Potential of GIS applications in archeological expedition and documentation

Hungarian Merowe Dam Salvage Project 2006

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This paper deals with the geoinformatical background of an archeological expedition: data collection in the preparation phase (satellite images, digital elevation models, etc.), potential of GPS navigation, data acquisition (field-work), data processing, integration and creating the archeological GIS (Geographic Information System) database.

1 Introduction

A new dam is under construction on the River Nile in Northern Sudan at the Fourth Cataract. This dam will create an approximately 170 kilometers long reservoir along the river valley. The Sudanese National Corporation for Antiquities and Museums has launched a major international project for missions to make surveys and excavations in the particular area before its inundation. The Hungarian team has joined to this work with archeologists, egyptologists, an architect and a surveyor, the first author of this paper. Figure 1 shows the international concession structure with the Hungarian area. The Hungarian expedition excavated twenty km of riverbank on the Nile's left side. The project: to explore the complete concession area in two seasons, surveying all historical objects from Stone Age to the end of the local Christian Age (13^{th} – 14^{th} century), and to excavate the most important artifacts. The first season was accomplished in February 2006.

GIS was applied in two domains:

– assistance of field works, including the navigation, locating the surveying area, support of local data collection, documentation
– data integratio

These two goals required appropriate preparation together with raw data collection about the expedition area and selection of GIS and measurement instruments.

2 Raw data collection, map design

2.1 First steps

The first challenge was to find detailed geographical data prior to the beginning of the expedition. An English and a Russian river survey is available from the 19^{th} century (Figure 2). These are not very detailed, but the important villages and towns are signed and named. They seem enough for orientation, but definitely not adequate to make a geoinformatical base map.

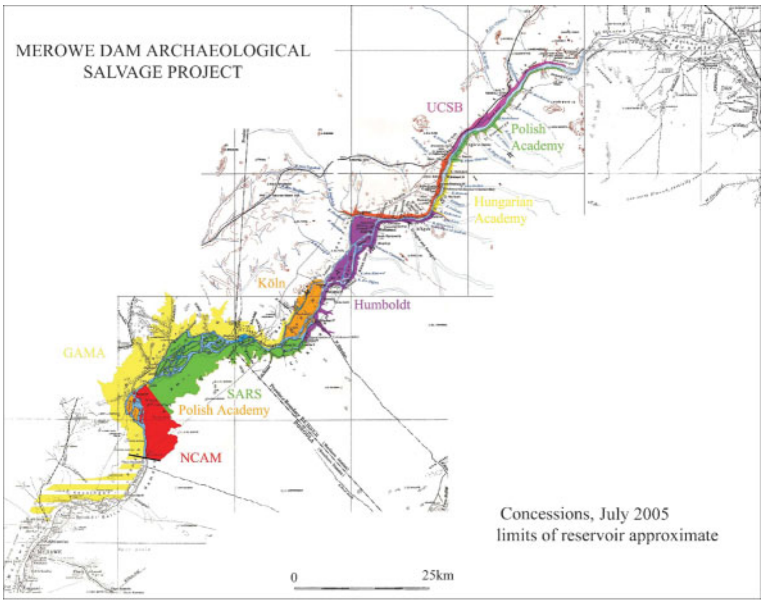


Fig. 1: The international concession structure of the project

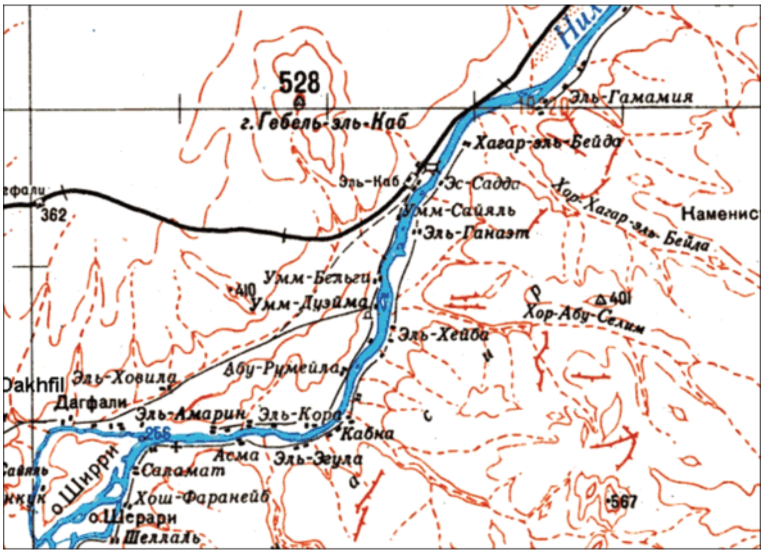


Fig. 2: Russian survey from the 19th century

The first direction of searching additional information sources was the internet. It is easy to find many maps about Sudan, but their quality are unreliable, and the maps usually contain inaccurate information. However, there are databases of many topographical maps on the net. This area was surveyed by the Soviets and also by the Department of Survey of Sudan. Even the largest soviet map scale (1:250 000) is inadequate for detailed work. The Sudanese topographical survey is more detailed (scale 1:100 000), but its transformation into WGS-84 system was insolvable due to the lack of necessary information in our short preparation time.

Another potential source is the Google Earth. It's very easy to find the territory by coordinates or simply by glancing through and zooming the images, but it's only for viewing; the quality is not good enough to construct a map. Based on the field-work, Google Earth enables the high quality representation of our results.

The best choice was the use of Landsat ETM+ satellite images (Figure 3) with SRTM digital elevation model. Figure 4 and 5 show the draped satellite image on the DEM. Their resolution is acceptable and they contain rich metadata about our territory. The multispectral channels enable the classification of water (the Nile), vegetation (agricultural area near the river), different minerals and types of rocks, and the built areas (like settlements) in the desert. The altitude and steepness information were gathered from radar survey of SRTM. It was crucial in planning of the field-work.

2.2 Data processing on the satellite image

The Landsat ETM+ satellite image has 28.5 m field resolution, and 7 + 1 channels. The first three channels are in the visible spectral range. The fourth and fifth are in the near-infrared, the sixth is in the far-infrared, the seventh is in the middle-infrared range. The + 1 is a black and white panchromatic image with 14.25 m resolution.

The most common channel combination in the desert was used: 5-4-1. The classification was almost perfect: the Nile, the vegetation, the sand desert from the rock desert and the types of rocks can be distinguished from each other. The location of human settlements can be estimated using maps, but they can't be found on the satellite image. Only some structured patterns on the flat grounds indicate the artificial grounds. Figure 6 shows the structure of a

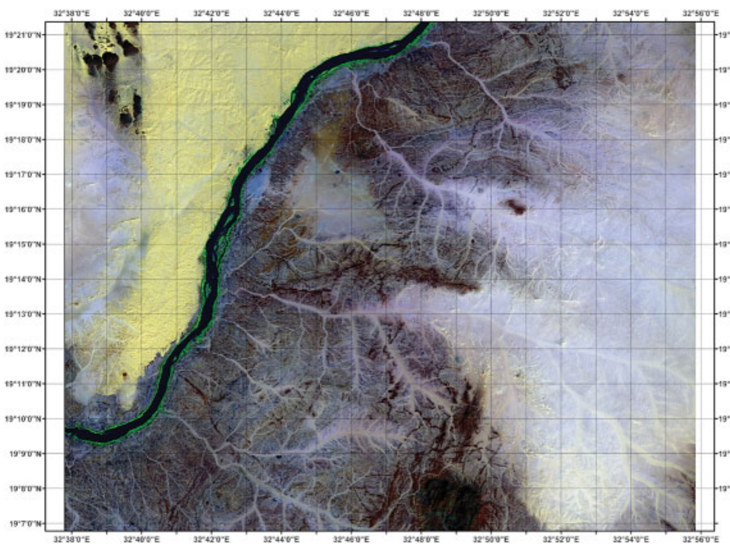
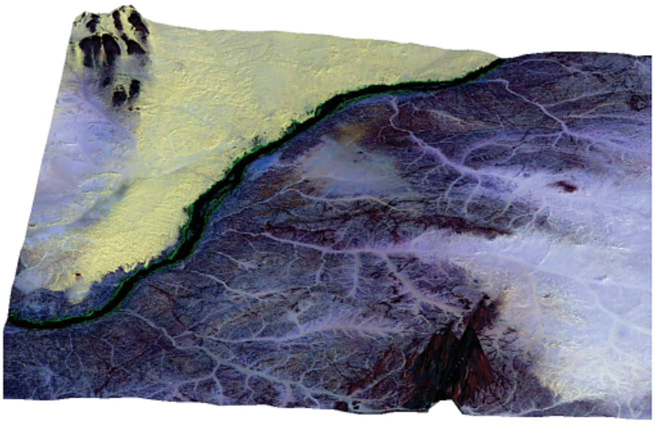


Fig. 3: Landsat ETM+ image about the area



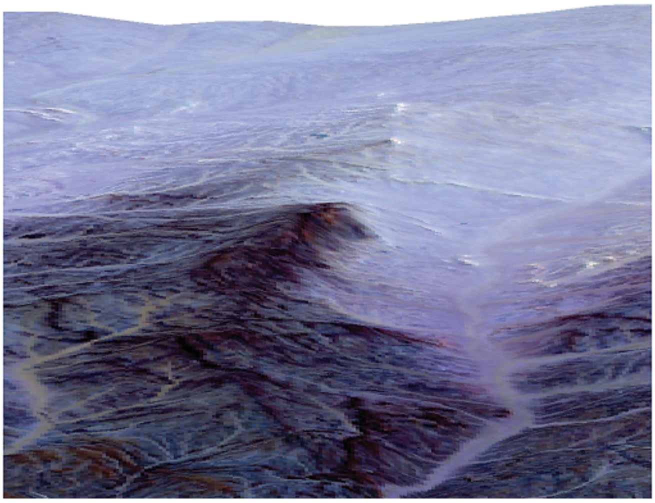


Fig. 4, 5: Draped satellite images on DEM

little city on plane surface near the river. In the Hungarian concession area all towns „stay invisible“. Looking other channel combination the result is the same. The artificial areas have the same radiometric features as their environment. During the field-work it became clear: the building material is the local soil, and the settlements' structure

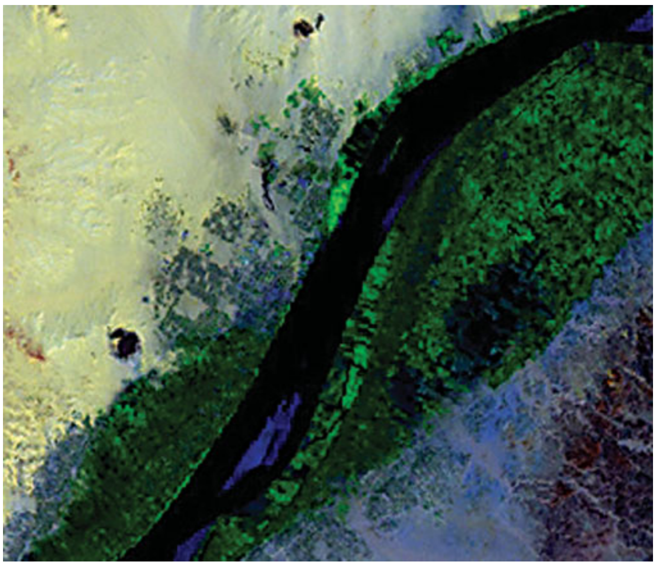


Fig. 6: Settlement at river Nile

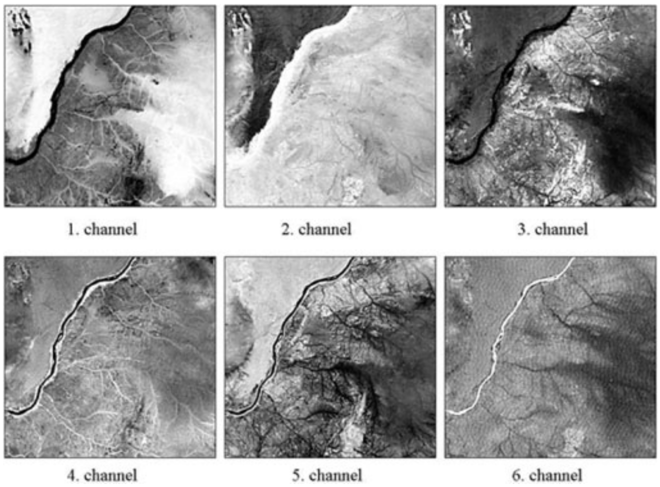


Fig. 7: Result of the PCA

strongly depends on the surrounding terrain, therefore no regular structures/patterns can be observed.
Studying various band combinations no significant differences can be observed. The unsupervised classification has similar results; certain classes don't give new information. The reason should be the high correlation among the bands. To justify this assumption, principal component analysis (PCA) has been carried out (Figure 7). The utmost details are accumulated on the first PCA-band, the other ones don't give significantly more information, hence they were ignored in the following procedure. An interesting result of PCA is that the riverbank vegetation only appears on the fourth PCA-band, because their volume isn't remarkable.
After these investigations, the base map creation with the 5-4-1 combination seemed reasonable. To have better resolution, the image was transformed with resolution merge using the panchromatic band. The pansharpened product has a resolution of 14.25 m.

2.3 Analysis and products

A georeferenced digital base map about the concession area has been created. Its resolution enables of printing an analogue map with a scale of 1:100 000. The digital map is to be used in GIS software environment and in real-time processing in the field with GPS-PDA system. Using these products the field work can be scheduled and planned, and the navigation become simpler. The printed map is always at hand even in areas with no electricity. It was a very important issue, because the electricity supply is rare and unreliable.
Rendering the satellite image on the digital elevation model gives additional useful information about the environment of expedition. The scenic visualization of 3D virtual terrain was very useful: that gave a previous knowledge about expedition area. This possibility made the project preparation simpler.
In order to know where the most endangered areas are, it was necessary to analyze the elevation model. The horizontal resolution of the SRTM model is about 90 meters so its analyses are just for limited use. Some hypothetical in-

undation models show where the lower terrains are and where is the most relevant field to be surveyed. The other product of DEM analysis is the contour-map: the best available version had a contour line interval of 10 meters. Areas endangered by inundation have been found using these contour maps, too.

3 Data collection and field measurement

There were four types of fieldworks: navigation during the travel in the desert, position logging of identified archeological objects with GPS, detailed surveying and support of excavations

During the navigation the accessible paths and routes to the surveyed archeological objects were recorded. With the „trackback“ function the most important routes can be revisited. The positions of the following types of archeological quarries were recorded:

Type	Object	Recording method
separate object	tomb, other significant waif	single point
small area	group of tombs, small settlements of Stone Age	single point
large area	largest group of tombs (cemetery), largest settlements of Stone Age, other largest quarry	point cloud

Additionally some checkpoints were recorded to verify the georeference of the digital maps. The checkpoints were well identifiable patterns on the surface, like wadis or road crossings. During the field work, the village border points were recorded to locate the built-up area.

After the general surveys the emphasis was put on the largest quarries, like cemeteries, settlements of Stone Age to measure them in more detail. The method of measurements: by each quarry the GPS coordinates of three base points were defined. All measurements were related to these points. The characteristic points of all objects were measured: center and circle of tumuli, baselines of box graves (Christian tombs) and all details of the settlements. The architectural structures of important objects can be transformed by these characteristic points.

4 Processing of the collected data

The final product is a GIS database containing all measured objects, with their relevant features. A part of data processing was accomplished during the expedition such as GPS point- and route conversion to GIS applications (to shape files), some archeological data integration to the data base, and some surveying measurement processing. But the major part of data processing is still running, the identification of archeological features requires the most time. Each work phases are illustrated with a general workflow in Figure 8.

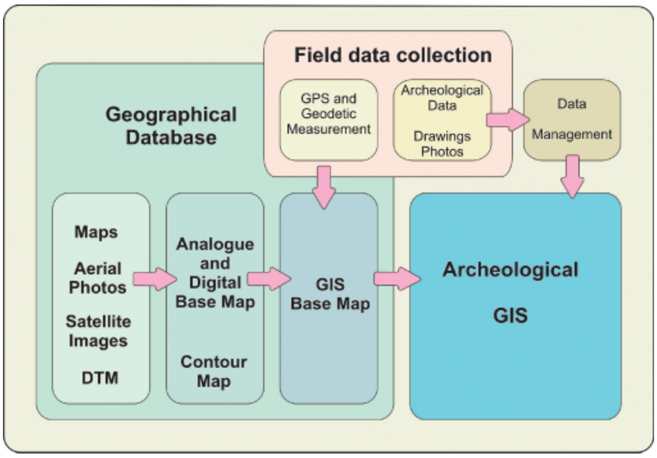


Fig. 8: Workflow

4.1 Construction of digital base map

The first step is to perform the integration of geographical data into a uniform system. The common coordinate system is the geographical (lat/long) system of WGS-84. The components of the data base are the satellite image (raster data), the surveyed archeological objects, and the environmental data (routes, villages).

The vector data were categorized to the following classes:

class	style
archeological objects	point
control points	point
accessible way	line
built-up area	area

A part of the complete base map can be seen in Figure 9.

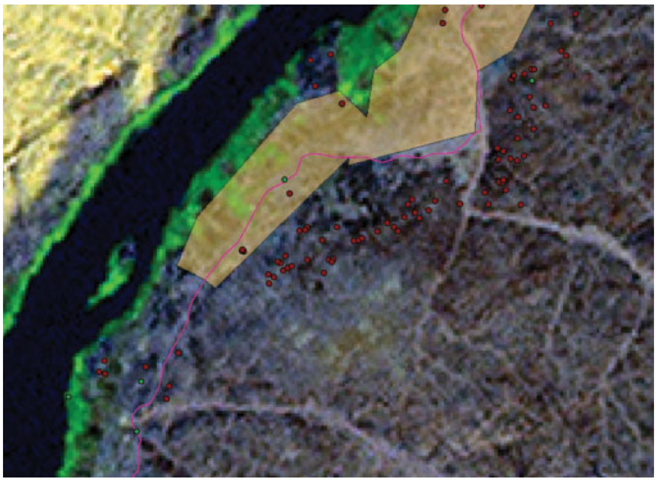


Fig. 9: Part of the base map completed

4.2 Integration of archeological data

The goal is to make a GIS database capable of storing archeological data. The most important archeological attributes are the different types of quarries, their waifs, the age of the artifacts, drawings, and images of quarries and excavations.

The data table contains the following features:
- Identification code
- Coordinates: latitude, longitude and elevation
- Relevant waifs: founded waif at sites with identification code and photo. List with codes.
- Age: estimated age of waif
- Photo, sketch or CAD drawing

Based on these features specific data SQL queries can be executed: find a certain site by code or by its waifs and make thematic maps by ages or site types.

4.3 Processing of surveying measures

After the calculation of analogue measurements the results were processed in CAD environment. Stone Age sites and the different cemeteries were measured in 2D. The most important archeological find is a Christian fortress on one of the Nile's island. It was measured in 3D. During the measurement the details have been drawn by the architect. The creation of final model is in progress.

5 Conclusion

The recently available free data bases are nice information sources for preparing similar archeological field works, but their limitations must also be kept in mind: geometric resolution, date of data acquisition, information content. These data bases contain not only aerial and satellite imagery (e.g. Google Earth), but also topographic maps, digital elevation models or multispectral images.

The prepared data base were taken to the field, all the daily data collections were stored in it. The geometric data were captured by various techniques, like GPS measurement, tachymetry, leveling. Simultaneously the most important attributes were also stored: waif and quarry code, estimated age, link to other relevant findings. During the whole field work all routes with precise navigation information were also recorded in the data base.

The on-site work was followed by a sophisticated post-processing, where all previously available and on-site collected data were consistently integrated in a unified GIS data warehouse. The refinement, check and completion of attribute information is still in progress, but the system already works fine.

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