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Facilitation of the 3D Scanning Process of Industrial Sites using a Self-Moving Autonomous Robotic System

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Abstract. **The present paper aims to examine how industrial sites can be more easily 3D scanned by integrating a self-moving autonomous robotic system and a large scale scanning technique. A case study is developed where an Unitree Go 1 Edu quadruped robot and a Trimble X7 3D laser scanning system are combined to illustrate the successful integration. For the full integration of the 3D scanner and the robot, several components are designed, using CAD software, and produced via Rapid Prototyping technologies. In the case study, different 3D scanning regimes are also tested. The case study showcases how the industrial 3D scanning process can be aided and potential ideas for the integration of 3D scanning technologies with quadruped robots are further discussed in the paper.**

Keywords: 3D scanner, industrial, quadruped robot, autonomous robotic system

I. INTRODUCTION

Self-moving autonomous systems of the quadruped robot type have undergone an extremely rapid development in the last few decades [1], correspondingly leading to the creation of various so called "robot dog" platforms [2]. These types of robots find increasingly wider applications in some areas, such as: surveying and mapping of hard-to-reach terrains [3], providing autonomous monitoring and guarding of objects [4], tactical actions, conducting rescue operations, lifting heavy loads [5,6], carrying-out manipulations in dangerous environments – for example, areas with an increased content of toxic gases or radioactive environment [7], etc.

Long range industrial-grade 3D scanners are key instruments in design and development of construction sites. By providing accurate and detailed measurements, the so-called scan to BIM (building information modeling) process can help to identify potential problems early on, avoid costly mistakes, and ensure that projects are completed on time and within budget [8,9].

Often the construction sites are large and their area exceeds the working range of the scanner. One of the main challenges in such cases is that the 3D scanning process cannot be fully automated – the scanner should be moved manually to another location after each scan is finished. Integrating the scanning system to a self-moving robot can help automate the process and to facilitate the operator's work. There are similar existing solutions on the market, but they are tied to specific equipment manufacturers and are expensive [10,11].

The present paper aims to examine how a quadruped robot Unitree Go 1 Edu and a Trimble X7 3D scanning system can be integrated together for facilitation of the 3D scanning process of industrial sites. In the case study, different 3D scanning regimes are also tested.

II. MATERIALS AND METHODS

Unitree Go 1 Edu quadruped robot is aimed in particular at higher education and professionals, for developing applications in fields ranging from service robotics to autonomous surveillance. Some of the important specifications of the robot are presented in Table 1 [12].

TABLE 1 SPECIFICATIONS OF UNITREE GO 1 EDU

Maximum speed	17 km/h
Maximum load capacity	10 kg
Weight	12 kg
Length	60 cm
Battery Life	20 min – up to 2.5 h (depending on application and battery capacity)

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The quadruped robot is shown in Fig. 1.

Fig. 1. Unitree Go 1 Edu quadruped robot.

Trimble X7 is a high-speed 3D laser scanning system allowing for scan and BIM data to be referenced, registered and refined in the field. Some of the important specifications of the 3D scanner are presented in Table 2 [13].

TABLE 2 SPECIFICATIONS OF TRIMBLE X7

Laser Wavelength	1550 nm, invisible
Scanning Speed	Up to 500 kHz
Scanning range	0.6 – 80.0 m
Accuracy	2.4 mm @ 10 m, 3.5 mm @ 20 m, 6.0 mm @ 40 m
Weight	5.8 kg
Size	Width = 178 mm, Height = 353 mm Depth = 170 mm
Controller	Trimble T10 Tablet with Trimble FieldLink over WiFi or Cable
Integrated Calibration System	Full auto-calibration of range and angular systems in 25 seconds with no user interaction or targets

The 3D scanning system is shown in Fig. 2.

Fig. 2. Trimble X7 3D laser scanning system.

The scanning system has several work modes. The scan modes with the corresponding parameters, according to the measuring system specification, are presented in Table 3.

One of the main challenges regarding the integration of the two systems is the mounting of the 3D scanner on the back of the quadruped dog. The construction of the fastening device should be as light as possible, while ensuring a secure attachment of the scanning system. For this reason an adapter plate is developed in a CAD environment. It is shown in Fig. 3.

TABLE 3 SCAN MODES OF TRIMBLE X7

Scan Mode	***Duration (min:sec)***	***Spacing (mm) @ 10 m***	***Spacing (mm) @ 35 m***	***Spacing (mm) @ 50 m***	***Number of points (MPTS)***
Stan-dard	1:35	11	40	57	12
	3:43	5	18	26	58
	6:39	4	12	18	125
High sensi-tivity	3:33	9	33	47	17
	6:54	6	21	30	42
	15:40	4	13	19	109

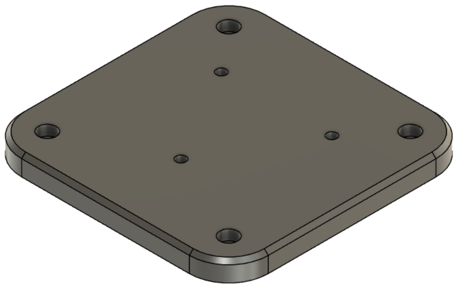

Fig. 3. Adapter plate in CAD environment.

The constructed adapter plate allows attachment to pre-placed V-slot 2020 aluminum profiles on the back of the robot by means of four bolts and four T-nuts. It is 3D printed using FDM/FFF Rapid Prototyping technology. The process parameters are shown in Table 4.

TABLE 4 PARAMETERS OF 3D PRINTING PROCESS

Material	PETG
Nozzle temperature	240°C
Platform temperature	75°C
Nozzle diameter	1 mm
Layer height	0.4 mm
Number of top layers	3
Number of bottom layers	3
Infill	Grid
Infill density	20%
Number of walls	2
Printing speed	45 mm/s
Wall speed	25 mm/s
Top/bottom speed	25 mm/s
Cooling	20%

The placement of the part in the working area of the printer and a visualization of the internal layers in Ultimaker Cura slicer are shown in Fig. 4. The approximate time to print the part is 2 hours and 7 minutes, and the required material is 80 g.

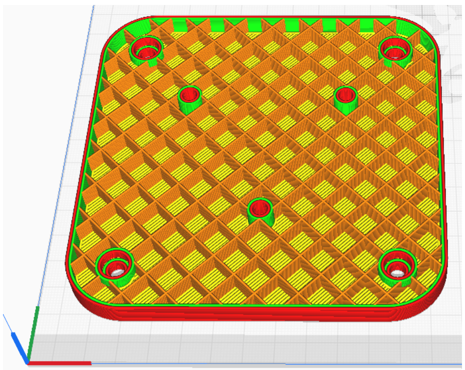

Fig. 4. Adapter plate in Ultimaker Cura slicer.

III. Results and discussion

After the assembling of the fastening device is done the scanner is mounted to the adapter plate using three bolts and is then installed on the back of the robot dog. The final result is shown in Fig. 5.

Fig. 5. Trimble X7 mounted on the back of Unitree Go 1 Edu using the constructed fastening device.

The total weight of the mounting jig including the two V-slot aluminum profiles, the adapter plate and the bolts is around 600 g. The total mass of the load including the 3D scanner and the fastening device is around 6.7 kg which is in the extended load capacity range of the robot dog. One of the main problems is that the 3D scanning system shifts the mass center of the system upwards, which inevitably leads to instability in dynamic conditions. For this reason, it is necessary to operate the robotic system carefully - to move without sudden accelerations and at a relatively low speed.

Two different industrial premises are scanned with the system. The first one is scanned at one location without moving the scanner using the high sensitivity scan mode. The resulting point cloud is shown in Fig. 6.

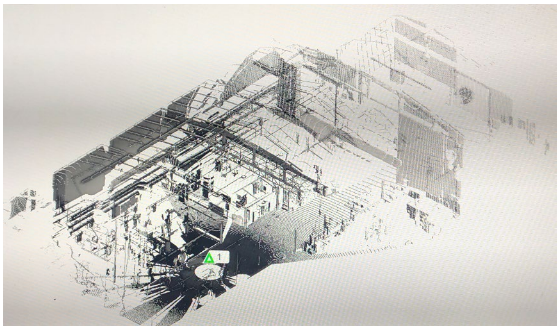

Fig. 6. Point cloud of the first industrial premise.

A black-and-white photography is also taken. Various measurements from the point cloud can be made and can be visualized on the photo, as shown in Fig. 7. The total time for the scan is around four minutes.

Fig. 7. Visualization of a measurement on the photo of the first premise.

The second industrial premise is scanned at two different locations – the robot dog is moved between the scans. The fastest standard scan mode is chosen – the full process takes around seven minutes, including the relocation of the system. The point cloud is shown in Fig. 8 – the scanning points are clearly visible.

Fig. 8. Point cloud of the second industrial premise.

The black-and-white photography of the premise with a measurement is shown in Fig. 9.

Fig. 9. Visualization of a measurement on the photo of the second premise.

The increase of the spacing between the points with increasing distance from the scanner is clearly seen on both of the 3D scans. Nevertheless, the density of the point cloud of the second premise is greater, although the scans are taken in the standard mode.

IV. Conclusions

The case study shows that scanning of an industrial site at different locations increases the density of the point cloud even when faster scan modes are chosen. The robotic system with the integrated scanner could be used for various industrial sites including but not limited to:

- Construction sites;
- Industrial sites and infrastructure;
- Plants and factories;
- Tunnels;
- Storage tanks;
- Warehouses;
- Mines;
- Large sites in the energy sector, such as thermal power plants, hydroelectric power plants, nuclear power plants, etc.;

The main disadvantage of the system is related to the dependence on batteries. The 4500 mAh battery of the robot dog is limited to around 30 minutes of active work with load. A bigger battery would be more suitable for larger sites [14].

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