Assessing Handheld Laser Scanner for Crime Scene Analysis

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Abstract

Forensics, also referred to as crime scene analysis, is a field of science that aids juries, prosecutors, and judges in assessing the tangible proof in a criminal case. It is important for finding and convicting criminals. The conventional approach to crime scene analysis requires more work and increases the likelihood of error. In this article, the use of a handheld laser scanner for crime scene documentation has been praised for its convenience and mobility in terms of data collection. In spite of this, the effectiveness of the Handheld Laser Scanner has been the focus of this research, specifically whether the level of data gathered is sufficient for further crime scene analysis. For analysis purposes, Leica RTC360 was used as a benchmark in this research to evaluate the performance of Leica BLK2GO handheld laser scanner. The Handheld Laser Scanner's data reliability and intensity have been found to be insufficient for crime scene analysis with small pieces of evidence, like bullets and typical trajectory rods due to the performance of the instrument, resulting the data is polluted with noise. When it comes to objects or crime scenes that do not require extreme precision, such as crime scene modelling, handheld laser scanners are suitable for the purposes. Despite the instrument's high mobility, analyzing a crime scene requires a higher point cloud intensity when collecting data for better analysis purposes.

Keywords: *Crime Scene Analysis, Handheld Laser Scanner, Bullet Trajectory Analysis*

1. Introduction

Crime scene investigation has been practised since Antistius conducted an autopsy on Julius Caesar, a notable Roman commander, in the year 44 B.C. In the modern era, a forensic examination of a crime scene is carried out with the purpose of determining why and how a crime was committed. It is possible that this evidence will be used throughout the trial to bolster the statements made by witnesses. The conventional method of handling a crime scene [1] entails making use of a DSLR (Digital Single Lens Reflex) camera, which is typically used for the purpose of picture recording purposes. Having said that, there is not much that can be done with the picture that has been supplied, and it is possible that some essential evidence may be overlooked owing to human error. The problem with a traditional crime scene is that it takes a long time and includes various agencies, which may lead to contamination of the evidence if it is not handled correctly. It is likely that by using technology such as a laser scanner, it will be feasible to see the crime scene

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in order to obtain evidence, the form of the region, and its features in a short amount of time while avoiding contamination. Due to the fact that just one person is required for the operation, the number of people who were really at the crime scene may be reduced. The point cloud data that was generated by the laser scanning instrument may be analysed by utilising particularly specialised software such as Faro Zone 3D in order to assist with the investigation of the crime scene. The non-contact features given by laser scanners include scanning millions of point clouds in a short amount of time to get a model of the crime scene without the need for replicas. This function is included as part of the non-contact features offered by laser scanners.

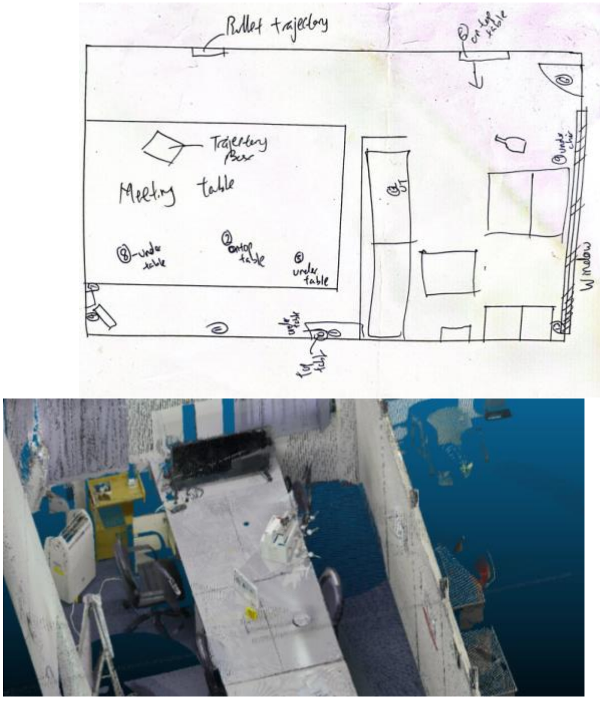

Figure 1. On the top, hand sketched diagram of crime scene and on the bottom, laser scanning data.

1.1 Overview of Laser Scanning

According to [2], 3D scanners are analogue cameras. The laser scanner measures the distances between the device and its surroundings while collecting data similarly to a camera. The laser, which moves at the speed of light, is used to measure distances. The following formula (Eq. 1) is used to determine the distances using the time to the speed of light: -

$$d = \frac{ct}{2} \tag{1}$$

Each point has a unique set of cartesian coordinates that are allocated to it, and almost a million distinct points are recorded every second (X, Y and Z). In addition to the distances, processing for locating points in a 3D environment is aided by other data such as horizontal angle and vertical angle. Substituting Eq.1 into Eq.2 as below.

$$X_p = d.\cos V.\cos H$$
$$Y_p = d.\cos V.\sin H \quad (2)$$
$$Z_p = d.\sin V$$

The coordinates of the point (X_p, Y_p, Z_p) are independently and separately determined using the specified formula. In addition, the scanner can identify an object's colour using RGB (Red, Green, and Blue) detection. Due to this, features can be scanned with a laser scanner even in the absence of light (e.g. At night or in a dark room). According [3], the laser also picks up intensity that is inversely correlated with the backscattering power signal. Environmental variables, equipment limitations, target reflectance characteristics, and scanning geometry may all have an impact on the backscattering signal. According to a research done by [4], to compare the results of day and night mapping, there are no appreciable alterations in the intensity of target surfaces since the difference between data collected during the day and at night is just 0.002 percent.

1.2 LiDAR Scanners

LiDAR stands for Light Detection and Ranging, and it utilizes laser light to measure distances by using the speed of light and the time it takes to travel between the transmitter and receiver. Because the speed of light is constant and time is variable, the distances between the instruments may be estimated using the simple formula d= (ct)/2, where (c) represents the speed of light, (t) represents the time of flight, and (d) represents the distance. LiDAR functions as an active sensor that detects reflected laser light generated by itself and displays information about the observed light intensity [5]. There are 2 types of sensors that exist which is active and passive sensors. Active sensors detect energy that own instrument that produce whereas passive sensors rely on light that is outside the source [6]. Phase shift has a smaller measuring range but a far more capable of dense data gathering than time of flight. It is discovered that each side has a valid point of contention. The time of flight instrument, for example, has superior accuracy than the phase shift instrument but is less effective at resolving small details [7]. Phase shift measurements are nearly identical to Time of Flight measurements in that time delay is taken into consideration while calculating variables. Since we are aware that the phase shift and frequency modulated (f) are defined by the reflectance of the same frequency and relative amplitude. It will then be possible to determine the difference between the broadcast and received signals. Using the equation, where t represents time delay, represents phase shift, and f represents frequency modulation. The value of d=(c*t)/2, where (c) signifies the speed of light, (t) represents the time delay, and (d) is the distance, may be calculated from the (t) time delay earlier [8].

The Leica BLK2GO Handheld Laser Scanner was used for this research subject, and Leica RTC360 will be the benchmark to assess the handheld laser scanner. The BLK2GO has a built in Inertial Measurement Unit (IMU) that measures the movement of the instrument and correct the orientation of the instrument to correct the recorded data. The RTC360 has the similar IMU inside it, but with integrated Visual Inertial System (VIS) to assist the positioning of the instrument without any prism as conventional terrestrial laser scanner. The instrument specification is stated in Table 1 and Table 2.

Table 1. Specification of the Leica BLK2GO Handheld Laser Scanner

Laser Class	1 (in accordance with IEC 60825-1)
Wavelength	830 nm
Field of view	360 degrees (horizontal)/ 270 degrees (vertical)
Range	Minimum 0.5m and up to 25m
Measurement rate	420,000 points/second
Camera	-High resolution 12 Megapixel 90º x 120º rolling shutter -Panoramic 3 camera system 4.8 Megapixel 300º x 135º global shutter
Performance	Range noise +/- 3mm Accuracy indoor +/- 10mm
Measurement Technique	Time of flight measurement

Table 2. Specification of the Leica RTC360 Terrestrial Laser Scanner

Laser Class	1 (in accordance with IEC 60825-1:2014)
Wavelength	1550nm
Field of view	360 degrees (horizontal)/ 300 degrees (vertical)
Range	Minimum 0.5m and up to 130m
Measurement rate	2,000,000 points/second
Camera	-High resolution 36 Megapixel 3-camera system captures 432 MPx raw data for calibrated 360º x 300º spherical image.
Performance	Range noise 0.4mm at 10m and 0.5mm at 20m Accuracy indoor +/- 1.9mm at 10m, 2.9mm at 20m and 5.3mm at 40m
Measurement Technique	Time of flight measurement

1.3 Crime Scene Investigation

A crime scene is a physical site that might be anywhere and includes evidence such as bodies, artefacts, a building, or anything else that investigators determine to be pertinent to the case. A crime scene is also known as a crime scene investigation. The evidence will be given in the courtroom, and the jury will decide which side will be used to demonstrate guilt against a party based on their decision. This is also mentioned in an article by [9], who claim that the evidence will be investigated in order to get information that will be useful in the courts, and they imply that this information will be gained via the analysis of the evidence. It is imperative that the crime scene be preserved and free of any contamination before the arrival of the investigator. This is because there is a possibility of contamination, which might result in a false accusation or the inability to provide the appropriate evidence at the site of the crime (for example, when an unauthorised individual smoke and leaves undesirable traces).

There are three different kinds of crime scenes: those that take place outside, indoors, and in transportation. When a crime occurred outdoors, the evidence at the scene has a greater chance of being lost, tainted, or destroyed in a very short length of time. Evidence must be obtained as quickly as feasible since it might be lost due to the unpredictability of the weather conditions at the site, as a consequence, evidence must be gathered as soon as possible. When a crime takes place indoors, the scene is considered an indoor crime scene. Although the evidence at an indoor crime scene is less likely to be tainted by environmental factors, there is still a possibility that it might be contaminated by human causes [10]. The key challenge consists of stopping unauthorised individuals from obtaining access to the crime scene and taking samples from there. According to [11], a crime scene involving a conveyance is created whenever a crime that involves a transport vehicle is committed, such as the theft of an automobile, the burglary of a vehicle, a homicide, a carjacking, or a major theft. In Edmond Locard's "exchange principle" idea, it is possible for suspects to leave evidence behind when they are trying to flee the scene of an incident.

1.4 Bullet Trajectory Analysis

The trajectory of a bullet is determined when it is fired from one place to another in the direction of a target. The trajectory of the bullet is essential for pinpointing the origin of the shooting, making it essential information for forensic investigators to gather at a crime scene. The trajectory of the bullet is very important for detecting not just the position of the shooter but also the location of the bullet casing, which helps to validate the shooter's position. The "stringing" technique was used in the past to predict the path that a bullet would take, however, the "stringing" method has been replaced by the use of an aluminium rod that has a laser pointer mounted on the end of the aluminium rod. According to [12], the bullet trajectory may be used to prove the suspect's statement, and a crime scene reconstruction can be done using the suspect's statement. They also said that a crime scene reconstruction can be done using the suspect's statement. When the suspect's statement was compared to the simulated trajectory of the bullet, it was found that the suspect's account was inaccurate. The investigator at the crime scene could utilise the fundamental trigonometry approach, in addition to measuring the diameter of the gunshot hole, in order to calculate the height of the suspect. On the other hand, the shape of the bullet holds changes in accordance with the inclination of the angle at which the bullet is discharged. A study made by [13] examined on how the morphology of bullet holes changes depending on the viewing angle, as well as how this affects the form of the hole. When shot in a straight line at an angle of ninety degrees, the bullet has the shape of a sphere, and the length of the bullet hole increases as the angle decreases.

1.5 Point Cloud Surface Reconstruction

The point cloud consists of millions of individual points and it is difficult to look at when its being zoomed closer. Due to intrinsic barriers such as noise, occlusions, sparsity, and density variation, exploitation of the geometry is difficult [14]. Pre-processing routines for 3D mesh geometrical derived from point clouds, on the other hand, can overcome these obstacles, potentially resulting in more refined geometry and topology characterizations.

There are two meshing method which is Ball-Pivoting Algorithm (BPA) and Poisson Reconstruction [15]. The idea of BPA method is using a virtual ball, with a specific size and rolled between the point clouds to create a surface that follows the shape of the point cloud and the ball rolled. Figure 2, from the left indicates that a bigger ball diameter size results in a loss of detail owing to the ball's coverage while a smaller ball diameter results in a hole in the coverage because the distance between the two points is greater than the ball. There are mixtures of big and tiny ball diameters in the final picture. In order to provide a smoother surface for surface reconstruction, the combination of these two has effectively filled in the majority of the gap.

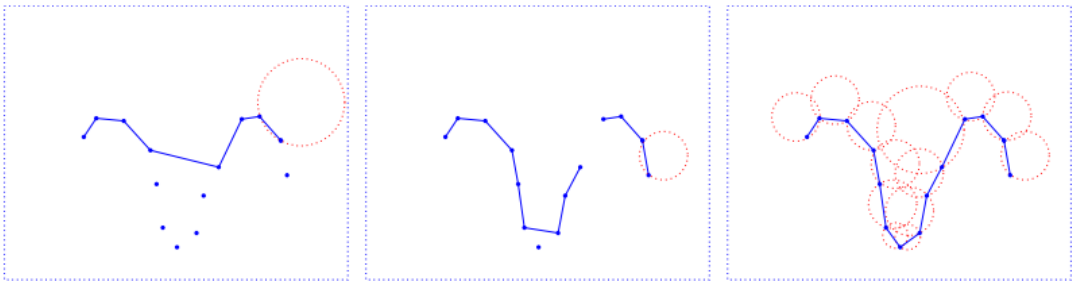

Figure 2. Ball-Pivoting Algorithms illustrated [16]. From the left shows a larger diameter of ball, second image shows smaller diameter and last image shows mix sizes.

Poisson reconstruction on the other hand is using an algorithm to smoothen the surface from dense point cloud. Poisson surface are more known for their resilience in rough and imperfect point cloud data [17]. Another statement by [18] states that Poisson reconstruction method is “enveloping” the data in a smooth cloth.

2. Methodology

For this evaluation to be carried out, a mock crime scene was constructed duplicating a real crime scene. Preparation for measurement analysis such as bullet was cut out from a copper and brass rod closely to actual measurement measured using Vernier calliper.

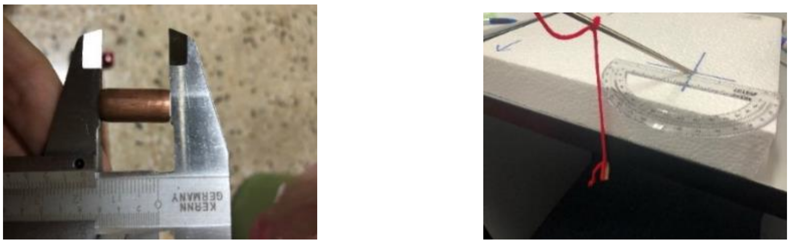

Figure 3. On the left, the measurement of bullet cartridge using Vernier caliper, on the right, measuring the bullet trajectory horizontal component.

Next, bullet cartridge will be placed arbitrary around the crime scene. The crime scene was replicated to a mock crime scene.

Figure 4. The crime scene

In order to test the efficiency of the instrument that was utilised, a fake crime scene was produced by employing items that are often discovered at crime scenes. The crime scene does not portray any actual instances and was created exclusively for the purpose of conducting research and experiments. The crime scene was a piece of fiction that has no resemblance to any actual crime scene that has ever been. The crime scene was placed within the context of a murder investigation that includes a gunshot wound and a stab wound caused by a sharp weapon. The witness had stabbed the suspect as the victim was being stabbed, and the witness had shot a couple of rounds at the culprit.

The figure 5 below shows the flowchart of the process during this research were taken place.

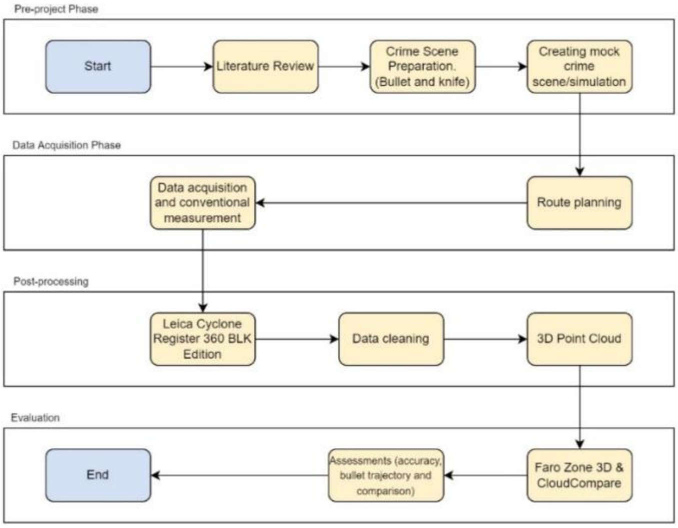

Figure 5. Flowchart of the whole process of this research

Figure 5 shows four research stages. The pre-project phase focuses on basic research, instrument setup, and crime scene preparation. During the data collection phase, conventional measurements and laser scanning data were conducted. During post-processing, raw data was turned to usable point cloud data and cleaned to remove unwanted points so software can handle it more readily. In the last step, called assessment, the cleaned point cloud was utilised for analysis and evaluations.

The data collection was simple since it relies on the device's technology. The Leica RTC360 was used to scan the crime scene across 6 stations in 50 minutes. Leica BLK2GO Handheld Laser Scanner can scan a crime scene in 1 walk and 6 minutes. Figure 5 shows the research instrument.

Figure 6. On the left is the Leica RTC360 and on the right is Leica BLK2GO Handheld Laser Scanner

3. Results

To conduct the analysis for the evaluation purposes, the Faro Zone 3D was used for bullet trajectory analysis whereas CloudCompare was used for measurement purposes. Both BLK2GO Handheld Laser Scanner data and Leica

RTC360 data were being evaluated the same way and will be compared to one and another. The measurement will also be compared with conventional measurement method of using Vernier calliper and protector.

Table 3. Measurement comparison between RTC360 and Vernier Calliper

No	Bullet	Cartridge Casing (Vernier Calliper) (mm)	RTC360 (mm)	Difference (mm)
1	9mm x 19mm Parabellum	19.19	18.028	1.162
2	9mm Largo	23.11	23.022	0.088
3	9mm Largo	23.03	21.213	1.817
4	PTRS Bullet (Anti-Tank Rifle Bullet)	114	111.61	2.39
5	9mm Largo (Brass)	23.2	23.022	0.178
6	9mm Winchester Magnum (Brass)	29.9	27.074	2.826

The data from Table 3 shows the comparison between conventional measurement and RTC360, it was found that there are no significant differences, maximum differences is 2.8 millimetre for bullet cartridge number 13. This is resulted from the performance of RTC360 capability to obtain a huge amount of point cloud per second. The denser it is, the higher number of data it can obtain.

Table 4. Bullet trajectory analysis comparison between RTC360 and conventional method

Hole Num	Conventional (Horizontal)	RTC360 (Horizontal)	Percentage similarity
1	90	89.8	99.777
2	150	142.4	94.933
3	170	161.9	95.235
4	142	137.1	96.549
Hole Num	**Conventional (Vertical)**	**RTC360 (Vertical)**	**Percentage similarity**
4	48	50.3	95.427
5	31	31.1	99.678

In the case of bullet trajectory analysis using the RTC360, the comparison between traditional and RTC360 laser scanner revealed a high degree of resemblance, with a similarity of over 90%. The RTC360 generates a high-resolution point cloud that allows for simpler analysis on thin rods with lesser noise. A higher noise could result in uncertainty when doing bullet trajectory analysis

For BLK2GO Handheld Laser Scanner, the resolution of the point cloud is too high for measurement with the Leica BLK2GO handheld laser scanner. The BLK2GO Handheld Laser Scanner's resolution prevents it from detecting anything too small. Measurement analysis is thus not feasible. Bullet trajectory analysis was still possible for hole number 1 and 2, result is shown in Table 5 below.

Table 5. Bullet trajectory analysis comparison between BLK2GO and conventional method

Hole Num	Original (Horizontal)	BLK2GO (Horizontal)	Percentage similarity
1	90	91	98.901
2	150	138.3	92.2
3	170	NIL	0
4	142	NIL	0
Hole Num	**Original (Vertical)**	**BLK2GO (Vertical)**	**Percentage similarity**
4	48	NIL	0
5	31	NIL	0

From the table 5, only bullet hole number 1 and 2 is able to be analyzed. The trajectory rod for bullet hole 3, 4, and 5 suffers a noise related due to the performance of the Leica BLK2GO. The figure 6 below shows the example of bullet trajectory rod for bullet hole 4 and 5.

Figure 7. Bullet trajectory at bullet hole 4 and 5. Scanned using BLK2GO Handheld Laser Scanner

Figure 7 illustrates how the handheld laser scanner makes an erratic noise while scanning an item like a trajectory rod. This is because of the resolution and the difficulty scanning thin and tiny objects caused by the moving Inertial Measurement Unit.

The handheld laser scanner scans at a rate of 420,000 points per second with an accuracy of 10mm. Small items cannot be scanned with the Leica BLK2GO, however the scene may be scanned for purposes of low precision modelling. The RTC360, on the other hand, scans at a pace of two million points per second with a precision of 2mm at 10m. Both devices contain an inside integrated measurement unit (IMU) that aids in tilting the instrument and corrects it. This 2 equipment require various amounts of time to scan the room. While the RTC360 might take up to 50 minutes with 6 setups, the Leica BLK2GO just needs 6 minutes and 1 walk.

RTC contains one hundred and twenty-four million points, while the point cloud data from the handheld laser scanner has only eight hundred thousand points.

Cloud	
Points	124,428,988

Figure 8. The number of point cloud scanned by Leica RTC360

Cloud	
Points	800,905

Figure 9. Number of point cloud scanned by BLK2GO Handheld Laser Scanner.

Based on the investigation, it was discovered that the performance of the handheld laser scanner makes it more susceptible to noise. The instrument has sensors that allow it to correctly align the corrections based on the device's tilting axis and could deliver some error in process of correcting it. In comparison to the RTC360 laser scanner, the handheld laser scanner has a lower density.

4. Conclusions

The performance of Leica BLK2GO is evaluated during this study based on how it contrasts with the performance of the Leica RTC360, which acts as the standard for this research. It has been shown that the Leica BLK2GO should not be used for crime scene investigations that call for scanning tiny things. There are a few important factors to take into account before making conclusions from this statement. The quality of the data gathered by the handheld laser scanner is lower than that of the Leica RTC360, despite its exceptional mobility. It was found that while scanning small objects, the data from the handheld laser scanner shows noise, making it difficult to perform bullet trajectory analysis. Another issue that came to light when utilizing the handheld laser scanner was that the results were filtered to create less dense point cloud data since the point clouds within a range of 1 cm were excluded by the device. The generated point cloud will be discarded rather than being clustered together into a dense point cloud. This has led to the discovery that small objects like bullet cartridges cannot be scanned. The result, nevertheless, is enough for use in simple modelling applications. This is evident from the fact that the crime scene's point cloud was captured by the Leica RTC360, which produced around 155 times more point clouds than the Leica BLK2GO. Despite that, an expert from the industry stated that for crime scene mapping and modelling, the accuracy does not require high precision as it does not have any analysis involved. Therefore, the Leica BLK2GO Handheld Laser Scanner is sufficient for crime scene mapping but not sufficient for crime scene analysis purposes.

In the original proposal of this research, the initial plan of the research is to test the performance of handheld laser scanner in a real environment and comparing with the data that is needed by relevant authorities such as police, unfortunately the process is not allowable due to confidential reasons. For future recommendations, working close with forensics authorities could be a benefit to check whether the requirement of handheld laser scanner is sufficient for data recording purposes. This could elevate the work of conventional method of crime scene investigation.

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