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# Geospatial quality in Archaeological sites

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***Abstract*** **– The field of Geomatics currently provides measurement equipment which allow massive data collection, enabling a detailed geospatial definition. To this end, it is essential the integration of Geomatics in Archeology. This fact makes possible its further dissemination, in addition to graphic and cartographic documenting of an archaeological site. However, the use of the geomatic equipment without a metrological control would lead to geospatial products with inadequate quality, or even worse, unknown.**
**In this paper, we present the latest systems for capturing the spatial information. In addition, it is exposed how the activity undertaken by the Technical Standardization Committee 82 of the Spanish Association for Standardization and Certification (AENOR) contributes to the metrological control of such sensors. This way it is possible to have a comprehensive graphic documentation with a high geospatial quality in the archaeological site.**

**Keywords: Geomatic systems, standardization, AENOR, archaeological site, metrological control**

## I. INTRODUCTION

In recent years, different measurement systems in the area of Geomatics have been developed. All of them are based on massive data acquisition in real time with a high metrological quality. New measurement systems provide huge spatial information and offer significant advantages in a large number of applications in the field of engineering and architecture, monitoring control, documentation of the cultural heritage, etc. The use of these systems will depend on the requirements that the work or project demands but, in all cases, the measurement systems should regularly be subject to metrological control, in order to ensure the quality of the measurements through the estimation of its uncertainty [1].

In the case of archaeological sites, the application of techniques of spatial information capture, offered by Geomatics, is essential if we intend to have a comprehensive graphic documentation in that archaeological site. This paper refers to the geomatic instruments most commonly used: total station (motorized or not), Terrestrial Laser Scanner (TLS) and GNSS (Global Navigation Satellite System) equipment. They all provide geospatial information whose accuracy should be controlled, and this will require a first equipment check. In order to achieve that scope, some measurement procedures are developed based on ISO international standards. Spain, through its technical committee AEN/CTN 82/SC 2/GT 7, participates directly in the design as a member.

## II. GEOSPATIAL QUALITY IN AN ARCHAEOLOGICAL SITE

The evolution of the instruments used in spatial data capture and further processing, as well as the development of new products with metric quality and its dissemination, have experienced an exponential evolution that continues today through the open lines of research in the field of Geomatics, understanding for Geomatics the science that integrates all the means used for spatial data acquisition, processing, analysis, storage of geographically referenced information and its dissemination.

In the process of planning a geomatic project it is necessary to determine the equipment to be used in data acquisition, as well as the methodology of observation to be applied. In doing so, it takes into account various factors such as the availability of equipment and personnel, the morphology of the terrain, surface considered, existing documentation, weather conditions, etc. The success in the choice of equipment and methodology will be reached in greater or lesser extent depending on the clarity with which the objectives to be achieved have been defined and therefore, depending on the degree of definition of the cartographic final product to be obtained.

Current measurement systems provide huge geospatial information to what a high accuracy is expected. In order to ensure this accuracy it is necessary to conduct a quality control of the system of measure, which means that it is necessary to consider all contributions to the measurement uncertainty of the equipment used in the data capture.

The equipment for capturing the spatial information most commonly used are:

- Total Stations, for the electronically measurement of angles and distances. They are named like that, because

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*Fig.1. Data capture with Total Station.*

they may be understood as real workstations themselves, see *Fig. 1*. Nowadays, Robotic Total Stations (RTS) is becoming widely used. They are total stations equipped with an automatic recognition of targets system. The operator is able to control the RTS distantly, from the observed point, using a wireless device or using a computer to follow the series of measures that have been previously scheduled. On the other hand, all manufacturers offer Reflectorless Total Station, automated or not, in which there is no need for a reflector, and using a red laser beam as emitting source [2].

- GNSS equipment, assigning 3D coordinates to points of interest in a global reference system by observing and receiving signals from satellites in a known position. GNSS includes all the satellite navigation systems, both the already implemented ones, for example GPS (Global Positioning System) administered by the United States Air Force, and GLONASS (GLObalnaïa NAvigatsionaïa Spoutnikovaïa Sistema) administered by the Russian Spatial Force and the Civil Spatial Agency, and the ones being developed. The essential parts of the GNSS system are the spatial, control and user sectors. The latter includes all kinds of equipment no matter the solution they present for obtaining the coordinates of a point. In geomatic applications it is possible to achieve millimeter accuracy [3]. See *Fig. 2*.

- TLS equipment is a powerful geomatic tool, which constitute a real time measurement system, being able to explore thousands of points per second and register the parameters that define every point of the object in the limits that have been fixed. TLS equipment provide vast spatial information, the subsequent treatment of which allows georeferencing the captured point clouds, its representation in 3D digital format, to generate digital elevation models, to create point cloud videos, orthoimages, etc. [4].

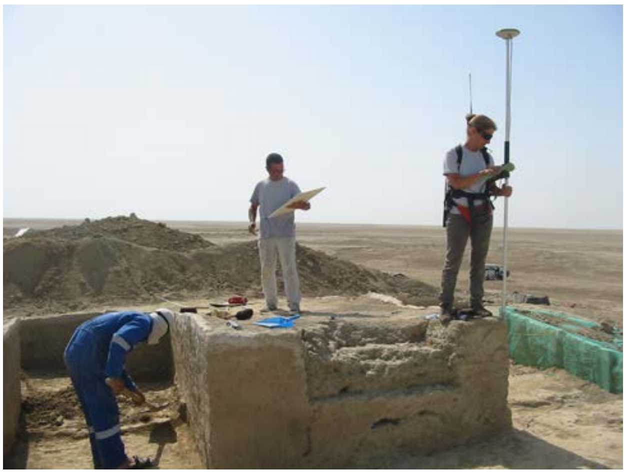

*Fig. 2. GNSS in Izat Kuli, Dehistan.*

The spatial information obtained from this equipment does not differ from traditional geodetic methods in relation to the implementation of quality management systems since in both cases apply quality management models in order to ensure that the required accuracy specifications are successfully reached [5]. Nevertheless, considering that the massive data acquisition can be considered as a new process, some changes must be carried out to allow us to accommodate the classic management to the new reality. This implies the developing of a new model for quality control based on a detailed and methodical procedure that gathers the specific characteristics of new technologies, especially GNSS and TLS, which allow massive data acquisition and, with a simply "push the button", the data, its treatment and calculation automatically flow. In general, the user neither knows the internal functioning of the equipment nor can accede to its interior and even, in occasions, is careless to perform checks and / or calibrations of the equipment regularly. On the other hand, the specifications of accuracy of the equipment provided by the manufacturers are generally vague and unsatisfactory, being frequent that the user thinks that the results of the measurements are always correct. However, this belief is inaccurate and, although the data acquisition is easier than applying classic methodologies, the entire process of the measure is now more complex and even the results are directly or indirectly influenced by the observer, especially when the measurement procedures are not made by professionals in the field of geomatics, [6].

When it comes to documenting graphically an archeological site and to obtain an optimal geometric representation, the appropriate and correct use of the new measurement systems enables a detailed geospatial definition of the area of archaeological interest. This requires that the elements comprising the representation with its characteristics are linked to a coordinate system on the terrestrial surface, that is to say, that are georeferenced, and properly specified in a catalog of objects and in a data model.

However, sometimes the spatial information has a questionable quality that makes an effective use of the representation even impossible. The appropriate utilization and rigorous geospatial analysis of the elements that define an archeological site depend on the quality of geospatial data which define the site. The quality of the data will depend on the quality of all the processes that are carried out to its definition; this way, the success of a project of graphical spatial documentation of a site depends to a great extent on the specialized personnel to apply correctly the precise procedures for the capture, management, analysis and modeling of geospatial data. In this regard, the integration of Geomatics in Archeology is considered essential.

In Geomatic projects, in which massive data acquisition is performed, there are certain aspects that may be associated because, even not having a direct effect on the data capture process, they will have a great influence on the measurement results. One of the most important objectives in any process of measurement, regardless of the specificity of the considered project, is to obtain accurate and reliable results. Achieving this goal requires to know and to minimize the sources of error which may occur, for which it is essential that the equipment to be used is in perfect conditions of use and to ensure that, by means of verification and / or calibration, is appropriate and fully functional. Measurements made with GNSS and TLS equipment are subject to external influences that are difficult to control, including a so wide field that only the suitable professional practice enables to define and quantify the indicators that can be considered as the most appropriate to achieve the best results of measurements that is to say, to define and to evaluate the causes of uncertainty that appear in the observations whose effect is to decrease the accuracy of the obtained spatial coordinates.

In order to control the complete measuring process with new technologies that achieve the required precision by the customer, it is important to carefully plan the different phases that can be considered in the overall process of data acquisition of the project.

The first phase of the measurement process consists of field work. The responsibilities are divided between the director of the work and equipment operators, which must have the suitable formation and training and have all the documentary information necessary to perform the measurements. Experience shows that in this phase are committed most of the errors which, even when corrected, could lead to reject the results.

The second phase is the treatment of the data. The main recommendation at this stage is that all the observations are processed as soon as possible to identify potential problems. Data recovery includes the transfer of the data captured and its verification, the backup and the organization of data in a database. The processing of data includes the validation of the results and the export to a CAD format. The different stages of this phase must ensure that the procedures of data processing can be repeated whenever necessary and that results are achieved in the same way.

Upon completion of field operations and data processing, the next step is to draft a final report with all the information needed to assess the quality of the results.

The implementation of quality management systems in organizations where measurement instruments are used requires that, whenever it is necessary to ensure valid results, the measurement equipment should be calibrated or verified at prefixed intervals or before being used. Furthermore, the standard indicates that calibration or verification of measurement devices shall be carried out with national or international traceable patterns, and in those places where such patterns are not available, the metrological level used for calibration or verification shall be documented.

The massive acquisition of data in an archaeological site could be carried out using any of the aforementioned equipment and sometimes by combining all of them. In any case, it is important to take into account that all the spatial information obtained must be georeferenced, what will require an exhaustive knowledge of the systems and global reference frameworks, as well as the IT tools that allow the processing and editing of data, without forgetting the need of a deep knowledge of the equipment of measure and their metrological control, which certainly helps to ensure that the geographical data obtained provide useful and reliable information to archaeologists.

The verification of the geomatic instruments may be carried out complying with the requirements of ISO 17123 series which, in addition to determining the repeatability of the instrument, allows checking the operating conditions, and this is a first step in the assessment of the measurement uncertainty.

One of the latest geomatic activities at a site run by Dr. F. Pareja was in the archaeological campaign of the Turkmen-Spanish Mission 2014 at the site Geoktchik Depe in the Dehistan region, Turkmenistan. During the campaign some of the most advanced techniques in the acquisition of geospatial information were used.

The choice of instruments for field data collection was determined taking into account factors such as the area covered by the project (100 hectares), weather conditions (very high temperatures and dust in suspension) and other specific characteristics of the area of action. We opted for the use of GNSS equipment, which was subjected to a metrological control that allowed assuring the quality of the measurements. In the process of data acquisition is clearly distinguish two phases: the establishment of a fundamental network and the massive data capture.

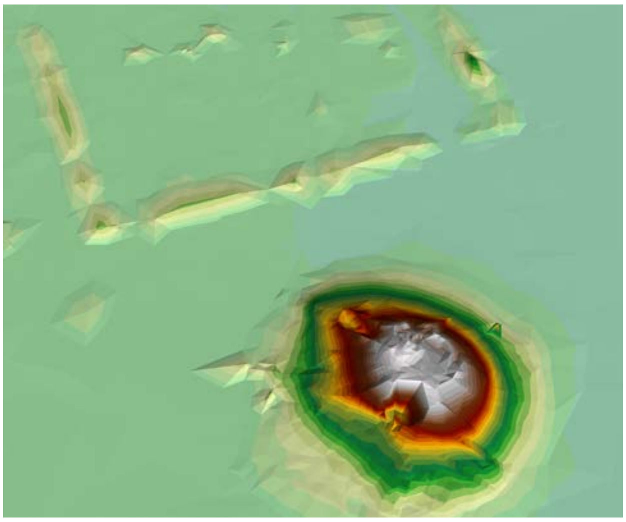

*Fig. 3. Digital Elevation Model of Geoktchik Depe.*

The fundamental network, in ITRS08 (International Terrestrial Reference System) on WGS84 (World Geodetic System) ellipsoid, serves both as reference and support for geomatics work in the 2014 campaign as for any further spatial documentation work that could be performed in the archeological area. This fact is extremely important because it will allow that any information obtained in future campaigns is geo-referenced, that is to say, the three-dimensional position with which there is defined the location of an object or element, remains represented in the same system of coordinates and datum.

The process of data acquisition using RTK (Real Time Kinematic) methodology was based on the fundamental network. The correct methodology carried out in the observation sessions and the quality of the observations made possible the mapping of the Geoktchik Depe site at scales 1/250, 1/500 and 1/1000, which will be part of the geoportal database that has been designed and implemented in this geomatic project. See *Fig. 3*.

## III. QUALITY AND STANDARDIZATION

The equipment measurement uncertainty is evaluated with procedures based on international standards, specifically the ISO 17123 series in whose development Spain participates.

The Spanish committee is the mirror of the ISO/TC 172/SC 6- *Geodetic and surveying instruments*. We have been directly and continuously participating over 10 years. In this committee the standards that we are working in are related with: Geodetic and surveying instruments, Ancillary devices for geodetic instruments, Laboratory procedures for testing surveying and construction instruments and Field procedures for testing geodetic and surveying instruments, being the ISO 17123-X series the most relevant ones.

Our experience is that the direct participation in the International Committee gives us a quite important knowledge for the good practices in the daily working with the instruments. And this does not depend on the final application. Therefore, Spain is doing a great effort for keeping its participation. Thereafter, the National Delegates spread this knowledge throught out the industry or scientifical areas related.

We briefly present the Spanish case in standardization and the implications for the quality of geospatial measurements.

The metrological control of measurement systems used in Archaeology ensures the quality of the geographically referenced spatial information, which will allow the development of new and interesting products with metric quality. Currently, the geomatic instruments most commonly used are total station (motorized or not), GNSS and TLS equipment. The metrological control of these equipment requires the determination of its repeatability and measurement uncertainty. In order to achieve that scope, some measurement procedures based on ISO international standards are developed.

For total stations, ISO 17123-5 standard proposes an interesting process in which repeatability of equipment is expressed by the experimental standard deviation of the position and height coordinates, [7]. The estimation of measurement uncertainty begins with the appropriate definition of the metrological model and the implementation of the law of propagation of uncertainty, which requires a deep knowledge of the measuring equipment in order to evaluate each of the contributions to the uncertainty of measurement.

The repeatability of GNSS equipment can be obtained following the proposed ISO 17123-8 standard procedure [8]. This procedure consists of several series of observations in different sessions over a determined period of time. This is to minimize, or even prevent, contributions to the measurement uncertainty due to corrections whose modeling is extremely complex, such as the corrections due to ionospheric and tropospheric effects.

Regarding the metrological control of TLS equipment, the Technical Committee ISO / TC 172, SC 6 is working on the development of part 9 of the ISO 17123 standard, which describes the procedure to calculate the experimental standard deviation and to estimate the uncertainty of measurement. Some researches about TLS equipment calibration have been published, [9] but, so far, there is no consensus on what the procedure to perform the equipment calibration would be. This is due to the fact that it is a complex system of measurement in which there are several non-independent magnitudes involved.

Among the activities carried out in the Laboratorio de Control Metrológico de Instrumental Geodésico y Topográfico (LCMIGT) of Universidad Politécnica de Madrid, it could be emphasized the research that is being conducted in order to evaluate the quality of measurement of TLS equipment. For that, various tests have been performed with TLS equipment from several manufacturers, both in field and laboratory conditions.

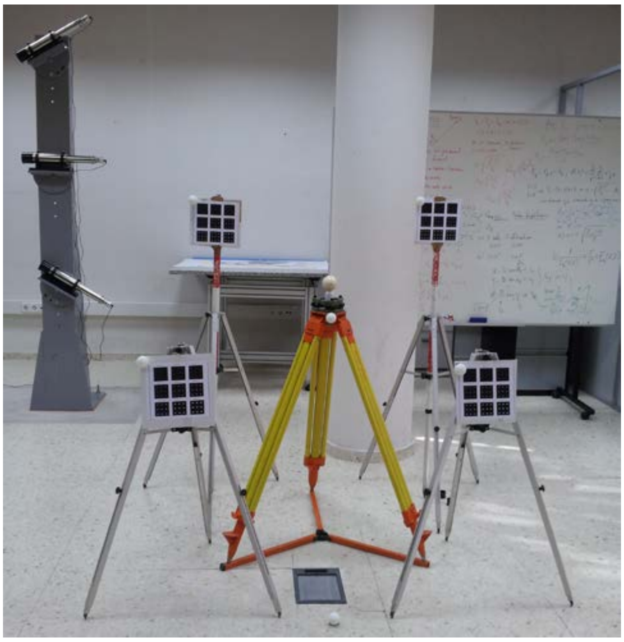

*Fig. 4. Equipment for determining the uncertainty of TLS in the LCMIGT.*

Although the research has not been completed yet, it might be said that the metrological model and the contributions to measurement uncertainty are well defined, and therefore, the LCMIGT is ready to evaluate the quality of measurement of TLS equipment, [10]. See *Fig. 4.*

Finally, we can state that the possibility of having a comprehensive and accurate graphical representation of an archaeological site that facilitates the integration of archaeological documentation and its dissemination will begin with a metrological control of the systems of measure, without forgetting the need for an appropriate professional practice.

## IV. CONCLUSIONS

The new techniques of capturing geospatial information applied in archaeological sites have obvious advantages. Nevertheless, if the quality of the final product needs to be ensured, it is essential the metrological control of measurement systems through the application of procedures described in the International Standards as well as the participation of technical experts in the area of Geomatics. It will guarantee both a rigorous use of equipment and the adequate geospatial information process. This way the management of web resources and the disclosure and dissemination of archaeological documentation is facilitated.

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