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Use of Geodetic Laser Scanner for Mapping Applications: A Review

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Abstract

In the past few years, slope were generated using topographic details captured using Total Station before the existence of Geodetic Laser Scanner (GLS). Although this method can give very high accuracy of measurement for generating slope model; it is expensive, time consuming, does not cover large area and need a physical contact on hazardous area. With GLS, generating slope model can be carried out without direct contact with hazardous area. There is a need of rapid data acquisition for slope mapping studies. The time of data acquisition is very important for fast decision making at the critical study area. Therefore, this study reviews the capabilities of GLS in slope mapping study which involves semi-undulation and undulation study area. This paper concentrates on the development of GLS in surveying applications, the source of errors in GLS measurement and scanning resolution. GLS is very useful in slope mapping studies especially for the rapid decision making for response agencies.

Keywords: *mapping, slope, GLS, accuracy*

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INTRODUCTION

The Geodetic Laser Scanner (GLS) send and capture a signal in x, y and z dimension which is nondirect physical contact with the object or surface [1]. The data then can produce the real surface condition, size and shape into the computer as a digital 3D model or constructing Digital Terrain Model (DTM) that was possible in photogrammetry using relevant processing software [2]. GLS measure details and capture free-from shape and quickly generate highly accurate point. Besides that, the 3D measurement spatial sampling for hazardous area could offer high resolution result using GLS. The x, y and z coordinates were measured based on the distance between instrument and the object which is almost same with the principle of the photogrammetry camera. Laser scanner could offer different wide angle and different scanning resolution which cannot be applied by photogrammetry method. The laser scanner calculated the three-dimensional coordinates for each pixel of the object which is bearing, distance and high. 3D laser scanner is ideally suitable for the measurement and inspection of contoured surface that massive around of data for their accurate description. GLS measured points based on reflectorless and contactless on the topography based on the time-of-flight distance measurement *via* infrared laser pulse. The GLS are able to send out about 30000 points per second within the range of 150 m or 500 ft. This equipment enables to capture a very sharp and high resolution of three dimensional images.

Previous studies have shown various types of GLS application such as landslide monitoring, historical monument and an accident [3–5]. These studies have shown that GLS can be used in these applications. The analysis and monitoring of topographic changes can be applied using 3D laser scanner and it also measures data in 3D very effectively and takes less time as compared to traditional technique [6]. GLS is used for monitoring large landslides, deformation measurement, engineering and geodesy works [7–9]. GLS is also applied in three-dimensional recording of the human face [10, 11] and optical monitoring of scoliosis [12] . GLS is used for the protection of historical buildings at China and study on reverse engineering of historical architecture [3]. Based on the previous studies, it was observed that GLS are able to be used in any fields. Today, the generation of 3D slope was done by conventional technique. From the measurement obtained, a contour will be created and a 3D slope will be generated. So with the advanced technology today, the 3D slope can be directly generated by using GLS. These 3D slopes give a real-time condition on the particular area.

GEODETIC LASER SCANNER (GLS)

GLS is synonym to several other names such as terrestrial laser scanning, ground-based remote sensing or 3D laser scanning. This equipment measure points based on the reflectorless and contactless on the topography based on the time-of-flight distance measurement via infrared laser pulse. This equipment is capable to send out 30000 points per second within the range 150 m or 500 ft [1]. Using this equipment enables to capture a very sharp and high resolution of three dimensional images. The advantages of GLS includes suitability for hazard assessment, ability to collect large amount of data, ability to supply high redundancy data, ability to supply digital data and ability to reconstruct object in 3D. The observation of hazardous area could be done in less time, minimum labour and minimum cost using GLS because it does not involve physical contact with the area of interest. In addition, GLS can collect large amount of point cloud data in a minute and could give the high resolution data. The 3D results are more detailed and accurate and almost same with the real object or surface. Figure 1 shows the Topcon GLS1500 instrument.

Fig. 1: *Topcon GLS1500 [1].*

As mentioned above, GLS is able to capture high redundancy data and it is suitable to detect the land deformation at centimetre level. The dense point cloud is represented in 3D space namely x, y and z relative to the scanner position and laser beam reflected intensity. Using these data, the analysis on 3D object or surface could be carried out.

Scanning from different position is required when it involves very complex surfaces or objects. The profile graph in 2D or contour lines results could be generated using GIS or CAD software and it can be extracted from the 3D reconstructed model. Some errors occur during GLS measurement such as random error, systematic error and axes error [13].

Random errors occur due to the speed of light in air, rise time of the pulse and signal-to-noise ratio of pulse detection. The relationship for these three factors can be illustrated in formula below:

$$\sigma_r = \frac{c}{2}\frac{t_{rise}}{SNR}$$

where,

c = speed of light in air

t_{rise} = rise time of the pulse

SNR = signal-to-noise ratio of pulse detection

Systematic errors can be achieved with the pulsed laser rangefinder. There are two main factors influencing the ranging accuracy. First, the error might be caused by the received pulse or transmitted based on the same relative position.

The rise time of received pulse usually depends on the detector load resistance and incident light wavelength. Second is the accuracy of time interval counter and its stability.

The axes errors are due to the imperfections of mechanical construction of the scanner, which further limits the measurement accuracy. These errors are referred to as axes errors. Due to the manufacturing tolerances, these axes are not perfectly aligned. Consequently the following errors appear. Figure 2 illustrates the collimation axis error applied to the laser scanner.

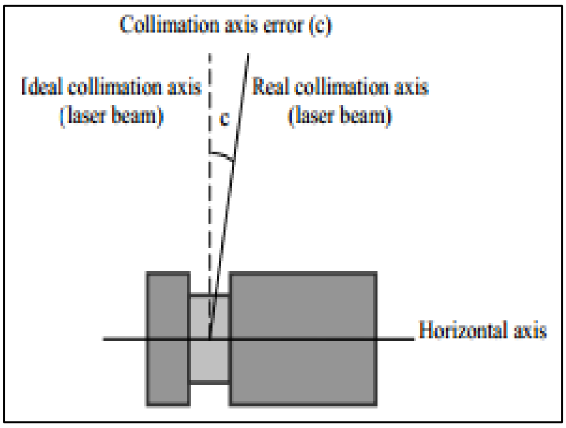

Fig. 2: *Collimation Axis Error Applied to the Laser Scanner [13].*

The angle between vertical axis and horizontal axis in the measured plane is known as horizontal axis error. Angle measurement system is a small rotating device used to deflect the laser pulse in laser scanners. The errors perpendicular to the propagation path can be affected by the angular or bearing reading devices. In normal condition, this error occurs due to the short distance between scanner and the object or surface being measured. Edge effects is due to the laser beam divergence. When the laser beam hits the edge of an object, one part of it is reflected from the object surface, and another from the adjacent surface or not at all (if no object behind within the scanner operating range). The scanners will generate wrong point at the vicinity of edges (Figure 3). The range error might contribute from a fraction of millimetres to decimetres. The point cloud representation might be larger than reality. The problem of edge effect cannot be completely eliminated. The best way to overcome it is to choose a laser scanner with a small beam divergence.

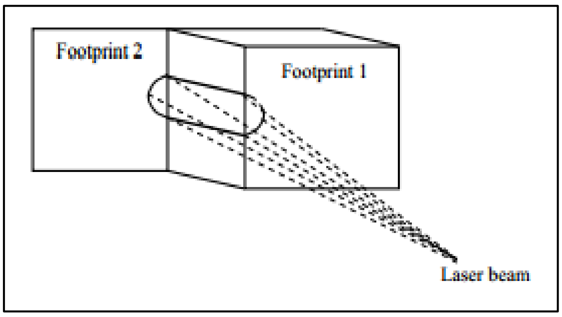

Fig. 3: *Edge Effects [13].*

APPLICATIONS OF GLS

There are various applications of GLS that has been used nowadays such as monitoring historical monument and accidents. Landslide monitoring is one of the applications of GLS [1]. The researcher used GLS to assess the potential GLS to monitor the change of landslide surface in Hulu Behrang, Perak, Malaysia. GLS are capable of monitoring the changes in landslide surface. GLS is used to monitoring landslide for ground deformation analysis [14, 15]. This study introduces the problems and solutions on deformation monitoring based on 3D laser scanner. The application of 3D laser scanner can be applied for deformation monitoring which is better than the traditional methods. 3D laser scanner can measure coordinates of object surface points. Measurement is changed from single point to multipoint. The rate of coordinate measurement is up to 1000 points per second, and the distance between points is less than 1 mm. The measurement is memorized and displayed in the point cloud format. The distance and angle can be measured in point cloud. Modelling based on point cloud is easy. Figure 4 shows the result obtained from monitoring the landslide before and after the movement.

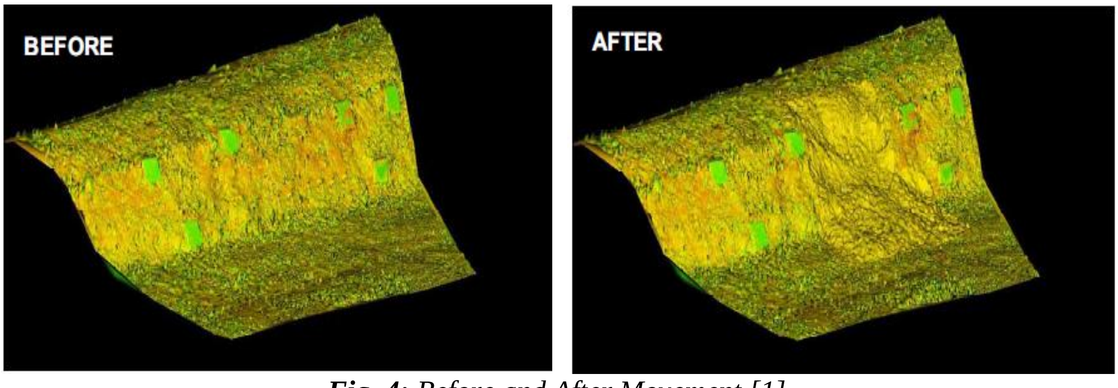

Fig. 4: *Before and After Movement [1].*

GLS is used in investigating the use of laser scanners to aid deformation monitoring of structures over a period of time [16]. The research investigates the resolution of the laser scanner, and determines the minimum deformation that can be detected through such a system. The experiments on landslide monitoring using laser scanner have been explored in Jingyang, Shaanxi province [17]. Laser scanner is also being used to collect data and reconstruct model of the historical building [3]. Fast data acquisition using laser scanner promises fast documentation for research purposes. The discussion on the precision and realistic for 3D model of the heritage site can insist on both the aesthetic and practical implications of restoration and conservation work in the future [18]. Thus, digital documentation of cultural heritage is very important as a digital reference and record for the future generations and refurbishment due to present information remains in the paper and photo format. Traditional 3D modelling tools are often insufficient for cultural heritage applications because of the shape complexity and high accuracy required, whereas 3D laser scanning technique is capably accurate to capture high details of the shape [19]. The generation of detailed 3D models of heritage buildings and artefacts have to accomplish some specifications and requirements in term of geometric accuracy and level of details [20]. The 3D point cloud's accuracy of laser scanner result is based on two factors, namely space resolution and distance accuracy [21]. GLS is used to capture data of historical building for digitization purpose [22]. Figure 5 shows the 3D visualised model.

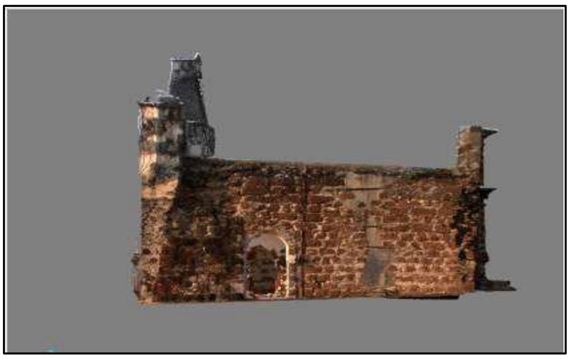

Fig. 5: *3D Visualised Model Using Terrestrial Laser Scanning [23].*

GLS is employed for 3D geospatial modelling of accident scene [4]. The analysis on motor vehicle collision scenes can help manufacturers to assess the vehicle design using laser scanner [5]. Laser scanner could also help in law enforcement to collect the roadside data during accident and use it for analysis purposes for road safety analysis. Assessment on road classification can be done qualitatively. Figure 6 shows the 3D cloud point of accident scene. GLS is utilized to measure accident scenes and able to provide the 3D animation and simulation using the scanning data [24]. The animation of accident sequence and dynamic simulations for the complex vehicle can be prepared using laser scanner system at the accident location. Therefore, laser scanner is very useful in accident investigation and accident reconstruction presentation.

Fig. 6: *3D Cloud Point of Accident Scene [4].*

CONCLUSION

GLS can produce the surface or object based on relevant software. The digital terrain model can be defined using professional surveying instruments such as laser scanner which is based on the positional data. The scanning resolution is directly proportional to the accuracy of the surface or object model. The rapid data acquisition using GLS is very useful for the emergency response agencies which require fast and high accuracy data. However, there are some errors that need to be considered during the measurement in order to avoid any blunder or outliers in the results. Laser scanner is very useful in the project which requires fast data acquisition and minimum manpower.

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