2016

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DOI: 10.4225/75/58a4fbe523bf2
Originally published as: Cusack, B., & Lutui, R. (2016). **Google earth forensics on IOS 10's location service**. In Valli, C. (Ed.). (2016). *The Proceedings of 14th Australian Digital Forensics Conference, 5-6 December 2016, Edith Cowan University, Perth, Australia* . (pp.25-33).

GOOGLE EARTH FORENSICS ON IOS 10'S LOCATION SERVICE

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Abstract

The easy access and common usage of GNSS systems has provided a wealth of evidential information that may be accessed by a digital forensic investigator. Google Earth is commonly used on all manner of devices for geolocation services and consequently has a wide range of tools that will relate real time and stored GNSS data to maps. As an aid to investigation Google Earth forensics is available for use. An investigator can use it by downloading geolocation data from devices and placing it on Google Earth maps, place geolocation data on historical archival maps, or by direct usage of the application in a device. In this paper we review the Google Earth forensics tool and use a simplistic scenario to demonstrate the power of the application for courtroom walk-throughs. The entry-level tool is free and can be used effectively to enhance the presentation of geolocation data.

Keywords
Digital Forensics, Location based service, GNSS, Google Earth forensics, Investigation

INTRODUCTION

Advancements in technology over the last 20 years have drastically altered the way people live and do business (Garfinkel, et al., 2009, p.3). The advancements have driven the growth of popularity and usages of mobile devices such as Smartphones and all the related application packages. This growth is expected to continue for the foreseeable future and the mobile devices market to expand (Liu, et al., 2012, p.145). The increasing storage capacity and functionality of these mobile devices have outnumbered personal computers and become the personal device of choice in our society. Large amounts of information from phone book to photo albums and videos, to emails and text messages, to financial records and GNSS (Global Satellite Positioning System) records, are stored in these phones (Mylonas, et al., 2012, p.249). Mobile devices have the ability to network especially via wireless connections such as Wi-Fi, cellular network such as 3G and 4G (Liu, et al., 2012). Mobile devices are relatively small, portable and widely used by all ages, and especially by young people. Mobile devices consist of Smartphones, Tablets, embedded devices, Personal Digital Assistants (*PDA*), and a range of evolving products (Bennett, 2012, p.159). The personalisation and control handed to the user make these anytime, anywhere devices the communication device of choice. The end user finds the usefulness, capability, numerous applications, high processing power and improved communication performance, to be in line with their demand for experience (Yusoff, et al., 2014, p.141).

Mobile phone forensics is defined by the National Institutes of Standards and Technology as, the science of recovering digital evidence from a mobile phone under forensically sound conditions using accepted methods (Jansen & Ayers, 2007, p.6). The new generation of digital mobile devices are known as Smart devices because of their processing power, memory and storage spaces that are very similar to that of a desktop computer. However, the operating system that runs on these Smart devices has its own file system and structure. On Smart devices, the operating system functions come from volatile memory whereas with computers it is in RAM and ROM. These Smart devices are capable of storing, transmitting and processing large amounts of private and confidential data (Owen & Thomas, 2011, p.25). Yet, the main challenge to forensic experts is the fact that Smart devices are different proprietary designs, software, and access controls. As a result, forensic experts must stay up-to-date with the latest technology in order to be able to adapt to technological changes and strategize new approaches (Rajendran and Gopalan, 2016, p.394).

The affordability of these devices, the proliferation of wireless hotspots and the availability of wireless location services have created new business opportunities and demand for use (Karygiannis and Antonakakis, 2009, p.308). This has led the researchers in the field to find a way of providing location based services to mobile clients.

This paper is structured to review previous literature on geolocation services, to review Google Earth forensic capability, and then to provide a test scenario and walk-through. The results are then discussed to elicit the implications for practice. The conclusion is that Google Earth is a powerful tool to visualise location data in context. However, it is important to practice with the tool and then to use forensic examination procedures to collect and to manage the evidence. This ensures the best opportunity that the findings can be admissible in the court of law.

PREVIOUS LITERATURE

Recently, the mobile sensing data are used for analysing users' activities such as, their emotions, health conditions, their usage patterns and social relationships. This is done in order to study and understand human's behaviour (Mo, et al., 2015, p.391). These studies were triggered by the widespread use of highly capable and multifunctional Smart devices, collecting and analysing mobile sensing data are given more attention in recent years. These days, Smartphones are very much part of people's everyday lives and including recreation. User's takes these Smart devices along everywhere they go. These Smart devices such as Smartphones consist of various sensors and technologies. As a result, they collect a variety of information such as the user's locations, activities, phone calls, SMS, e-mails, call logs, contact list, applications, and so on. Recently, various smart application services have been developed using GNSS, RFID (Radio Frequency Identification) and sensor network connectivity.

The GNSS has been successfully applied for outdoor location tracking by many applications, but it might still be insufficient in an indoor environment where GNSS signals are often severely obstructed.

Location Based Services

Researchers in the field have been working on the possibility of providing location based services (LBSs) to mobile clients. Researchers believed that such technology can be very helpful if available indoors in places like shopping malls, train stations, airports and universities for sharing information, schedule change of train and flight, and so on (Sadhukhan, et al., 2010, p.10). As a result, the indoor location tracking systems has shown its importance for personal information use. GNSS is the well-known and commonly used technology for providing location information services. Location Based Services (LBS) on the other hand, has limitations of dependency on satellite visibility and problems with accuracy and consistency of service in cities, covered areas and multi-path contexts (Kim, et al., 2014, p.89). Mobile RFID applications has been utilised to play a role in the implementation of an indoor tracking system for exhibition service (Kim et al., 2014, p.96). RFID-Based Navigation System is utilised to reduce localization errors (Reza and Buehrer, 2012, p.1023). However, the intensity of experience that satisfies end user geolocation requirements is driving use of positioning technology for security applications, quality control in manufacturing, and safety applications in high-risk areas (Werner, 2014a, p.74).

Location-based services are built by detecting the environments of a mobile device. The inherent complexities of buildings and the localization problem inside buildings that make most indoor location based services use a large amount of environmental information from various sources (Werner, 2014b, p.169). Nonetheless, it's always being sufficient to detect the location of the user with regards to the planned route. The navigational events consist of directional changes yet, inside buildings, the people are missing the navigational experience (Werner, 2014b, p.169).

Mobile Sensing

In order to understand human's behaviours, mobile sensing data is collected and analysed to show activities, usage patterns, emotions, health conditions and social relationships (Mo, et al., 2015, p.391). The customer location tracking system is also used to send location specific information advertisements to users via their mobile Smart device (Keikhosrokiani, et al., 2011, p.527). A mobile smart device such as Smartphones has the characteristics of personalization. As a result, they are utilised to develop a platform for home care for the elderly combining with alarm clock. This allows the device to remind the patients to take their medicine (Cheng, et al., 2011, p.259). Sensor-equipped mobile device revolutionised sectors of our economy including business, healthcare, social networks, environmental monitoring, and transportation (Lane et al., 2010, p.140). Also Ultra-High Frequency (UHF) RFID technology has been applied to supply chain, asset tracking, antifraud system and intelligent transportation systems and so on (Eo, et al., 2008, p.730). RFID technology on Smart devices incorporates the RFID technology with the cellular network. This allows access to information stored on the tag through the RFID reader on the Smart device such as Smartphone (Peng, et al., 2012, p.243). RFID technologies have been utilised in retail to track inventory, in manufacturing to track product status, and also in airlines to track lost baggage (Wang, et al., 2009, p.495). However, researchers in the field have identified two primary types of GNSS location traces - location-only and location-based. Location uses the reference data for visual inspection to infer trip purposes (Wolf et al., 2003, p.6). Location-based studies on the other hand, incorporate other supplementary data such as related trip information (Schönfelder et al., 2003, p.8; Stopher et al., 2008, p.2).

Location Value

Location plays a key role in defining the nature of human activities. Location can determine users' requirements, buying behaviours and service choices (Rao and Minakakis, 2003, p.63). If the provider knows the user's exact location and has the ability to target valuable information, the benefits can be reciprocated. However, awareness of the user's location is only part of the problem (Schönfelder, et al., 2003, p.1). The Human trajectories3 application has sets of time-stamped locations describing individuals' movements in time (typically over a day), and are potentially of great use for many different interested parties. On their own, they reveal the fundamentals of human mobility patterns (Gonzalez et al., 2008, p.780). Therefore, human-carried mobile devices, routing and broadcasting algorithms deployed in various cellular networks should take advantage of the properties of human mobility in order to be effective (Marin et al., 2014, p.204). Thus, based on the where, how, why, when, and who with, users' are routing. Someone can be in a rugby game with friends most likely to have different LBS profile from that of a person on a routine trip to the supermarket or shopping mall. If the provider has the ability to deliver reliable information to users, they might have difficulty identifying what the user is doing or looking for at that location (Heinemann and Gaiser, 2015, p.55). All of these matters can become evidential and in this day and age they are stored digitally.

Significant developments and advances in the field of wireless communication technologies, location sensors and global networking, are driving a new world (Saha and Mukherjee, 2003, p.25). The Smartphone generation is accustomed to the connected world; it becomes a custom to be connected to any person, anytime, anywhere. In fact, people want to be able to monitor and control everything in their lives at anytime from anywhere (Siewiorek, 2012, p.323). However, in the inter-connected world, people prefer not to only limit to Smart devices only. The Internet is being extended to connect every device around us, and is generally known as the Internet of Things (IoT) and the Internet of Everything (IoE). IoT is a concept of a dynamic that is constantly building up and escalating into a future technology full immersion experience (Jun, et al., 2011, p.3). According to Kantarci and Mouftah (2015), IoT interconnects billions of objects that are uniquely identifiable and that have communications, computing and sensing functionalities (p.1865). In such an environment, the acquired data mainly used to analyse human's behaviour, looking for patterns that can be useful in location based service (Vlassenroot, et al., 2015, p.19). However, in some cases even if the data is stored offline, the size of the data is so large and distributed; it will require the use of big data analytical tools for processing (Aggarwal et al., 2013, p.383). Big data comes from various sources, in this case, the location based service sensor, the mobile device GNSS signals, sensors used to gather climate information, social networking sites data, digital photos and videos, and so on. These data is known as *Big Data*, and analysing such data sets strengthens new streams of productivity growth, innovation, and consumer surplus. Learning gained from the result of analysing *Big Data* can help to answer human technology immersion and proximity questions (Ciobanu, et al., 2014, p.4). In addition all of this data and information can become evidential and useful to forensic investigation.

GOOGLE EARTH REVIEW

Google Earth Forensics is a practical and easily accessible tool kit for using with Google Earth Geo-Location services. Google Earth (GE) is a tool that enables its users to view the planet through a virtual globe. Users can navigate through satellite images, aerial photography, and even views of street level imagery and 3D models of the world. This includes locations like oceans, the moon, Mars, and outer space. Features in GE allows tours of locations, historical archive mapping, and to fly across locations using a flight simulator (Harrington and Cross, 2015, p.1). GE provides a representation to real locations within the material limitations of the data collected and the visual presentation. When a location is entered into GE, a map will display and it will include the labelled position of the place you are searching for. It will also allow zooming to see 3D structures or actual photos of a location. GE also allows the viewing of areas of the earth using custom maps or overlays which contain data imported from GNSS units and other digital devices. It is an information source and geolocation search application for multiple usages (Parks, 2009, p.537).

GE is known to be utilised by Police throughout the world in various ways to investigate crimes and share information with the general public. Analysts in law enforcement agencies gather data from police reports and other sources and made it available through GE. For instance, the Shawnee Police Department in Kansas provides data that can be loaded into GE to see locations where robberies, auto thefts, vandalism and other crimes have taken place (Shawnee PD, 2010, p.1). In the digital forensics domain, knowing where a computer or device has been is very important in an investigation. However, we are living in an age where mobility is highly vital. As a result, knowing the exact location of a device when involved in a certain activity is vital information to a forensic investigator (Google Earth Forensics, 2015, p.1). It is possible to chart user's movements from data found on Smartphones from metadata of a photo and other media. The data by itself, however, may not mean much. It needs to be translated into a meaningful form. Perkins and Dodge (2009) argued that, secrets are strongly associated with visual culture, where they are hidden from view but may be revealed. They are ubiquitous, but often unseen and are particularly associated with certain spaces. Google Earth Forensics (2015) note that, many devices store location data as a matter of course – even, sometimes, when the user has asked it not to (p.546).

Forensics is the use of scientific or technological techniques to investigate and establish facts. In a criminal case, the facts you are looking for will be evidence of how a crime was committed and who was responsible (Harrington and Cross, 2015, p.4). Throughout a process of preserving the crime scene and identifying, gathering and examining evidence, information is carefully documented. This is used in the hopes of understanding what occurred, and so that it may be used to identify, arrest and convict the perpetrator (Takeuchi, et al., 2012, p.183). GE can be used to search and display location-specific information in a way that is more telling than the raw data. Using GE as a forensic tool, you can also:

- Import data from mobile devices and GNSS units to determine a route that was taken, or locations that a person visited
- Determine the location where a photo was taken using geo-location information stored in a digital picture
- Create maps that display locations that a device visited, and movies that covey location-based information in a compelling format for investigations and court presentation

The following screenshots illustrate the use of Google forensics for the processing of data taken from a mobile device. XRY (figure 1) is used as the extraction tool and then the data is imported into Google forensics to demonstrate its usefulness. The screen shot show a step-by-step process guide for the use of the tool and instruction for others who wish to use it.
Harrington and Cross (2015) stated that, GE can be incorporated into various phases of the digital forensic procedure. Most often, users may surprise to know that it is used in later parts of a case, when coordinates from various sources needs to be analysed or a tool to create presentations relating to geographic locations. In some cases, it may also be used to acquire GNSS data from a device, although other tools may be more suited to collecting such data for a forensic investigation (p.73).

In this example, the XRY was used to acquire data from an iPhone 6 plus 64GB running on iOS 10.0.2. Figure 1 showed XRY logical was used to acquire the data from the iPhone 6 Plus. The XRY Reader v6.18 - 32bit as showing in figure 2 is used to read and analyse the data. The forensic process was done on HP laptop running on i7 processor with 8GB of RAM. Operating system is Microsoft Windows 10 Professional.

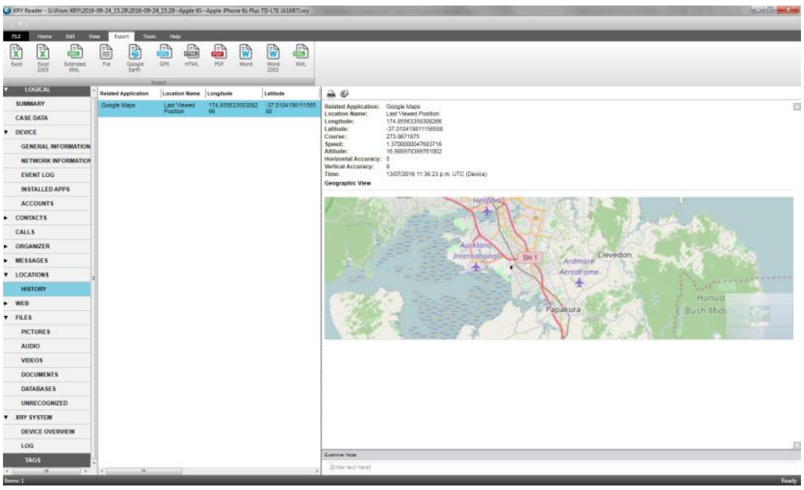

Figure 1: Preliminary view provided by XRY

The XRY Reader in figure 1 showed detailed information on the location data found and selected in the data acquired. This information includes longitude, latitude, altitude, and also date, time, and a preview of the location in google map. This location data can also be exported in various formats such as pdf, word, excel, GPX, XML, HTML or GE.

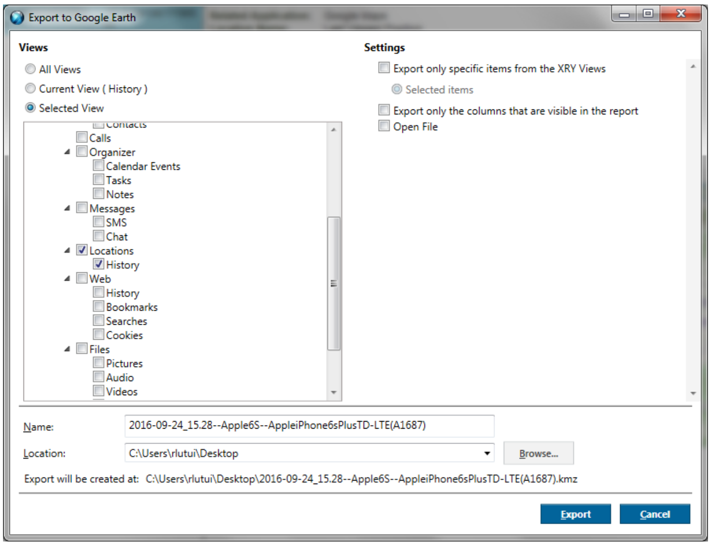

Figure 2: Exporting location data into Google Earth format

In this study, the location data was exported into GE format as shows in figure 2 and then opened with GE. For this study, GE 7.1.7.2600 was used.

Figure 3 shows the result when the exported file is opened in GE. This shows a much clearer view of the location showed in figure 2. GE itself is not a recognized or standardized forensic tool but has the functionality to display geolocation data. All of the issues with accuracy and timeliness require declaration and any variations reported. Figure 4 has the Google forensics import GNSS data panel.

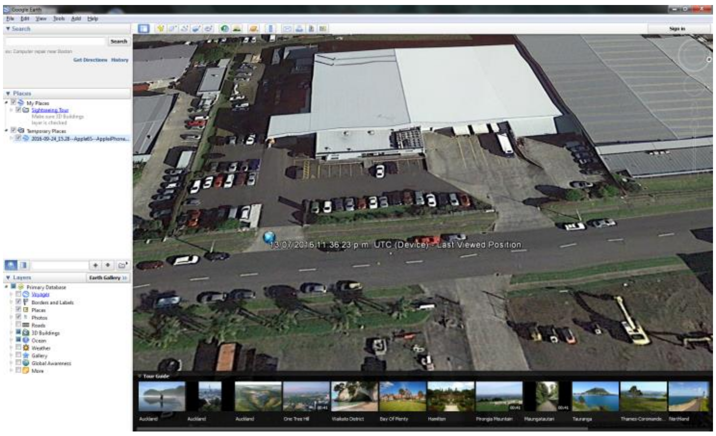

Figure 3: Google Earth view

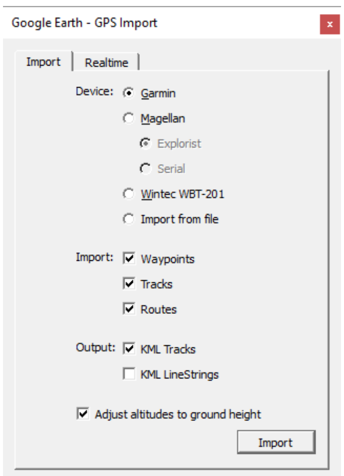

Figure 4: Google Earth GNSS import panel

Compliance is important because any matter may be cross-examined or challenged in court. For instance, instead of simply plugging the GNSS device directly into a USB port, it is highly recommended to make sure that a software write protection or a hardware write blocker is used to prevent any accidental modification of data. Acquiring the GNSS location data in this manner, it shows the number of waypoints, tracks and routes that are imported from a GNSS device. However, importing GNSS data in this way has disadvantages because it copies the data directly off the device into GE. It only performs a logical acquisition and does not retrieve any deleted or even hidden data on the device.

To import the data direct in to GE, perform the following steps.

1) In GE, click on the *Tools* menu, and then click the *GNSS* menu item
2) When the *GNSS Import* dialog box appears select the type of device you are importing from. As our scenario involves a Garmin GNSS unit, we would click the *Garmin* option to import from that device
3) In the *Import* section, select what you want to import: n Waypoints – these are individual locations marked on the GNSS unit. n Tracks – these are where the GNSS has been. n Routes – these are a series of locations where the user wishes to navigate.
4) In the *Output* section, select the output to be used with GE.

When ready to start obtaining data, clicking the Import button, GE will import the data from the device. A summary of the imported data will be displayed on the screen once finished.

APPLICATION OF GOOGLE EARTH FORENSICS

In the previous section a step-by-step guide has been provided on how to use GE with Google forensics. In this section, a simple scenario is adopted to demonstrate how generated data can be displayed as a courtroom walk-through.

"Alleged young children kidnapping and trafficking"

A deal gone wrong and from the crime scene, a mobile Smart device was found and suspected of being involved in some criminal activities. As a result, the Smart phone was taken back to the lab for processing. Upon examination of the Smart phone, there were several geotagged photographs which led the investigator to look at the geolocation data on the device.

In this case, the geolocation file has been acquired from the device, and the location data can be imported into GE. In GE, the placemarks can also be modified. This is a commonly used feature and very important for pinpointing locations and presenting information regarding a crime scene in this case or even other places related to a case. To add a placemark in GE, click on the *Add Placemark* button on the toolbar.

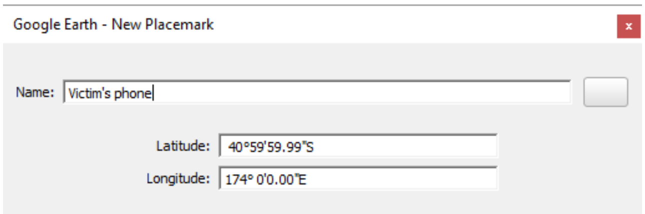

Figure 5: Customising placemark dialog

Fill out the upper portion of the dialog with the information shown in Figure 5 and click *OK* when done. Once the location file from the Smart device is loaded into GE, it displays the waypoints as shown in figure 6.

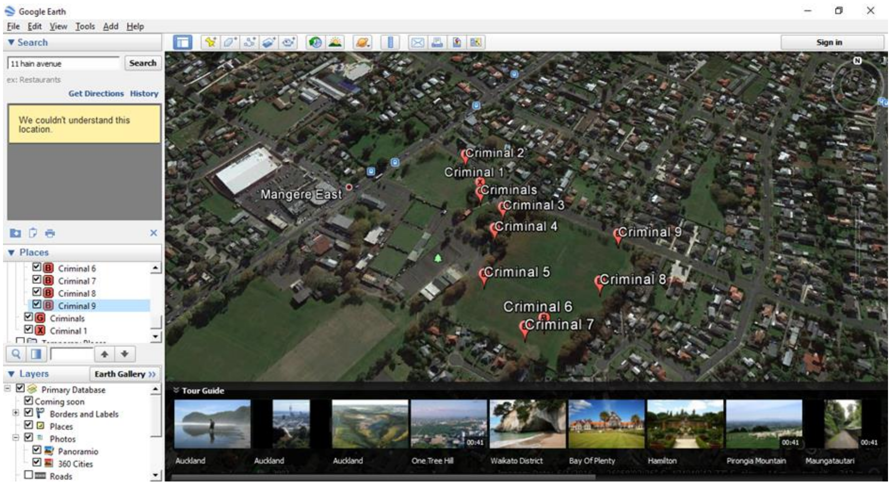

Figure 6: Waypoints

In relation to the case scenario, the illustration in figure 6 showed the places in the public park where the events are located. Zooming in to get a ground level view, allows a representation of the crime scene in three-dimensional space. The images can be overlaid with evidence as it has been collected and GNSS located. Placemarks in GE can be customised according to the nature of the case depending whether it is a phone, a vehicle or other matter at the crime scene. It is not only the placemarks but also content may be added to describe area around the placemark to link it to reports and photographs and narratives. In this way three-dimensional and historical image mapping may be used to reconstruct a crime scene and presented in visual format in a courtroom.

CONCLUSION

Access to Google forensics is extremely helpful to all forensic investigators. The entry-level packages is free and provides considerable capability to process and demonstrate geolocation data. Geolocation and psycho location data are readily available from Smart devices in this day and age and provide a whole multidimensional image of human behaviour. In this paper we have provided a step-by-step guide as to how to use the tool and to apply it to a courtroom walk-through. We have also cautioned that acceptable forensic practices must also be used for the data acquisition and management processes. Further research and demonstration of historical archiving Google forensics capability can also be helpful in cold cases.

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