CO-223

ACTIVE REMOTE SENSING FOR ARCHAEOLOGY

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ABSTRACT

Interdisciplinary studies has an increasing importance in scientific studies. Each discipline can serve in one part of the related study by using its own knowledge and improved technology. The combination and analysis of all these results from studies of diverse professions result with more accurate, fast and economic in terms of labor and manpower. There also some disciplines that can serve others more than one point, especially when there are studies related to Earth. Geomatics aims to map the Earth (or Space). Geomatics with varied surveying techniques and technologies (tachymetry, remote sensing (RS), photogrammetry, geodesy, geographic information systems (GIS)) has become an increasingly important componential discipline in archaeological researches. Archaeology needs the results of Geomatics tools for extracting exploring, archiving and analyzing of cultural heritage. Especially the use of remote sensing techniques allows archaeologists to uncover unique data that is unobtainable using traditional techniques. The remote sensing technology also offers a methodological procedure in a rapid, accurate, and quantified manner for detecting, inventorying, and prioritizing surface and shallow-depth archeological information, which are often invisible to the naked eye. Remote sensing methods employed in the service of archaeological investigations including terrestrial, aerial and satellite imaging (e.g. optical, multispectral and hyperspectral sensors, thermal infrared multispectral scanners, light detection and ranging systems (LIDAR) and radar systems. The newly RS technologies such as LIDAR and spaceborne radar systems, i.e. active remote sensing, are new challenges in archaeological researches. Ground-based geophysical methods such as Ground Penetrating Radar (GPR) and Magnetometry are also used for archaeological imaging which are often classed as near surface remote sensing techniques, are not the subject of this paper.

PAST and RECENT STUDIES on ARCHAEOLOGY-REMOTE SENSING

Remote sensing in archaeology is used for different aims. The main aim is to explore the remains and map of these archaeological remains over landscape. It is significiant and convenient to understand archaeological prospection methods in general for remote sensing and archaeology connection. Aerial Archaeology and Landscape Archaeology are two main prospection methods in archaeology. Aerial archaeology includes photogrammetry and remote sensing tehnologies whilst landscape archaeology covers field surveys (i.e. geophysical methods, GPS campaigns, tachymetry). From the invention of photogrammetry, it is a prospection tool in archaeological studies (Sever, 1990; Lillesand and Kiefer, 1994). Archaeology did not miss the advantages of developing spaceborne systems in terms of reducing time and financal aspects and is one of the first disciplines that use remote sensing (Sever, 1990). The other major advantage of spaceborne or airborne systems is obtaining data from different parts of electromagnetic spectrum (EM) (Figure 1). These varied parts of EM provide different reflection properties of surface that are traces to detect subsurface archeological remains (e.g. radar systems, optical or multispectral systems, each are effective in one part of the EM).

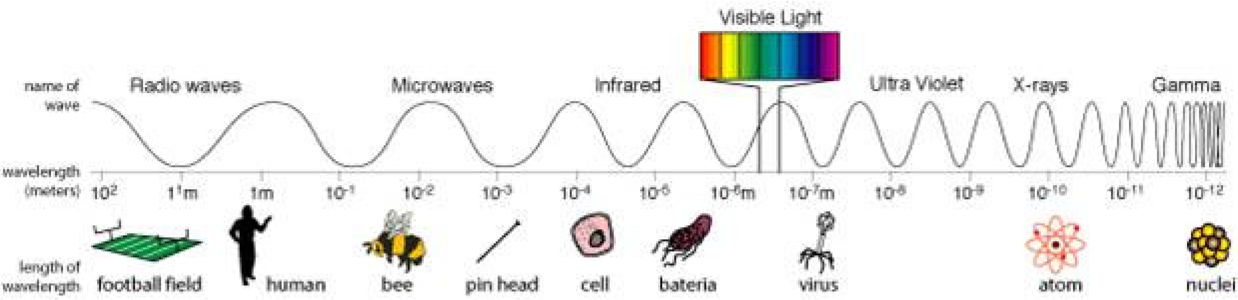

Figure 1: Electromagnetic Spectrum (Url 1)

The archaeological traces currently can be detected from their surface effects by using aerial photos (optical systems). The development in spaceborne systems is a driving force to get more accurate and fast results in combination with other data sources. Lambers and Sauerbier (2006) used orthomosaics, satellite imagery, scanned topographical maps and Digital Terrain Model (DTM) in Peru-Nacka. They designed a conceptual data model for these data in GIS environment and after analyses they investigated “Nacka

Lines”. Rowland and Sarris (2007) insisted on benefits of multispectral remotes sensing in exploring subsurface archaeological remains. They used a wide variety of data from diverse sources, Compact Airborne Spectrographic Imager (CASI), Airborne Thematic Mapper (ATM), LIDAR and GPR. Doneus (2001) studied with oblique and vertical aerial photographs and revealed crop marks belong to Roman buildings in Teurnia (Carinthia), Austria. The general idea behind most of the archaeologial studies on subsurface remains is to to get data from different sources, technologies. Then by using these data comparable, the results would be more convenient and accurate in terms of subsurface archaeology.

The subsurface materials can be detected from anomalies on the surface by using remote sensing and photogrammetry as mentioned. There are three main marks that provide information from subsurface; crop marks, soil marks, shadow marks. The results of light-shadow-contrasts are shadow marks, soil marks are the differences in the tonal differences in the soil and if there are height differences in topography and differences in color of the cultivated fields means there are crop marks (Campana and Francovisch, 2007).

The mentioned methodologies till here to detect archaeological remains are passive remote sensing systems (analog and digital photogrammetry, multispectral images from spaceborne systems). The newer active remote sensing systems have started to be executed and analyzed in combination with other data sources in archaeology. Airborne Laser Scanners (ALS) and spaceborne Radar (e.g. Synthetic Aperture Radar - SAR) systems are two new options in archaeological studies.

APPROACH & METHODS

Topographic model of the archaeological area is an important factor from the planning to the excavation and analyzing the results. In the beginning of the study, it is important to get information about the landscape. Especially by using Digital Terrain Model-DTM of the landscape, it is possible to analyze and detect some traces of archaeological remains over or beneath the Earth. It is helpful in detecting archaeological remains by analyzing multiple views of DTM before an excavation. These analysis helps to manage a cost-effective and prevent time-consuming efforts of the project. There are several ways to generate DTM of the landscape to obtain its topographic model. The development in airborne and spaceborne data acquisition systems serve to produce that requirement. Radar systems and LIDAR are two new technologies that are in use for DTM generation in topographic modelling. The accuracy of the DTM is depended on the accuracy of the data obtained by the technology. Another important point is the scale of the archaeological area that is a criteria to choose the appropriate technology-spatial resolution- for the project. For instance by using ALOS PALSAR radar system, it is possible to generate DTM but the spatial resolution is 12.5 meters. This resolution is not enough to detect an archaeological remain that has smaller dimensions than this resolution. But if the aim is to detect linear anomalies (e.g. paleo rivers) of the landscape that can be an indirect trace of an ancient civilization and support the project indirectly. On the other hand LIDAR technology provides DTM with higher accuracy. The other advantage is LiDAR has significantly better vertical accuracy compared to the horizontal (Toth, 2008), which is an significiant property to get traces from DTM of the arhaeological area. The second study area for archaeological traces from radar and LIDAR is the backscatter properties of the targeted area. The understanding of the backscattering from the archaeological areas and differantiate these from the other landscape components needs further studies. The prior study is to understand active remote sensing (i.e. radar and LIDAR) in combination with archaeological studies.

Active microwave sensors, known as radars, transmit an electromagnetic energy that they produced and receive the backscatter energy from the target (Wagner, 2010). Radar systems use microwaves that are less influenced by atmospheric effects. It is also possible to obtain data 24 hours a day because radar produces its own energy and is not depended on sun energy. The wavelength of the electromagnetic radiation in radar systems is longer than the other portions of EM (Figure 2). The measurement unit is in centimeters (1cm – 1m) in radar systems and varies between K and P bands considering by requirements of the study (Table 2, between red brace). From archaeological point of view near surface remote sensing instruments like Ground Penetrating Radar (GPR) is also using microwave energy to obtain information from subsurface features and can be mentioned as another platform for microwave use. But it is not going to be discussed in this paper.

The pulse from electomagnetic radiation is generated by radar system and sent to target by transmitter along antenna. Then the backscattered radiation from the target is obtained by the receiver. The processing step is executed with appropriate mathematical solutions through special software packages and signal processors (Mold, 2007). The penetration capabilities of radar, especially in arid areas (e.g. deserts in Egypt), is a powerful tool to explore water traces beneath the earth that is possible to detect traces of ancient civilizations (Parcak, 2009 pp.25-26; Patruno etal., 2009).

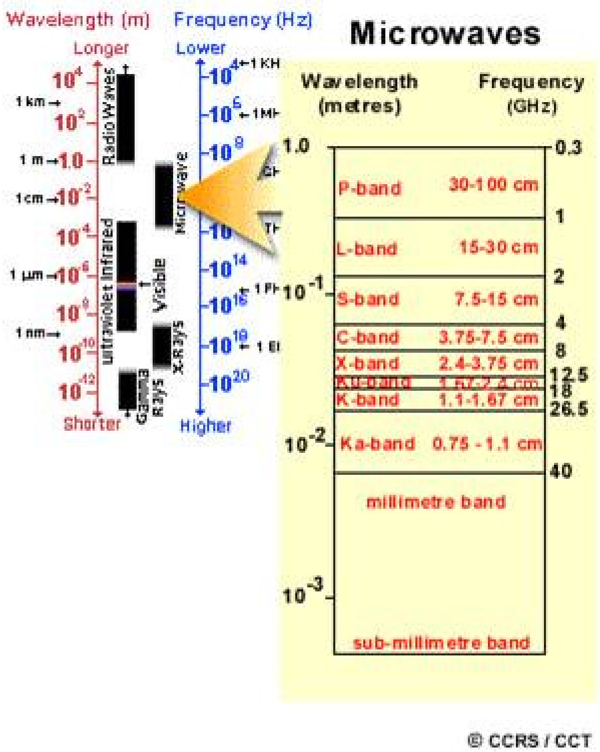

Figure 2. Electromagnetic Spectrum and Microwave Portion (Url 2)

Comer (2008) tried to define and differentiate the reflection properties of landscapes including buried archaeological remains and statistical calculations of results were implemented. Patruno etal. (2009) used ALOS PALSAR (Synthetic Aperture Radar), with other data sources (ALOS PRISM and orthophotos) and evaluated the “L-Band” back scatter properties of PALSAR for archaeological remains. They pointed out the spatial resolution consantraints of PALSAR and the advantage of the capability to obtain additional information on electromagnetic properties of targeted area (or objects) 24 hours a day and all seasons in a year . In another study (Kurtcebe etal., 2010), after image processing techniques, two different polarization (HH and HV) of ALOS PALSAR were analyzed to understand the effects of polarization on archaeological areas. Then the results were compared with other data sources of the archaeological area (orthophotos and Google Earth). The preliminary results (concentrated on HH polarization data) were promising in detection archaeological areas by using other spatial data sources.

The other technology is Airborne Laser Scanning (also known as LIDAR (Light Detection and Ranging)) that has been used as a new technological development in topographic data acquisition over open and forested landscapes (Mandlburger etal., 2007; Pfeifer etal., 2004). The word laser is an acronym for light amplification by stimulated emission of radiation. Except generating a high accurate DTM, LIDAR provides and alternative method to detect archaeological areas in forest or covered by dense vegetation.

LIDAR is an active system, i.e. produces its own illumination and independent from sun energy. In airborne laser scanning, radar measurement principles are applied, because high range dynamics have to be covered (Wehr, 2008).

LIDAR has these main components: scanner, GPS and Inertial Measurement Unit (IMU) or Inertial Navigation System (INS) (Figure 3). LIDAR collects a set of points to produce the terrain model, is called point cloud. This point cloud is composed of individual pulses from laser (pulse echo) or to use continuous beam of laser radiation like fullwaveform systems.

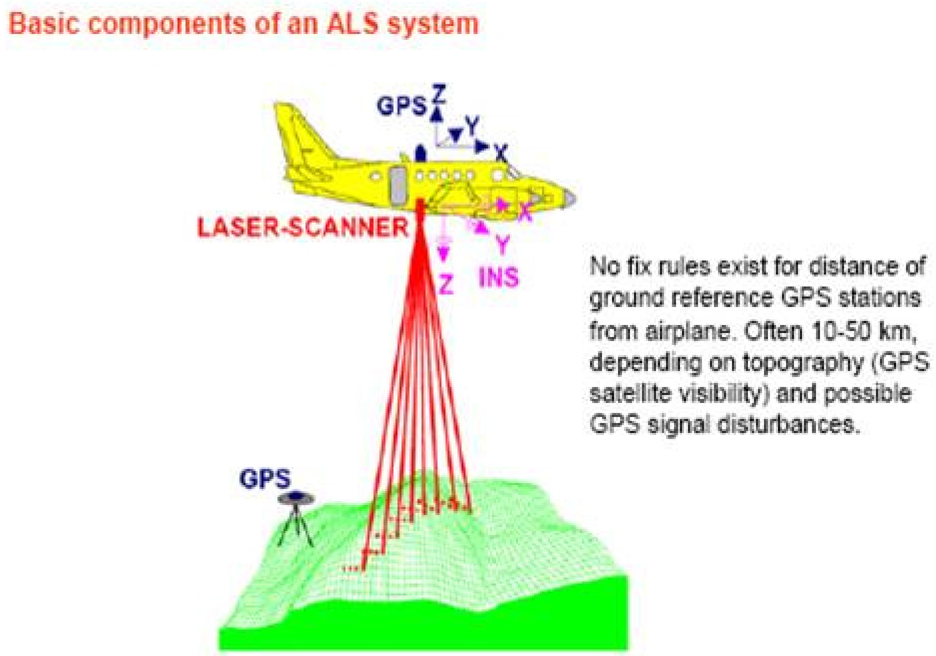

Figure 3. LIDAR components (Baltsavias, 2009).

The basics of LIDAR working principles will be explained over pulse echo: in LIDAR system, it is possible to seperate first and last echo. First echo is stemmed from the tree canopy, and from the ground last echo is obtained. The first model of the terrain is Digital Surface Model (DSM). This model includes objects related to terrain and all the other objects on the terrain (e.g. trees, vegetation, buildings, in another words off terrain points). The second part is to seperate the terrain and off terrain points of scanned landscape and generate DTM. The other data acquired by newer LIDAR systems is intensity which characterize the reflectance. This property can be useful in archaeological studies to differantiate archaeological areas/remains and the other terrain points.

The use of LIDAR in archaeology is a newly study area. There is not much studies but the results of existing studies are encouraging. Doneus etal. (2008) studied over archeological areas covered by dense vegetation and buried remains. They generated DTM of archaeological landscape by using LIDAR to interprete the landscape for buried remains that are not visible from ground or by using current optical or remote sensing data. In the other study, the researchers targeted on exploring unknown subsurface archaeological sites. Because of their unknown location, it is difficult to protect these archaeological sites. The extension of these sites should be detected and mapped for further steps of protection studies. An integration of ALS, field surveys and aerial photographs were used in this study to discover unknown subsurface archaeological sites in Austria (Doneus etal., 2007).

CONCLUSION AND FUTURE PLANS

Each system has its own advantages and disadvantages in archaeological use, especially in terms of subsurface archaeology. LIDAR system does not have any penetration capability but for accurate, fast and economical DTM generation in wide areas LIDAR is very effective. The topographic model derived from LIDAR provides very accurate terrain properties that can be analyzed and visualized for all archaeological projects. On the other hand radar systems can penetrate the ground but the current spatial resolution is not enough for all archaeological aims. The studies over wide areas is a chance to use radar to get some clues like water existence or linear anomalies beneath the terrain. All these traces can be indirectly related with an ancient civilization. The other aspect for further studies by using both active remote sensing technique is to understand the backscattering mechanism of archaeological remains. Both radar and LIDAR systems collect reflectance of terrain. For a better understanding in reflectance properties/differences of archaeological traces, more study is required as a future study.

A rational planning stage and aim (including the terrain properties and all components of the archaeological project) are crucial steps of the archaeological project before data acquisition. The other conclusion is about using diverse data sources. Because every technology has its own advantages and disadvantages. Diverse data sources usage can minimize the disadvantages of each technology. The current and past studies mostly pointed out the importance of using diverse data sources for analyzing archaeological areas. Different parts of EM is sensitive for different properties and improved data aquisition technologies provide alternative information on terrain of archaeological areas.

The third conclusion is about the colloborative studies centered Archaeology. The term "Archaeomatics" will be used to define the interdisciplinary approach for subsurface archaeology. The methodologies and tools of Geomatics is used both in landscape archaeology (e.g. land survey, terrestrial laser scanning-photogrammetry) and aerial archaeology (e.g. airborne laser scanning, remote sensing images). GIS is also another tool that is one of the subjects of Geomatics education and is a common procedure for all disciplines covering and studying spatial data. The main components of Archaeomatics are, Geomatics, Archaeology, Geology and Informatics (Figure 4). There are lots of studies under each of these disciplines. They have some common study areas (e.g. GIS, programming, topographic modeling, aerial remote sensing). The improvement in one discipline support and directly or indirectly effect the studies/results of other disciplines. Archaeomatics is the intersection set of these diverse professions which has Archaeology in the center of overall study. The main idea here is the necessity of interdisciplinary planning in and the requirement for a new area of specialization that can provide and support the requirements of any archaeological area.

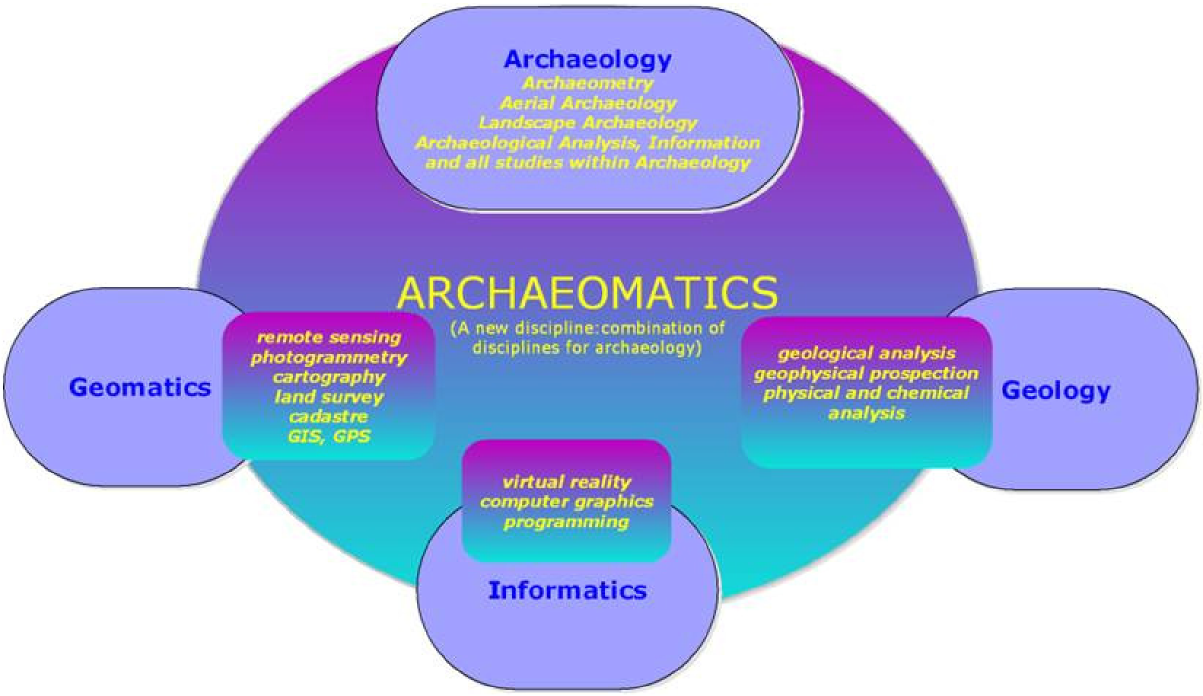

Figure 4. Components of Archaeomatics

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