Smart Scanning of Tunnel Using LiDAR and Point Cloud Data

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Abstract : It is tedious and time consuming job, to perform detail measurement of a site using conventional measuring equipment like digital distance meter, tapes .etc. Now a day's safety of transportation tunnels (such as subway tunnels) is of great importance. Therefore, they need to be regularly monitored to ensure that they are neither deformed, nor displaced excessively. The tunnels are traditionally monitored by regular measurement of some set points, employing land surveying instruments such as total stations. The traditional technique in which very few benchmarks are recorded is quite time-consuming and costly so LiDAR is used

IndexTerms – LiDAR, SD-card, Point cloud sdata, Arduino-Uno.

I. INTRODUCTION

It is tedious and time consuming job, to perform detail measurement of a site using conventional measuring equipment like digital distance meter, tapes .etc. Now a day's safety of transportation tunnels (such as subway tunnels) is of great importance. Therefore, they need to be regularly monitored to ensure that they are neither deformed, nor displaced excessively. The tunnels are traditionally monitored by regular measurement of set points, employing land surveying instruments such as total stations. The traditional technique in which very few benchmarks are recorded is quite time-consuming and costly. As a result, the redundancy of the acquired data is quite low implying that its reliability is also low. The traditional methods require physical presence of land surveyors in the tunnel, which interrupts the regular train schedule. Poor environmental conditions in tunnels can also negatively affect the quality of the collected data. Mobile mapping technology, does not have any of the above mentioned shortcomings since mobile laser scanning (MLS) systems provide quite fast data collection with very high redundancy, which improves the reliability of the acquired data. Moreover, poor environmental conditions do not have a negative impact on MLS systems since they collect data automatically by using active Light Detection and Ranging (LiDAR) sensors. so, the processing of large-volume MLS data can be time-consuming and expensive. Automation of MLS data processing increases its pace and decreases the associated costs. As a result, deformation and displacement analyses can be carried out more frequently, which enhances the safety of tunnels.

II. RELATED WORK

The literature review is based on the assumption that knowledge accumulates, and that we learn from and build on what others have done.

Mustafa Arastounia,[1] proposed an Automated As-Built Model Generation of Subway Tunnels from Mobile LiDAR Data as fully-automated methods for as-built model generation of subway tunnels employing mobile Light Detection and Ranging (LiDAR) data. The employed dataset is acquired by a Velodyne HDL 32E and covers 155 m of a subway tunnel containing six million points. First, the tunnel's main axis and cross sections are extracted. The developed algorithm is applicable to tunnels with any horizontal orientation and degree of curvature since it makes no assumptions, nor does it use any a priori knowledge regarding the tunnel's curvature and horizontal orientation.

Keith Williams et al. [2] proposed briefly on the basics of LIDAR technology in depth of current mobile LIDAR trends, including system components and software. An overview of existing quality control procedures used to verify the accuracy of the collected data is presented. The different case studies provides a clear description of the advantages of mobile LIDAR, including an increase in safety and efficiency. The final sections of the review identify current challenges the industry is facing, the guidelines that currently exist, and what else is needed to streamline the adoption of mobile LIDAR by transportation agencies.

Farsam Farzadpour et al. [3] Presents a coverage model for a class of mechanical LIDAR (Light Detection and Ranging) sensors based on a new performance measure characterizing the difference between the sensor and the target configurations in the 3D space. In particular, this measure is developed on those parameters of the sensor carrying significant impact on the LIDAR coverage performance, within a geometric constraint derived from the physical principles of the LIDAR sensor. The validity of the proposed performance characterization is examined by the simulation carried out for the deployment optimization of the LiDAR sensor network for covering a 3D environment using a gradient-based control law.

Mohammad Awrangjeb et al. [4] presents a new segmentation technique for LIDAR point cloud data for automatic extraction of building roof planes such that the raw LIDAR points are separated into two groups: ground and nonground points. The cells containing the black pixels are clustered such that each cluster represents an individual building or tree. Second, the non-ground points within a cluster are segmented based on their coplanarity and neighborhood relations.

Chen Tongtong et al. [5] presents an improved ground segmentation method for 3D LIDAR point clouds. This approach builds on a polar grid map, which is divided into some sectors, then 1D Gaussian process (GP) regression model and Incremental Sample Consensus (INSAC) algorithm is used to extract ground for every sector.

Pierre Olivier [6] proposed that technologies which are capable of providing a detection and ranging functionality, fom the position information, presence and speed can be retrieved so technologies capable of detection and ranging can be universally applied to all remote sensing applications with the help of Leddar technology.

Hanieh Deilamsalehy et al. [7] Proposed that the data from a 2D *light detection and ranging* (LiDAR) sensor, which can only estimate the pose in a 2D plane is fused in an *extended Kalman filter* with the data from camera and inertial sensors showing that, despite the incomplete estimation from the 2D LiDAR, the overall estimated 3D pose can be improved. So they also compare this scenario with the case where the 2D LiDAR is replaced with a 3D LiDAR with similar characteristics.

G.Vosselman et al. [8] proposed that several techniques that can be used to recognise specific geometric shapes or more general smooth surfaces structures in point clouds. Applications in industry, urban planning, water management and forestry document the usefulness of the proposed techniques.

Manlin Xiao et al. [9] proposed utilization of mobile laser scanner to obtain space data with high resolution which has been applied to get tunnel information. This paper provides a surface flattening algorithm which is based on mechanics revision which could be used to the 3D point cloud data from laser scanners. The damage or destruction located on the tunnel's inner wall could be detected and located based on the 3D laser point cloud data. The first step of this algorithm is the reconstruction of triangular mesh surface to the point cloud data.

Radu Bogdan Rusu et al. [10] presents an advanced and extensive approach to the subject of 3D perception using PCL (Point Cloud library, to provide support for all the common 3D building blocks that applications need. The library contains algorithms for filtering, feature estimation, surface reconstruction, registration, model fitting and segmentation.

III. PROPOSED SYSTEM

The proposed system consist of the tunnel which will be scanned through the LiDAR, that is the rays transmitted from LiDAR and reflected back from the object are obtained in controller and saved in SD card. Then from SD card the data is transmitted to pc and the data is in the point form. Then the point data obtained is triangulated and by doing some calculations on the point data 3D point data is obtained using software like Matlab, Python, and openGL.

Block Diagram of System and Description:-

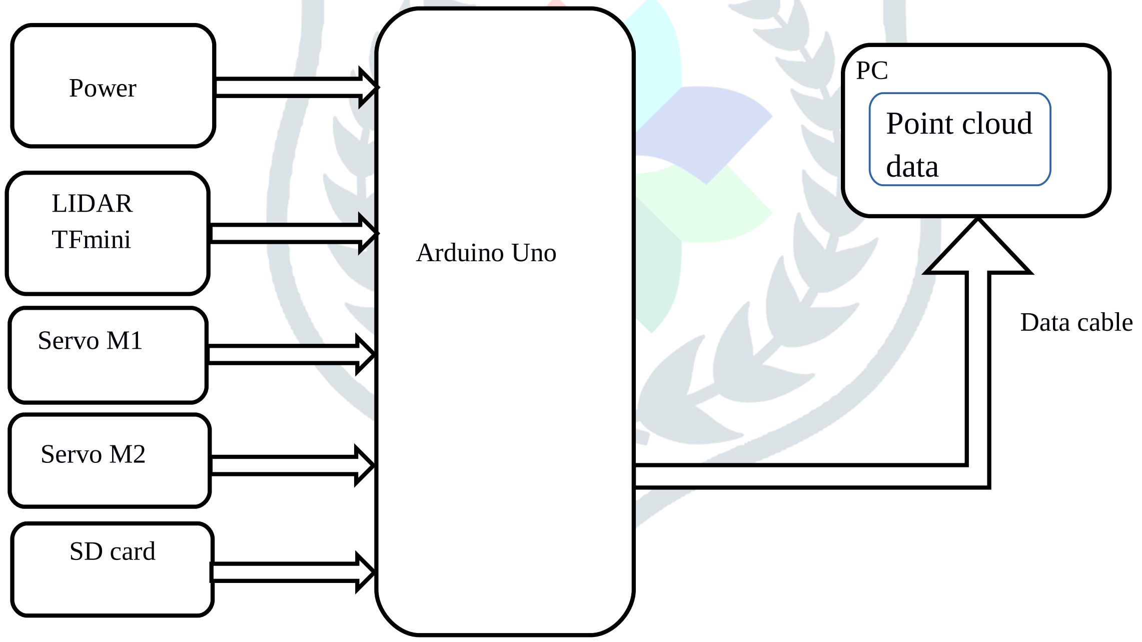

Fig1. - Block diagram of system

LiDAR TFmini:-

Light Detection and Ranging(LiDAR) Technology is a method of using focused light beams to detect distant objects. It works very much like RADAR and in fact the mnemonic "LIDAR" was initially a fusion of the words "RADAR" (Radio Detection And Ranging) and "Light". A more common definition of "LIDAR" is Light Inspection, Detection and Ranging, this more accurately defines LIDARs role in inspection applications. Some publications use the letter "L" in "LIDAR" to mean "Laser" although a LIDAR unit can be built using light sources other than a laser.LIDAR functions by sending out a light beam and measuring its reflected signal. Several aspects of the signal are measured including the light intensity and angle. These measurements can be used to calculate the distance to the reflecting object as well as some information regarding its reflectivity.In many applications the light beam is moved or scanned to get several points of reflection, this data is often displayed in a three dimensional array known as a "point cloud". With a wide array of functions, this sensor has a large variety of applications, including drones, general robotics, industrial sensing and more.

- Input Voltage: 5v
- Average Power: 0.12W

- Communication Protocol: UART (Baud rate: 115200)
- Operating Temperature: -20℃~60℃
- FOV: 2.3°

Servo Motor:

The main feature of servo motor is the ability to precisely control the position of their shaft. A servo motor is a closed-loop system that uses position feedback to control its motion and final position. Inside a hobby servo there are four main components, a DC motor, a gearbox, a potentiometer and a control circuit. The potentiometer is attached on the final gear or the output shaft, so as the motor rotates the potentiometer rotates as well, thus producing a voltage that is related to the absolute angle of the output shaft. In the control circuit, this potentiometer voltage is compared to the voltage coming from the signal line. A servo motor is controlled by sending a series of pulses through the signal line. The frequency of the control signal should be 50Hz or a pulse should occur every 20ms. The width of pulse determines angular position of the servo and these type of servos can usually rotate 180 degrees (they have a physical limits of travel). Generally pulses with 1ms duration correspond to 0 degrees position, 1.5ms duration to 90 degrees and 2ms to 180 degrees. Though the minimum and maximum duration of the pulses can sometimes vary with different brands and they can be 0.5ms for 0 degrees and 2.5ms for 180 degrees position.

Table1: Wire Configuration:

Wire Number	Wire Colour	Description
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

TowerPro SG-90 Feature:

- Operating Voltage is +5V typically
- Torque: 2.5kg/cm
- Operating speed is 0.1s/60°
- Gear Type: Plastic
- Rotation : 0°-180°
- Weight of motor : 9gm
- Package includes gear horns and screws

Arduino Uno:-

The UNO is the best board to get started with electronics and coding. The Arduino Uno can be programmed with the (Arduino Software (IDE)). Select "Arduino/Genuino Uno from the Tools > Board menu (according to the microcontroller on your board). The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header using Arduino ISP or similar.

Logic converter:

Logic systems that have different voltage levels is as follows:

A 3.3 volt OUTPUT can be connected directly to a 5 volt INPUT. This arrangement is not only safe, it also works as the 5 volt input will have a threshold of 2.8 volts for a digital one, within the range of the 3.3 volt output. A 5 volt OUTPUT cannot be connected directly to a 3.3. Volt INPUT. Doing so could possibly damage the 3.3 volt logic device! Some method of voltage reduction or conversion is required.

SD Card Reader:

SD cards are 'raw' storage. There are two ways to interface with SD cards - **SPI mode** and **SDIO mode**. SDIO mode is faster, but is more complex and as far as we can tell, requires signing non-disclosure documents. For that reason, never encounter SDIO mode interface code. They're just sectors in a flash chip, there's no structure that you *have* to use. That means you could format an SD card to be a Linux file system, a FAT (DOS) file system or a Mac file system. You could also not have any file system at all! However, 99% of computers, cameras, MP3 players, GPS loggers, etc require **FAT16** or **FAT32** for the filesystem. The tradeoff here is that for smaller microcontrollers (like the Arduino) the addition of the complex file format handling can take a lot of flash storage and RAM.

IV. SOFTWARE (ALGORITHM &FLOWCHART) .

Algorithm

1. Start
2. Initialize
3. Verification and system calibration
4. Scan the target area
5. Save the data i.e xyz coordinate format .

6. Import point format data .
7. Analyse the point format data.
8. Triangulate the point format Cartesian data to 3d format
9. Stop

FLOWCHART:

Flowchart for controller

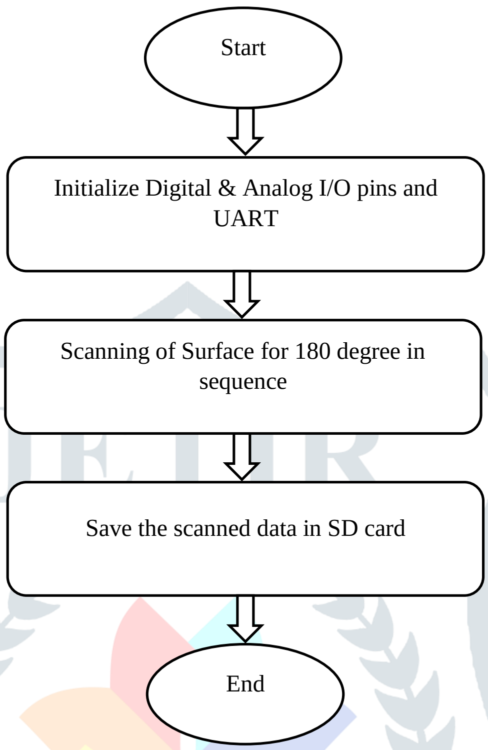

fig2: Flow chart for controller

Flowchart for pc

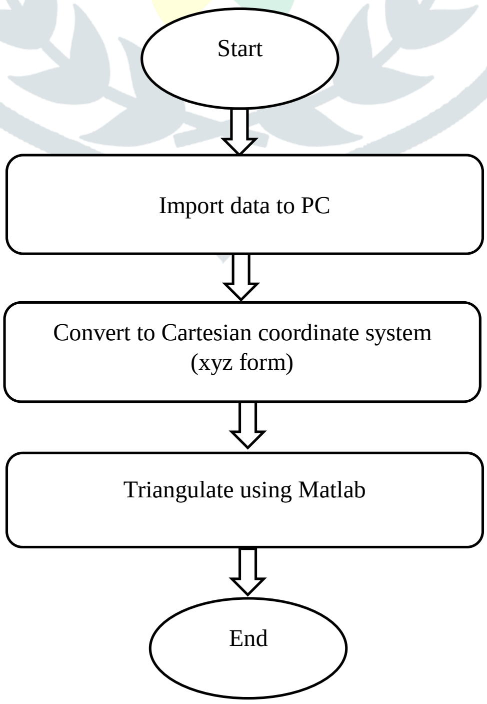

Fig 3: Flow chart for PC

V. RESULTS AND DISCUSSION:

This literature review highlights the use of mobile LIDAR in transportation, including a discussion of current and emerging applications, data quality control, existing guidelines, and challenges. The review shows that there is a lot of interest for mobile LIDAR in transportation, provided appropriate guidance is in place. From this review, there is a lot of discussion of what is being done, but not a lot of how and how well it is being done. Generally, most information related to MLS use are presentations at conferences or short web articles that do not go into detail regarding the work performed. Most quality control checks that are discussed in these reports are verified for vertical accuracy only. Very limited research exists to understand fully the capabilities and limitations of these systems. Given the limited amount of experience that has been documented in the literature, to date it is important that future demonstration/pilot projects be adequately documented and the results disseminated both within a transportation agency and between agencies regarding the challenges, successes, and lessons learned from projects incorporating mobile LIDAR.

VI. CONCLUSION:

From the proposed system we got the distance of the object ,wall structures with the help of LiDAR sensor as well as the 3d view of the structures by rotating the LiDAR in 180 degree in x and y planes and the position can be obtain from the distance of object. Complex industrial structures in metal and mining industries are mostly inaccessible due to high altitudes and hazardous gas-prone zone. To install new accessoris or attachments to this sites there is need of detail survey and measurements of dimensions in this sites this project can be used.

VII. ACKNOWLEDGMENT:

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