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Title: "Use of GIS and Differential GPS in Mapping of Spatial Distribution Evidence for Outdoor Crime Scene: A Simulation Study"

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Abstract—It is vital to envisage the location of the evidence to get an idea on how the crime took place and in what manner. Managing outdoor crime scenes with the application of conventional method can be a demanding job to achieve exclusively when the crime emerged in big space, where there is lack of reference points and tress being surrounded. In this research, two simulated outdoor crime scenes were created, where both manual tape measurement and DGPS unit was applied to see if the differential GPS offers an accurate and reliable alternative for mapping the scene over the baseline method. To develop a final digital map of the simulated outdoor scenes was utilized using Geographical Information System. The result indicates that the DGPS unit provides a consistent reading when compared to manual tape measurement giving an average reading difference of 0.06 cm and 0.13 cm. The study concluded through statistical analysis that DGPS unit can be a viable alternative for mapping the outdoor crime scenes.

KEYWORDS: Forensic Science; Outdoor Crime Scene; Simulated; DGPS; ArcGIS.

INTRODUCTION

The documentation of the structure and appearance of physical environments in an outdoor crime scene is often a critical process in many applications. Forensic scientists are required to collect evidential data, locations of objects, as well as topological and metric layouts. They are required to do so in a meticulous and resourceful manner, with a careful and traceable recording of findings, often within constrained time limits. Mapping or sketching is considered one of the primary means of documentation as it portrays the distance and dimensions of the crime scene and the physical evidence within it [1]. Nevertheless, outdoor scenes are not processed with the same high standards as indoor scenes [2]. Law-enforcement protocols for processing indoor scenes are well established and provide scientifically validated, court-room defendable reconstructions of past events, whereas, outdoor scenes are basically nonexistent [3].

Mapping the scene which is relatively large can be time consuming and are susceptible to human errors. There are cases where the evidences are found from one end to other or where no reference points are found in assisting the scene mapping and thus, the complication occurs during this time and this is where hand-drawn maps or traditional manual method become difficult to complete even with the help of total station. This is where an interstice in crime scene documentation occurs. It is apparent that the exact position or location of the evidence cannot always be derived from the photographs or videography Advance technology like 360°, total stations, and 3D laser scans are available, but require specific expertise and it's cost effective. The use of such techniques are routinely applied in the field of archaeology work but uncommonly used in the forensic field [4].

In recent years, to record locational data of evidence at a forensic scene, technology is being constantly adapted that provides an inclusive spatial component for analysis [5]. However, the standard global positioning system (GPS) units commonly do not offer the appropriate degree of accuracy for mapping the remains at the scene [6]. In a more recent study, DGPS with post- processing was implemented in situations where scattered remains and scavenging patterns of human cadaver are extensively dispersed in a topographically varied area [7-8]. Such enhanced unit like differential global positioning system (DGPS) has the potential to collect accurate positional information of objects and provide the location of the object on the earth. But studies show that close proximity i.e., (approximately 12 feet) without post processing was the limitation [8-9]. The DGPS unit conducted in past research has determined a virtuous result for artifacts found at the open environment but the accuracy limitation was covered only when the data were differentially corrected using post-processing against the closest base station. However, there is a drawback to post processing as it requires a supplementary work where the unprocessed data are transferred to a desktop computer and imported to Trimble Path finder to get the processed data. Also, the use of DGPS (Trimble R1GNSS) without the need of post-processing in crime scene management is unheard as it is relatively a new technology that needs to be comprehensively engaged in mapping the scene, concerning the different aspects of this utility, close proximity, lack of reference points. Such type of DGPS which does not need post-processing further reduces potential sources of error, hence, increased accuracy. The present study focusses on utilizing such type of DGPS which does not require post-processing. In the Indian context, the use of the conventional method is still very much in practice by the investigators. And in order to ease the work of the police investigators, this particular research has been conducted whether DGPS could be a viable alternative over the conventional method and to examine the level of accuracy that can be achieved with the use of DGPS (Differential Global Positioning System) in the outdoor crime scene.

2. MATERIALS AND METHODS:

The study was conducted within the University campus, SHUATS, Allahabad. For this study, a handheld standalone DGPS device (Trimble R1GNSS) and TerraFlex software was used. The conventional method is still utilized for crime scene documentation. For these reasons, tape measures and compass was used for crime mapping. Thus, this study compares the DGPS with hand-drawn rather than other electronic techniques. In order to test the accuracy for outdoor scenes and for shorter distances, two crime scenes were set up.

Two scenarios were constructed to depict a couple of examples that may be encountered in reality. One represents the lack of reference points (Scenario 1), close proximity (Scenario 2) in an open space. A baseline was developed to conduct the measurements which basically require two fixed points where X and Y coordinates location of the evidence was measured with a tape to get the exact position of the evidence. Measurements were taken from the baseline at an approximate 90-degrees angle from the baseline to a point on the identified item or area of the crime scene. Most measurements were made either to center mass of the item or to the nearest point of the item to the baseline.

2.1 Data collection parameters of differential GPS

The differential GPS data collection was done right after the manual measurement was completed. The R1GNSS device (Figure.1) was placed in a vertical direction as it was found to be more accurate than horizontal direction [7]. Furthermore, while collecting the data, the device was positioned at a predetermined point adjacent or close to the evidence on the ground and remained stationary throughout the collection of each data. The accuracy of the DGPS information for every area was checked and the length of time taken to finish the data collection of each scene was recorded. This standalone unit delivers GNSS positions in real-time without the need for post-processing because correction sources such as SBAS and RTX networks are applied to suit the location giving the desired accuracy in achieving reliable GNSS information anywhere in the world.

2.2 Application of Trimble Terra Flex Software:

Trimble Terra Flex Software which provided "real-time" differential correction was used. In order to collect the data, a device was required so in this study Samsung Tablet (SM-T5S) was used. This particular software was installed in the Samsung tablet that provides a set of tools where Crime Scene Project was created and templates were designed by utilizing the drop and drag box. For the collection of data to be more organized, various attributes based on outdoor crime scenes were listed down for the crime scenes which includes information like date, type of crime, the location of crime, overall photographs, evidences, types of evidence, the photograph of the evidences, collector name, signature etc. Data collected from the field were automatically synced; the plugin automatically pulls the data back from Terra Flex into the feature class without any intermediary file import or export steps, saving time and effort. The data were downloaded directly as CSV format that includes all the crime scene pictures and locations (latitude and longitude) of all the data which was saved automatically in Microsoft Excel sheet.

2.3 Map creation using ArcGIS software

The tools available in GIS analysis have not yet been utilized to assess their usefulness for an outdoor crime scene. The collected data were exported to ArcGIS software with the point data for analysis and creation of the map for the outdoor scene. The distances between the points of the corners, reference points and the evidence to that of the baseline were measured using the measuring tool in ArcGIS and were further compared with the manual measurement. The final map was created and the base map (world imagery) was layered to give geography of the crime location.

3. STATISTICAL DATA ANALYSIS:

T-test is used to compare two different set of values for comparison, therefore in the present study, the T-test was applied for drawing conclusions from the data. The calculated value of T was compared with the tabulated value at 5% level of probability for the appropriate degree of freedom [10]. In this study, T-test was applied to see if the DGPS unit gives a consistent reading as that of manual reading. The formula for T-test is given below:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{x_1 x_2} \bullet \sqrt{\frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}}}}$$

Where,
X_1 = Sample mean for first set of values.
X_2 = Sample mean for second set of values.
$S_{x_1 x_2}$ = Standard Deviation.
n_1 = Total number of values in first set.
n_2 = Total number of values in second set.

4. RESULTS OF SIMULATED SCENARIOS

Scenario 1 was conducted at a place where there were no reference or static points and the overview of the simulated scene is shown in Figure 2. The accuracy for this area was 46 cm and the time taken by manual method was 25 min and DGPS 35 min. Since there were no trees or poles to conduct the measurements, the baseline was taken from the two sides at 15 m each so as to measure the evidence at 90 degrees to the baseline. Figure 3 depicts the hand-drawn sketch. The final Arc map and the base map generated for the simulated scene is displayed in Figure 4. The map and sketch show the relationship and distance of all the evidence found at the scene. The average difference between these two methods was 0.01cm which is shown in Table 1; whereas Table 2 indicates the T-test analysis showing that both the methods gave a consistent reading

Scenario 2 was created in a big spacious area where the overview of the scene is displayed in Figure 5 where two trees were taken as the Static Reference Points to conduct the measurements. The accuracy of DGPS for this area was 51 cm. In this scenario, a series of blood drops were made close to each other to see the accuracy between close proximity. The collection time taken by the traditional method was 30 min and the DGPS unit was 40 min. This particular unit used for this research was able to distinguish the evidence lying close to each other without showing any overlapping. Figure 6 displays the hand-drawn sketch, the final Arc Map and the base map generated from ArcGIS is displayed in Figure 7. Measurements between two methods gave an average difference of only 0.05 cm which is displayed in Table 3. The analysis shows that the reading of the DGPS unit is found consistent with the manual reading indicated in Table 4.

5. DISCUSSIONS

The problem ascends in investigation especially for cold cases when the exact location of peace of evidence is not visualized. The recording and visualizing of this spatial distribution are needed in order to reconstruct or recreate the crime scene [4]. The conventional method can produce errors as human are liable to mistake. Two parameters were considered for implementation of DGPS unit for mapping the outdoor crime scenes. The accuracy calculated from the two scenarios produced consistent reading from both the methods. Furthermore, at places where there are no reference points, pieces of evidence in close association, and places where tree density cover affect the accuracy [9], DGPS unit used for this study was pretty convenient to handle as compared to the manual method. The time taken by both the method in all the simulated scenes showed a difference from 5 to 10 min only which from this research it recommends that DGPS method has more advantages over the manual method as these locations can always relocate back even after decades passed for cold cases because the coordinates once taken will never change.

Limited research has been conducted concerning the use of DGPS in crime mapping. In relation to the forensic investigation, the GPS and GIS have been used for geographic profiling and crime mapping [11-13]. The GPS receiver used in a recent study could not distinguish the items that are close to each other [9]. However, in our study, the DGPS unit used for the study was able to differentiate the items that are 24cm apart from each other. Studies conducted 12 years ago, shows error level of 1.7m for DGPS unit in open environment [14], which clearly demonstrates that there is rapid pace in DGPS technology when compared to centimeter level accuracy without the need of post - processing determined from this study. The readings collected from the manual method and DGPS unit, produced a consistent result which was statically analyzed using T-test. Therefore, it can be concluded from the above data that there is no technical difference between the two methods, however practically with the use of DGPS unit it is more accurate and reliable because of its portability and ease to use for a long distance, long duration. The device used for this study is rugged, compact and does not have any issue with the environmental condition as it is waterproof, therefore to use this device for any weather condition is highly recommended especially for outdoor crime scenes. The use of Geographical Information System (GIS) should be implemented to ensure a successful combination of all the data and subsequent mapping of the distribution of the evidence and its context [4]. Therefore, ArcGIS was utilized in this study to present the final map of the simulated outdoor crime scenes where the world imagery base map was layered to give a better view of the geography of the scene.

DGPS unit has advantages over the conventional method. With the use of DGPS unit single person can handle in collecting the coordinates, however, for conventional method, it requires at least two to three people to conduct the measurements. Single ArcMap can be established which includes all the measurements layered by real - world imagery which will give a better scenario about the crime scene. With the manual readings, recreation or reconstruction is not possible at the actual crime scene after decades due to change in nature and environmental factors. Nevetherless, with the use of DGPS coordinates, recreation/reconstruction of crime scenes is possible for cold cases as the coordinates once taken will never change. With the use of this device, an error could be reduced below 2 cm based on this study. The implementation of this advanced technology will definitely help the law enforcement, the investigators providing integrity to the justice system. Further research on error levels for other DGPS units could be studied as only a single unit was considered for this study.

6. CONCLUSION

Mapping an outdoor crime scene could be a challenging job for the investigators due to various physical conditions. The study concludes that, the device used for this research, Trimble R1GNSS along with the software Trimble Tera Flex could be a good alternative to implement for the outdoor crimes scenes. GIS was used to measure the distance with the help of a measuring tool, providing an informed justified map. The receiver used in this research was quite applicable for areas where trees were surrounded, pieces of evidence found close to each other and lack of static reference points. Though several factors may affect the accuracy, the error produced in this study is achievable for mapping the outdoor crime scene. To relocate back the location, the use of DGPS coordinates is achievable anytime. However, the use of DGPS for mapping indoor scenes was not feasible due to its indoor limitations.

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Tables

1. Table 1 Measurements between Manual method and DGPS unit.

Sl.No	Code	Name of the Evidences	MM (M1) (In meter)	DGPS (M2) (In meter)	Diff. Between M1 and M2	Avg. diff. (cm)
1.	CRP1	CRP1-CRP2	42.5	42.53	-0.03	
2.	CRP2	CRP2-CRP3	67.4	67.86	-0.46	
3.	CRP3	CRP3-CRP4	44	45.52	-1.52	
4.	CRP4	CRP4-CRP5	56.3	56.18	0.12	
5.	CRP5	CRP5-CRP2	56.3	56.18	0.12	
6.	E1	Series of blood	23.7	22.62	1.08	0.06
7.	E2	-do-	27.6	26.19	1.41	
8.	E3	-do-	21.7	24	-2.3	
9.	E4	-do-	22.2	21.7	0.5	
10.	E5	Knife with blood stain	34.11	33.9	0.21	
11.	E6	Hair clip	22	23.8	-1.8	

Table 2 Unpaired T-test for two samples assuming equal variance

Category	Calculated value	Table Value	Degree of Freedom	Alternate Hypothesis	S/NS
Crime Scene 1	0.03	2.08	20	Rejected	NS

3.

Table 3 Measurements between Manual, DGPS unit and Recreation

Sl. No.	Code	Name of the Evidences	MM (M1) (In meter)	DGPS (M2) (In meter)	Diff. Between M1 and M2	Average diff.
1.	CRP1	CRP1-CRP2	6.31	5.49	0.82	
2.	CRP2	CRP2-CRP3	13.50	13.41	0.09	
3.	CRP3	CRP3-CRP4	5.50	5.36	0.14	
4.	CRP4	CRP4-CRP1	13.69	14.08	-0.39	0.13
5.	SRP1-SRP2	Trees (RP1-RP2)	4.00	4.18	-0.18	
6.	E1	Tablet cover	2.63	2.23	0.40	
7.	E2	Watch	1.98	1.91	0.06	

4. Table 4 Unpaired T-test for two samples assuming equal variance

Category	Calculated value	Table Value	Degree of Freedom	Alternate Hypothesis	S/NS
Crime Scene 2	0.05	2.17	12	Rejected	NS

Figures

1.

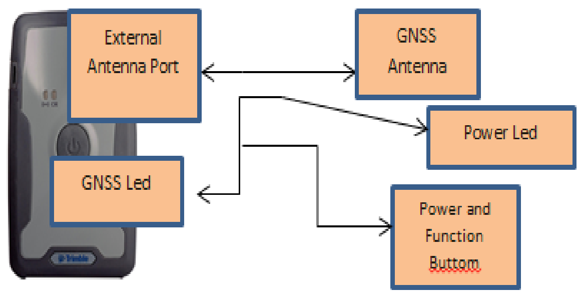

Figure 1: Trimble R1GNNS

2.

Figure 2: Overview of Simulated Scene 1

3.

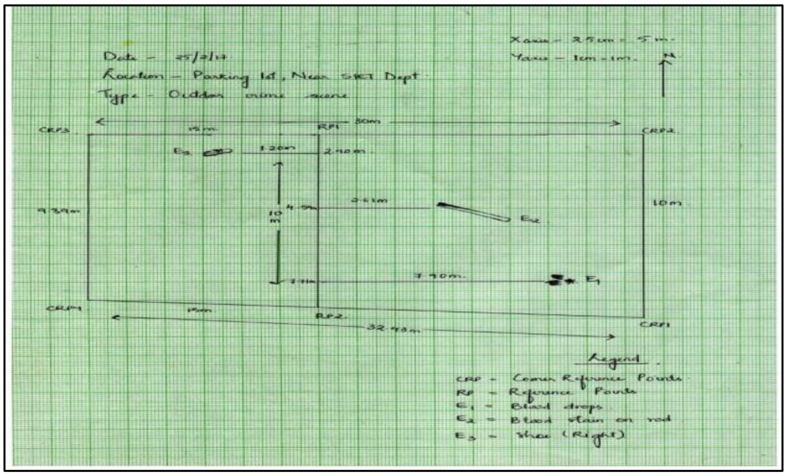

Figure 3: Hand drawn sketch of simulated scene 1

4.

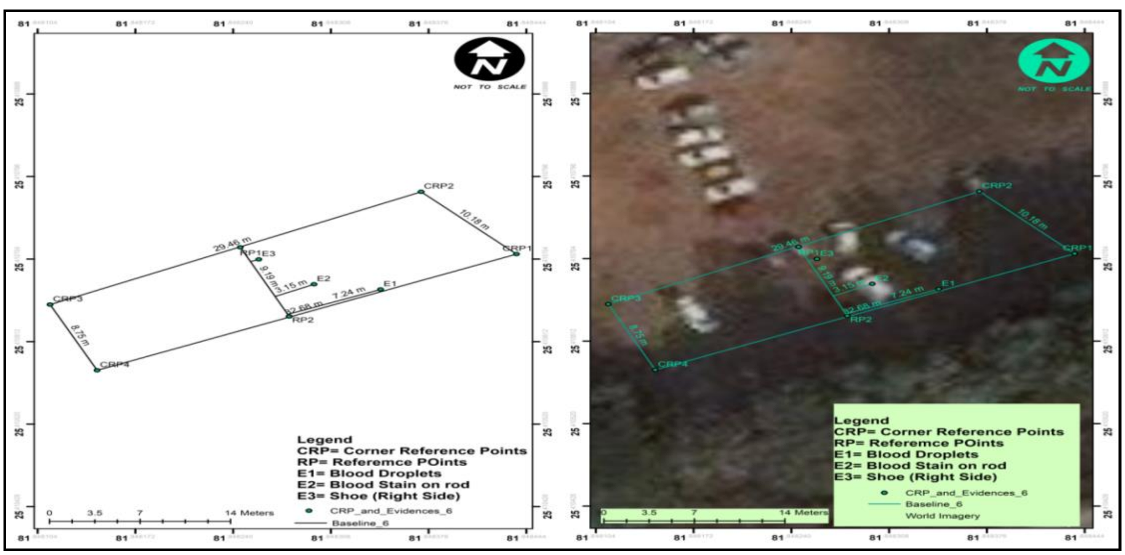

Figure 4: Final ArcMap and Base Map through ArcGIS of simulated scene 1

5.

Figure 5: Overall view of simulated scene 2

6.

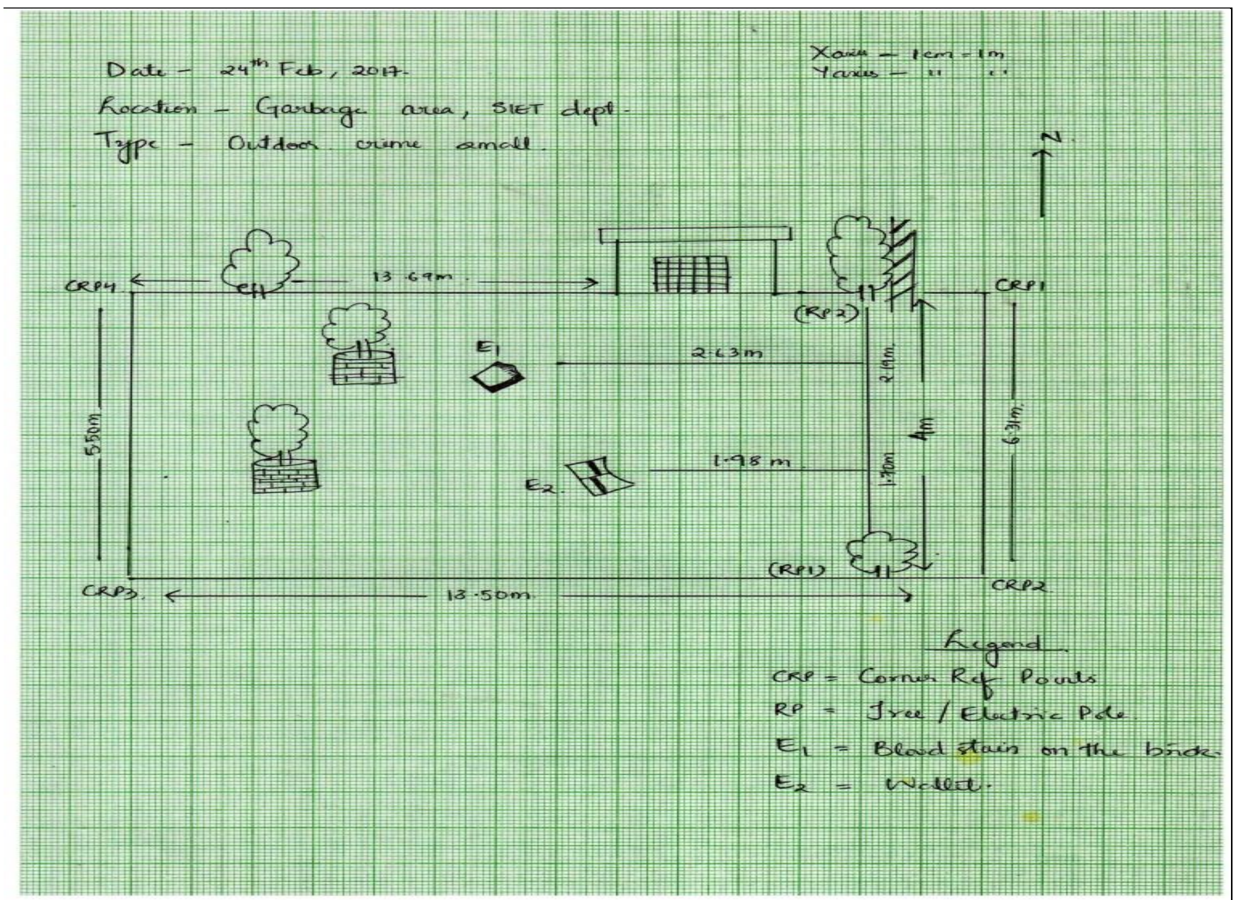

Figure 6: Hand drawn map of simulated scene 2

7.

Figure 7: Final ArcMap and Base Map through ArcGIS of simulated scene 2

<u>Figures/ Legends Illustrations</u>

Figure 1: Trimble R1GNNS

Figure 2: Overview of Simulated Scene 1

Figure 3: Hand drawn sketch of simulated scene 1

Figure 4: Final ArcMap and Base Map through ArcGIS of simulated scene 1

Figure 5: Overall view of simulated scene 2

Figure 6: Hand drawn map of simulated scene 2

Figure 7: Final ArcMap and Base Map through ArcGIS of simulated scene 2