Investigation Without Destruction : The Impact of Modern Technology in Archaeological Research

Vishnu Sreevalsan
Research Scholar in History
Kerala University Library
Palayam Trivandrum

Abstract:

Over the past few decades very few fields of social sciences have benefitted from the application of modern technology as much as the discipline of Archaeology. The use of computers, sophisticated electronics and satellites have revolutionized both field archaeology and archaeological analysis and interpretation. This paper tries to analyse the ways in which technology has revolutionized archaeological research and how it has made field archaeology a less destructive process all the while allowing scientists and researchers to come up with a more complete picture of our past.

Keywords: Archaeology, History, Archaeological Research, Technology in Archaeology, Computation Archaeology, GIS and Archaeology, GPS and Archaeology, Field Archaeology, Exploration, Excavation

Introduction

Computers have come a long way since their early inception as 'super calculators' aiding military and scientific research. The influence of computers and information technology is now seen in all fields of research.

By far the greatest advance in encouraging the use of computers by historians -- and indeed, all humanists -- is the development of the Internet and the possibility it affords for remote access to other machines and information. Examples of such resources are library catalogues, databases, electronic texts, and software archives. Information can usually be retrieved from user-friendly World Wide Web sites, which store their documents in a standard form. These documents consist of text but can be linked to graphics, sound files, and movies, and to other documents, creating a hypertext environment.[1]

Archaeologists the world over began to make use of computers from the 1970s and 80s. They were initially used for purposes like cataloging, mapping, storage and publication. From the middle of the 1980s they have been employed in more uses such as terrain mapping, Geo information systems or GIS and in the production of hybrid maps using satellite images and the making of contour plans. Archaeological problems of great complexity, both theoretical and applied, have been opened up for resolution by the use of a wide range of computer-based information processing software.

1. Computational Archaeology

The method of taking conventional archaeological data and using it in specially designed computer software applications is known as Computational Archaeology (CA). As it is a rather new branch it sometimes carries other names such as archaeological informatics or *archaeoinformatics*.

The term, 'computational archaeology' is usually reserved for the complex mathematical methods that could be calculated in no other manner but by computer. However, CA is not limited to mathematics. In archaeology, computer software can replicate an entire site, stratum by stratum and rebuild the missing architecture into an interactive, three-dimensional, fly-over movie.

CA might include geographical information systems (when applied to spatial analysis), statistical or mathematical modelling, and simulations of possible human behaviour or habitation. All of these operations would be impossible without the aid of computer processing power.

CA can be seen developing in two distinct areas: Theoretical and Applied.

1.1. Theoretical Computational Archaeology

This area focuses on research about the structure, possibilities, and properties of archaeological data, its inference across multi-disciplines, and building a greater knowledge base. The theoretical approach includes modeling the foggy uncertainties in archaeological data, arriving at the optimal strategies for sampling, scale effects, and spatio-temporal effects.

1.2. Applied Computational Archaeology

This area is devoted to the design, development, and writing of specific computer software and algorithms to make the theoretical knowledge perceptible to the researcher. CA provides a high-tech tool to the archaeologist who otherwise could not process the voluminous and complex information stores that archaeology continues to stockpile.[2]

Data analysis depends on constructing and manipulating complex databases of archaeological information. Data from many levels of an excavation and from many sources must be brought together in order to draw conclusions. For example, information about where in a site objects were found can be combined in a single database with data recorded later in the lab-after the objects have been cleaned-to reveal patterns of distribution of similar objects. The capacity to enter and manage more categories of information permits increasingly sophisticated hypotheses to be formed and tested. And, with the advent of portable computers that can be used to enter data on site, analysis performed each evening can be used to guide researchers in the next day's digging.

Data presentation itself can also provide powerful analytical aid in the form of visualization tools. Graphics programs derive intricate stratigraphic sections directly from electronic measurements taken in the field. Views can be rotated and color-coded to emphasize particular characteristics. Distribution patterns that suggest how artifacts came to be deposited, or how they may have been used, become immediately apparent.[3]

Other uses of computers in Archaeology include 3-dimensional reconstruction of artifacts and buildings, processing of GPS co-ordinates, surveying and graphic display of excavation, topographic and geophysical data, on-site recording of excavations and post-excavation analysis, graphic display, including building reconstructions and 'fly-past' simulations, computer-assisted learning, quantitative analysis using *statistical analysis* or *spreadsheet* software, *database management systems*, both for research and for official databases such as Sites and Monuments Records, now including graphic image data etc.

2. Global Positioning Systems-

Global Positioning System (GPS) is a space-based radio-navigation system, consisting of 24 satellites and ground support. Operated by the United States military but open to civilian uses, GPS provides users with accurate information about their location and velocity anywhere in the world. GPS is one of three satellite-based radio-navigation systems. The Russian Federation operates the Global Orbiting Navigation Satellite System (GLONASS), which also uses 24 satellites and provides accuracy similar to GPS. The European Union (EU) launched the first satellite in its planned Galileo program, also known as the Global Navigation Satellite System (GNSS), in December 2005.

The GPS system was designed for 24 satellites. Each satellite lasts about ten years. Replacement satellites are placed in orbit regularly to ensure that at least 24 satellites are always functioning. The device that receives the GPS signal is known as a *receiver*. Handheld or wrist-mounted GPS receivers are available to the civilian population; GPS receivers can also be installed in automobiles and boats.

GPS has three components: the space component, control component, and user component. The space component includes the satellites and the Delta rockets that launch the satellites from Cape Canaveral, in Florida. GPS satellites fly in circular orbits at an altitude of 20,100 km (12,500 mi) and with a period of 12 hours. The orbits are tilted to Earth's equator by 55 degrees to ensure coverage of polar regions. Powered by solar cells, the satellites continuously orient themselves to point their solar panels toward the Sun and their antennas toward Earth. Each satellite contains four atomic clocks.

Several techniques have been developed to enhance the performance of GPS. One technique, known as differential GPS (DGPS), employs two fixed stations on Earth as well as satellites. DGPS provides a horizontal position accurate to about 3 m (about 10 ft).

2.1. GPS Projection:

The ellipsoid surface of the earth must be projected into a flat surface. This ellipsoid is projected onto a flat surface to produce a map. Different ellipsoids apply in different areas and a GOS generally has a bewildering array of ellipsoids build into the system. All that is necessary, if one wishes to work with a GPS and an existing chart is to look up ellipsoid or datum for the chart and set the GPS to this datum. The coordinates on the GPS will then plot correctly on the map. The map is projection and by its nature a projection is a compromise. It is impossible to make a map or a chart of a three dimensional surface like an ellipsoid. Some projections therefore attempt to maintain the correct length of the meridians while, distorting the areas close to the poles. The Mercator projection exaggerates the difference between meridians by the same degree as the length of the parallels in order to obtain an orthomorphic projection. One needs to know how these projections affect the measurement of distance in different regions of the earth. For example, in the Universal Transverse Mercator (UTM) projections only work up to about 5° of longitude before they become inaccurate. Hence it’s important to look at the limitations of the projections used with regards to the area one is working on.

2.2. GPS in Archaeology:

Obtaining 3D data for excavation units and for artifacts and features within the excavation units is traditionally conducted by use of theodolite or total station to establish a datum point and an intersecting baseline. Locations of in situ artifacts and features are established in relationship to the datum point. During excavations, artifacts and features must be continuously measured from the baseline to establish 3D position and carefully documented prior to removal or destruction.

In recent years, several studies have been conducted to explore the use of GPS technology in the field of archaeology, which provide both innovation as well as efficiency in data collection.

GPS was used successfully in establishing site location or for creating a baseline for excavation units in several of the studies. Establishing site locations on dry land, however, comprised most of the recent archaeological work that took advantage of GPS technology. Chapman and Van de Noort (2001) used GPS experimentally to determine if the use of differential GPS (DGPS) was a viable method of surveying points in archaeological prospection of wetlands on the British Isles. By noting differential desiccation, that is, the different rates at which the ground dries, in wetland environments, manmade features can be discerned that cannot be observed by normal aerial reconnaissance. Chapman and Van de Noort demonstrated that DGPS allowed for a much quicker and efficient collection of 3D data than with traditional optical methods.

Moreover, the DGPS system they used required only a single person rather than two and the data collected were more easily imported into GIS software from which excavation trenches were planned. Once the locations of the trenches were planned, they were positioned using, again, the DGPS equipment. Their conclusion was that GPS used with GIS is now a proven technique in archaeology.[4]

3. Geographic Information Systems-

Geographic Information System (GIS), computer system that records, stores, and analyzes information about the features that make up the earth's surface. A GIS can generate two- or three-dimensional images of an area, showing such natural features as hills and rivers with artificial features such as roads and power lines. Scientists use GIS images as models, making precise measurements, gathering data, and testing ideas with the help of the computer.

Many GIS databases consist of sets of information called *layers*. Each layer represents a particular type of geographic data. For example, one layer may include information on the streets in an area. Another layer may contain information on the soil in that area, while another records elevation. The GIS can combine these layers into one image, showing how the streets, soil, and elevation relate to one another. Engineers might use this image to determine whether a particular part of a street is more likely to crumble.

A GIS is designed to accept geographic data from a variety of sources, including maps, satellite photographs, and printed text and statistics. GIS sensors can scan some of this data directly—for example, a computer operator may feed a map or photograph into the scanner, and the computer “reads” the information it contains. The GIS converts all geographical data into a digital code, which it arranges in its database. Operators program the GIS to process the information and produce the images or information they need.

The Canadian government built the first GIS, the Canada Geographic Information System, during the 1960s to analyze data collected by the Canada Land Inventory. Other governments and university laboratories soon built similar systems. However, GIS systems were not widely used until the late 1970s, when technological improvements and lower costs made computers widely available. GIS sales boomed during the 1980s, as governments and businesses found more uses for the systems. A number of companies began producing new GIS software to program computer systems to increase their functions.[5]

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer-aided design (CAD) program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of by the traditional method of tracing the geographic form on a separate digitizing tablet (heads-down digitizing).

A GIS can also convert existing digital information, which may not yet be in map form, into forms it can recognize and use. For example, digital satellite images generated through remote sensing can be analyzed to produce a map-like layer of digital information about vegetative covers. Another fairly recently developed resource for naming GIS objects is the Getty Thesaurus of Geographic Names (GTGN), which is a structured vocabulary containing around 1,000,000 names and other information about places.

3.1. GIS in archaeology-

GIS or **Geographic Information Systems** has over the last 10 years become an important tool in archaeology. The combination of GIS and archaeology has been considered a perfect match since archaeology is the study of the spatial dimension of human behavior over time, and all archaeology carries a spatial component.

Since archaeology looks at the unfolding of historical events through geography, time and culture, the results of archaeological studies are rich in spatial information. GIS is adept at processing these large volumes of data, especially that which is geographically referenced. It is a cost effective, accurate and fast tool. The tools made available through GIS help in data collection, its storage and retrieval, its manipulation for customized circumstances and, finally, the display of the data so that it is visually comprehensible by the user. The most important aspect of GIS in archaeology lies, however, not in its use as a pure map-making tool, but in its capability to merge and analyse different types of data in order to create new information. The use of GIS in archaeology has changed not only the way archaeologists acquire and visualise data, but also the way in which archaeologists think about space itself. GIS has therefore become more of a science than an objective tool.[6]

3.1.1. GIS in Archaeological Survey-

Survey and documentation are important to preservation and archaeology and GIS makes this research and fieldwork efficient and precise. Research done using GIS capabilities is used as a decision making tool to prevent loss of relevant information that could impact archaeological sites and studies. It is a significant tool that contributes to regional planning and for cultural resource management to protect resources that are valuable through the acquisition and maintenance of data about historical sites.

In archaeology, GIS increases the ability to map and record data when it is used directly at the excavation site. This allows for immediate access to the data collected for analysis and visualization as an isolated study or it can be incorporated with other relevant data sources to help understand the site and its findings better.

There are different processes and GIS functionalities that are used in archaeological research. Intrasite spatial analysis or distributional analysis of the information on the site helps in understanding the formation, process of change and in documentation of the site. This leads to research, analysis and conclusions. The old methods utilized for this provide limited exposure to the site and provide only a small picture of patterns over broad spaces. Predictive modeling[7] is used through data acquisition like that of hydrography[8] and hypsography[9] to develop models along with archaeological data for better analysis. Point data in GIS is used to focus on point locations and to analyze trends in data sets or to interpolate scattered points. Density mapping is done for the analysis of location trends and interpolation is done to aid surface findings through the creation of surfaces through point data and is used to find occupied levels in a site. Areal data is more commonly used. It focuses on the landscape and the region and helps interpret archaeological sites in their context and settings. Areal data is analyzed through predictive modeling which is used to predict location of sites and material in a region. It is based on the available knowledge, method of prediction and on the actual results. This is used primarily in cultural resource management.

3.1.2. GIS in Archaeological Analysis

GIS are able to store, manipulate and combine multiple data sets, making complex analyses of the landscape possible. Catchment analysis is the analysis of catchment areas, the region surrounding the site accessible with a given expenditure of time or effort. Viewshed analysis is the study of what regions surrounding the site are visible from that site. This has been used to interpret the relationship of sites to their social landscape. Simulation is a simplified representation of reality, attempting to model phenomena by identifying key variables and their interactions. This is used to think through problem formulation, as a means of testing hypothetical predictions, and also as a means to generate data.[10]

In recent years, it has become clear that archaeologists will only be able to harvest the full potential of GIS or any other spatial technology if they become aware of the specific pitfalls and potentials inherent in the archaeological data and research process.

Archaeoinformation science[11] attempts to uncover and explore spatial and temporal patterns and properties in archaeology.

4. 3-dimensional (3D) modeling & reconstruction

Three-dimensional (3D) modelling of an object can be seen as the complete process that starts from data acquisition and ends with a 3D virtual model visually interactive on a computer. Often 3D modelling is meant only as the process of converting a measured point cloud into a triangulated network (''mesh'') or textured surface, while it should describe a more complete and general process of object reconstruction. Three-dimensional modeling of objects and scenes is an intensive and long-lasting research problem in the graphic, vision and photogrammetric communities. Three-dimensional digital models are required in many applications such as inspection, navigation, object identification, visualisation and animation. Recently it has become a very important and fundamental step in particular for cultural heritage digital archiving. The motivations are different: documentation in case of loss or damage, virtual tourism and museum, education resources, interaction without risk of damage, and so forth. The requirements specified for many applications, including digital archiving and mapping, involve high geometric accuracy, photo-realism of the results and the modelling of the complete details, as well as the automation, low cost, portability and flexibility of the modelling technique. Therefore, selecting the most appropriate 3D modelling technique to satisfy all requirements for a given application is not always an easy task.

Digital models are nowadays present everywhere, their use and diffusion are becoming very popular through the Internet and they can be displayed on low-cost computers. Although it seems easy to create a simple 3D model, the generation of a precise and photo-realistic computer model of a complex object still requires considerable effort.

The most general classification of 3D object measurement and reconstruction techniques can be divided into contact methods (for example, using coordinate measuring machines,callipers, rulers and/or bearings) and non-contact methods (X-ray, SAR, photogrammetry, laser scanning). This paper will focus on modelling from reality rather than computer graphics creation of artificial world models using graphics and animation software such as 3DMax, Lightwave or Maya. Starting from simple elements such as polygonal boxes, such packages can subdivide and smooth the geometric elements by using splines and thus provide realistic results. This kind of software is mainly used for movie production, games, architectural and object design.

Nowadays the generation of a 3D model is mainly achieved using non-contact systems based on light waves, in particular using active or passive sensors. In some applications, other information derived from CAD models, measured surveys or GPS may also be used and integrated with the sensor data. Active sensors directly provide range data containing the 3D coordinates necessary for the network (mesh) generation phase. Passive sensors provide images that need further processing to derive the 3D object coordinates. After the measurements, the data must be structured and a consistent polygonal surface is then created to build a realistic representation of the modelled scene. A photo-realistic visualisation can afterwards be generated by texturing the virtual model with image information.

Considering active and passive sensors, four alternative methods for object and scene modelling can currently be distinguished:

4.1. Image-based rendering (IBR)-

This does not include the generation of a geometric 3D model but, for particular objects and under specific camera motions and scene conditions, it might be considered a good technique for the generation of virtual views. IBR creates novel views of 3D environments directly from input images. The technique relies on either accurately knowing the camera position or performing automatic stereo-matching that, in the absence of geometric data, requires a large number of closely spaced images to succeed. Object occlusions and discontinuities, particularly in large-scale and geometrically complex environments, will affect the output. The ability to move freely into the scene and view objects from any position may be limited depending on the method used. Therefore, the IBR method is generally only used for applications requiring limited visualization discontinuities, particularly in large-scale and geometrically complex environments, will affect the output. The ability to move freely into the scene and view objects from any position may be limited depending on the

method used. Therefore, the IBR method is generally only used for applications requiring limited visualization.

4.2. Image-based modeling (IBM)-

This is the widely used method for geometric surfaces of architectural objects or for precise terrain and city modeling. In most cases, the most impressive and accurate results still remain those achieved with interactive approaches. IBM methods (including photogrammetry) use 2D image measurements (correspondences) to recover 3D object information through a mathematical model or they obtain 3D data using methods such as shape from shading, shape from texture, shape from specularity , shape from contour, and shape from 2D edge gradients. Passive image-based methods acquire 3D measurements from multiple views, although techniques to acquire three dimensions from single images are also necessary. IBM methods use projective geometry or a perspective camera model. They are very portable and the sensors are often low cost.

4.3. Range-based modeling-

This method directly captures the 3D geometric information of an object. It is based on costly (at least for now) active sensors and can provide a highly detailed and accurate representation of most shapes. The sensors rely on artificial lights or pattern projection. Over many years, structured light, coded light or laser light has been used for the measurement of objects. In the past 25 years many advances have been made in the field of solid-state electronics and photonics and many active 3D sensors have been developed. Nowadays many commercial solutions are available based on triangulation[12] (with laser light or stripe projection), time-of-flight, continuous wave, interferometry or reflectivity measurement principles. They are becoming a very common tool for the scientific community but also for non-expert users such as cultural heritage professionals. These sensors are still expensive, designed for specific ranges or applications and they are affected by the reflective characteristics of the surface. They require some expertise based on knowledge of the capability of each different technology at the desired range, and the resulting data must be filtered and edited. Most of the systems focus only on the acquisition of the 3D geometry, providing only a monochrome intensity value for each range value. Some systems directly acquire colour information for each pixel while others have a colour camera attached to the instrument, in a known configuration, so that the acquired texture is always registered with the geometry. However, this approach may not provide the best results since the ideal conditions for taking the images may not coincide with those for scanning. Therefore, the generation of realistic 3D models is often supported by textures obtained from separate high-resolution colour digital cameras. The accuracy at a given range varies significantly from one scanner to another. Also, due to object size, shape and occlusions, it is usually necessary to perform multiple scans from different locations to cover every part of the object: the alignment and integration of the different scans can affect the final accuracy of the 3D model. Furthermore, long-range sensors often have problems with edges, resulting in blunders or smoothing effects. On the other hand, for small and medium size objects (up to the size of a human or a statue) range-based methods can provide accurate and complete details with a high degree of automation.

4.4. Combination of image & range-based modeling-

In many applications, a single modelling method that satisfies all the project requirements is still not available. Photogrammetry and laser scanning have been combined in particular for complex or large architectural objects, where no technique by itself can efficiently and quickly provide a complete and detailed model. Usually the basic shapes such as planar surfaces are determined by image-based methods while the fine details such as reliefs employ range sensors.[13]

3D reconstruction has many practical uses in archaeology. These include the virtual reconstruction of perishable and valuable artifacts as well as visualization of grand structures of the past that now lie in ruins.

The Pompey Theatre was constructed in 55 B.C. on a site in Rome that is now occupied by the Campo Marzio and its surrounding buildings. Based on extensive archaeological work and previous reconstructions dating from the nineteenth and early twentieth centuries, tools including 3D Studio Max[14] and SoftImage XSI[15], were used to model views of the enormous theatre structure, establishing in the process that the columns that form the backdrop to the stage would have dwarfed the human figures taking part in performances. The scale of the architecture can be fully appreciated using the freely downloadable TurnTool[16] viewer, which allows the user to walk, pan, zoom and move around the reconstruction.

Another research area in the field of 3D reconstruction of archaeological evidence involves the Investigation of realistic lighting schemes for internal and external spaces. Predictive lighting techniques adjust the environments shown in 3D visualizations to take into account more plausible renditions of how the surroundings may have been perceivable to contemporaneous characters. One open source tool that can be used to simulate potential light values is called Radiance[17]. With this command line driven system, users can specify coordinates and take advantage of the ray tracing functionality to produce output as colour images, numerical values or contour plots.

There are important applications for the visualization of objects as well as environments and landscapes, as can be seen at the University of Birmingham VISTA Centre, where a 3D representation of the contents of a sealed canopic jar can be displayed on a Powerwall58 system. This very large back-projected wall-sized screen enables the display of geometrically accurate stereoscopic images, and in combination with the use of active stereo glasses, provides users with an extraordinarily convincing feeling of the three dimensional presence of the object. Other equipment at the VISTA centre includes immersive screen technology and a haptic workstation featuring Reach-In[18] technology, allowing users to experience two and three dimensional touch-enabled applications.[19]

The three-dimensional package, Rhinoceros[20], a NURBS[21] 3D modeling program, is typical of a range of similar packages that allow three-dimensional visualization of a site. This system was used by the Institute of Nautical Archaeology at Tektash during the 1999-2001 seasons to plot all artifacts on the site. Rhino is a very sophisticated, yet easy to use, program, and a complete three dimensional site plan was created with this system.

The Rhino program has the usual three dimensional modeling, four window format including plan, front, side and perspective views. A wire-frame model of each object was generated, usually from a photograph or the object itself. To keep the file sizes small, a generic example of each artifact was made. The outline of an amphora was produced and then rotated around the vertical axis to produce a solid wire-frame object and then scaled. The handles are generated separately and added or attached to the main body of the amphora. Additionally, the three target points on the mapping labels are then added. Other artifacts were generated in a similar way, although only the amphorae had the mapping label arrangement. The small objects were either placed in their approximate position, or two or three selected points were measured on the object and used to locate its position.

Once an amphora was surveyed using PhtoModeler[22], a set of three X, Y and Z coordinates for the top, left, and right targets on the mapping label were obtained. The amphora wire-frame was then placed on the Rhino plan. An extremely useful function in Rhino is the ‘orient’ key which movies and orients any two or three points chosen on an object with the target X, Y and Z points. Using this features, the whole object was moved so that the three points on the wire-frame were placed exactly on the three coordinates calculated by PhotoModeler.

As the model developed, the wire-frame objects could be rendered so that they appeared solid. It was then possible to view the site in perspective, rotate it, and view it at any particular angle. This was an extremely useful way of analyzing the composition of the site and how it had been formed, and it provided far more detailed information than the conventional archaeological site plan.[23]

A splendid use of virtualization and 3D modeling can be seen in the British Museums’ Mughal India[24] web page, which takes visitors on a virtual tour of the Mughal Empire in India, including but not limited to the history, architecture, coins and arms.

5. CAD

Originally developed for architectural and engineering purposes, CAD (Computer-Aided Design) software is now used in a multitude of disciplines and integrates seamlessly with the archaeological point data that may be acquired from a variety of sources including Total Station surveys and GPS (Global Positioning System) readings.CAD packages enable the user to create 2D and 3D vector-based drawings and work with a coordinate referencing system, x and y for position and z for height. The coordinates can refer simply to the drawing itself or can reference either an excavation site plan or, perhaps in the case of a regional survey, might reference National Grid coordinates or the UTM[25] (Universal Transverse Mercator).

Drawings can consist of layers of information which can be edited and manipulated either separately or together adding functionality to the pre-digital technique of pin-bar drafting (using transparencies to overlay a base sheet using registration pins to ensure accuracy). An extensive range of functionality allows entities within the drawing to be scaled, rotated, distorted, skewed, re-aligned etc., and line types and the rendition of objects as wire frames or solid models can be selected. Raster images can also be imported to be used either as background or as textural elements within the vector-based environment.

Where CAD and GIS packages start to overlap is the ability not only to store CAD objects in libraries for reuse in other contexts, but also to store attribute information about the objects separately, in a database if needs be. Some CAD packages also include their own programming and control language allowing application-specific front end menus to be built. Commercial systems like AutoCAD[26] and SolidWorks[27] give the user enormous expressive power to visualize 2D and 3D models but for those with more modest requirements and limited budgets, QCAD[28] may suffice for 2D modeling whilst the freely downloadable Google Sketchup[29] is very user-friendly and enables 3D models to be developed very rapidly.

6. Image Capture-

The capture and analysis of image data is an integral part of the archaeological process and digital applications and techniques have revolutionized methods of data gathering, no more so than with aerial and satellite photography. Software applications have enabled new processing and analysis techniques for these types of images and problems such as the abutting of oblique angled photographs of undulating terrain can be carried out using, for example, the rectification component of the Bonn Archaeological Software Package (BASP), a collaboratively developed suite of tools in development since 1973 which also includes functions for seriation, clustering, correspondence analysis, and mapping. Airphoto[30] is a low cost orthophoto program which allows the user to correct a distorted aerial view and represent terrain as a relief model, combining the geometric accuracy of a map with the detail of a photograph. The use of multiple photographs to determine accurate measurements and to produce digital terrain models (DTM's) is a highly technical process known as photogrammetry, for which a range of software is available. Image manipulation packages such as Adobe Photoshop[31]
or Gimp[32] can be used on digitized versions of images to enhance areas that are obscure and bring out features in the landscape that might indicate the presence of sub-surface archaeology.

7. Google Earth-

Google Earth is a virtual globe, map and geographic information program that was originally called Earth Viewer, and was created by Keyhole, Inc, a company acquired by Google in 2004. It maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and GIS 3D globe.

References to Google Earth's interoperability with GIS data assume the use of Google Earth Pro version, which requires licensing after a 7 day trial period. The benefits of using this system are enticing and begin to offer the user some quite sophisticated geospatial referencing functionality. In conventional GIS (Geographical Information Systems), the overlaying of one map onto another, or one layer of information over a related image, is carried out by a process of geo-referencing where point data on both source files are matched up sequentially, ultimately allowing the images to be accurately superimposed. Google Earth provides a 'rubber-sheeting' function which involves specifying corner markers and stretching one terrain over another to provide a similar degree of synchronization between two representations. In conjunction with a GIS data import function, distance measurement tools, and the ability to find, mark, map and export data to other applications, Google Earth has the potential to provide serious benefits to archaeologists, not least in terms of the time that it takes to achieve certain tasks in comparison with using standard GIS packages and dedicated aerial or satellite imagery.

8. Computerized Documentation-

Information needs to be recorded with a clear idea of the questions that are likely to be asked about it at a later stage, and the archaeologist must be aware of these factors while recording these artifacts. The presence or absence of a long list of attributes must be recorded for every layer of soil, post-hole, wall or whatever else is encountered, including dimensions, location, soil colour and texture, any finds, stratigraphical relationship to adjacent features etc. This stage is tedious and time-consuming, but with forethought it is simplified and speeded up by abbreviated codes and well-designed computer programs that check the data as it is being entered.

Time devoted to computerized recording is repaid when writing the excavation report, because a comprehensive site database can be indexed in many different ways to produce specific information sorted into any desired order. For example if the dimensions of excavated features have been digitized, GIS systems allow data and plans to be combined in all sorts of combinations.

The advantages of computerized recording become particularly obvious if the alternative is considered, multiple card-indexes, masses of site-plans, photographs, notebooks and perhaps only the memory of the excavator for some details. Sorting these manual data for the required information will be tedious and time consuming.[33]

9. Remote Sensing-

Remote Sensing is the term used for the technique of gathering images using equipment that is at some degree removed from the subject matter and therefore covers a very wide range of techniques for analyzing the environment. The Wroxeter Hinterland Project, commenced in 1994 and managed by the University of Birmingham, was an innovative model for the combined use of a number of these techniques and amassed a very significant amount of data about the Romano-British town of Wroxeter and its surrounding landscape without recourse to excavation. Magnetometry is a technique for measuring and mapping the magnetic properties inherent in soil and will determine whether certain areas of sub-surface material have been subject to disruption or movement. If soil from one area has been moved to another, the variations in the magnetic properties can be plotted using software tools. At Wroxeter, more than 2 million data points were collected during the principle magnetometer survey and using the principle that relatively non-magnetic building stone can be differentiated from the surrounding soil, the ancient Roman street system was largely reconstructed showing evidence of higher and lower status buildings in particular parts of the town, as well areas which may have been dedicated to agro-industrial activities.

The presence of archaeological features (e.g. a buried wall, a cobbled road surface) will also affect the electrical resistance of soil and a resistivity meter is a device that passes a weak electrical current between metal electrodes which are inserted into the soil every 0.5 or 1m apart. Once again, this data is fed into a graphics program to plot the results.

Ground Penetrating Radar (GPR) was also used at Wroxeter over an area of 2.25 hectares and involves the use of equipment that can measure the nanosecond delay times of microwaves that 'bounce' back off buried archaeological features. In combination with seismic surveys, where the reflection of soundwaves are measured to identify sub-surface features (also applicable to maritime archaeology in the form of sonar), and a range of airborne techniques such as multi-spectral photography and airborne thematic mapping, the amassed data has enabled researchers at Wroxeter to put together compelling evidence to explain the changing fortunes of this historically important provincial Roman city[34].

10. Resistivity Surveying-

When an electric current is passed through the ground between electrodes, the resistance to its flow may be measured. A current will pass relatively easily through damp soil, but drier compact material such as a buried wall or a cobbled road surface create higher resistance. Resistivity surveying is rather cumbersome, because it normally requires a number of electrode probes to be pushed into the ground at precise intervals for each reading.

Because of the laborious procedure involved, resistivity is best suited to the direction of linear features such as roads, walls or ditches by taking measurements along a straight line at 90°
to their suspected position. Some electromagnetic instruments measure soil conductivity without probes, and although less sensitive they have proved particularly successful on arid sites in desert areas.

11. Magnetic Surveying-

Magnetometers also detect deviations from the general background of the subsoil, in this case indicated by variations in its magnetic field. Several aspects of past human occupation has suitable anomalies. Heating at approximately 700°C or above by hearths, kilns, furnaces etc, causes the randomly aligned magnetic particles present in most soils and clays to realign along the prevailing magnetic field of the Earth, and to retain this new alignment on cooling. The alignment of magnetic particles is also affected by digging and refilling ditches and pits; solid features, such as walls or road surfaces, contain fewer magnetic minerals and therefore provide lower readings than their surroundings.

Magnetic surveying does not require probes in the ground; the instrument can be carried along a line or a grid by its operator, and it is generally preferred to sensitivity for this reason when conditions are favourable. One form of instrument, the **proton magnetometer**, takes readings for the absolute magnetic field at given points on a grid. The **proton gradiometer** is less sensitive, but in many ways easier to operate; it measures the difference between two separate detector bottles at either end of a pole held vertically by the operator. Buried anomalies affect the lower bottle more than the higher, and difference is recorded, rather than the absolute field. This permits rapid surveying of areas threatened by development, especially if a ‘bleeper’ mechanism produces an audible sound when an anomaly is detected. Even more rapid is the **fluxgate gradiometer**, which takes continuous, rather than spot readings. Gradiometer results are easier to interpret than magnetometer readings, which are more easily disturbed by natural variations in the subsoil, or by the effects of wire fences, electrical storms or railways. Magnetometers are also an effective aid in surveying ship wreck sites on the seabed, where metal rivets or larger objects such as cannon may have been dispersed over a large area and covered by sediments.

Some additional types of magnetometers and soil conductivity meters are employed in the surveying of archaeological sites. Unlike normal magnetometers, they inject a signal into shallow surface deposits and records the way the response is altered by magnetic susceptibility. Since susceptibility is influenced by human occupation and other activities, particularly when burning has been involved, it is particularly useful when it is necessary to determine the full extent of a site, for only a few very widely spaced measurements need be taken. On a smaller scale, susceptibility is a good indicator of intensively utilized domestic or industrial areas within sites, it provides a useful compliment to the results of phosphate analysis, which reflect different kinds of activities such as waste-disposal or animal husbandry.

12. Radar and Sonar location devices-

A recent development with considerable potential for the examination of buried sites in future is the use of radar, but a disadvantage is that it performs best on very dry deposits. It works in the same way as sonar scanning, but electronic signals are transmitted into the soil, and bounces back into the receiver. The signals are altered by the density and position of whatever they encounter, and the patterns are received from the ground are plotted as a diagram. When colour is used to enhance the variations, it is possible to see the shapes not only of solid features, such as buried walls, but also the profiles of pits or ditches. Radar images have been used in England at the Anglo-Saxon burial ground at Sutton-Hoo to look for signs of possible ship burials below mounds and at York to examine sites before excavation. Sonar scanning is a routine technique used in seabed surveys and it is able to detect archaeological anomalies such as ship-wrecks as well as natural rocks and sand banks.[35]

Conclusion:-

The advantages of using computers and modern technology in archaeology cannot be underestimated. It saves valuable time, money and effort in different fields of archaeology from exploration and excavation to analysis, archiving and publication. Adoption of these technologies has certainly helped to make archaeology more accessible even to common people. Using modern survey methods have helped in reducing the scale of archaeological excavations while still yielding as much information and artifacts from large scale excavations. This is because modern exploration techniques have helped to pin-point areas that have the most potential. This has in-turn helped excavation become a less destructive process, by minimizing the size of the dig. 3-dimensional recording helps students and enthusiasts to virtually rotate turn and study valuable and perishable artifacts like Babylonian clay tablets without actually touching it. Virtualization helps in recreating a past city, building or community digitally with the aid of computers using available historical archaeological data. This virtual reconstruction of the past makes a lot easier understanding to the common people. Publishing archaeological information on websites has made it universally accessible.

End Notes

[1] http://www.nyu.edu/its/pubs/connect/archives/97fall/hugheshistorical.html
[2] http://www.archaeologyexpert.co.uk/ComputerArchaeology.html
[3] http://www.upenn.edu/computing/printout/archive/v08/2/museum.html
[4] Chapman, H., & Van de Noort. (2001, April). **High-resolution wetland prospection, using GPS and GIS: Landscape Studies at Sutton Common (South Yorkshire), and Meare Village East (Somerset)**. *Journal of Archaeological Science*, 28(4), 365-375.
[5] Goodchild, Michael F. "Geographic Information System." Microsoft® Student 2009 [DVD]. Redmond, WA: Microsoft Corporation, 2008.

[6] Renfrew Colin, Bahn Paul 'Archaeology : Theories Methods & Practice, Third Edition [2000] Thames & Hudson Ltd. London.
[7] **Predictive modelling** is the process by which a model is created or chosen to try to best predict the probability of an outcome.[1] In many cases the model is chosen on the basis of detection theory to try to guess the probability of a signal given a set amount of input data
[8] **Hydrography** focuses on the measurement of physical characteristics of waters and marginal land. In the *generalized usage*, "hydrography" pertains to measurement and description of any waters
[9] Hypsography studies the distribution of elevations on the surface of the Earth. Most often it is used only in reference to elevation of land but a complete description of Earth's solid surface requires a description of the seafloor as well. Related to the term hypsometry, the measurement of these elevations of a planet's solid surface are taken relative to mean datum, except for Earth which is usually taken relative to the mean sea level.
[10] http://www.esri.com/industries/archaeology/index.html

[11] **Computational archaeology** is also known as **archaeological informatics** (Burenhult 2002, Huggett and Ross 2004) or **archaeoinformatics.**
[12] **Triangulation** is a navigation method for determining location trigonometrically: a navigation technique that uses the trigonometric properties of triangles to determine a location or course by means of compass bearings from two points a known distance apart. Space-age global positioning systems enable people to triangulate their location relative to the known positions of Earth-orbiting satellites.
[13] http://www.3darchaeology.org/pdf2008/extra/remondino_elhakim2006.pdf
[14] http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=5659302
[15] http://www.softimage.com/products/xsi/
[16] http://www.turntool.com/
[17] http://radsite.lbl.gov/radiance/HOME.html
[18] http://www.reachin.se/
[19] http://www.methodsnetwork.ac.uk/redist/pdf/wkp06.pdf
[20] http://www.rhino3d.com/
[21] **Non-uniform rational B-spline** (**NURBS**) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces which offers great flexibility and precision for handling both analytic and freeform shapes.
[22] http://www.photomodeler.com/index.htm
[23] Green Jeremy, *Maritime Archaeology – A Technical Handbook* second edition [2004] Elsevier Academic Press, San Diego, California, USA.
[24] http://www.mughalindia.co.uk/room.html
[25] The **Universal Transverse Mercator** (**UTM**) coordinate system is a grid-based method of specifying locations on the surface of the Earth. It is used to identify locations on the earth, but differs from the traditional method of latitude and longitude in several respects.
[26] http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=2704278
[27] http://www.solidworks.com/
[28] http://www.ribbonsoft.com/qcad.html
[29] http://sketchup.google.com/
[30] http://www.uni-koeln.de/~al001/airphoto.html
[31] http://www.adobe.com/products/photoshop/family/
[32] http://www.gimp.org/
[33] Archaology Green Kevin 1996 BT Batsford Ltd London
[34] http://www.methodsnetwork.ac.uk/redist/pdf/wkp06.pdf
[35] Archaology Green Kevin 1996 BT Batsford Ltd London