THE LIGHT FANTASTIC: USING AIRBORNE LIDAR IN ARCHAEOLOGICAL SURVEY

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ABSTRACT:

English Heritage is the national body with the responsibility for the survey and management of archaeological and historic remains in England. The Aerial Survey & Investigation team within the Research Department deals with the recording and interpretation of sites and landscapes visible on aerial imagery. In England aerial photography has been examined in this way for over 40 years, but it is only in the last decade that the potential of using lidar for archaeological survey has become apparent. As greater interest has developed in the technique and its use has become more widespread, it became clear that there was a need to produce guidance to help those intending to use the data for archaeological survey. Lidar data can be immensely useful and has unrivalled capabilities for mapping in certain environments, such as within particular types of woodland. There are, however, still lots of uncertainties within the broader archaeological community about just what it can and cannot do. There are also many aspects of the data collection that need to be clearly understood and correctly specified if the data provided is to be as useful as possible. To this end English Heritage has produced a set of guidelines to help those intending to use lidar for archaeological survey. These cover the major aspects of data collection (i.e. issues of resolution and data formats), as well as issues related to using the data in day-to-day survey ranging from producing viable hard copy printouts for use in the field, to mapping with fully interactive raster surfaces in CAD and GIS.

1. INTRODUCTION

England has a very long history in the use of aerial remote sensing in its broadest sense, for research into aspects of the cultural heritage. It is also recognised as one of the pioneering nations in this field and has developed techniques and systems that are used by many other countries. The earliest aerial photograph of an archaeological site in England was taken of Stonehenge over 100 years ago from a tethered balloon; the earliest mapping from archaeological aerial photographs was carried out less than 30 years later (Crawford & Keiller 1928) and it was only ten years later that entire landscapes were being mapped (Crawford 1934-38). Extensive landscapes in this country have been mapped from aerial photographs for over 50 years with a national programme of mapping dating from the late 1980s. By contrast airborne lidar has only been recognised as a potential new tool since the turn of the century and as such is still very much in its infancy. Interest in the technique, however, is growing at an increasing rate and its use is becoming more widespread within the archaeological world. The experience of English Heritage, working through a number of projects with various partner organisations, has shown that there is a need for guidance to help those intending to use the data for archaeological survey. To this end English Heritage has recently produced a set of guidelines, aimed at end users of lidar data (Crutchley & Crow 2009). It is not the aim of this paper to reproduce the guidance in full, but rather to highlight how the guidance came about and how lidar has been developed to work as a practical day to day mapping tool, together with noting some of the key issues raised.

2. HISTORY

There is no doubt that lidar is an extremely useful tool in the analysis of certain landscapes, such as deciduous woodland. There are, however, still many questions within the broader archaeological community about how to get the best use out of the lidar data. For example, for the most part airborne lidar is well suited to large area survey such as is categorised as English Heritage Level 2 survey. *Details of the different levels of survey defined by English Heritage are given in the guidance document on understanding the archaeology of landscapes* (English Heritage 2007). Where more detailed survey is required (and ground survey is not thought to be appropriate) it may be more fitting to use photogrammetry, including digital photogrammetry, that has the benefit of allowing both stereo viewing of colour imagery and the creation of DTMs (Stone & Clowes 2004). English Heritage has experienced many of the issues surrounding the use of lidar during the last ten years whilst the application of lidar for archaeological survey in this country was at the developmental stage (Holden et al 2002). After a series of projects beginning with Stonehenge World Heritage Site (Bewley et al 2005) working through the Forest of Dean (Devereux et al 2005; Hoyle 2007), Witham Valley (Crutchley 2006), the Mendip Hills (Truscoe 2006 & 2008) and Savernake Forest (Crutchley 2008; Crutchley et al 2010) we have now reached a stage where we are confident that the lidar data, in various forms, can be effectively utilised for archaeological research and can be integrated into the practical day to day mapping and interpretation carried out by the Aerial Survey & Investigation team.

3. USING THE DATA

The experience of using lidar data has shown that whilst it can be applied to any type of landscape it is particularly useful in two areas, woodland and upland areas that have not seen intensive modern ploughing.

3.1 Woodland

Because of its ability to penetrate certain types of woodland canopy and reveal the archaeological remains below, lidar is particularly useful in areas with a large percentage of mixed or deciduous woodland; it is less effective in dense conifer plantations and indeed is only really successful if flown at the correct time of year when there is minimal vegetation cover. When used in the right conditions, however, the results can be dramatic. Savernake Forest is an area of ancient woodland that had been established as a royal hunting forest by the time of the Domesday survey in 1068. It is now an area of largely deciduous woodland managed by the Forestry Commission covering an area of some 40 sq kms that is used both as a timber resource and as an area for recreation. As part of a new management plan the Forestry Commission decided to commission a lidar survey to record the area and English Heritage worked in partnership with them to map the area as part of the National Mapping Programme (NMP) (Bewley 2001 & 2003). Using a combination of lidar data and traditional aerial photographs, including historic imagery dating back to the 1930s, over 300 new sites were recorded, doubling the number of known features in the survey area. Some of the most important sites recorded were a potential early roman temple complex and several new prehistoric settlement enclosures (Fig 1). As well as these entirely new features the survey also added considerable detail to the Roman roads that run through the survey area (Crutchley et al 2010).

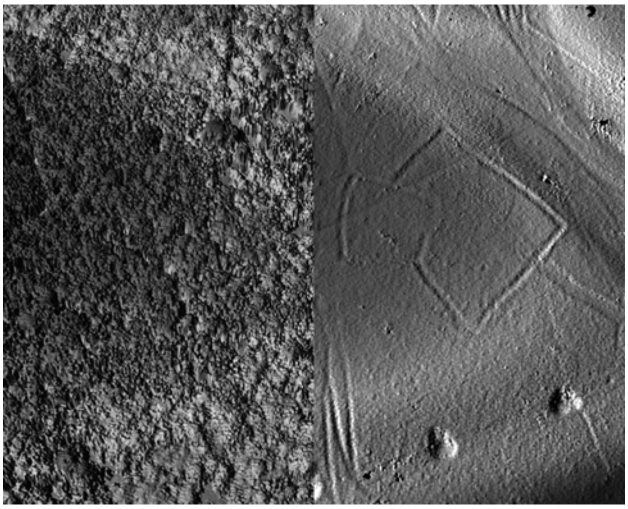

Figure 1 – A late Iron Age enclosure in Savernake Forest seen in first return (left) and last return (right) lidar data. (lidar © Forestry Commission; source, Cambridge University ULM (May 2006)).

3.2 Uplands

The other sphere where lidar has proven to be particularly useful is in areas of extensive upland archaeology. This is rather different from woodland survey where lidar allows the recording of features that would otherwise be extremely difficult even to see, let alone record; in upland areas the features are generally visible on the ground and could be recorded using traditional techniques, but the use of lidar makes surveying much quicker and more efficient. An area of the North Pennines is being mapped as part of a multi-disciplinary project entitled “Miner–Farmer landscapes of the North Pennines Area of Outstanding Natural Beauty (AONB)” that evolved from the management plan for the AONB. The landscape is sparsely settled with considerable height variation between the valleys and the unenclosed moorland The area is being surveyed using a combination of lidar and other remote sensing techniques and then mapped as part of NMP using a combination of this data and what traditional aerial photography of the area exists. Detailed analytical fieldwork is then being undertaken for the core project area, taking printouts of the lidar data and desk based interpretations into the field for further analysis as well as identifying features not seen on the lidar data. Apart from revealing features that are difficult to identify on much of the traditional aerial photography, the lidar data is also proving useful as it provides an extremely accurate base map against which other sources can be registered and mapped (Fig 2).

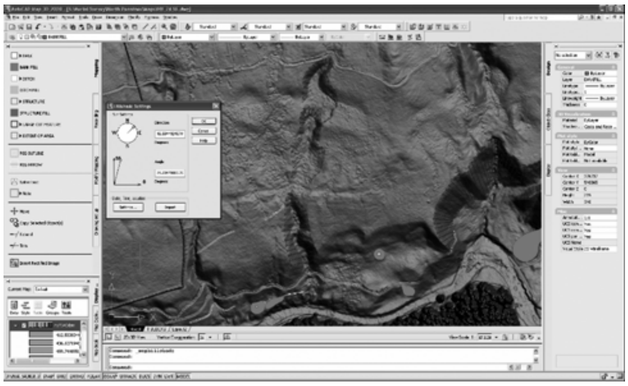

Figure 2 – Using lidar as control

Lidar also allows the accurate mapping of extensive features such as the remains of the mining industry that would otherwise take a long time to survey on the ground and therefore enables field survey time to be concentrated on those areas identified as most important or too confusing from the lidar data alone.

3.3 Environment Agency standard image tiles

Whilst English Heritage has mainly been working with the lidar data specifically captured with archaeological use in mind, we have also been examining the use that can be made of the readily available data that has been collected by other agencies for non-archaeological use. The largest example of this in the UK is the Environment Agency, the body with the role “to protect and improve the environment, and to promote sustainable development”. One of their key areas of interest relates to flood management and to this end they have been carrying out lidar surveys around the UK for over ten years; they have concentrated mainly on the coast and major river valleys to record the topography and how this relates to possible flooding. They have established a reference archive of lidar derived imagery as a series of georeferenced image tiles covering on average 1 – 4 sq km. These tiles are created as hillshaded images and are colour coded according to a consistent set of height gradients. On first viewing, often these do not reveal very much archaeological information, but with a little simple manipulation within Adobe or another standard image processing program it is possible to bring out features of archaeological interest not necessarily visible on standard aerial photographs. Although this is not as effective a method as full manipulation of the source lidar data, it does provide a quick and easy way into the data that is useful for preliminary archaeological survey.

4. ISSUES

The experience of using lidar data through these projects has also revealed a number of issues relating to the data that need to be understood by anyone intending to use lidar for archaeological survey. These include the question of resolution and data formats, as well as issues related to using the data in day-to-day survey, ranging from producing viable hard copy printouts for use in the field, to mapping with fully interactive raster surfaces in CAD and GIS.

4.1 Data capture

One of the key elements that needs to be understood when using lidar data is the question of resolution. This is a twofold issue; it relates not only to the actual final resolution at which the data is displayed, something that limits the size of the features that can be seen and recorded, much in the same way as for other image-based data, such as satellite or standard aerial photography. It also relates to the original resolution of the data defined by the number of hits within a square metre and the footprint of the laser beam when it strikes a surface. A combination of these two elements can mean that although an average of one point per metre is nominally collected, it is possible for small features to be entirely missed by the survey and not recorded. A good example of this, illustrated in the guidance note, is shown by the bluestones at Stonehenge in that the lidar data captured at one hit per square metre does not appear to show several of the bluestones (Crutchley & Crow 2009, p16).

Whilst it is unnecessary for the user to understand everything about the techniques used during data capture and initial processing, it is important to be aware of the stages of processing the data have been put through, as these can result in data artefacts that can be misleading. These issues are discussed in further detail in the guidance note.

4.2 Interpretation

Lidar data is primarily a record of x,y,z coordinates that provide a view of the land surface. In order to differentiate between archaeological features created by human interaction with the landscape centuries or millennia ago and the remains of modern agricultural or other practices this data requires interpretation. There are various aids to viewing the data to aid the interpretation process.

The main product of lidar data tends to be imagery viewed as hill-shaded images. These appear similar to vertical photographs of earthworks lit by low sunlight, so the analysis of lidar for the identification and characterisation of archaeological sites requires similar skills as those applied to air photo interpretation, for example the ability to recognise slight earthwork banks or ditches based on their appearance with reference to shadows and highlights, while filtering out features due to modern agricultural practices, geology and data processing artefacts.

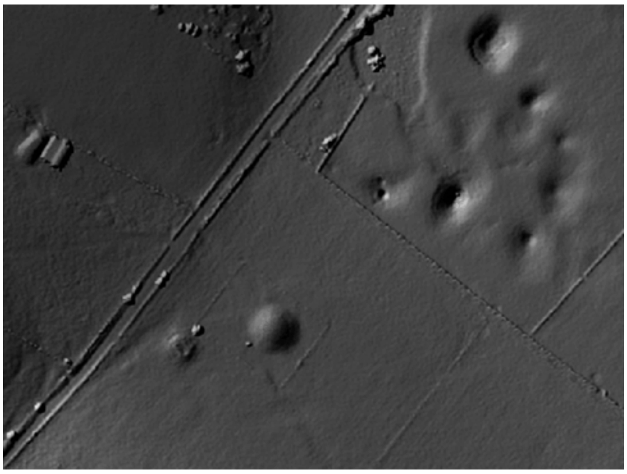

Figure 3 - Feature misinterpretation – lidar derived image (lidar © Mendip Hills AONB; source, Cambridge University ULM (April 2006)).

This can be demonstrated by an example from the guidance note that shows the potential confusion between features of archaeological interest and those of modern origin. The feature seen in the bottom centre-left of figure 3 gives every appearance of being a burial mound, being of a similar size and shape to other known barrows in the vicinity here on the Mendip Hills. Using not only all available mapping data, but also analysing all readily available aerial photographs, both traditional and digital, simultaneously with the lidar data, will help to ensure correct interpretation, as in this case where the evidence from aerial photographs and mapping (Fig 4) reveals that the feature is in fact the site of a covered reservoir.

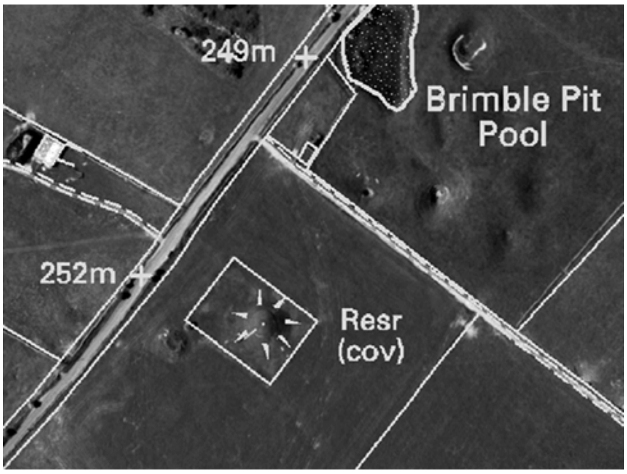

Figure 4 - Feature misinterpretation – aerial photograph showing the true nature of the feature (photo PGA_ST5050_2006-04-30_part. Licensed to English Heritage for PGA, through Next Perspectives™; OS background map © Crown Copyright. All rights reserved. English Heritage 100019088. 2009).

4.3 Usage

Whilst lidar data is remarkably useful and has generated great interest in archaeological circles, it is not necessarily inherently user friendly and many organisations who might wish to make use of it may not have access to the hardware, software and expertise required to manipulate the data to best effect. The new English Heritage Guidance paper aims to advise people as to how they can get the most out of lidar data in a normal working environment using everyday technology. The most obvious example of this is simply using paper print outs in the field, an application that can be used either by professional analytical field surveyors looking for additional data sources, or by amateur archaeologists undertaking local research or walk through surveys. As noted above, one of the most common ways in which lidar data is used is as a hillshaded image and this is the simplest way to work with a printed image. The advantage that lidar has over a conventional aerial photograph is that it is possible to control the direction of the lighting and thereby light from angles impossible in the natural world so as to reveal otherwise hidden features. Unfortunately the simplest hillshaded image to produce, that lit from a single direction, has the possibility of missing any features that are aligned on the direction of the light source as shown in figs 5 -6.

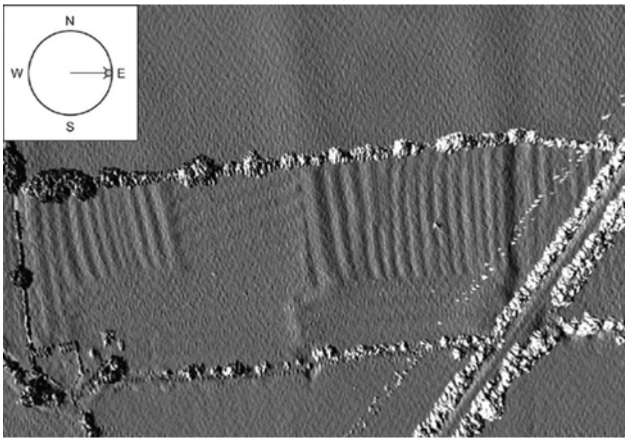

Figure 5 - Ridge and furrow near Alchester illuminated E–W (lidar © Cambridge University ULM (Dec 2005)).

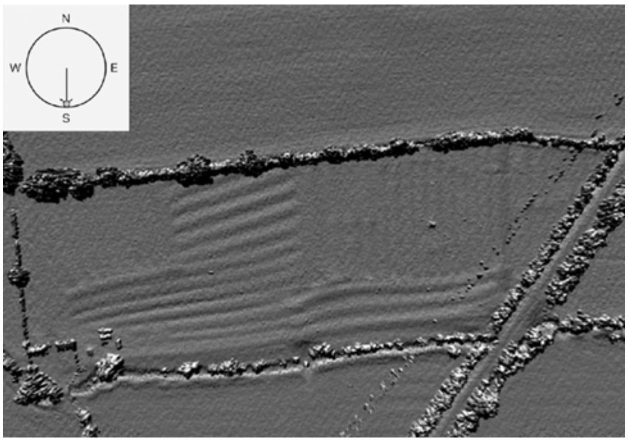

Figure 6 - Ridge and furrow near Alchester illuminated N–S (lidar © Cambridge University ULM (Dec 2005)).

In order to get around this for hardcopy imagery it is necessary to produce composite images. This can be done by creating composite images using the transparency tools within image editing or GIS packages, but a more effective process is now seen in the use of principal component analysis (PCA) a statistical method to examine multiple hill-shaded images and compile a composite image that shows the main features from each image (Devereux et al 2008). One negative element of this, however, is that the false colours and the multiple combined lighting angles mean it can be difficult to differentiate between cut and built features as shadow and highlights can be present for both.

4.4 Interactive mapping

Whilst high quality "flat" images using hill-shading or PCA techniques can provide a relatively user friendly way of working with lidar, they do not fully capitalize on the interpretative potential of the lidar data. For the professional user there are great benefits from working with lidar data interactively, by manipulating the data as part of the interpretative process, so as to highlight specific features and understand as much as possible about their form and extent. Key to the necessary workflow is the ability to view and manipulate the data in 3D (although currently this is strictly only 2½D within affordable software) something has been made possible by combining viewing and mapping software. English Heritage has developed over time working practices for archaeological interpretation and mapping from aerial photographs, and these have now been greatly enhanced by the integration of the use of lidar data.

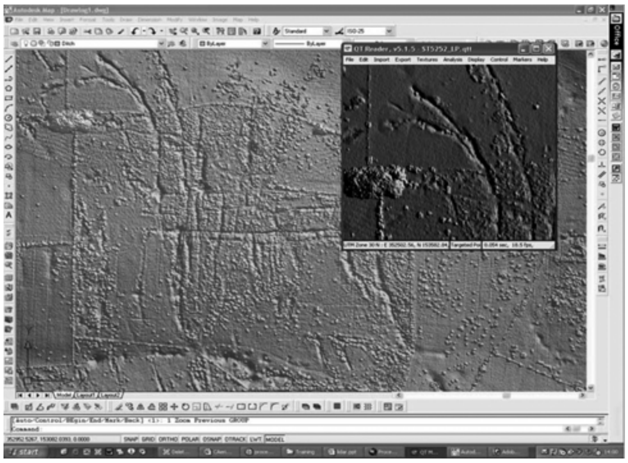

Figure 7 – Interactive use of lidar data in viewing and mapping software

5. CONCLUSION

Lidar data can be an immensely useful tool for archaeologists and has unrivalled capabilities for mapping in certain environments, such as within particular types of woodland. There are, however, still lots of uncertainties within the broader archaeological community about just what it can and cannot do. There are also many aspects of the data collection that need to be clearly understood and correctly specified if the data provided is to be as useful as possible. To this end the English Heritage guidelines will hopefully help those intending to use lidar for archaeological survey to avoid some of the pitfalls and maximize the value for money of this new technique. The guidelines are available as a downloadable PDF through the English Heritage website http://www.english-heritage.org.uk/publications/light-fantastic/ and there is further information available on the Aerial Survey & Investigation web pages http://www.english-heritage.org.uk/aerialsurvey.

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