Applying Archaeological and Forensic Science methods and experience to outdoor and indoor mapping

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Abstract

The science of archaeology, and forensic analysis methods, are intrinsically geo-centric but have not been viewed as “geo” or as mapping applications even though they require the recording of the locations of items and features. The purpose of this paper is to show the role that both forensic method and archaeology can play in the development of geomapping for recording of data at crime scenes, at archaeological sites and similar. By synergising geo-knowledge with existing forensic methods we can build a richer archaeological dataset for future analysis.

Keywords

Design, standardisation, forensic method, archaeological, indoor mapping, outdoor mapping

1 Introduction

The application of archaeological and forensic science methods and experience to outdoor and indoor mapping would rely on taking existing methods and methodologies and simply reapplying them to another area of work. Surveys carried out for archaeology research have yielded important information about key sites. For example, at Stonehenge researchers used a single multi-receiver electromagnetic induction (EMI) survey conducted over a 22 hectare area within the Stonehenge landscape the results of which shed light on the genesis of the landscape, and allowed for a better definition of potential paleo-environmental and archaeological locations. (Smedt P et al, 2014). This allowed greater understanding of the historic landscape for future research and conservation planning. This example can be expanded as the rationale to show that the techniques and methodology of archaeological survey have applications beyond that relatively narrowly defined domain. The discussed applications are not intended to improve positioning knowledge over the traditional means of technology which offer greater accuracy and positioning, rather they offer the means to give additional data regarding geo-locations and in adding that knowledge in the form of data to be used as a set of guidance markers in further position and navigation applications. The techniques that are most commonly used for surveys in archaeology and forensics are ground penetrating radar (GPR), global positioning satellites (GPS), magnetometers, and earth resistivity. They allow features and sites to be “seen” and recorded when in the ground or on the surface.
GPR and GPS can be used in urban environments effectively to record features and see beneath the ground. Researchers and investigators already use GPR for urban surveys in cemeteries for example to work out where there is new or available space for new graves. GPR can give researchers and investigators the ability to “see” through modern urban construction materials such as tarmac and concrete in order to detect and to utilise features such as pipes and lines. While in a rural environment the methods GPR, GPS, Earth Resistivity and Magnetometer can all be used with few restrictions as we move into urban areas and urban green space magnetometers become progressively less useful as uncontrolled metal objects and materials (e.g. cars) interfere with the instrument.

2 Review of Current Practises

2.1 Archaeology

2.1.1 GPS

GPS surveys have been used in archaeology almost as long as commercial sets have been available. The GPS data collected in the UK are to Ordnance Survey standard. This allows the dimensions of the features to be recorded. More points equal higher resolution of detail to be collected about the features. Points can be collected using an automated roaming setup which allows a large area to be covered quickly but may lead to less detail of features being collected or missed all together. It can be used indoors as well as outdoors though depending on the location collecting GPS data does depend on satellite signal strength and the number of satellites that can be picked up. Though with the coming of the Galileo satellite network the issue of signal strength and satellite coverage should become less of a concern. The powerful ability of GPS surveys to record large sites was shown in the Chacas Valley Project in Peru. They focused on gathering both archaeological data and topographical information as necessary. The kinematic GPS method they applied gave the needed accuracy in representing the geometric properties of the objects and to preserve the geometric properties between the structures and to document the relations with the ground morphological aspects of the site. The data collected allowed the space relation between geographic and urbanized landscapes to be realized. (Capra A et al, 2002) Furthermore, data generated from GPS surveys can be immediately transformed into thematic maps useful for integration into a geographical information system (GIS) application which is part of the smart city architecture. Part of the development of smart city data sets wills most likely rely on digitizing traditional paper records and bring them into the GIS application and merging them with the any new data that is collected or created. The site of the ancient city of Throikos in Southern Greece through excavations had led to the creation of many detailed hand drawn maps of the different insulae. But no high quality overview map existed, only a generalized version. With GPS they carried a topographic survey of the area then digitizing the old maps they brought the data together into a GIS and proceed to match and merged the cartographic data together. (Lieffering et al, 2011) This allowed a better overview of the ancient city to be observed. Any smart “type” project will have to rely on old and new data sets being brought together allow people to have access to the full amount of information that is available. Instead of having to use both new smart application and a legacy application to have the
full amount of information available. The discussed method would be the easiest to bring into indoor and outdoor mapping as it is already being used as a navigation method and this extant applications offers a way to turn what is seems to be purely a way of navigating into a way to collect geographic data.

2.1.2 GPR

The concept of radar is familiar to most people. In this instance, the radar signal – an electromagnetic pulse – is directed into the ground. Subsurface objects and stratigraphy (layering) will cause reflections that are picked up by a receiver. The travel time of the reflected signal indicates the depth. Data may be plotted as profiles, or as plan view maps isolating specific depths. This makes GPR a non-destructive method of subterranean mapping. GPR can be a powerful tool in favourable conditions (uniform sandy soils are ideal). It is unique both in its ability to detect some spatially small objects at relatively great depths and in its ability to distinguish the depth of anomaly sources. The principal disadvantage of GPR is that it is severely limited by less-than-ideal conditions. The high electrical conductivity of fine-grained sediments (clays and silts) causes conductive losses of signal strength; rocky or heterogeneous sediments scatter the GPR signal and data collection is relatively slow. The reflected echoes that allow precision of features to be picked up varies by quality of the equipment. When GPR was first used it was planned to be the gold standard but poor results and mixed success of detecting features led to it being side lined in the UK. There was better success with GPR in the USA, mainly because the drier conditions of the mid-west gave far better results in detecting features, thus spurring development of better sets. Studies in the USA show the details they can detect. Surveys using multi frequency antennas were conducted along an 875m section of the Lollie Levee near Conway, Arkansas, USA, to assess the levee's structural integrity. Many subsurface animal burrows, water-filled cavities, clay clasts, and metallic objects were investigated and identified. These anomalies were located at different depths and have different sizes. To validate the observations, hand dug trenches were excavated to confirm several anomalies with the results showing matches between GPR interpreted anomalies and the observed features. (Chlaib et al 2014) In the UK the urban use of GPR has been most prevalent in surveying graveyards, because graveyards and cemeteries globally are increasingly designated as full, there is a growing need to identify unmarked burial positions to find burial space or exhume and re-inter if necessary. GPR can reveal unmarked burials, extra/missing individuals from parish records and a variety of burial styles from isolated, brick-lined, to vertically stacked individuals. (Hansen et al, 2014). The ability to keep up to date records of space aligns itself nicely to the ethos of Smart infrastructure planning. Also GPR surveys can be conducted inside buildings to reveal features within and beneath the building which can aid in tracking and mapping the locations of utility features.

2.1.3 Magnetometers

Magnetometers used in geophysical survey use a single or two spatially separated sensors to measure the gradient of the magnetic field (the difference between the sensors). In most archaeological applications the gradiometer configuration is preferred, where one sensor is high up and the second is below
it near to the ground, because it provides better resolution of small, near-surface phenomena. Magnetometers may also use a variety of different sensor types giving varying degree of resolution detail. Every kind of material has unique magnetic properties, even those that we do not think of as being “magnetic.” Different materials below the ground can cause local disturbances in the Earth’s magnetic field that are detectable with sensitive magnetometers. Magnetometers react very strongly to iron and steel, brick, burned soil, and many types of rock, thus archaeological features composed of these materials are very detectable. Where these highly magnetic materials do not occur, it is often possible to detect very subtle anomalies caused by disturbed soils or decayed organic materials for example ditches, pits and sometime post hole. The chief limitation of magnetometer survey is that subtle features of interest may be obscured by highly magnetic geologic or modern materials. They can be used in fields beyond the archaeological as shown in 1993, during the removal of a diesel and a gasoline underground storage tank at the municipal garage in Wisconsin, soil testing revealed environmental contamination at the site. A site investigation revealed the possibility of a second on-site source of petroleum contamination. Limited historical data and the present usage of structures within the suspected source area precluded the use of most invasive sampling methods and most geophysical techniques. A fluxgate magnetometer survey, followed by confirmatory excavation, was conducted at the site. The fluxgate magnetometer survey identified nine possible magnetic anomalies within the 18 × 25 m area. The subsequent excavation near the anomalies revealed the presence of five paired and two individual 2000 litre underground storage tanks. (Biersel T.P et al, 2002)

This geophysical survey technique is a considered a standard method of collecting information about features hidden beneath the ground. It is a quick method of surveying a site and offers good resolution when it reveals features it reveals beneath the ground. Motorised mobile systems have offered the ability to uncover past landscapes covering many square miles to be revealed, for example dried river beds and lost villages can be revealed which would not appear in small one man surveys. This can be achieved with the use of a “Superconducting quantum interference device” (SQUID). The system provides mapping of large areas while allowing high resolution as well as lateral precision to be obtained. The properties of the SQUID were tested intensively at the large Neolithic double-ring ditch enclosure of Niederzimmern near Weimar, Germany. It revealed the wider historic landscape and details high previous had not been observed from smaller surveys. (Schultze et al, 2008) While the focus is on detecting historic features it will show modern features such as, pipes and electrical wires which would be usual for utility maps though these features are generally ignored on archaeology surveys or if included are marked to prevent there damage when a site is being excavated.

2.1.4 Earth Resistivity (E.R)

Is the oldest technical geophysical method and could be considered the simplest. It involves creating a current in the ground and allows travelling between probes and then measuring the resistance. The changes in resistance allow features to be identified. Using Ohm’s Law, the resistivity of a material is derived using current and voltage values as measured by the electrodes. Differences in the amount of resistance are in response to the differing
conductive properties of the sample body. This is determined by the amount of interstitial water and various salts held within. For example high resistance is indicative of stone features as the current has further to travel while low resistance is indicative of moist features such as ditches and large pits. The technique will also pick up geological features and modern man made features in the ground. However if there is little or too much moisture in the ground will prevent clear measurements from being taken. This enables archaeologists to non–invasively ‘read’ what is below the surface, either as a two-dimensional plan or, more recently, as a three-dimensional profile or section of the stratigraphy. (Mol and Preston, 2010) Due to the reliance on being able to create a current through the ground there are optimal times of the year to carry out surveys depending on soil types and land use. Generally surveys now use combined techniques which allows for corresponding data to be compared and correlated. This was used in a geophysical survey in Iznik/Nicaea, Turkey which led to the discovery of a Byzantine Church using GPR, E.R and microgravity. This allowed them to identify and differentiate the foundations, voids and the natural bed rock. (Rabbel et al, 2014) It is used to inform about the natures of site before any excavations are started to ensure there is no blind digging into the ground so only features that are shown on the survey results are targeted for further study.

2.2 Forensic Science

The application of these surveying methods to forensic science uses the same techniques and methodology but there is a greater detail in recording information to ensure the highest standards when the evidence is presented to the judicial and police service and to maintain integrity of the chain of evidence. This has led to search methodologies being established for specific geology’s for example detection of clandestine graves in coastal beach environments. (Pringle et al, 2012). The application in forensic science is mainly in the identification of human graves. Due to the nature of these methods they can also detect buried objects. This allows a detailed record of sites to be created and that affords the opportunity to build intelligence maps of locations and crimes. Though only for major or serious crime are these geophysical techniques brought in to be utilized. Any standards that are created for forensic science can be easily adapted to archaeology which means in turn there should be any standards to indoor and outdoor mapping standards.

3 Evolution to Geo

The uses and applications of these techniques can be applied to civic planning in both urban and rural areas with relative ease since they are ready used in a limited way already. It can be taken that they have the potential to have an expanded use. One of the issues that limit greater use is the problem of information dissemination of their potential application. Since companies and intuitions are not obliged to make their data open source. Encouraging the data to be shared in an open way would aid in potential speeding up the introduction to greater areas of use. These methods and techniques are a form of intelligence gathering with the raw data processed to sought the needs of the specialized area that they are being applied to so to apply these methods to indoor and outdoor mapping should cause too much of a problem.
The application of the techniques to Indoor GML would be to provide data either for utilitarian or provide a record of location of features. The methods that could most easily adapted be used are GPS and possibly GPR. Though GPR it would be most likely to ensure continued coverage between blocks of ground as GPR can penetrate most modern materials. Surveys aimed at populating a City GML record can then rely mainly on GPS and GPR because they are the two methods which can effectively penetrate through modern building materials, though in open green space there is a possible use of E.R and Magnetometer but if there too many cars or the equipment is used too close to buildings they could affect the results that could be gained.

Any rural version of GML if implemented could use all methods with fewer problems though results would vary due to localized soil and geological conditions.

4 Conclusion

Already widely used this paper has illustrated a few cases where with careful re-use the existing geo-data gathering techniques in use in archaeology and forensic science can augment and enhance the data models using in smart cities and general mapping. The benefits of these techniques is that trained personnel exist who are trained in their use although often in domains such as archaeology. In applying these techniques to other geo-domains such as civic planning and smart city initiatives the data models can be expanded quickly and build a much richer geo-data resource than if such sources were ignored. Furthermore the alignment of these data sources could come about in a short span of time if the resources were made available.

The methods and techniques described here offer a means to bring additional data resource to integrate into navigation and mapping with a view to maximising the data and information value of smart cities. While these techniques and methodologies can be applied to smart city it is considered that maintaining the lines as independent, with archaeology, forensic science and geo-planning forging their own paths is counterproductive. The examples illustrate that convergence is possible and the assertion of this paper is that if convergence is seized upon then all domains will benefits.

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