Using geoinformatics tools in archeology

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The technological advancements in data sourcing and processing techniques gives entirely new possibilities in the field of archeology. These range from quarry discovery to 3D modeling of artifacts. Introducing new technologies holds several advantages, such as improving the effectiveness of quarry discovery, shortening the time required for the excavation, more detailed and more accurate data sourcing and processing methods, usage of complex databases, which can directly lead to more detailed analytical approaches, and last, but equally importantly, the 3d modeling and visualization of artifacts and analysis results.

I. DISCOVERY OF EXCAVATION SITES

Using aerial photographs is a well known technique used to find excavation sites. The different types of vegetation, unusually regular shapes in plant life, and at the end of winter season, the snow melting patterns can indicate remains of manmade structures. These discovery methods have been extended with the following approaches:

Parallel to taking aerial photographs, taking high resolution laser mapping images of the surface *(LIDAR)* is also available. These dataset can contain up to 8-10 data points -or more- for every square meter, taken from 1000-1200 meters in the air with an approximately 0.15m absolute elevation precision. The relative precision can be much higher, and a result, the difference between the ground surface and artifacts can be as low as ~2-3 centimeters. This means that it can not only visualize data and information that's practically invisible to the human eye, but also give us the opportunity to look at the current advancement state of the plantation. Thus, the discovery of hill and earth forts through the usage of detailed and accurate surface models is much more effective, especially since there's no historical written material regarding the building of these structures, only this sort of representation can visualize their existence.

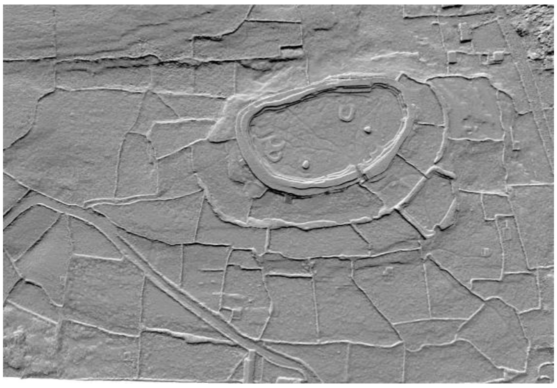

Figure 1. Surface model calculated from LIDAR imagery [1]

Walls and other remains within the soil can alter groundwater levels and generally the water percentage of the soil, which results in different plantation development and advancement levels. If the recording and the analysis is made within the spectrum that can be used to detect the smallest variance, then we can use image processing, namely spectral distribution analysis to find possible excavation sites. Figure 2. shows a site on an infrared snapshot. The sub-soil lines of buildings is much more apparent compared to the original aerial imagery.

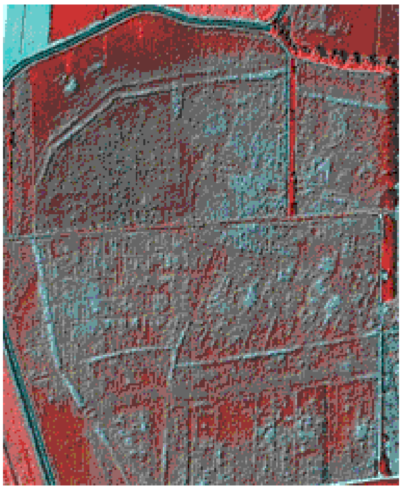

Figure 2. Excavation site on an infrared image [2]

High resolution and high precision surface models can be also reached by using unmanned aerial vehicle *(UAV)* discovery flights. By only using amateur photography equipment, we can record images up to 1-2cm precision level, while flying low altitude, given ideal conditions. By applying it on a smaller surface area, repeating the process 8 to 10 times, the processing software can produce imagery that matches the precision and resolution of the original recordings. The end result is normally a surface mesh of the ground surface. The advantage of the UAV data sourcing is that it can be used on territory that's complicated to access or not accessible at al.

Among the various geophysical methods *(magnetometer*, *soil resistivity*, *seismic)*, we used radar technique in our exploration practice. The basic principle of its mechanism that electromagnetic radiation entering the soil is reflected from strata with different dielectric constant. The result is more unambiguous and nicer in non-urban areas where there are no interfering objects such as underground utility lines. It is less efficient to use in densely built urban environment, since the signal is reflected not only from underground lines but also from debris and rocks, and it is difficult to filter the data of archaeological value from the “noisy” image.

Figure 3. shows an earth fort detected by ground penetrating radar by the evaluation of our own survey [3], representing the sections on a satellite image. Remains of medieval buildings can be observed in the central area. The homogeneous appearance of the buildings of the earth fort on the radar image is due to the fact that no human activity - other than agriculture - was carried out over the past centuries which could have deleted the effects of the methodology applied in the construction of the earth fort. Therefore, these phenomena can be easily detected even at present.

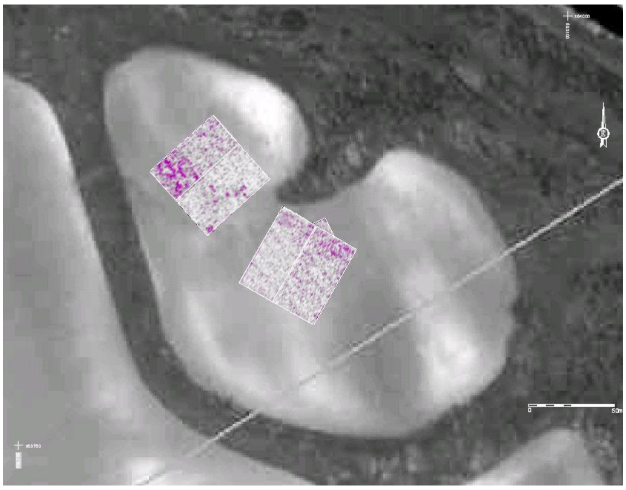

Figure *3*. Earth fort explored by ground penetrating radar near Szabadhídvég [3]

Underwater imaging is not a new technique in archaeology but it has to be mentioned for the sake of completeness. In this field as well, the spectral sensitivity and the geometric resolution of imaging systems have increased in the recent past which yields greater accuracy after processing.

II. Survey and Documentation of Artifacts

“Act No. LXIV of 2001 on the Protection of Cultural Heritage (hereinafter: Act on Heritage Protection) contains the main terms regarding the conservation of archaeological relics.

The protection of archaeological heritage involves the discovery, evaluation, documentation, registration, conservation of the archaeological heritage and the establishment of protection on archaeological sites [Act LXIV of 2001, Section 7, Item 7/A "[4]

Archaeological artifacts discovered underground or below some structure and the circumstances of their discovery were traditionally recorded with geodetic measurements, scaled drawings and paper-based, later digital images over a long period of time. New data acquisition and processing techniques – partly due to the geodesists participating in the surveys, partly due to the appearance of the new generation of archaeologists – are beginning to spread within the discipline. This considerably decreases the time necessary for the exact surveying and documentation of artifacts. These economic and other advantages – e.g. less field days, time schedule of constructions – are benefits not only for archaeologists but in many cases also for other, affected disciplines, such as road construction and utility services. In the case of a survey in residential area, these benefits are experienced by the residents as well who have to face the inconveniences resulting from the closure of public areas for a shorter period of time.

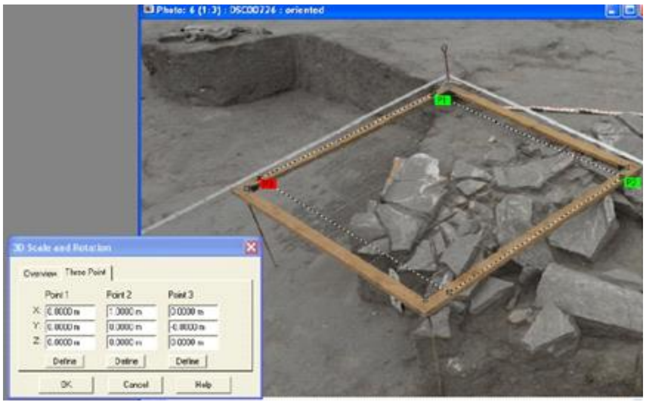

Figure 4. Conventional documentation of an archeological survey in the planned trajectory of the M6 motorway, Baracs, 2009. [5]

Apart from economic advantages, it is very important for archaeologists that the quantitative and qualitative properties of recorded data improved by orders of magnitude due to digital data registration and modern technologies in geoinformatics.

Advantages of technologies in geoinformatics:

- site survey without its “disturbance/damage”
- greater accuracy during surveys,
- more detailed artifact recording,
- options for 3D modelling,
- shared database with data form other sources
- option for complex analysis (geographical information software)
- various visualization options
- options for subsequent data acquisition

It has to be noted that the spread of technologies was also facilitated by the fact that these days the images recorded with so-called amateur cameras are also suitable for processing, and some user software can be downloaded for free.

Below we present a few examples where geoinformatics technologies were applied in archaeological surveys and documentations.

- **ground laser scanner**

When surveying with the ground laser scanner, the laser beam emitted from the instrument and reflected from the surface of the surveyed object determines the exact place of reflection. Before the measurement we can set the point density to be obtained on the surface of the scanned object. Generally, the details of terrain objects can only be surveyed from several positions, partly due to the dimensions of the objects but in some cases also because of the dead angle of measurement of the laser scanner. The results of each scanning can be integrated which also enables the merging of internal and external scanned point clouds of buildings or building remnants. Based on these, we can prepare the section views of the object. Likewise, the point clouds produced from aerial and ground laser scanning can be also handled together. The latter solution is suitable for building a 3D city model which does not only provide a spatial view but the shared point cloud enables high accuracy data can be searched, sections can be plotted, such as the structure gauges of roads bounded by trees. Figure 5. shows the presentation of point clouds produced by the external and internal scanning of the medieval Anna Chapel.

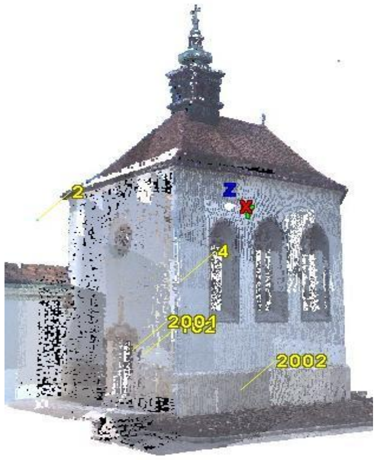

Figure 5. External point clouds of the Anna Chapel in Székesfehérvár [6]

Simultaneously with laser scanning, pictures were taken of the surveyed object. Their colors can be linked with the detected points which gives a colored point cloud. With sufficient point density, the scanned object can be viewed as a continuous model appearing in original colors, being able to distinguish fine details and exact coordinates can be read. In the archaeological use of the survey technology, it can be also highlighted that the spectral values linked to the points can serve as further information.

- **UAV, photogrammetry**

Digital images taken by unmanned aerial vehicles can be used for the composition of orthophoto tile image and the surface model of excavation areas. The sensor fitted to the aerial vehicle (UAV) - most commonly a high resolution ordinary camera - can take pictures of 1-2 cm resolution due to the low flying level. Due to repeated overlapping, high accuracy data can be obtained even after processing. Under favourable circumstances, data accuracy is close to, or may even reach the on-site resolution value of original images. The accuracy of fitting to the national projection system used by archaeologists is affected by the determination method of points used for fitting. Fitting points can be determined with a measuring station in such a way that measurements are carried out for known reference points but these can be determined by GNSS technology as well.

Figure 6. Kopter type UAV

Figure 7. and 8. shows the works of the excavation carried out in the historical centre of Székesfehérvár and the orthophoto tile image presenting the developed area. The image, free of distortion, shows wall remains from different ages. These can be compared with the previously explored and documented, nearby wall remains in a joint database with geographical information tools. The results obtained by the analysis may be included in the arguments of a dispute of decades, as to whether existed a royal castle/palace in the vicinity of Grand Prince Géza’s four-wing church, that is to say, near today’s Basilica. (Fejér Megyei Hírlap, 1 October 2016)

Figure 7. Development of the church of Grand Prince Géza

Figure 8. Orthophoto tile image of the development area

In the dispute of archaeologists and historians, the possibility of visualization cannot be negligible. Whereas historians place a greater emphasis on occurrences in historic documents, archaeologist consider the discovered artifacts as more significant. A 3D visualization may move both theories to either accept or reject the other hypothesis.

Unmanned aerial vehicles, commonly known as drones, can be purchased at an affordable price. The expectations regarding the cameras on the drones are not as strict as for the professional photogrammetry survey cameras. As such, digital cameras providing good optical quality images can also have a role in this technology which is applied in an increasing range of areas. Since these tools collect such a large amount of data from the area of archaeological surveys which could have only been gathered with several weeks of field work in the conventional documentation previously applied in archaeology, their purchase price returns soon, even several times. Developers offer several software for the processing of images and their use is now easier to learn This explains why they spread so fast.

Figure 9. Wall remains outlined based on the visual interpretation of the orthophoto

The polygons delimiting the wall remains are classified based on the archaeological dating according to the time of their origin, into different layers. The development has been completed, the excavation area has been backfilled, the public area serves for its original function. Detailed documentation and the joint database enables comparison with the previously explored and also backfilled wall remains, as well as the analysis of the presumed relationship between them.

- **Close-range photogrammetry**

  These days not only the images taken by photogrammetry cameras are suitable for evaluation but also the good quality, overlapping digital images taken by ordinary cameras can be used for preparing the proportional, 3D model of objects and the discovered artifacts. We can fit image details to the surfaces of the space model by which we can achieve the photo-realistic visualization of the object. The model can be scaled afterwards and it can be transformed in the field system by using points of known coordinates. The newer versions of the software determine the object points by bearing based on the homologous radii of overlapping images and automatically generate a high-density point cloud.

Figure 10. 3D model of a dish [6]

III. ESTABLISHMENT OF DATABASES, ANALYSIS AND VISUALIZATION OPTIONS

All presented data acquisition and documentation procedures enable the generation of spatial, digital products which can be raster and vector data as well. The software applied during data processing enable the conversion of different data formats by which the data obtained as a result of various technologies can be integrated in a joint database. Geographical information software can handle various data together, enable searching with logical conditions, filtering and analysis. Data organized in layers in a practical way – e.g. according to their time of origin – can be visualized in arbitrary combinations, therefore they provide opportunity to examine the relationships among them. Previously this was possible only with visual interpretation and the manual redrawing of different thematic archaeological maps. There are various ways for the visualization of results obtained by the analyses. Different plans, sections can be prepared but it is also possible to read spatial models and transform the into another system.

During the preparation of urban development plans, care must be taken of the presumed archaeological sites, the protection and unearthing of valuable artifacts. The legend of Figure 11 and its legend shows that the historical city wall was partly developed in the centre of Székesfehérvár but there are also presumed sections of the wall. The medieval city walls have to be made visible after development. Geoinformatics technologies can be applied both for development and making the walls visible. A well established archaeological database can be used as a source of information when preparing urban development plans, the formation of local construction regulations and the control of their observation.

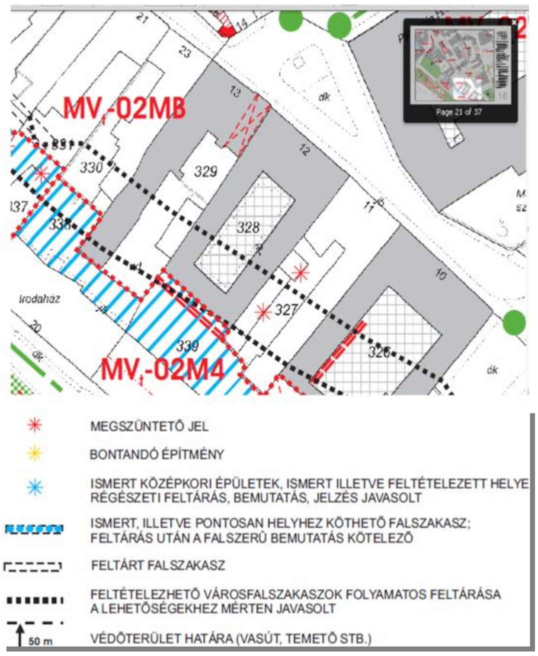

Figure 11. Detail of the development plan of Székesfehérvár and its legend

The presented examples clearly show that modern data acquisition methods, data processing technologies and 3D modelling options can be used in various ways in archaeological operations. These make the survey of archaeological sites more successful, they provide more efficient, more accurate and more detailed documentation. These enable subsequent data acquisition after the backfilling of the site. Digital databases with practical structure and geographical information software enable complex analyses. The spatial and temporal relationship of remains developed in different periods can be examined. The spatial visualization of models can bring history closer to the broader audience.

IV. SUMMARY

Although some of the measuring equipment used in geoinformatics technologies, such as the laser scanner are rather expensive but the data acquisition carried out by them is more efficient, more detailed and more accurate. Therefore, with sufficient utilisation, their purchase price or the costs of the measurements carried out with them, result in a relatively quick return. Among the modern tools used in archaeological surveys, UAVs are affordable nowadays, they can provide the expected measurement accuracy for the documentation of artifacts. The data gathered by this technology also enables quick plotting of plane projections, sections and the spectacular 3D visualization of artifacts and their environment.

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