Section 3.2
The Analysis of Aerial Photographs

To the archaeologist, aerial photographs are much more than just impressive pictures of familiar sites. Aerial photography is an important research tool, particularly for prehistorians because many ancient sites survive only as dim shadows of once massive structures cruelly levelled and eroded by millennia of cultivation and intensive land-use. Aerial photography is the single most important technique for the discovery of archaeological sites, and is also one of the most important for their recording and subsequent analysis (Darvill 1996).

3.2.1 Archaeological Survey using Aerial Photographs (APs)

Aerial Archaeology:
- A remote sensing discipline, i.e. one in which the information being interpreted is recorded from a distance
- Started in the 1920s
- Most commonly for the discovery of previously unknown sites
- Also for inventory-level recording and mapping

...other than the incomplete and seriously outdated large scale Ordnance Survey maps, we have no detailed account of our landscape (Aalen 1985)

The reasons for performing survey from APs:
- To record otherwise unknown or unmapped sites
- This is important for preserving them, in the current climate of accelerating rural development
- Realistically, sites are preserved by merit, so survey information is essential
- Wide area archaeological landscape research is a relatively recent area, which requires survey information
- Any aerial survey expects to discover new sites, e.g. the Bruff (Co. Limerick) survey increased the known sites by up to 200% in some areas
- Excavation costs are increasing, and therefore the number of excavations being carried out is dropping: there is a need for non-invasive (i.e. remote sensing) techniques such as geophysics and aerial photography

The archaeological evidence available in APs:
- Upstanding sites: often 'low profile' and badly damaged - most visible from low level, oblique angle and early morning/late evening in the winter
- Cropmarks: positive cropmarks show buried ditches; negative cropmarks show buried wall/road foundations etc. (see picture below)
- Soilmarks: recent plowing upturns differently coloured soil resulting from decayed buried features

The tools and techniques used:
- Low contrast archaeological features can be accentuated and even discovered through traditional darkroom re-development or through digital image enhancement
- Rectification of distorted oblique photos was traditionally manual and carried out using mobius networks, paper strips, and parallel plates. Since the 1970s computers have automated this work
- The mapping of archaeological information can be manual, semi-automated, or fully automated by computer (an area of current development)
• Overlapping stereo pairs of vertical photographs can be studied manually in 3 dimensions using stereoscopes, and the height information extracted using photogrammetry technologies
• Archaeological evidence can be recorded and interpreted manually, semi-automatically or automatically:
  ⇒ Recording morphological (shape) features as well as topographic and local archaeological context
  ⇒ Classification via the recorded information above as well as available literary information and historical associations
• Digital image enhancement has been used for a number of years for the discovery of faint, low-contrast and damaged archaeological sites

3.2.2 Mapping from APs

Mobius Networks:
• The most common technique for manually rectifying oblique photos
• Assumes that the ground is flat
• If 5 or more points can be identified on the photo and a map then these can be joined to form a network
• Intersecting lines in the network provide further points of reference, which can also be joined together on both map and photo
• The network acts as a visual scaling guide when sketching archaeological features from the photo

Computerised Rectification:
• The "Aerial" program has been used by archaeologists for a number of years
• It automates the manual rectification process
• Control points are identified by the user, and map co-ordinates given for them
• Archaeological features are then traced by the user, using a graphics tablet, and the program automatically converts the traced co-ordinates into map co-ordinates
• Can also deal with hilly terrain by creating an approximate DEM from a scanned Ordnance Survey contour map

Three-Dimensional (Elevation) Mapping:
• Overlapping (stereo) pairs of vertical photos can be used to derive topographic information (see picture)
• Photogrammetry is the art of science of generating elevation models of a landscape from stereo photos
• Traditionally carried out using expensive technical equipment which physically projects the two images and allows the user to track contours which are drawn on a map or digitised
• Now also carried out by computer (‘softcopy photogrammetry’) - the approach is to measure the parallax distance between corresponding pixels, and mathematically determine the heights from these
• Useful for landscape and individual monument analysis - viewsheds, watersheds, area of influence analyses, volume estimations, slope, aspect
3.2.3 Computer Assisted AP Analysis

Data Management:
- A lot of data can be produced from APs, and it is therefore crucial that databases are well designed and GIS compatible.

![Data Management Diagram]

The tables and related data files for a computerised aerial photograph analysis system. A single photograph can have many control points and many monuments associated with it; all other relationships depicted are on a one-to-one basis. It should be possible for Data files to be loaded and saved in common GIS, database, and CAD file formats.

Automatic and semi-automatic image analysis:
- The aim is to assist the user in identifying, mapping, and measuring archaeological monuments in aerial photographs.
- Ideally such a system would automatically identify monuments, rather than merely assist in their discovery.
- The first step in automatic scene understanding is normally the application of an edge-enhancement filter, which determines how different pixels are from their neighbours: abrupt changes in brightness are interpreted as the edges of objects.
- The aim is to automatically recognise objects in the scene, which are assumed to be characterised by their edges.
- This technique works well in industrial applications where objects are typically of very high contrast with their backgrounds, but the edges of archaeological features tend to be of very low contrast, indeed lower contrast than many of the modern features visible in the photographs.
- The problem of automatic monument discovery has not yet been solved, since low contrast objects are extremely difficult to find automatically unless their shapes are very well known, and archaeological features are not generically characterisable as perfect circles or any other shape.

- One semi-automatic approach is search not for entire circular objects, but rather for many small arcs of varying centre point and radius.
- These arcs are determined through the estimation of pixel values on an arc, which are tested these against the estimated pixel values on an arc with the same centre but with a radius of 1 pixel less.

![Semi-automatic Monument Boundary Tracing]

Semi-automatic monument boundary tracing. The user identifies the area containing the feature of interest; the computer then extracts arcs of varying strength, centre, and radius, rejects outliers, and smoothes the remaining arcs together using weighted moving averages into a coherent shape which is approximated at weak areas.
3.2.4 Classification

- Archaeological sites seen from the air are often classified into a number of types, and may include both above- and below-ground evidence.
- Archaeological classification is generally used for two main purposes: descriptive summary of data, and as a means of generating useful hypotheses
- It is towards the first of these that most aerial archaeology efforts have been directed, for without useful summary schemes it is impossible to usefully assemble or retrieve the archaeological information at county or regional level
- Through classification of the archaeological evidence visible in aerial photographs, representative samples of sites of current and possible future interest, may be listed for future study

Automatic classification: cluster analysis

- Cluster analysis automatically finds natural clusters in a group of observations, where a number of variables have been measured for each observation
- The resulting classification scheme can then be automated through the A.I. technique of Neural Networks

Cluster Analysis "dendrogram" resulting from morphological measurements on 125 monuments from the Bruff survey. Monuments are presented along the top axis. The distances at which linkages are made from this top axis are inversely proportional to the strengths of those linkages, i.e. the similarity between the groups being linked. Resulting classes are shaded.

Automatic classification directly from APs: the arguments for and against:

- It produces archaeologically abstract classes
- This classification also disregards other important information about a site, such as cultural affinities.
- It is useful as a means to produce at least some useful information from sets of raw morphological data, particularly in the case where no other information regarding a monument is available
- It allows the effective querying of large (regional or national) monument databases, through the selection of monument groups by class;
- It alleviates the problem of subjectivity in recording, which occurs inevitably when many different archaeologists contribute to a database
- It is an effective technique for use by wide-area discovery-oriented surveys from aerial photographs.

Variables for classification of archaeological sites:

- Available by analysis of APs:
  - Rectangularity
  - Circularity
⇒ Elongation
⇒ Slope
⇒ Aspect

- Requiring ground survey and/or other information:
  ⇒ Compass direction of entrance
  ⇒ Bank and ditch dimensions
  ⇒ Measurements of internal structure
  ⇒ Spatial relationships with nearby archaeology and/or other environmental information

### 3.2.5 Topographic Analysis using Stereo Photo Pairs

**Methods of Obtaining DEMs:**
- Digitising from contour maps (slow, inaccurate)
- Ground survey using e.g. EDM (very slow, very accurate)
- Traditional photogrammetry (accurate, expensive)
- Softcopy photogrammetry (fast, quite accurate)

**Essential concepts:**
- Ground control points are required to determine the orientation and scale of the photos
- With constant flying height, truly vertical photos, and an 'ideal' camera, parallax measurements are directly proportional to the height of the points measured
- The main work of softcopy photogrammetry systems is to match the thousands/millions of points in the stereo overlap... this isn't always easy as the two images will be slightly different