Industrial area 3D geometric documentation using Terrestrial Laser Scanners

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Key words: laser scanning, 3D point cloud, geometrical info, maintenance, Oil and Gas Industry

SUMMARY

The safety and enforcement of preventive maintenance procedures specifically for equipment in large industrial infrastructures is a matter of major importance in particular, in the Oil and Gas industry. For example, a pump or extruder malfunction may cause disruption to the production line and thus, result in significant economic damage. An increasing number of machines, complexity of technical checks and maintenance procedures, expansion of industrial infrastructure and the volume of production have increasingly given prominence to the safety and technical maintenance of equipment. In order to optimize the availability and utilize industrial maintenance the corresponding digital twin and its properties must be captured. This is possible using terrestrial surveys by means of new technologies. More specific, digital 3D scanning devices has provided new means to preserve geometric and photorealistic 3D point clouds.

This study takes a close-up look at measurement laser campaign and GNSS positioning for reference frame implementation and digital documentation. It describes both the fieldwork and the processing of the measured data. Additionally, the value of this paper lies in stressing the importance of the terrestrial 3D laser scanners and the practical applications they have in many domains, such as the oil and gas industry where special machines configuration is existing. The current study took place at Hellenic Petroleum facilities in Northern Greece.

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1. INTRODUCTION

The complexity of technical inspections and maintenance procedures, the extension of industrial infrastructure as well as the volume of production, has highlighted the goal of safety and technical maintenance of equipment more relevant than ever. The advent of new digital 3D laser scanners provided new means of digitally capturing the performance of machines and their complex installations by creating geometric and photorealistic point clouds or 3D models.
A big number of 3D mapping and modeling applications has been applied for the documentation of Cultural Heritage sites and monuments (Almukhtar, A., et al. 2021, Fröhlich, C. et al., 2004, Cardenal Escarcena, F., et al. 2011, Pavlidis, G., et al, 2007, Yastikli, N., 2007) and in general constructions of special interest as well as the creation of educational tools for trainee researchers and engineers (Heine, E., et al. 2009). In terms of industrial maintenance, the provision of information to the right staff in real time and its presentation with augmented reality techniques on mobile devices, combined with intelligent decision-making methods based on machine learning techniques are the future of modern industry and will simplify the equipment maintenance procedures and will facilitate the technical staff in their operational procedures (Schwald, B., and De Laval, B., 2003). Other incentives for applying photorealistic models include visualization from a point of view that is impossible in the real world due to size or accessibility, interaction with non-hazardous objects and maximum staff safety, especially in industrial areas with high hydrogen sulfide content, like the facilities of an oil refinery which our study is focused. The Hellenic Petroleum oil refinery is located several kilometers away from Thessaloniki city center and is one of the leading energy groups in Southeast Europe, with activities spanning across the energy value chain and presence in 6 countries.

2. FIELD MEASUREMENT CAMPAIGNS AND RESOURCES

Terrestrial laser scanning is a popular methodology that is used frequently in the process of documenting historical buildings, cultural heritage, highway surveys and special structures like forested areas (Liang, X., et al. 2016). It can be used for both outdoor and indoor surveys and delivers millions of 3D points measurements with mm-accuracy, even in situations where other classical surveying techniques are difficult or impossible to use. One of these cases is the oil industry where complicated machines are installed and operate 24/7. The production of 3D models of special objects and sites in their current state requires a powerful methodology able to capture and digitally model the geometry and appearance in fine detail (high resolution) with the best possible accuracy.

Our study focuses on presenting the stages which we followed to apply laser scanning to obtain the 3D point clouds of several extruders in oil industry. Apart from streamlining measurement taking by making it faster, 3D laser scanning also provides convenience by minimizing travel and revisit. Many oil and gas sites are far away from the main facilities, so making multiple trips for extensive measurements would spend substantial time. With terrestrial 3D scanning, surveying engineers travel once, set up the laser instrument in a sparse locations network, gather field measurement data in minimum time but perform exhaustive analysis at office work. Another efficient way is to perform digital scanning survey at the area of interest, apply basic registration work on portable devices such as tablets or smartphones, and get valuable information in near real time. The high accuracy and precision of 3D laser scannings mean employees won’t have to make multiple trips to re-collect faulty data.

Thus, to obtain the 3D point cloud of a special instrument, Leica RTC360 scan station (Figure 1) was used due to its characteristics: capable of scanning up to 2,000,000 points per second, in a range from 0.5 - up to 130 m from the instrument’s center of origin with high accuracy: 1.0 mm + 10 ppm. It is embedding a 3-camera system of 36MPixels resolution, able to provide a spherical panorama image of about 432 MPx. The spherical panorama with a Field of View (FoV) of 360^{o} in horizontal and 300^{o} in vertical directions is used to colorize the cloud of measured points using the pre-calibrated information of the imaging sensors. Additionally, the instrument can perform in 2 passes to automatically remove moving objects and uses 1 minute for full spherical HDR image at any light condition.

Figure 1 - The Leica RTC Laser Scanner in the area of Oil refinery

The field work is quite simple and is comprised of the instrument's placement in locations that will optimize the measurements inside and around the area of interest. In order the survey team to move within the installation area and more specific inside the Continuous Catalytic Reforming (CCR) unit, proper safety clothing (figure 2) fulfilling the ATEX (French acronym for "explosive atmospheres") protocol were used (Jespen, T., 2016). In general, ATEX directive covers equipment and protective systems intended for use in potentially explosive atmospheres.

Figure 2 - Survey staff with RTC scanner in CCR area

Also, in order to provide georeferencing information of the scanning sessions proper printed targets were installed and measured using GNSS data with help of the relevant positioning. More specifically, A Leica GNSS receiver (Viva GS15) was utilized operating in multi-frequency and tracking signals from GPS, Glonass, Galileo and Beidou satellite constellations. The nominal accuracy performance in static scenario is for Horizontal: 3 mm + 0.1 ppm (rms) while for vertical component is 3.5 mm + 0.4 ppm (rms). Their coordinates were finally referred to the modern reference system Hellenic Terrestrial Reference System (HTRS07) which use the Transverse Mercator as projection plane (Fotiou 2007, Fotiou and Pikridas 2012).
The targets were checkerboad markers printed on A4 paper size covering a square dimension of about 16x16cm that they could be clearly identified in the scans panoramic images and they could also be automatically recognised from the registration software. Additionally, a set of natural characteristic points (e.g. small metallic columns) that pre-existed near the scan area were measured and used for the georeferencing of the scans. The linking of the scans was performed on site using special software (Leica Field 360) installed on a tablet allowing the surveyor to assess the quality and the coverage sufficiency of the measured point clouds. Figure 3 demonstrates the scanner traverse positions (red bullets) of a 3D survey at a unit compressor installation. Colored lines draw the connection between measuring points (scanner stations).

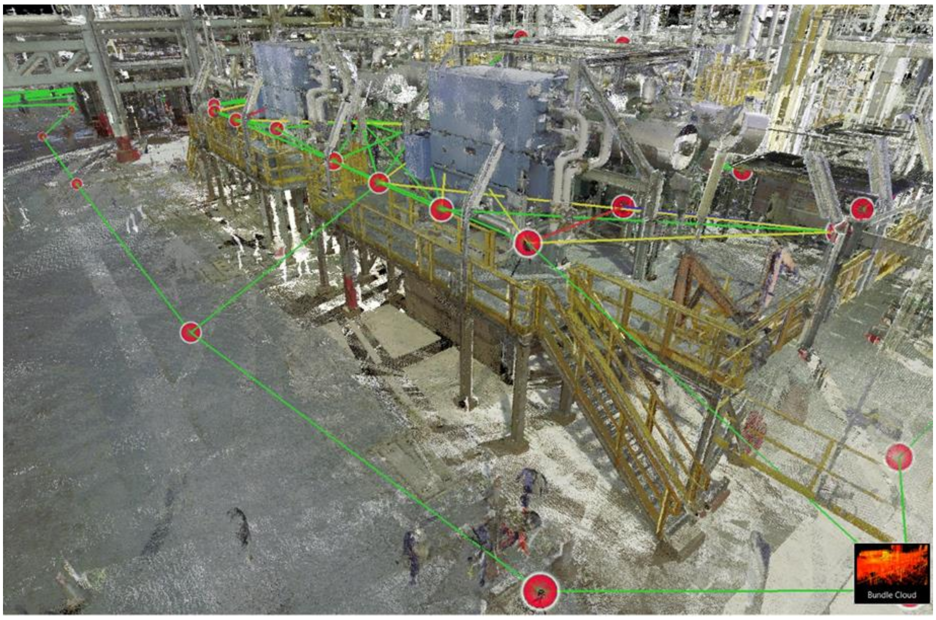

Figure 3 - Automatic cloud registration using the appropriate software

A total number of 127 (laser scanner) traverse points were implemented, fully covering each compressor to be captured and their neighboring installations. After the fieldwork was completed and in order to obtain the unified point clouds and clear the noise, special software (Leica Cyclone Register 360) was used. The scans from the separate dates' sessions were brought in a common reference system and then merged to create a unified model. All the connections of the point clouds from the individual scans were made with an accuracy of 1-2 mm which is a basic criterion for the creation of a reliable three-dimensional digital model with an overlap of 45% (average value). Automatic cloud registration identifies properties of each cloud station, such as point density, station height, matching errors, cloud point number, and cloud stations clashes. Figure 4 illustrates the results of the automatic cloud point registration during the process.

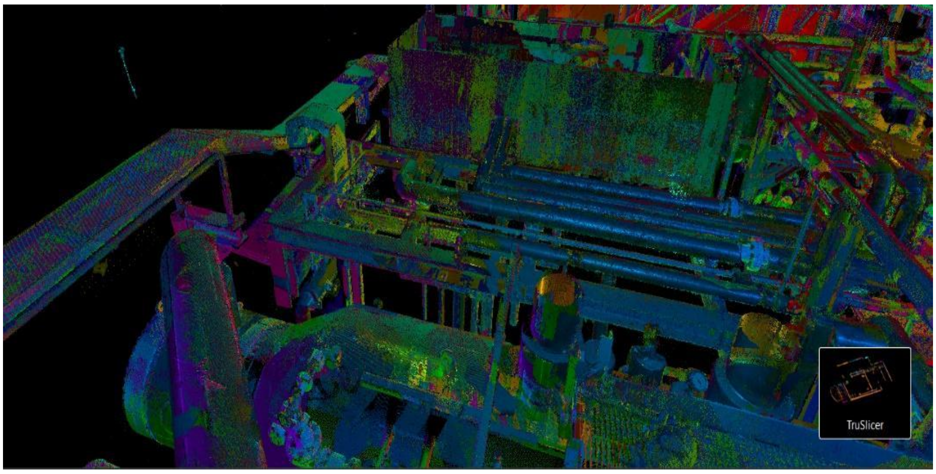

Figure 4 - Automatic cloud registration using register 360.

The quality aspect of surveying using laser scanners needs careful consideration throughout the measurement and process. In general, several 3D model errors can appear from a session of measurements. Their sources can be summarized as instrument errors, target positioning errors, the human/staff errors and the atmospheric conditions where the air temperature, humidity and pressure can affect the proper functionality of the instruments. Based on the above results and using the Leica Cyclone v.2020 software a model of each compressor was created. Cyclone software allows users to move from import through analysis and publishing their models and results. Figure 5, illustrates the produced 3D model during the process of the relevant point clouds.

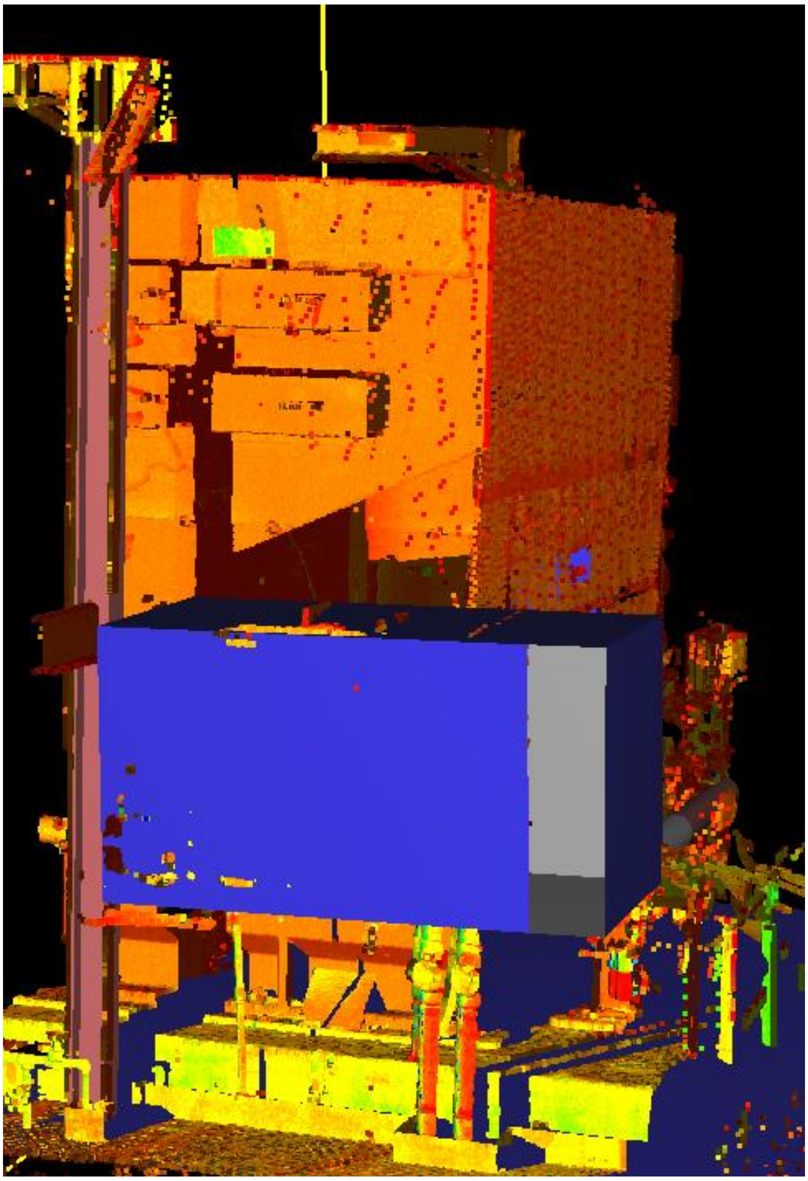

Figure 5 - Model creation of a compressor using Cyclone software

Another flexible way for handling the register point cloud data is the LGS files. The allignement software that was used to unifiy the point clouds from different dates (Cyclone Register 360) provides the option to extract the 3D surveys into these special files (LGS) files which are Leica's Universal Digital Reality project files. This file format saves a lot of metadata with point cloud and images inside one single file. LGS files can be directly imported in a viewing and examination software (free to download and use by anyone) to support rapid visualization of the models in a context to allow users (mainly the end user of the surveyed area) to access all of the project data including points, imagery and supplemental information (GeoTags, metadata etc.). Figure 6 shows a part of a LGS file screenshot (image + point cloud) with additional measuring info calculated between specific points.

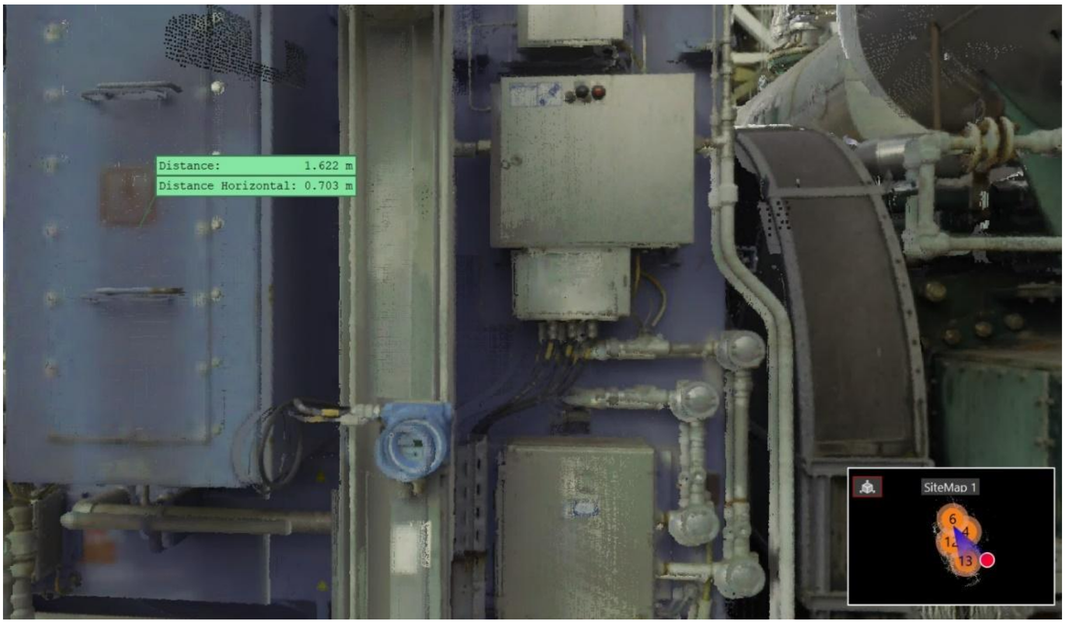

Figure 6 - Part of image with point cloud information extracted from LGS file

3. RESULTS AND DISCUSSIONS

The study described in this paper presents the stages that followed when creating a 3D digital survey of complex installations using terrestrial laser scanning. It shows that when it comes to factory planning as well as mechanical engineering and construction, laser scanners can be used to efficiently and completely survey production facilities, like in our case mechanical equipment, pipelines, special machinery. This modern and efficient method is particularly suitable for surveys with regard to modernization, production optimization and expansion of production capacity. As laser scanning is realized without physical contact, 3D surveys can be obtained during normal operation of the installation. The scan result is a point cloud providing information about the scanned object. Geometries can be derived from the point cloud partly in automated modus. Another motivation for applying photorealistic 3D models or proper point clouds include visualization from views that are impossible in the real world due to size or accessibility, interaction with non-hazardous objects, and maximum staff safety, especially in Oil and Gas industry.

ACKNOWLEDGEMENTS

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T2EDK-00708).

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BIOGRAPHICAL NOTES

Stylianos Bitharis, holds a MSc degree in Geoinformatics with specialization in Modern Geodetic applications and his PhD at the Department of Geodesy and Surveying (Faculty of Engineering, School of Rural and Surveying Engineering) at Aristotle University of Thessaloniki. His PhD research is related to GNSS data analysis, Geodetic velocity estimation, and their implementation in Geodetic Reference Frames.

Ion-Anastasios Karolos, holds a diploma in Rural and Surveying Engineering (2012) and a Postgraduate Degree of Specialization in Geoinformatics (2015). From January 2016 until present, is a Ph.D. Candidate in School of Rural and Surveying Engineering, Aristotle University of Thessaloniki. His research interest mainly focuses on hardware and software development of high precision GNSS receivers using technologies like PCB designing (embedded design), 3D printing and smartphone applications. He is a member of the research Project tilted "Liver3D" (https://www.liver3d.com/) for 3D printing of human liver for medical purposes, co-funded by EU and National Funds. He has a lot of programming experience using a big variety of programming languages (Swift, Objective-C, Kotlin, Java, Python, C/C++) and software development kits (iOS SDK, Android SDK).

Vasileios Tsioukas, Professor in the Dept. of Geodesy and Surveying, School of Rural and Surveying Engineering, Aristotle University of Thessaloniki. Education: Ph.D. in digital Photogrammetry and Remote Sensing for the extraction of reliable geometric information from close-range, aerial and satellite sensors (2000), B.Sc. in Electrical Engineering at the Aristotle University of Thessaloniki. He has served as an assistant professor in the Dept. of Architectural Engineering of the Democritus University of Thrace (2003-2011). Visiting Professor (2005-2021) in the Postgraduate Programme "Geoinformation in Environmental Management" at the Mediterranean Agronomic Institute of Chania. Scientific co-operator of the Cultural and Educational Technology Institute of Greece (CETI), since 2004. His research has focused on Terrestrial Laser Scanning, Mobil Mapping Systems, Photogrammetry and Remote Sensing for the determination of 3D models of Cultural heritage, Digital Terrain Models using stereoscopic aerial images and satellite SAR scenes for the generation of orthoimages and large (1:50) and small scale maps (1:50.000).

Christos Pikridas, Professor in the Dept. of Geodesy and Surveying, School of Rural and Surveying Engineering, Aristotle University of Thessaloniki. PhD in Satellite Geodesy by the same University. He is currently the Director of the Geodetic methods and Satellite Applications Lab. at the Department of Geodesy and Surveying of AUTh. He is an expert on GNSS data analysis. He has over 20 years' research experience on GNSS modelling error sources, algorithm development, quality check and specifications for permanent GNSS monitoring networks installation, GNSS applications in engineering projects and natural disaster monitoring and management.

Vasileios Bantis Holds a B.Sc from Aristotle University of Thessaloniki, Faculty of Sciences, School of Physics. Also received a B.Sc of Informatics from Hellenic Open University of Patras. His professional activity focuses on application development, algorithms, databases, as well as application quality control and programming configuration. He is a certified ISO 9000 Quality Management Systems Inspector**.**

Theodosios Gkamas, received his B.Sc. and M.Sc. degrees in Computer Science from the University of Ioannina, Greece, in 2008 and 2010, respectively, while he obtained a Ph.D. degree in Signal and Image Processing from the University of Strasbourg, France, in 2015. He was a postdoctoral Researcher with CERTH-ITI in Thessaloniki during 2018-2019. In 2020, he started working as a Senior AI Researcher, Lead AI Software Engineer and Project Manager at the Department of Mathematics in the University of Ioannina, Greece. His research interests mainly include Signal and Image Processing, Medical Image Analysis, Bioinformatics, Machine Learning, Deep Learning, Computer Vision, Pattern Recognition and their application to Medical/Biological Imaging, Industrial IoT sensory data and financial data.

Sotirios Kontogiannis, graduated from Democritus University of Thrace, Department of Electrical and Computer Engineering. He received a M.Sc. in Software Engineering and Ph.D. from the same department, in the research area of algorithms and network protocols for Distributed systems. He is currently a scientific staff member and director of the Distributed MicroComputer Systems Laboratory team MCSL at the Dept. of Mathematics, University of Ioannina.

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