread of small, remotely piloted aircraft, which can fly at low altitude and carry small technical instruments on board. On the other hand, traditional geophysical sensors, if suitably miniaturized, can be reduced to such dimensions that they can be mounted and used on drones. In this way it becomes possible to exploit the technology related to the use of drones, which has reached a level of maturity and ease of use such as to make it suitable for the most varied mapping applications with considerable time savings, to overcome the problems related to the aero-magnetic survey, currently limited by the above mentioned need for low-level flights, which are influenced by the particular conditions and the morphology of the terrain. Thanks to a drone, in fact, the data can be collected at a minimum and constant distance from the ground. Through a drone equipped with a system of magnetometric sensors, it thus becomes possible to obtain rapid geophysical measurements at relatively low altitudes, even in sites that are difficult to access, directly in situ, acquiring really significant information on the presence and actual speed confirmation of any anomalies present in the subsoil, attributable to hidden structures.

As part of the project was possible to develop a modular system that includes the following elements (Fig. 1).

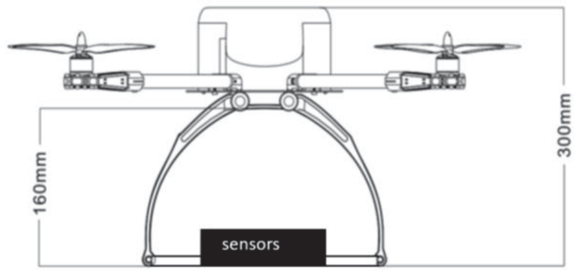

Fig. 1. Scheme of the acquisition system

- *i) drone;*
- *ii) Sensors;*
- *iii) Acquisition system;*
- *iv) Control and management software;*
- *v) Connection cables;*
- *vi) Remote management and control unit via GSM / GPRS (or satellite network) which can be interfaced with the internet.*

The data acquisition unit consist in the sensors capable of recording the total field at different heights and consequently the vertical gradient of the field itself.

III. FIELD EXPERIMENT

In order to verify the potentiality of the new instrumentation a series of measurements were performed in some sites of archaeological interest.

Magnetic prospecting was conducted in two areas (zone 1 and zone 2) with a total size of 2800 m2 (Fig. 2). The inaccessibility conditions of the areas investigated due to the presence of various obstacles (tall grass, bushes) conditioned the choice of the geophysical methodology. Gradiometric prospecting was therefore carried out with a miniaturized drone gradiometer.

Fig. 2. the surveyed areas

The distribution model of the gradient physical parameter of the magnetic field relative to zone 1 is shown in Fig. 3.

From the distribution model of the magnetic gradient (Fig. 3) it results a variation of the gradient itself ranging from -35nT to +40 nT (nanoTesla).

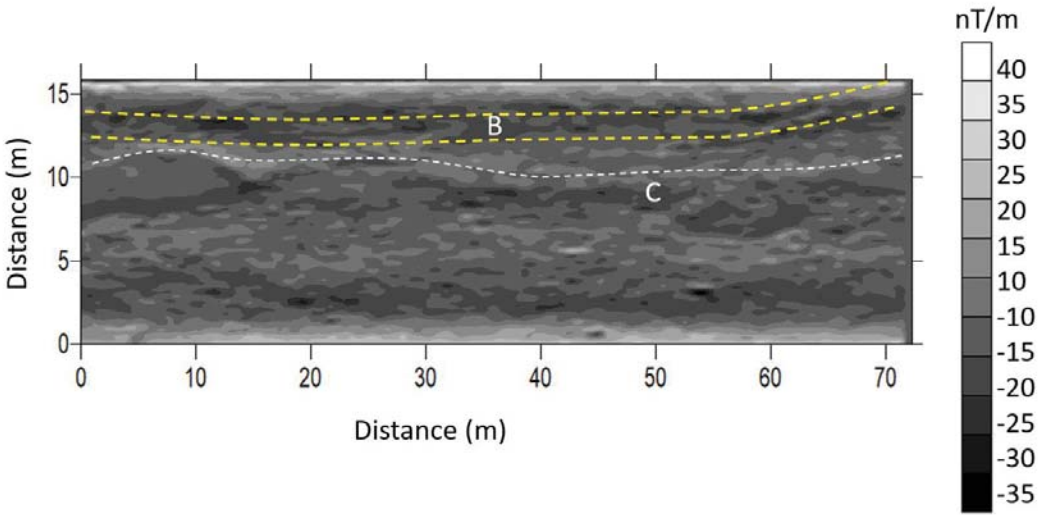

Fig. 3. gradiometric map of zone 1

The presence of various anomalies that can be associated with probable structures of archaeological interest is evident. In particular, the structure indicated with B (dashed yellow lines) could be due to the probable presence of a road while the anomaly indicated with C (dashed white line) could be linked to the presence of a canal. Their depth is between 1.0m and 3.0m. The distribution model of the gradient physical parameter of the magnetic field relative to zone 2 is shown in Fig. 4. From the distribution model of the magnetic gradient (Fig. 4) it results a variation of the gradient itself ranging from -

35nT to +40 nT (nanoTesla).

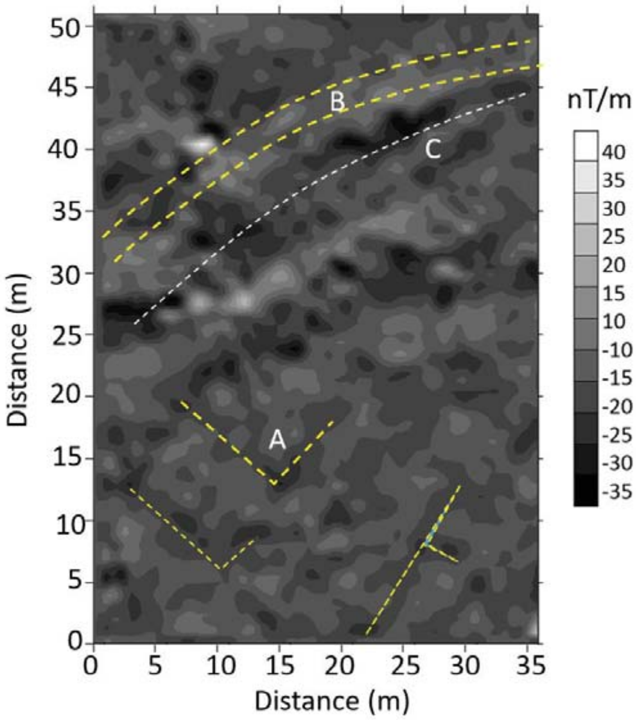

Fig. 4. gradiometric map of zone 2

It is evident the presence of an anomaly indicated with B (dashed yellow line) which could be due to the probable presence of a road while the anomaly indicated with C (dashed white line) could be linked to the presence of a channel. The anomaly indicated with A could be due to the presence of wall structures. Their depth is between 1.0m and 3.0m. In Fig. 5 the distribution model of the magnetic gradient is superimposed on the orthophoto in order to facilitate the location of the anomalies in situ.

Figure 5. gradiometric map on orthophoto

IV. CONCLUSIONS

Some results related to the SAGAcE project were presented. These are related to the project of the magnetic sensors for soil investigations. The application of the projected sensors on the archaeological sites have provided good results in identifying structures present in the very first subsoil. Specifically, the magnetic method made it possible to extend the survey to a depth of approximately 3.0 m, highlighting anomalies probably attributable to structures of archaeological interest.

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