BMT22
4th International Conference
Business Meets Technology
Ansbach, 7th – 9th July 2022

POTENTIAL PERSPECTIVES OF 3D LASER SCANNER FOR REAL-LIFE DOMAINS

Almerich-Chulia, Ana Isabel [a] **and Moreno-Puchalt, Jesica** [b]

[a] *Universitat Politècnica de València, Spain (analchu@mes.upv.es)*
[b] *Universitat Politècnica de València, Spain (jemopuc@mes.upv.es)*

ABSTRACT: The 3D laser scanning technology called the accurate scene reproduction technology can support the 3D design of all kinds of tested objectives in the favorable data. It simplifies the construction project cost and improves work efficiency, but the results of its data evaluation are more reliable and comprehensive. During the last half of the 20th century, 3D laser scanning was developed to recreate the surfaces of various objects and places accurately. Technology is beneficial in the fields of research and design. The 3D laser scanner has been applied in some industries to represent its immeasurable value. In this paper, these cases used in cultural heritage, sculptures, engineering applications are more than representative to show a variety of laser scanner applications. The data processed in the follow-up are used in mapping, finite element analysis, simulation analysis, virtual reality, and other aspects.

Keywords: *Technology; Point cloud; 3D laser scanner; Reality capture.*

1. INTRODUCTION

Laser scanning is the state-of-the-art technology for high-quality focusing on real objects. It is becoming an essential tool for producers who need an accurate dimensional inspection, virtual imaging, analysis, and even manufacturing physical prototypes. 3D object scanning improves the design process, speeds up and reduces errors in data collection, and saves time and money. Therefore, it is an attractive alternative to traditional data

How to cite: Almerich-Chulia, Ana and Moreno-Puchalt, Jesica. 2022. Potential Perspectives of 3-D Laser Scanner for Real-Life Domains. In Proc.: 4th International Conference Business Meets Technology. Ansbach, 7th – 9th July 2022. Doi: https://doi.org/10.4995/BMT2022.2022.15619

collection techniques because conventional methods are slow, time-consuming, and present many evident limitations.

3D laser scanning is used in a variety of fields and academic research. 3D laser scanning is used in numerous applications: industrial, architectural, civil surveying, urban topography, mining, reverse engineering, quality, archaeology, dentistry, and mechanical and dimensional inspection are just a few of the versatile applications. 3D laser scanning technology allows for high resolution and dramatically faster 3D digitizing over other conventional metrology technologies and techniques. Animation and virtual reality are fascinating applications (Edl et al., 2018).

The domain of 3D scanning serves a variety of typical engineering sectors apart from the societal spheres. Javaid et al. reflect in Figure 1 the several potential areas of 3D scanning applications that are most dominating, specifically in science and education sectors, design and manufacturing domains, reverse engineering fields, art & design, etc. (Javaid et al., 2021)

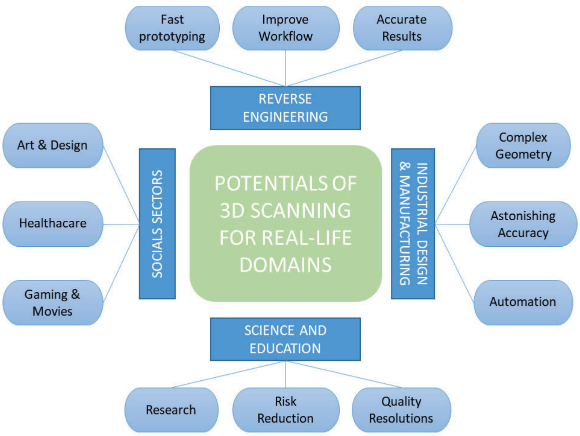


Figure 1. Capabilities of 3D scanning for Various Industrial Spheres.

3D scanning technology applies environmental analysis techniques to obtain information about shape, color, or texture. This information becomes the basis for the creation of the 3D digital model. The device used to perform this type of analysis is a 3D scanner. Many different technologies can be used to build these 3D scanning devices. In Figure 2, Todea et al. show a classification of the 3D digitization in contact scanning (refers to mechanical contact of surfaces) and non-contact 3D scanning (using optical sources, laser, or a combination of both for accurate reproduction of the scanned surface) (Todea et al., 2018).

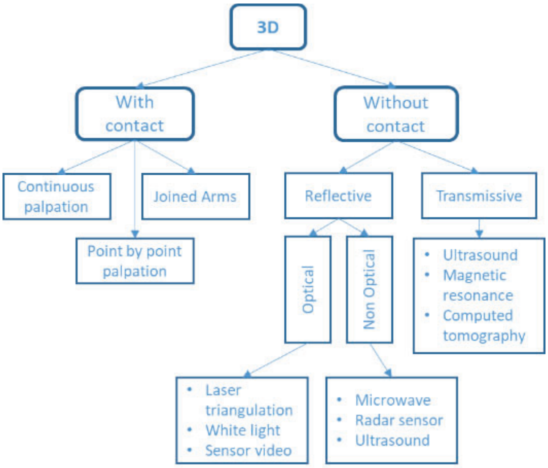


Figure 2. Types of 3D digitization

2. 3D LASER SCANNER

The 3D scanner is a device that captures the shape and characteristics of any volume or environment. It is possible to build a three-dimensional model of it on a real scale through specific software. Several technologies are used for capturing with the 3D scanner, such as physical touch, optics, and ultrasound. Each type of technology has its advantages and disadvantages and is used for various purposes. But it is necessary to establish a reference system between the object and the scanner in all of them.

Laser scanning systems (LSS) make it possible to obtain spatial coordinates of millions of surface points on objects with a very complex shape (Fig. 3) (Pukanská, 2013), which cannot be obtained by classical methods or photogrammetry in the concise term. The result of a scan is a cloud of points, which later has to be processed, known as reconstruction, to determine how those points are united and obtain the 3D model that represents the three-dimensional image of the objects, scans, and complex shapes.

Figure 3. Point cloud of the Likava castle and survey stations of scanning.

2.1. 3D model acquisition process

The 3D model acquisition process consists of two main stages, which are:

- 3D scanning,
- data processing.

The purpose of a 3D scanner is usually to create a 3D model. This 3D model consists of a point cloud of geometric samples on the subject's surface. These points can then be used to extrapolate the subject's shape (reconstruction). If color information is collected at each point, the colors on the subject's surface can also be determined.

3D scanners share several traits with cameras. Like most cameras, they have a cone-like field of view; like cameras, they can only collect information about surfaces that are not obscured. While a camera collects color information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. The "picture" produced by a 3D scanner describes the distance to a surface at each point in the picture. This allows the three-dimensional position of each point in the image to be identified.

In most situations, a single scan will not produce a complete subject model. Multiple scans, even hundreds, from many different directions are usually required to obtain information about all sides of the subject. These scans must be brought into a standard reference system, a process usually called alignment or registration, and then merged to create a complete 3D model. This whole process is generally known as the 3D scanning pipeline.

Measurement of spatial data with a laser scanner consists of several steps influencing the qualitative result of measured data, thereby affecting the quality of the final model. It consists of the following steps (Fig. 4) (Pukanská, 2013).

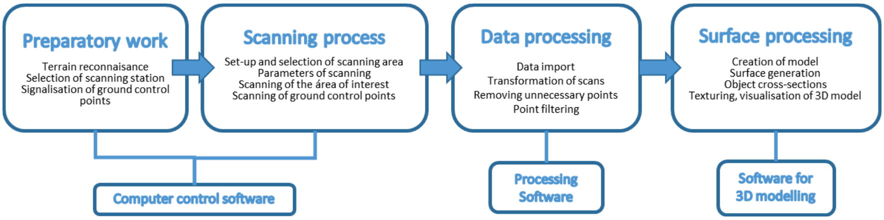


Figure 4. Overview of 3D laser scanning process.

3D scanners can be very accurate and even capture color information, so the models obtained will be completely realistic and proportionate, with the type of technology being a determining factor. Usually, the capture with a 3D scanner will not produce a complete model in the first scan. Still, multiple scans from different directions will be necessary to obtain information from all sides of the object. These scans are integrated into a standard reference system. Then, through alignment of the information obtained at all stations, a complete model is obtained in a single file (Fig. 5) (Pukanská, 2013).

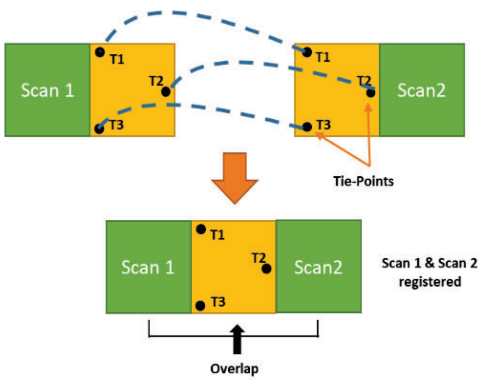


Figure 5. Registration using tie points.

After the initial processing of data – joining and deleting unnecessary data – it is possible to proceed to further processing into 3D models, according to the required outputs. For specific particular tasks, the initially processed point cloud is usually sufficient for the object visualization, project activities, measuring the direction and size of changes in a shift of the point cloud.

The resulting display is the final part of object modeling so that it resembles reality as close as possible and accurately represent the object. It is a process rather graphically intensive regarding the assignment of colors, materials, textures, and illumination. The resulting model can be used further for virtual animation, video sequences, overflights, etc.

3. CASES IN REAL-TIME DOMAINS

3D model creation and visualization are often used to preserve the looks and structure of historical buildings digitally. Virtual reality (VR) technologies facilitate this 3D model creation and visualization. A 3D scanner can be used to accelerate data collection and model creation. 3D displays can improve visual perception, and 3D printing can be used for physical model creation (Hrozek et al., 2012).

In this paper, sculpture, tower, church, pipeline, and other scenes will serve for the demonstration of 3D laser scanning capabilities.

Statue of Marc Anton (Austria)

In Vienna, the Marc Anton sculpture shows the Roman commander and statesman Marcus Antonius sitting on a chariot and being pulled by three lions. There is a fourth lion next to the chariot (Fig. 6). The socket is approximately 5m by 2.5m and has a height of 0.8m. The highest point (Marc Anton's head) is about 3m above the ground. The object's surface contains numerous regions with high detail (e.g., the lions' manes, Marc Anton's face, clothing). Some holes between the spokes of the chariot's wheels increase the surface's complexity. Due to the complex structure, occlusions cannot be avoided, and some areas cannot be acquired without tremendous effort (Fig. 7) (Vozikis et al., 2004).

Figure 6. Marc-Anton sculpture at the Viennese Secession

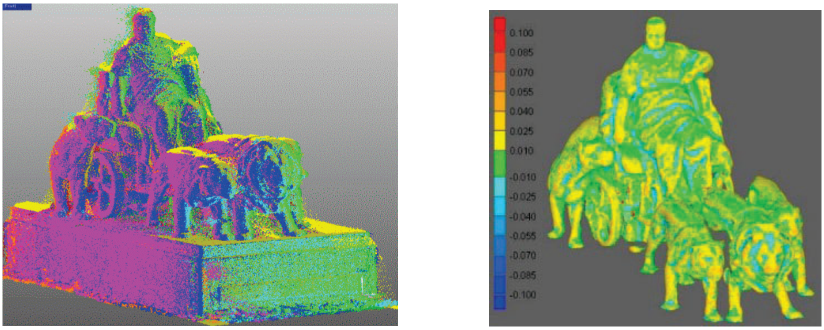
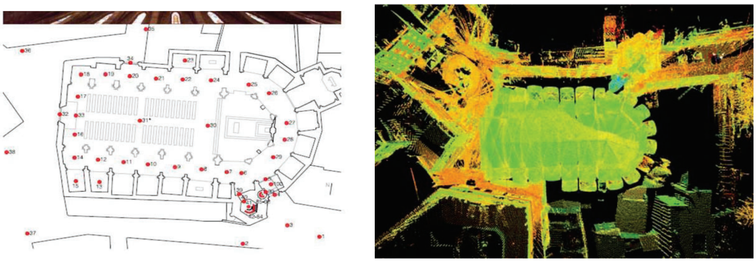


Figure 7. a) Individually Coloured Point-Clouds b) Differences: Original minus Final

Santa Catalina Church in Valencia (Spain)

The Church of Santa Catalina is a unique building within the historical heritage of the city of Valencia due to different aspects. Its medieval origin and unusual plan layout should be noted, because of the asymmetry of its side chapels and its particular ambulatory with an even number of radial chapels. Moreover, uncertainties of its constructive evolution are reflected in the façade of Lope de Vega square. In addition, its bell tower is important, which is considered a vital example of the Valencian Baroque (Fig. 8) (Moreno Puchalt, 2016).



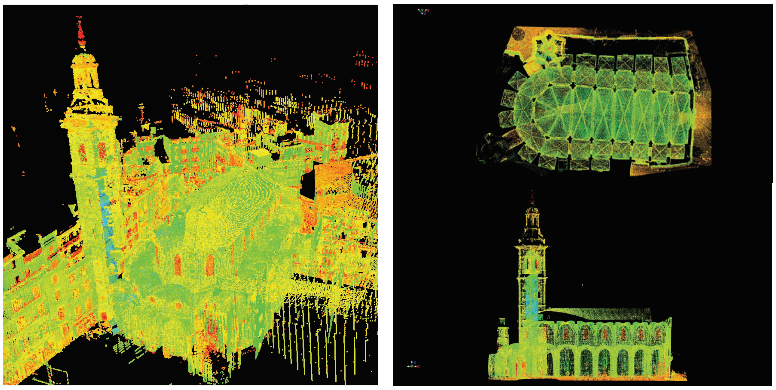


Figure 8. Point cloud of Church of Santa Catalina

Historic Greek catholic Church in Hačava (Slovakia)

This church is in a small village, Hačava, situated in the Slovak Karst. The sacral dominant in Hačava is the Greek Catholic church of the Nativity of the Blessed Virgin Mary from the 18th century. The church was built in the period of artistic directions of Baroque and Classicism. The use of an accurate 3D laser scanning solution made it possible to automatically create accurate sections and elevations of the building(Fig. 9) (Tkáč & Mesároš, 2016).

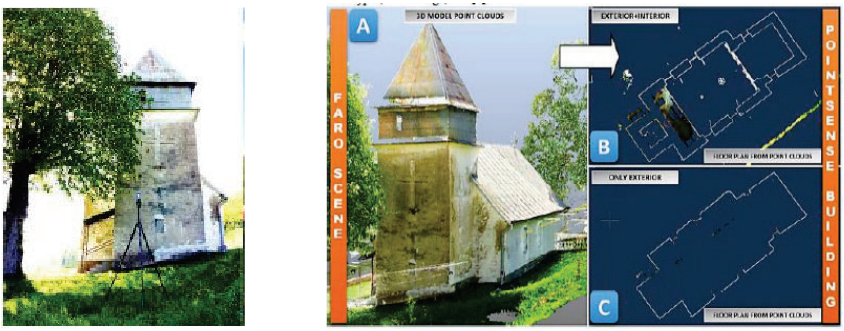


Figure 9. Nativity of the Blessed Virgin Mary Greek Catholic Church- Hačava. a) 3D model point clouds, b) floor plan (exterior & interior), c) floor plan (only exterior)

The riblike sheet of the Eduardo Torroja Institute (Spain)

The exterior chapel built in the Alarifes' courtyard of Eduardo Torroja Institute was designed as a riblike sheet in 1969 to symbolize the possibilities that reinforced concrete technology offered at that time. The result was a reinforced concrete sheet 10 m long and

6.5 m high with thicknesses ranging between 6 and 40 cm and defined by a Bernoulli Lemniscate guideline. Through a 3D scanning (Fig. 10), the volumetric survey of the structure and the three-dimensional modeling were carried out to perform the FEM analysis. It allowed an evaluation of the flaws observed in the sheet, a study of the deformations suffered, and its resistant behavior and structural safety (Echevarría et al., 2014).

Figure 10. Point cloud of the riblike sheet, stations of scanning.

Engineering Applications

Laser scanning has a wide range of applications in areas with poor access, for example, industrial plants or under hazardous conditions. Expansion of laser scanning within the engineering works allows re-searches and companies to construct of different as-built models of engineering projects and for monitoring their conditions and safety.

Point clouds are used, for example, as the basis for collision detection, volume inspection, and verification, structure testing, geometric measurement, detection of spatial position... The scanners are ideally suited for capturing contoured surfaces, complex geometries, and high-density of infrastructure where massive amounts of measurement data are required to ensure accurate depiction. The laser captures exact size and shape and converts real-world objects into 3D digital representations for storage and manipulation on a computer (Garvey, 2012).

Typical measurement problems in the industrial field deal with (i) the control of machined surfaces, for the quantitative measure of roughness, waviness and form factor, (ii) the dimensional measurement and the quality control of products (Fig.11a), and (iii) the reverse engineering of complex shapes (Setkowicz, 2014). The data appears as a "point cloud" which accurately represents the surface of the physical objects (Fig. 11b). The laser captures exact size and shape and converts real-world objects into 3D digital representations for storage and manipulation on a computer.

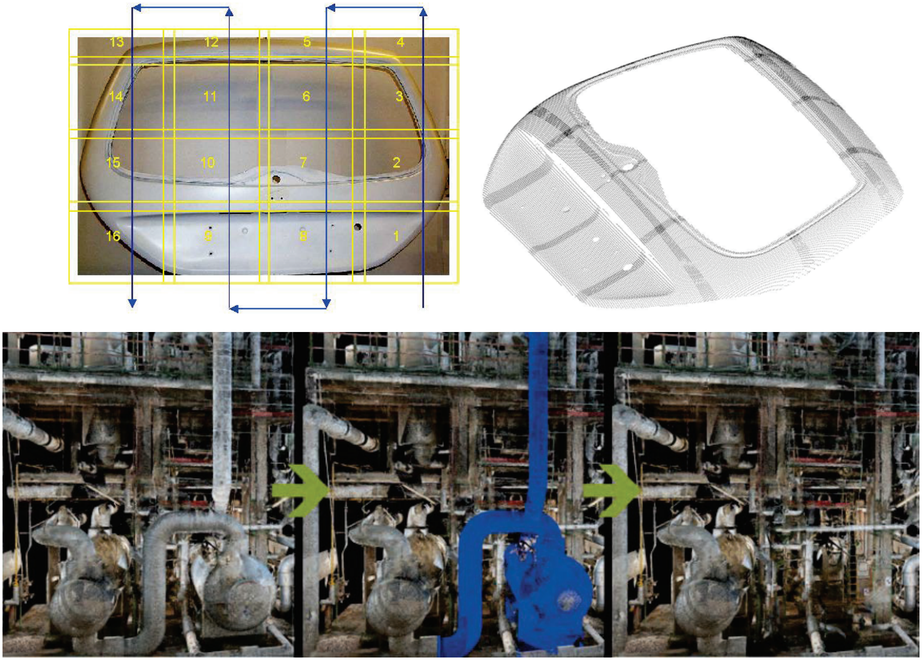


Figure 11. a) point cloud of the car back door (Sansoni et al., 2009). b) 3D laser scanning of the pipeline system (Fraunhofer IFF Magdeburg, 2018)

Others Scenes

3D point cloud that allows for virtual analysis and examination of the area of investigation. Especially significant applications of this technology are systems that use models of the human body, e.g., in the medical, forensic, clothing, and gaming industries (Škorvánková et al., n.d.).

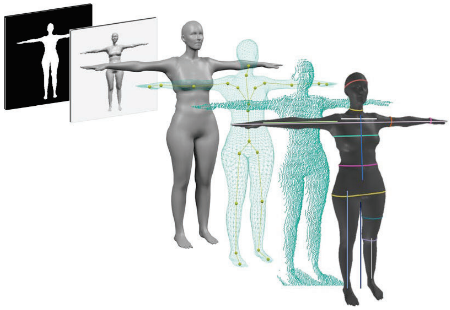


Figure 12. Human silhouette images, gray-scale images, 3D models, skeleton data, 3D point clouds

In consumer technology, depth cameras and, more recently, sensors have been integrated into handheld devices, allowing near-real-time 3D reconstruction. They are also used in 3D scanners and autonomous robotic devices. Thanks to combining these developments, most of the environments encountered in everyday life can now be digitized in three dimensions as shown in Figure 13. (*Visualizing Point Clouds in Game Engines | GIM International*, n.d.)

Figure 13. Digital models of real-time scenes.

In forensic applications, introducing laser scanners on the scene specialist save a lot of time. Furthermore, all necessary measurements can proceed with millimeter accuracy. Figure 14 presents the example of 3D modeling the crime scene (Sansoni et al., 2009)

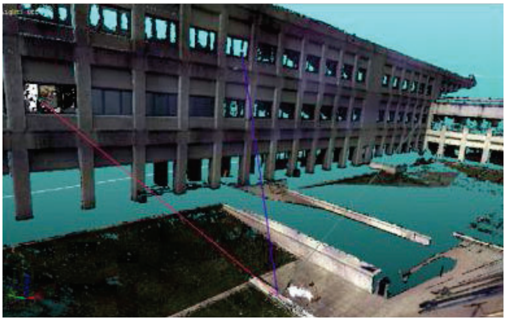


Figure 14. Crime scene capture by a 3D laser scanner

CONCLUSIONS

In this paper, a review of the most important 3D laser scanning uses has been presented. The aim is to highlight the wide range of measurement problems that can be solved by using 3D laser scanning. 3D laser scanning is, probably today, the most progressive non-contact method for the actual surveying state.

This research establishes the viability of using the 3D laser scanning technology to perform 3D data acquisitions at different stages. The overview of the state-of-art 3D acquisition systems proposed in this paper yields several conclusive remarks. Some advantages of 3D laser scanning are that a dense point cloud is faster obtained with precision and accuracy. And some disadvantages are the specialist equipment for the 3D acquisition and skilled personnel.

It is believed that with the development of information technology, 3D laser scanning technology will continue to improve, and the application of 3D terrestrial scanners will continue to be deep-en and extensive.

Conflict of interests

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

A-C.A: Conceptualization, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Supervision. **M-P.J**: Conceptualization, Methodology, Validation, Writing - review & editing, Visualization, Supervision.

REFERENCES

Echevarría, L., Garnica, C., & Gutiérrez, J. P. (2014). La costilla laminar del Instituto de Ciencias de la Construcción Eduardo Torroja (IETcc-CSIC). Levantamiento mediante láser-escáner y evaluación estructural. *Informes de La Construcción*, *66*(536), e038–e038. https://doi.org/10.3989/IC.14.116

Edl, M., Mizerák, M., & Trojan, J. (2018). 3D Laser scanners: History and Applications. *Acta Simulatio*, *4*(4), 1–5. https://doi.org/10.22306/ASIM.V4I4.54

Fraunhofer IFF Magdeburg. (2018). *Guidelines on laser scanning in plant design*. https://www.iff.fraunhofer.de

Garvey, M. (2012). 3D Laser Scanning Technology Benefits Pipeline Design. *Pipeline & Gas Journal*, *239*(10). www.pipelineandgasjournal.com

Hrozek, F., Sobota, B., & Szabó, C. (2012). Digital preservation of historical buildings using virtual reality technologies. *Open Computer Science*, *2*(3), 272–282. https://doi.org/10.2478/S13537-012-0022-8

Javaid, M., Haleem, A., Pratap Singh, R., & Suman, R. (2021). Industrial perspectives of 3D scanning: Features, roles and it's analytical applications. *Sensors International*, *2*, 100114. https://doi.org/10.1016/J.SINTL.2021.100114

Moreno Puchalt, J. (2016). *La iglesia de Santa Catalina de Valencia: Historia, construcción y estructura* [Universitat Politècnica de València]. https://doi.org/10.4995/Thesis/10251/64074

Pukanská, K. (2013). *3D visualisation of cultural heritage : by using laser scanning and digital photogrammetry : monograph*. Vysoká škola báňská - Technická univerzita Ostrava.

Sansoni, G., Trebeschi, M., & Docchio, F. (2009). State-of-The-Art and Applications of 3D Imaging Sensors in Industry, Cultural Heritage, Medicine, and Criminal Investigation. *Sensors 2009, Vol. 9, Pages 568-601*, *9*(1), 568–601. https://doi.org/10.3390/S90100568

Setkowicz, J. A. (2014). *Evaluation of algorithms and tools for 3D modeling of laser scanning data*. Norwegian University of Science and Technology.

Škorvánková, D., Riečick´y, A., & Madaras, M. (n.d.). *Automatic Estimation of Anthropometric Human Body Measurements*. Retrieved May 12, 2022, from http://skeletex.xyz/portfolio/datasets

Tkáč, M., & Mesároš, P. (2016). 3D Laser Scanning of the Historic Greek Catholic Church - Case Study. *Czech Journal of Civil Engineering*, *2*(1), 123–128. https://doi.org/10.51704/CJCE.2016.VOL2.ISS1.PP123-128

Todea, N.-A., Dolga, L., & Dolga, V. (2018). *Reconstruction of 3D Part Models for Flexible Technology Systems Robotica Management*. 23–25.

Visualizing Point Clouds in Game Engines | GIM International. (n.d.). Retrieved May 13, 2022, from https://www.gim-international.com/content/article/visualizing-point-clouds-in-game-engines

Vozikis, G., Haring, A., Vozikis, E., Kraus, K., & Greece, A. /. (2004). Laser Scanning: A New Method for Recording and Documentation in Archaeology. In *Workshop-Archaeological Surveys WSA1 Recording Methods*.

