Section 2. Aerial Photography, Remote Sensing and Archaeology#

Section 2.2 Digital Remote Sensing#

2.2.1 The Development of Digital Remote Sensing

Remote sensing for archaeology is still largely based on low altitude aerial survey techniques at optical and near infra-red wavelengths. The most important developments since the 1970s were the introduction of digital multispectral imaging sensors, thermal imaging radiometers,imaging RADAR and more recently Lidar. These sensors have increased the wavelength range at which images can be acquired into the short wave, middle (thermal) infra-red, and microwave range. The data are produced in a digital form that can be enhanced, rectified and reclassified using a wide variety of algorithms and specialist software. The output of such procedures can be used to identify a wide variety of features which may be of interest to researchers.

Until very recently available civilian optical satellite imagery has been of low spatial resolution and of limited use in archaeology. There have been a few notable studies that have demonstrated its value in particular circumstances. However, new developments have altered the value of spaceborne satellite imagery. Both the Russian and American military spy satellite programmes have released photography with up to 2m ground resolution and such digital imagery has good geometric fidelity and can easily be integrated into Geographical Information Systems. Other important developments have been made in RADAR imaging since Charles Elachi first showed that NASA's Shuttle Imaging Radar (SIR) could penetrate very dry and smooth sand surfaces to reveal buried structures (Elachi 1982). The Shuttle radar system has been considerably enhanced and may soon be followed by an orbiting radar sensor.

2.2.2 Current Developments

Remote sensing for archaeology has developed swiftly in the past decade and perhaps the greatest change has been in the use of lidar imagery (using laser beams to record the landscape, (**Li**ght **d**etecting **a**nd **r**anging) (see Crutchley and Crow 2009). There are important new developments in space imaging that may see vertical aerial photography replaced by high resolution satellite digital images. Airborne sensors are improving all the time and becoming much cheaper to build and deploy. Thermal and RADAR imaging sensors have also improved recently and these offer considerable potential for detecting buried structures. Satellites also provide accurate positional information on the Earth's surface using the US Navstar Global Positioning System (GPS) or the Russian GLONASS which is especially important for the accurate mapping of relatively small-scale archaeological features.

The science of image processing has also developed very rapidly since its birth in the 1960s at NASA's Jet Propulsion Laboratory. It is now possible to convert prints and films from analogue to digital form relatively cheaply, and to use widely available processing techniques geometrically to correct or visually enhance the imagery. High quality image scanners are now relatively cheap to buy and so digital image processing can be used to improve the geometry or visual quality of oblique and vertical aerial photography as well as digital sensor data (Scollar et al 1990).

2.2.3 Sensor Types and their Use

Airborne multispectral scanners

Archaeological structures can usually be seen well from the air while crop and soilmarks are more difficult to detect with certainty. The visibility of cropmarks in particular depends on vegetation type, illumination and soil conditions. Multispectral remote sensing is able to look simultaneously at a wide range of different wavelengths, many of which are more sensitive to vegetation status than either the human eye or photographic film. The limited spectral range of photographic film (350-1100nm) is overcome by the use of photoelectric sensing devices that record their data in a digital form. These devices separate light into a number of discrete narrow wavebands, hence the term *multispectral*. This has the advantage of allowing scientists to look at particular parts of the wavelength range in isolation, or to combine different wavelength ranges that are of particular interest.

In the United Kingdom, research work has been undertaken by the Natural Environment Research Council (NERC) in part of the Fenlands (Donoghue and Shennan 1988a; 1988b; Shennan and Donoghue 1992), the Nottingham area (Allsop and Greenbaum 1989), the Vale of Pickering (Pryor, Donoghue, and Powlesland 1992; Powlesland and Donoghue 1993; Powlesland et al. 1997), Wroxeter (unpublished) and the Welland and Nene valleys (unpublished) to assess the archaeological potential of multispectral data. In the United States, a number of studies have been undertaken to record the archaeology and environment at Chaco Canyon in New Mexico and other sites (Lyons and Avery 1977, Lyons and Mathien 1980, Avery and Lyons 1981). These studies were undertaken in areas unsuitable for the formation of crop and soilmarks and have demonstrated the value of near infra-red and thermal infra-red imagery in enhancing the archaeological record.

Airborne Thermography

Thermal prospection techniques have many important applications in geology, archaeology and environmental monitoring. Both pre-dawn and daytime thermal imagery have proved valuable in detecting or providing additional information on buried archaeological structures. Unfortunately, much of the information content in thermal imagery is hidden by the relatively uniform temperature of the ground surface. However, heat flow is governed by time, depth, density, heat capacity and thermal conductivity, all properties relevant to ground disturbance. Pre-dawn and mid-day images can be combined to compute the diurnal heat capacity (otherwise termed the thermal resistance to temperature change or apparent thermal inertia) of the ground. Apparent thermal inertia (ATI) offers considerable potential for the detection of buried archaeology. Seminal work by Tabbagh has illustrated the value of these techniques (Tabbagh 1976, 1979; Scollar et al 1990).

In the UK, NERC operates an airborne sensor capable of thermography. Other sources of thermal imagery include analogue sensors flown by the UK Royal Air Force and Police. Although not widely available, these data have been used to detect ground disturbance associated with archaeology. Airborne thermal radiometry can cover large areas at low unit cost and provide digital data that can be combined with other sources of information.

Optical Imagery from Space

Optical space photography dates back to the first manned space flights. However, systematic coverage of the Earth is obtained from orbiting satellites that use conventional film or digital imaging devices. Relatively high resolution panchromatic imagery can be obtained from the French SPOT-3 satellite (10m) and the Indian IRS system (5m). The best available Russian photography is from the KVR-1000 camera where the photographic film is digitised to provide 2m resolution over a 40km by 40km area. The best American data come from commercially available digital camera systems. Earlybird (3m), Carterra-1 (1m), Orbview-3 (1-2m) and Quickbird (0.82m) are either just recently launched or soon to be launched. An illustration of this type of imagery is given by Fowler (1996) for Wiltshire. Some of these new systems have a limited multispectral capability that may be of value.

Radar Imagery from Space

The value of spaceborne radar imagery has been its ability to penetrate very dry, smooth sand and tropical forest canopies to reveal archaeology beneath. Data from NASA's Shuttle Imaging Radar (SIR) system have been used to demonstrate the existence of palaeo-channels in desert areas of the USA, north Africa and the Middle East (McCauley et al 1982). The same system has been used to reveal important archaeology hidden under dense forest canopy, such as Mayan canals in

Mexico and Guatemala and around the city of Angkor in Kampuchea. There have only been four SIR missions. The last was in 1994, and so the data is only available for a part of the Earth. Spaceborne radar works independently of weather, day and night, because it supplies its own energy to illuminate the ground. Most radar sensors have poor spatial resolution and are not useful for directly detecting archaeology. However, they are good at many forms of environmental mapping.

Ground-based Imagery

The archaeological examination of standing structures, such as historic buildings and monuments, may be aided by the use of ground-based remote sensing techniques to enhance or elucidate concealed information. Typical applications employ multispectral imaging to provide geological and construction phase differentiation in walls and related building features, laser contour profiling and thermal prospection to reveal features hidden under plaster.

In the UK, research work has been undertaken at the University of Nottingham (Brooke 1989, 1994) examining historic buildings and monuments over a wide area and timescale. In Germany, thermal prospection has been employed successfully for many years to reveal hidden building construction and concealed features (Cramer 1981).
