A Study of Applying Light Detection and Ranging (LIDAR) to Crime Scene Documentation

Che-Yen Wen¹, Ph.D. ; Hsuan-Hsiao Chen², M.S. ; Chao-Kuo Lin³, M.S. ; Wen-Chao Yang⁴, M.B.A

¹ Department of Forensic Science, Central Police University, No.56, Shu Jen Road, Taoyuan 333, Taiwan, R.O.C.
² Forensic Science Section, Pingtung County Government Police Bureau, No.119, Zhongzheng Rd., Pingtung City, Pingtung County 90007, Taiwan, R.O.C.
³ Forensic Science Center, Taichung City Government Police Department, No.588, Sec.2, Wenxin Rd., Xitun Dist, Taichung City 40708, Taiwan, R.O.C.
⁴ Computer Center, Central Police University, No.56, Shu Jen Road, Taoyuan 333, Taiwan, R.O.C.

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Abstract

The Laser Detection Ranging (or Light Detection and Ranging/LIDAR) is a technology based upon remote sensing. The main advantage of applying LIDAR to crime scene documentation is that we can obtain the true-to-scale and non-contact measurement of scenes. However, there are some properties and limitations of LIDAR we should notice when we use it. In this paper, we demonstrate how to apply LIDAR to 3D crime scene data acquisition and point out some particular surfaces that should be considered and prevented. The acquisition and electronic storage of the true-to-scale color digital data can be seen as a virtual conservation of evidence and crime scenes. Finally, three real crime scene cases are proposed to show the performance of applying LIDAR at crime scenes.

Keywords: LIDAR, crime scene documentation, forensic science

Introduction

The main steps of crime scene investigation include scene preservation, case comprehension, scene documenting, evidence collection, result interpretation, and scene reconstruction [1,2,3]. Scene documenting is the most crucial and time-consuming one among above steps. The Laser Detection Ranging (or Light Detection and Ranging/LIDAR) is a technology based upon remote sensing. The main advantage of applying LIDAR to crime scene documentation is that we can obtain the true-to-scale and non-contact measurement of scenes.

Some research works of applying 3D laser technologies to forensic science have been proposed. In bloodstain analysis, 3D laser technologies provide a useful way for analyzing the number and position of bloodstains. The vertical component is determined more precisely than using conventional methods [7]. We can create a virtual crime scene for reconstruction based upon those 3D laser technologies (such as 3D documentation, data merging and animation). The created virtual crime scene can help investigators understand what happened in the crime scene. [8]. Applications of hand-held 3D laser scanners for ephemeral evidence are also done. We can do some measurement on the collected 3D models and get more information than 2D data. They also show the ability to reconstruct missing elements from partial evidence. Ambient lighting also has no negative effect, unlike traditional photography [9]. Comparison between 3D laser scanning, single-image rectification and ground-penetrating radar also had been done. In the case, a laser scanner acts as the gold standard for the comparison due to the quality of the geometrical results provided [10].

*Corresponding author : cwen@mail.cpu.edu.tw
However, few researchers mentioned about the limitations of 3D laser scanner [11]. 3D Risk Mapping [12] indicates that the laser beam is affected by the absorption of the signal travelling through the air, the reflection of the material being measured and the angle of incidence between the laser beam and the surface being measured. This means that for very dark (black) surfaces that will absorb most of the visible spectrum, the reflected signal will be very weak, therefore the point accuracy will be corrupted by noise. However, if the reflectivity of an object is too high (such as metal surface), the laser beam is fully deflected in the mirroring direction, and will hit another surface or spread into the open. This deflection results in the point being measured not being the point that the laser is pointing at, but another point or no point at all. This type of noise is called speckle noise. Surfaces with proper reflectance (i.e. bright surfaces) give more reliable and precise range measurements.

In this paper, we show some experiments and examine results that may affect the 3D point clouds. Three real crime scene cases are also proposed to show the performance of applying LIDAR in crime scene.

Materials and methods

For the 3D documentation of the crime scene, a 3D laser scanner RIEGL VZ400 Fig.1 is utilized in this paper. Such a system allows for the generation of millions of 3D points in no time. The 3D laser scanner sends laser beams to the investigation environment while rotating with a horizontal angle of up to 360° and a vertical angle of up to 100°. A 3D model of the crime scene is created out of the point cloud, using the RiSCAN software. The 3D laser scanner and experimental procedures are summarized as follows:

1) The terrestrial laser scanning system (Hardware)

The terrestrial laser scanning system (Riegl VZ-400) used in this article is comprised of a rapid and accurate 3D scanner with the associated software (RiSCAN Pro) [4,5,6] (please see Fig. 2). The measurement is performed by using the time of flight to determine the range and two encoders for the angular evaluation. Time of flight scanners use a diode pumped laser and the distance is determined based on the return flight time of each laser beam (please see Fig. 3). Time of flight scanners is well suited for large ranges, but they may have a higher signal to noise ratio in short and medium ranges than other comparable technologies. The accuracy of these systems ranges between 3 and 8 mm and seems enough for purposes in crime scene construction. Precise mechatronics systems are used for positioning the mirrors that orientate the laser beam to the measured field. A rotating mirror with 90° travel is used for vertical measurements and a servo motor that rotates 360° allows horizontal scanning. Furthermore, the laser scanner used in this experiment uses an infrared Class 1 laser, which indicates that it is inherently safe and there is no possibility of eye damage. The technical characteristics of the laser scanner are shown in Table 1.
Table 1 Technical data from the Riegl VZ-400 terrestrial laser scanner according to the manufacturer datasheet [4–6].
2) RiSCAN PRO (Software)

RiSCAN PRO is the accompanying software package for RIEGL 3D laser imaging scanners [4–6]. It allows users to perform a large number of tasks including sensor configuration, data acquisition, data visualization, data manipulation, data post-processing, and data archiving [5]. Fig. 4 shows the workspace of RiSCAN PRO.

![Fig. 4 Workspace of RiSCAN PRO [4–6].](image)

3) Experimental procedures

In order to document scenes, the procedures include two steps:

A. 3D data acquisition

1. New position n
2. Set the scanner at position
3. Set the scan pattern
4. Start scanning
5. Photoing

B. Post-process

1. Data visualization (Color from images)
2. Data registration
3. Multi Station Adjustment

Display results (Produce animations)

![Fig. 5 Flowchart of 3D data acquisition.](image)

![Fig. 6 Flowchart of Post-process.](image)
Experiments

There are three main parts in our experiments: first, we use the scanner to do a room scanning and check the results; then, we use the scanner to test some translucent materials. Finally, we apply the scanner to real crime scene cases. The parameters of scan pattern panorama as 0.040° to scan mirror surface in all the experiments (about 20 million 3D point clouds in one time scan).

1) Data-shadowing

Laser beams move forward linearly like a light source which will cause objects to shadow one another and holes or voids to appear in the scan data. The effects of shadowing can be minimized by setting more scan positions from multiple angles. However, in some cases, objects are very close to each other, data shadowing is unavoidable, see Fig. 7.

The Riegl VZ-400 has a minimum scanning range 1.5m. Anything in the area can't be recorded, see Fig. 8.

2-1) Particular surface- translucent materials

We set the parameter "scan pattern panorama" as 0.040° to scan six kinds of translucent materials. Fig. 9 and Table 2 describe those materials. Figs. 10 and 11 show their point clouds. With the scanning results, we can see the point clouds of translucent materials are difficult to get.

<table>
<thead>
<tr>
<th>NO.</th>
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<tr>
<td>1</td>
<td>Half glass bottle of water with a scale in it</td>
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<tr>
<td>2</td>
<td>Glass bottle</td>
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<tr>
<td>3</td>
<td>Glass bottle with uneven surface</td>
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<tr>
<td>4</td>
<td>Half plastic bottle of water with a black cap</td>
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<td>5</td>
<td>Plastic bottle</td>
</tr>
<tr>
<td>6</td>
<td>Plastic drawer with uneven surface</td>
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</table>

Fig. 9 Six kinds of translucent materials.

Table 2 Six kinds of translucent materials

Fig. 10 The scanning result of front view of six translucent materials.
A number of materials have a semi-transparent coating that allows the laser beam to refract and reflect in the material itself (i.e. plastic, marble) (please see Fig. 12). These effects lead to an addition constant to the distance measurements, which has to be regarded in the computation [12].

![Fig. 12 Refraction effects in translucent materials [12].](image)

**2-2) Particular surface - glass**

In burglar or gunshot cases, we usually see lots of broken windows. The patterns of broken windows may help us determine what kind of tools or weapons the suspect used. However, it is difficult to get the point clouds of glass materials correctly.

Fig. 13 (a) and (b) show the front view and lateral view of a gunshot window. We cannot get the correct point clouds. When we put window films on the windows, two situations would happen. One is that the laser will penetrate and hit the objects behind, another is that the laser will be blocked. The effect may due to the highly reflective substance, some window films have special ingredients, like metal (for heat insulation or privacy) or something else. Figs. 14-17 show some experiments.

![Fig. 13 The scanning result of a gunshot window](image)

(a) Front view          (b) Lateral view

![Fig. 14 The scanning result of a windshield with window films on it](image)

(a) Front view          (b) Behind the windshield

![Fig. 15 The scanning result of a windshield with window films on it](image)
2-3) **Particular surface-Automotive paints**

Automotive paint is another issue of effecting the construction of point clouds. Some paints have peculiar composition, such as mica segments, metal (aluminum, zinc...) powder. Figs. 18-24 show some car paint surfaces documented by our laser scanner.
2-4) Particular surface-mirror

Figs. 25 and 26 show the scanning results on mirror surface. In order to display scanning results, we remove some unconcerned point clouds. With the scanning results, we find that when a laser beam hits the mirror surface, it will be reflected from the surface and hit the object, then return again to the mirror surface. Finally the laser beam reaches the instrument receiver. Point cloud of virtual objects behind the mirror will be generated.
2-5) Particular surface-metal

Figs. 27 and 28 show the scanning results on metal surface. In order to display scanning results, we remove some unconcerned point clouds. We get a similar result as the mirror surface experiment.

Fig. 27 The metal doors for metal surface scanning.

Fig. 28 The result of metal surface scanning.

3) Beam Divergence

Beam divergence is the expansion of a laser beam (in diameter) as it moves outward from the instrument. The location data of the measured point return to the sensor can be anywhere within the bounds of the laser spot size. Therefore the data at greater distance can be less reliable and less accurate. There are ways to minimize the effects of beam divergence such as focusing the laser at greater distances (long range mode) or set more scan positions. However, beam divergence is still an important consideration in projects. Fig. 29 shows the control panel of our scanner. The technical data come from manufacturer datasheet. Panorama scan 0.010° represents angular Stepwidth between consecutive scan lines. "0.010° = 2cm@100m" means distance between two point cloud at 100m away. We set scan pattern panorama 0.040° and distance 5m, 10m, 15m, 20m to scan some scales, labels and tags which are commonly used in scene documenting. Fig. 30 shows labels, tags, and scales which are used at crime scene. Figs. 31 and 32 show the scanning results of Fig. 30.

Fig. 29 The control panel for parameters of panorama setting on our scanner.
Fig. 30 The labels, tags, and scales which are used at crime scene.

Fig. 31 The scanning results of the labels, tags, and scales.

Fig. 32 The scanning results of the meter rod.
4) Color (RGB) information/Intensity/Texture

In addition to collecting surface measurements for an object, many laser scan systems include the option to collect intensity values as well as color/RGB information. Intensity data is a measure of the reflective value of a surface and is typically displayed as grayscale whereas RGB data is full color. While RGB collection adds a photo-realistic quality to scans, it can be difficult to collect accurate color information for an object. RGB color captured internally or externally to the scan system is subject to the lighting environment in which a scan is taken. If the lighting changes or fluctuates during the data acquisition process, individual scans will vary in brightness and contrast across the object and can result in color artifacts if not properly adjusted during data processing. In short, when combining multiple scans across an object or structure, it can be a challenge to get uniform and consistent color across the object.

5) Size/Thickness

The technical data of the Riegl VZ-400 terrestrial laser scanner according to the manufacturer datasheet indicates that accuracy is 5mm. In order to find out if it will affect scanning results, we prepared 5x5 cm paper planks and overlapped, see Figs. 33 and 34. We set panorama 0.040°, 5m to scan the paper planks. With the scanning results (Fig. 35 and Table 3), we find that when layers more than 3, we can identify the paper plank from background. When comes to more than 4 layers, we can distinguish obviously. But the premise is that there are enough point clouds. We can increase point clouds by setting more scan positions or shortening the scanning range.

Fig. 33 Paper planks for our experiment (first row is side by side).

Fig. 34 Paper planks for our experiment.

Fig. 35 The scanning result of Fig. 33.
Table 3 Paper planks for our experiment.

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6) Real cases

From the results of above five experiments, we can see some limitations for using LIDAR. So, we need to be care and avoid any improper explanation for the point clouds of crime scene.

In the following experiments, we use LIDAR to record three real crime scene cases. From Figs. 36-38, we can see the capability of LIDAR for recording the whole model of crime scene. However, we need to beware when we check the point clouds of models based upon above limitation experiments.

The first case is a construction site burglary (Fig. 36). A notebook and some money in the office were stolen. The second case is a house burglary (Fig. 37). The thief destroyed the grille of the kitchen, and stole some cash and jewels. The third case is also a burglary (Fig. 38), the type of residence is three-bedroom apartment. Some cash and consumer electronics devices were stolen.