Műszaki Tudományos Közlemények vol. 13. (2020) 122–125.
DOI: Hungarian: https://doi.org/10.33895/mtk-2020.13.22
English: https://doi.org/10.33894/mtk-2020.13.22

LASER SURVEY TOOL AND SURVEY METHODOLOGY FOR DIRECT ARCHITECTURAL CAD SOFTWARE CONNECTION

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Abstract

Building Information Modeling (BIM) has been the fastest growing methodology in architectural design, construction, preliminary works and in several other engineering activities in the past few years. It is mostly implemented in the fields of design, construction and building operation, however, there are still unexploited possibilities in further areas – such as building surveys. Many tools are available today to produce detailed and accurate 3D survey data, but specialists and custom software usually have to be involved in the process. Transforming this information into BIM models is also a time-consuming task, as their direct architectural design software integration is limited. The following article introduces a possible solution in order to improve communication and the modeling process.

Keywords: *building survey, algorithm, building information modeling, 3D printing.*

1. Introduction

Building surveys accompany different phases of design, from planning preparatory surveys, through control measurements, construction and monitoring of progress', to a quantity take-off for a simple repainting of an existing wall.

Besides the traditional tools that have been in use for a long time (e.g. tape measures, laser rangefinders), nowadays state-of-the-art technologies also support engineering work (e.g. laser scanners, photogrammetry devices) [1]. Thanks to these modern tools, it is now possible to produce and display more accurate and detailed 3D files than ever before.

However, the efficiency of the process can only be ensured once the right survey tool and methodology is chosen. A number of manufacturers offer products that incorporate all necessary features in a single device (e.g. Leica RTC360 laser scanner and Leica Cyclone software, or Leica BLK360 laser scanner [2] and OrtoGraph software [3]), but the use of these and post-processing work requires a high degree of expertise. Furthermore, the price of these tools can also be extremely high. On the other hand, devices with lower user competence requirements and lower price also exist (e.g. Leica Disto professional laser scanner products [2]), but these usually have limited functionality. It can be stated that compromises need to be made in both cases. However, according to our supposition, the two categories can be approximated to each other and instead of their own software environment, close collaboration with architectural design software may be ensured, which also provides higher functionality.

2. Concept, principles and build-up

When defining the basic concept of the asset development, the aspects described in the introduction have been taken into account. The goal is to create a tool that serves the purpose of efficient use and brings forth the possibility of 3D architectural refurbishment and redesign via simple tool management and automated post-processing of survey data. With the help of an algorithm, survey data is converted into 3D building model elements and building components in the native environment of the design software. The setup is based on the operational principles of terrestrial laser scanners (TLS) [4] With the help of a laser module, an "ultra-low-density" point cloud is produced by taking multiple point-to-point measurements on each surface or edge. This is then convertible into model elements that can be interpreted in architectural design software using a processing algorithm.

The development process is currently at the stage of implementing the second version. Previously, the Ministry of Human Resources, Human Resources Support Manager's application for the "National Young Talent Scholarship" with the ID „NTP-NFTÖ-18" provided the opportunity to test the feasibility of the concept and to release the first product version. However, during the development process, further details emerged that are modifiable and open to improvement. These have been elaborated in the current work phase.

The workflow began with a review of the device framework, the control electronics and the program lines responsible for functionality, created during the previous process. The supervision revealed that only by improving the existing details is it possible to make the expected progress, therefore the whole project had to be redesigned using the experience accumulated so far. Extensive replacements of previous hardware components (motors, sensors, modules), redesigning and 3D printing of the device framework, and rewriting of the program lines have also been carried out.

The basic unit of the control electronics is still provided by the Arduino environment. [5] However, its hardware replaces the previous Arduino Uno R3 device with a special (RobotDyn) Arduino Mega2560 motherboard with integrated ESP8266 Wi-Fi module. (Figure 2 – „A") This construction provides wireless communication over a Wi-Fi protocol, to operate the laser module and any other complementary units, and to control stepper motors once the engine control module (Figure 2 – „B") is connected (Figure 1).

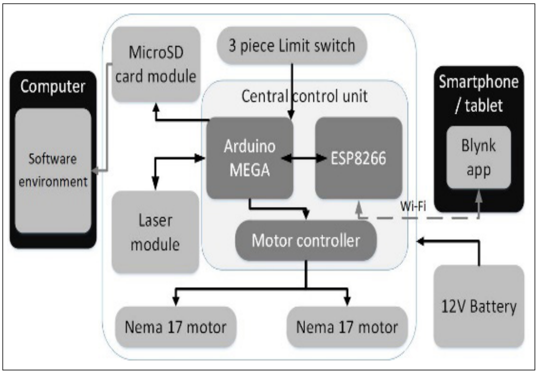

Figure 1. *The logic outline of the setup.*

Stepper motors (Figure 2 – „C") are conventional, low current (0.4 A) NEMA 17 type units that are responsible for 360-degree rotation around the XY axis and for moving the laser module along the YZ axis. In the latter case, 98 degrees of rotation is adequate for covering the usable interval, thus the range of rotation is limited by software.

The built-in laser unit (Figure 2 – „D") is identical to the types found in traditional laser rangefinders. (Figure 2.) It is controlled by simple, character-based commands through its communication ports. These include for example command "D", on which the module performs a measurement, or "S" on which relevant voltage and temperature

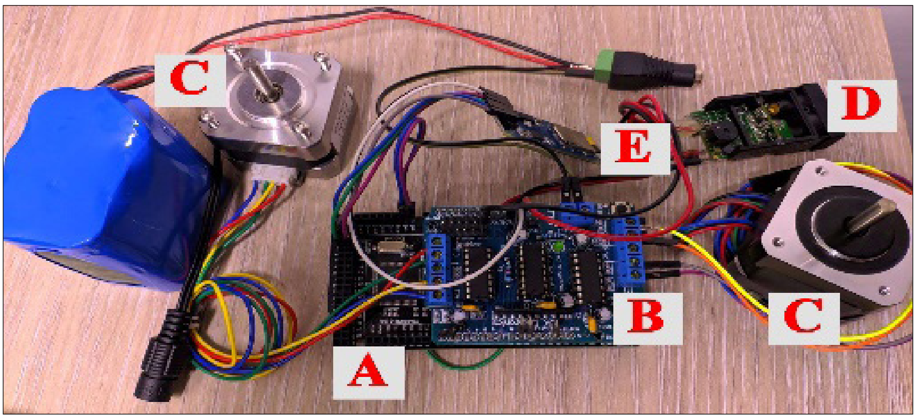

Figure 2. *The physical setup of the system.*

data is displayed. These are also used for managing the instructions when communicating with the Arduino motherboard.

3. Operating mechanism

The measurement process begins with positioning using a smartphone or a tablet. Through a mobile application [6] a control and feedback environment can be established (Figure 3), which is able to connect to the survey unit via Wi-Fi protocol and instruct it to take action. Once the device has been set up and desired position of the point to be surveyed has been adjusted, the type of building structure to be surveyed must be chosen and then the laser module can be activated and the measurement can be carried out.

The laser beam reflected from the surface determines the distance between the unit and the measured point. The measured value is displayed in the application and stored on the micro SD card (Figure 2 – „E") that is inserted in the device. In the case of contiguous planar surfaces, the process described above must be performed at least two more times to ensure that at least three measurement points are available from each surface, so that the planes are clearly defined. The developed program lines also provide the possibility of performing shape measurement instead of surface measurement. Shape measurement is interpreted as capturing the geometry of structures and objects by surveying their characteristic points.

Measured distances and other complementary and unique identification information are continuously recorded on the micro SD card. When designing the data structure, the goal was to create a simple framework that can comprehensively serve the needs of later use and provide appropriate basis for coordinate calculation.

The data management process includes the calculation and grouping of the coordinates of the measured points from the data generated during the survey. The environment for this is currently

Figure 3. *The setup of the control panel.*

provided in a complex chart. During the operations, the position of the device is considered as the base point (0,0,0,) which establishes the frame of reference for the survey points that can be recorded in a relative coordinate system. Since in this case the distance, the rotation values and all three coordinates of the base point ("origin") are known, trigonometric functions – angular functions – can be used to determine the spatial position of the other point. The spatial position of the points is the basis of algorithm-based processing, therefore the validation of the calculation is essential. For this reason, the following formula (1) is used after each measurement to determine the distance between 2 spatial points (P_1,P_2) [7] to make sure that the calculations are correct.

$$d(P_1, P_2) = \sqrt{(x2 - x1)^2 + (y2 - y1)^2 + (z2 - z1)^2} \qquad (1)$$

The final step after coordinate calculation is to generate geometries that can be interpreted by design software. The algorithm was compiled in the Dynamo add-on for Autodesk Revit design software. The algorithm uses the relevant data from the coordinate table to visualize the results of the survey and to match the surfaces - which are defined by the points - to the building structures (walls, slabs, windows, doors, etc.). During processing of the data, the program lines differentiate information by survey type identifiers. For example, windows and doors are mapped using their 4 corner points, while simple walls and slabs are placed on a plane that is expanded between 3 measured points.

The entire process goes on automatically and the final products are BIM entities identified as native model elements for the design software which entities also carry information content and can be modified later using the program functions (Figure 4).

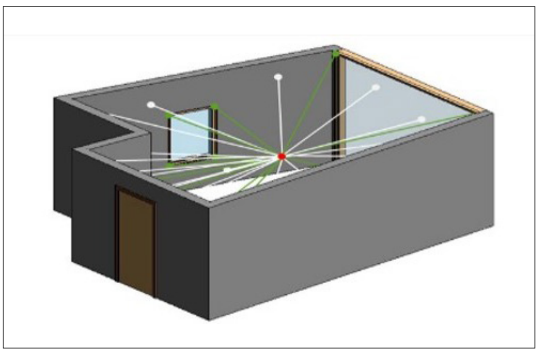

Figure 4. *The 3D model generated by the algorithm.*

In the case of surveying multiple spaces or using several standpoints, fitting is possible with the help of 3 auxiliary points. These reference points are recorded using the same IDs as for the structural elements.

4. The shell of the device

Designing and manufacturing the exterior shape is also a crucial part of preparing a prototype. Scheme models and components are created in a 3D modeling software, which are then 3D printed from Polylactic Acid (PLA) material. With this workflow concept sketches can be re-designed, modified and re-produced in a short period of time (**Figure 5**).

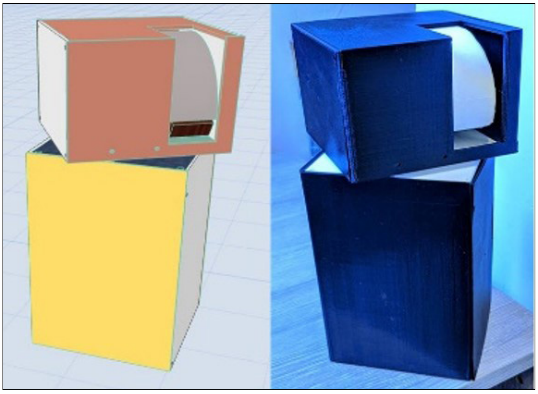

Figure 5. *The model and the assembled device.*

5. Conclusions

Both the survey tool and the methodology fulfill the goals, thus, the results of research and development activities can be described as positive and promising. Its direct connection to design software broadens the range of users, resulting in more efficient and economic processes. Amateur users might also be able to carry out a simplified survey of an interior space. The produced files provide architects with an initial 3D model that can be used as a basis throughout the elaboration of the design. Based on this, we consider the further optimization of the device and improvements for enhanced functionality. Automating the measuring process, instant visualization of data on a mobile device and integration with further design software predict many future challenges.

Acknowledgments

Supported by the ÚNKP-19-3 New National Excellence Program of the Ministry for Innovation and Technology.

References

[1] Bayyati A.: *Modern Surveying Technology: availability and suitability for Heritage Building Surveying and Heritage Building Information Models* (HerBIM). London South Bank University, (2017) 2–7.

[2] Leica Geosystems, *Termékek* (letöltve: 2020. február 2.). https://leica-geosystems.com/hu-hu/products

[3] OrthoGraph Enterprise (letöltve: 2020. január 20.) https://www.orthograph.com/

[4] Petrie G., Toth K. C.: T*errestrial Laser Scanners. In: Topographic Laser Ranging and Scanning, Principles and Processing*. (Szerk.: Shan J., Toth K. C.). Taylor & Francis, CRC Press, 2009. 87–92.

[5] Arduino: *What is Arduino?* (letöltve: 2020. január 20.). https://www.arduino.cc/en/Guide/Introduction

[6] Blynk: *Miből áll és hogyan is működik a Blynk?* (letöltve: 2020. január 20.). http://docs.blynk.cc/#intro

[7] Soo T.: *Coordinate Systems and Vectors in 3-Space.* In: Single Variable Calculus: Early Transcendentals. 1st Edition (Szerk.: Soo T.), Cengage Learning, 2010. 911.