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Low-cost Remotely Operated Underwater and Unmanned Aerial vehicles: new technologies for archaeo-geophysics

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***Abstract* – In this paper we present a device for magnetic survey devoted in particular for archaeological purposes. The device is able to perform accurate measurements of the total magnetic field, it is a flexible device, programmable by the users to be suitable for any specific need. The device relies upon microcontroller, a digital three axes Fluxgate magnetometer, a GPS, and a Real Time Clock (RTC) module. The device is compact and lightweight to be assembled on aerial and marine drones. Recently, Remotely Operated Vehicles (ROV) and Unmanned Aerial Vehicles (UAV) gained great potential for archaeo-geophysics because of their versatility and low cost, therefore the magnetometer represents a very useful tool for fast and reliable measurements.**

I. INTRODUCTION

Magnetometry is one of the most widely employed geophysical techniques in archaeology [1]. The technique is able to detects buried structures through the analysis of the anomalies in the Earth's magnetic field because anthropogenic features have usually different magnetic properties from the cover terrain.

Magnetic surveying employees operator-carried devices on backpacks or carried by hand carts. Such methods have a good reliability in term of data quality, but they are time consuming and strongly limited by the accessibility of the archaeological site since inaccessible or uneven terrains, or the presence of obstacles represent great limitations for the survey.

The diffusion of autonomous vehicles is making faster, more reliable, and even safer, to perform observations, surveys and mapping also for archaeological purposes; the limits of previously inaccessible areas are today easily overcome. Remotely Operated Vehicles (ROVs) are underwater vehicles, operated from the surface, widely employed in seabed exploration. There is a class of micro ROV (<3 kg) suitable in particular for shallow waters: they are easy to maneuver and with extensible architecture, easily adaptable to any specific research needs. Unmanned Aerial Vehicles (UAVs) are flying vehicles able to self navigate to complete a programmed mission, or to be remotely controlled; they are prompt to perform tasks, having no obstacles like any other ground vehicle. Also UAVs have a flexible architecture that allow the implementation of various tool on the vehicle.

In order to combine the reliability of a standard archaeo-geophysical survey and the flexibility provided by the drones, we developed a prototype of a magnetometer transportable either by a ROV or a UAV, programmable by the users to be suitable for any specific need.

II. THE PROTOTYPE

The prototype is based on a specifically designed 8-Bit microcontroller board based on the ATmega2560 commercial model (Fig. 1). It manages the high-resolution, digital 3-Axis Fluxgate Magnetometer (Applied Physics Systems, Model 1540).

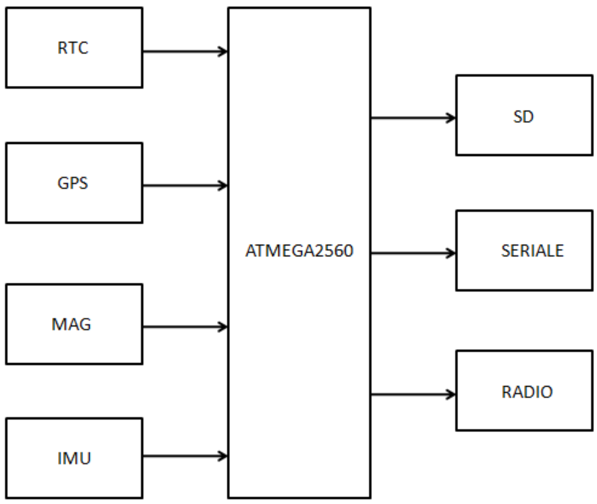

Fig. 1. Scheme of the prototype.

A fluxgate magnetometer consists of a small, magnetically susceptible core wrapped by two coils of wire. An alternating electric current passes through one coil, driving the core through an alternating cycle of magnetic saturation. This constantly changing field induces an electric current in the second coil, and this output current is measured by a detector. In a magnetically neutral background, the input and output currents are equal. When the magnetometer is exposed to a background field, it is more easily saturated in alignment with that field and less easily saturated in opposition to it. Hence the alternating magnetic field, and the induced output current, are out of step with the input current and depends on the strength of the background magnetic field. The output current is proportional to the magnetic field. The three components of the magnetic field are measured separately and are later combined by the code to calculate the total magnetic field. The magnetometer sample rate is set to 1 Hz and the unit is Gauss (G). The 24-bit converter allow to measure quantities in the order of ±0.65G, lowering the noise level of the system (5 μG peak-to-peak) without signal filtering.

The device carries also an Inertial Movement Unit (IMU), a Global Positioning System (GPS), and a Real Time Clock (RTC) module (Fig. 2).

The IMU contains several types of sensors, namely a 3-axis accelerometer, a 3-axis gyroscope, a digital compass, a barometer, and a thermometer. The GPS (GY-NEO6MV2 model) provides time and position for each measurement when the instrument is carried by the UAV, whereas it only provide the time if carried by the ROV. In the latter arrangement the position is calculated after the processing of the data provided by the IMU. The RTC (Maxim, DS1307 model) provides information about seconds, minutes, day, month and year for each measurement.

Finally the system have a radio transmission system for real-time data visualizing and a SD card for data storage and easy data transfer to other computers. Moreover, there is also a serial port to: i) configure sampling mode; ii) access data; iii) format the SD card.

The firmware is based on the divide et conquer (D&C) approach. It is a very effective approach to solve several types of computational problems. It is based on multi-branched recursion and it works by recursively breaking down a problem into two or more sub-problems of the same or related type, until these become simple enough to be solved directly. The solutions to the sub-problems are then combined to give a solution to the original problem. The firmware is partly based on the OpenRov project but it has been largely rewritten. The core of the system, the modules manager, is substantially a real operating system, and contain the files that manage the whole device.

The output file shows, for each measurement, the values coming from the various components of the system: magnetometer, GPS, IMU, and RTC.

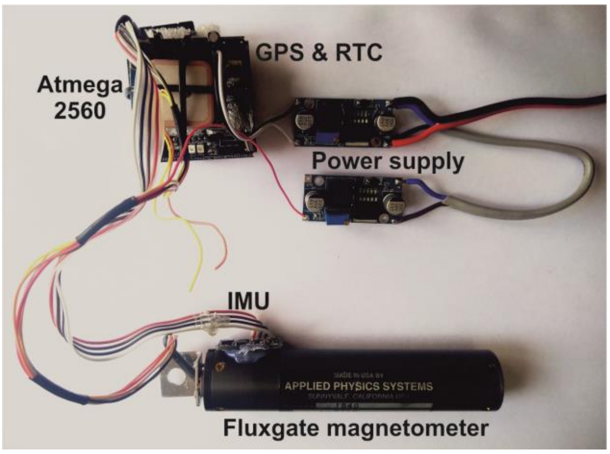

Fig. 2. The prototype

III. TESTING

The prototype was tested against a reliable commercial device: an overhauser magnetometer-gradiometer (GEM-19 from GEM Systems) with accuracy of 0.2 nT. The two devices were assembled together (Fig. 3) to ensure the same height from the ground, and the same survey track. The tests consisted of several experiments including: i) recordings with alternate device and with the two devices simultaneously; ii) static and walking-mode registrations; iii) recordings along linear and circular paths.

Various tests have allowed to find the optimal setting of the prototype, especially in term of voltage supply, then defined at 12 V. The comparison between the two magnetometers shows a good overlap of the recorded values and also the noise level between the two devices is comparable.

Fig. 3. The testing set-up with the GEM-19 magnetometer and the prototype.

IV. CONCLUSIONS

The prototype of an adaptable, lightweight and reliable magnetometer has been designed and tested. The results of the comparison testified the effectiveness of the device and its suitability to be assembled either on ROVs and UAVs. Accordingly, we are still developing our prototype in order to equip the vehicles and perform further tests.

Of course we have to face several problems to obtain reliable systems; amongst others the electromagnetic interferences with the electric-powered vehicles and a hydrodynamic or aerodynamic support for the instrument. Moreover, for the ROV application we have to deal with a waterproof case and a more robust code for the accurate vehicle positioning; for the UAV application we have to deal mainly with the free oscillations of the hanged instrument.

The final device will have broad potential applications, also considering that magnetometry is one of the most widely employed geophysical techniques in archaeology for its ability to detects buried structures and objects.

References

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