Malaysian Journal of Science **27** (3): 13 - 17 (2008)

Making the Most of Maps: GIS and Topographical Survey on the Island of Jarak

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ABSTRACT The purpose of the GIS and topographic survey was to gather survey data on the natural, topographical and geological features of the island of Jarak, as well as its elevations. The topographic survey in this expedition fundamentally involved the production of maps and plans which were true to scale in the study area. The developed topographic maps will accurately represented details of both the natural and built environment on the island. Elevations data were taken with surveying equipment at several points on the island and plotted using GIS software. Through GIS analysis and field verification techniques, the dominant, natural and topographic features of the island have been identified and mapped.

ABSTRAK Tujuan penggunaan GIS dan tinjauan topografi dalam kajian ini ialah untuk mengumpul data ukur bagi ciri-ciri semulajadi, topografi dan geologi kepulauan Pulau Jarak serta aras ketinggiannya. Pada dasarnya, ukur topografi dalam ekspedisi ini melibatkan penghasilan peta dan pelan yang benar-benar tepat bagi kawasan kajian. Peta topografi yang terhasil akan mewakili kedua-dua perincian persekitaran semulajadi mahupun terbina sebagaimana yang terdapat di pulau tersebut. Data ketinggian dikumpul dengan menggunakan peralatan pengukuran di beberapa tempat pada pulau, dan seterusnya diplotkan dengan menggunakan perisian GIS. Menerusi analisis GIS dan teknik pengesahan di lapangan, ciri-ciri semulajadi dan topografi semasa yang nyata pada pulau tersebut telah dikenalpasti dan dipetakan.

(GIS, topographic survey)

INTRODUCTION

The Pulau Jarak area acts as a case study and central focus for the survey (Figure 1). The geographic information system (GIS) and Global Positioning System (GPS) field survey took place on 23-27 November 2007 with a team of four persons, each assigned to fieldwalking, GIS/GPS tasks, control points collection and analysis, and topographic research. From the outset, the expedition has adopted GIS and GPS as an organizing framework on which to 'hang' all data collection. Our survey was equipped with laptops as well as primary GIS equipments and GPS. The survey was carried out based on existing topographic maps and concentrated on landscape features while Arc GIS was used to plot maps across the landscape and within intensively sampled sites.

Topographical Survey

Topographic surveying is essential in the production of maps and plans which are true to scale and accurately represents details of both the natural and built environment. Therefore, when conducting a topographic survey, data on the natural and man-made features of the land as well as its elevations are gathered [1]. A three-dimensional (3D) map is then created from the information where symbols representing features or data too small to produce to scale are included. Height

Figure 1. Study Location.

information is added in most cases as spot heights and feature elevations; this height information is related to a control datum or a fixed local datum. Height information is also used to generate contours to provide a better visual representation of the changes in terrain height across the site. Precise control networks are established using GPS survey techniques. The outcomes of a topographic survey are survey drawings which could be easily duplicated via a range of hard and soft media and in any file format [2].

In the expedition, all survey data were digitally captured using Garmin instrumentation. The topographic map was prepared using Arc GIS software immediately after collecting the data in the field. The following were carried out during the topographical survey:

- Gathering survey data on the natural, topographical and geological features of the islands, as well as its elevations.
- Establishing horizontal and vertical control that will serve as the framework of the survey.
- Determining enough horizontal location and elevation (usually called side shots) of ground points to provide enough data for plotting when the map is prepared.
- Locating natural and man-made features that may be required by the purpose of the survey.
- Computing distances, angles and elevations.
- Producing maps and plans of the study areas which are true to scale and accurately represent details of both the natural and environment on the islands.

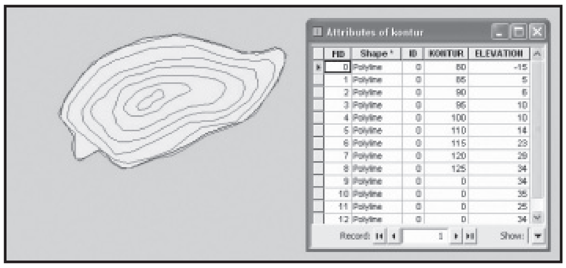

Figure 2. Attribute and Spatial Data of Pulau Jarak joined to the GIS Database.

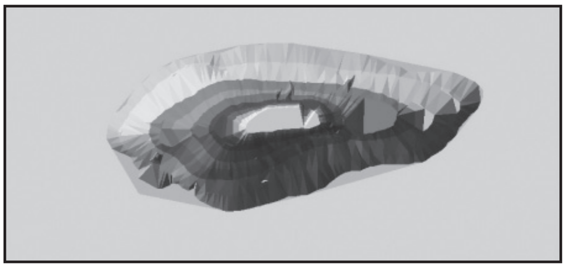

Figure 3. Pulau Jarak TIN surface generated from 3D analysis tools.

MAP CONSTRUCTION AND RESULTS

The data collected in the field survey were exported into Global Mapper software, each identified with a point number, latitude (UTM), longitude (UTM) and altitude. These data were then imported into the Geographic Information System Arc GIS 9.2. Coordinates were used to produce a point map that was exported into a drawing package. The proximity between points was large enough for drawing the lines that formed the cartographic phenomena. The final topographical map was constructed within the drawing package and included both the information collected with the GPS system and the classical field survey.

Mapping using GPS and initial tracking analysis enabled an accurate location of Pulau Jarak. Pulau Jarak is located at 100° 06.017'E, 3° 58.676'N and about 96km from Hutan Melintang Jetty. This tiny island, barely 0.08 square kilometres, rises 50m above sea level and is covered with lush green vegetation where many sea eagles nest. At the top of the island is a lighthouse. The highest peak is about 125 metres. The fieldwalking covered in each survey plot, followed of 5m at which counts of all material observed, record of ground surface visibility, and other characteristics of the landscape were made. At the end of each day, survey plots and feature descriptions, including counts of material observed and descriptions of material collected, were entered into an attribute database joined to the GIS (Figure 2).

The developed picture of the topographical landscape was used to direct further survey. We developed a few preliminary simple 3D analytical plots to assist with the exploration of the data collected. Figure 3 shows the 3D map of Pulau Jarak generated from 3D analysis tools extension menu to create Triangulated Irregular Network (TIN) surface.

The field survey area has a large number of topographic features scattered throughout the landscape. There is no beach on Pulau Jarak, only granite sloping down to the sandy sea bed with small patches of stony, encrusting and soft corals. Hard corals dominate the seascape with several large boulders carpeted with sponges. There are no accommodations or settlements on the island except for one army base on the southwest of the island. It is rich with marine life and famous for its pelargic fishes such as barracuda, jacks and king sailfish. In fact, it is a common sight to see the king sailfish and dolphin doing their acrobatic dance on the surface. The island's boulder-strewn coastline makes it virtually inaccessible, leaving Pulau Jarak's pristine wonders mostly unexplored. Due to its location right in the middle of the Straits of Melaka, it has one of the best water visibility among the islands on the West Coast.

GIS PROCEDURES AND RESULTS

The field area is a total of 0.08 square kilometres. A digitized map of Pulau Jarak with the scale of 1:50,000 was used as the base map for the thematic layers and listings of each processed data. Spatial and non-spatial data were analyzed through various functions of GIS techniques, such as geoprocessing, data analysis and overlaying, and modelling.

The ArcToolbox application in ArcGIS 9.2 provided a powerful set of geoprocessing functions, one of which was used to import the GPS survey data and map layers into ArcMap application. Each of the different shoreline types and boundaries was imported as different layers. In the geographic data

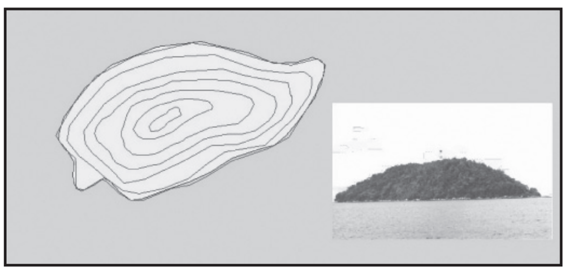

Figure 4. ArcMap allows the inclusion of several components when producing a map.

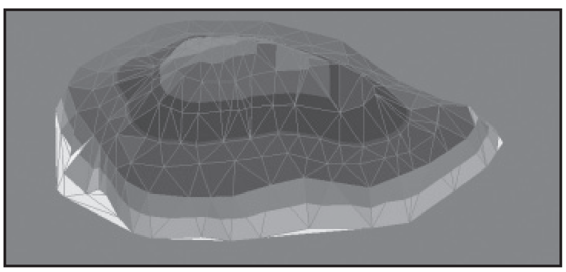

Figure 5. 3D Model generated from Arc GIS-Arc Scene tool.

view, layers representing the GPS survey data were compiled into GIS data sets. A table of contents interface organized and controlled the drawing properties of the GIS data layers in the data frame.

ArcMap also enables the use different inbuilt symbols to represent some important environmental and human resources. These map elements included birds' habitats, beaches, settlements and special areas designated by legislation such as fishing resources and nature reserves. In the page layout view, we modified the layout to improve the design and visual balance of the composition by adding new map elements and changing the properties of the existing map elements. ArcMap also allowed the inclusion of several key components when producing a map. These included the title, scale bar, legend and north arrow [3]. ArcMap also integrated attributes tables, text files and digital photographs in the digital maps as shown in Figure 4.

The GIS database was created by scanning existing maps and photos at higher resolutions and then registering their corners to geographic coordinates (latitude/longitude). The aerial photos (4,500 x 4,500 pixels) were registered by selecting ground control points from the topographic map coverage, rectifying and mosaicking with Arc GIS georeferencing tool.

Our fieldwork in Pulau Jarak faced some difficulties as the reference map used RSO map coordinates, which were relative to local datums. We solved the problem by calculating a false position for our base station that alligned the GPS latitude/longitude with the map latitude/longitude (the differences in ellipsoid over the area of our survey was irrelevant) and achieved correspondence of approximately five meters (1 mm on the map) between GPS and map-scanned locations of unequivocal features (light tower, threshing floors, and triangulation points). This accuracy exceeded our expectations of scans made from vintage paper maps.

While we had achieved visually satisfactory matching of air photographs in the mosaic, our study area was a zone of high relief, and the offset between the actual (map/GPS) position of features and the position in the air photomosaic could be as high as 25 m. This precluded direct overlay of the topographic map and air photographs for plotting of survey units, many of which fell in the 10–20-m size range. We hope to be able to reduce these errors through orthorectification, allowing us to work with the aerial photomosaic as our primary map base. This will permit rapid and accurate delineation of survey units directly from the map base in the future; the topographic maps do not provide sufficient detail for this.

We created a Digital Elevation Model (DEM) for the survey area by digitization of 20m contours and interpolation in Arc GIS- Arc tool box 3D analysis extension and generated a 3D model using Arc GIS-Arc Scene as shown in Figure 5. Owing to the highly dissected topography, this very coarse DEM was quite adequate for creating general three-dimensional views of the survey area draped with the aerial photomosaic, topographic map coverage, geology, or survey results. However, a more detailed version will be required for analysis of site locations relative to the local topography. We are now building this more detailed DEM using 3D analysis extension for semiautomated contour vectorization.

DISCUSSION

The application of GIS technology has resulted in the development of a detailed map from the topographical survey that is no longer a static product of limited usage. The map was produced using an automated information system that is capable of recording and maintaining data, readily producing relevant maps. The use of digital maps facilitates updating of available data, thus allowing spatial queries to be performed at any time. However, the use of the map is not only restricted to topography and geography, but may also be applied to other disciplines in a broader context.

The developed GIS spatial database will be used for data storage and management, spatial analysis, map manipulation and spatial modelling. The database will also be useful in utilizing, presenting and distributing existing data and information on Pulau Jarak to a wide variety of users, including scientists, decision makers and the general public.

CONCLUSION

Although we have only just started the project, the adoption of a GIS database approach as an integral part of SESMA has paid substantial dividends in data organization, production of working documents for field use, and rapid production of preliminary results at the end of our field work. Furthermore, the use of such system allows a very accurate and fast mapping and a full integration with GIS [4]. These can be significant factors for its implementation, despite its relatively high cost; the system has applications for a wide range of mapping purposes in the framework of earth, biological or social sciences. In areas without or with bad topographic maps the GPS can also be used to generate or to correct the topographic background.

The adoption of GIS has certainly necessitated a significant investment of time and expertise and the availability of substantial equipment. While this level of equipment and expertise may not be available to all projects, obtaining these facilities should be a high priority for any substantial field project.

It is worth noting that the availability of GIS has influenced not only our procedures but our whole approach to the survey. The ability to easily capture and manipulate map data and associated attributes has encouraged us to take a flexible map-based approach. As a result, we can make greater use of existing resources (topographic maps and aerial photographs), and we record geographic features and data within defined survey plots (requiring mapping and mathematical standardization) rather than using a more conventional grid-based approach that would, of course, yield more directly comparable data values.

As the project progresses, the integrated database generated from our fieldwork will form an integral part of the results of the project, allowing scholars to reassess our results, compare them with other surveys, or carry the analysis further. We hope that it will form a model for detailed topographical landscape analysis through GIS. We have just commenced the next preliminary field survey with a bigger team, aiming to finish the more specialized aspects of the study and finalize the methodology in preparation for future seasons with a larger team of volunteers.

ACKNOWLEDGEMENTS

We thank the Institute of Ocean and Earth Sciences (IOES) for research and logistic support. The field survey was funded by University of Malaya, and the supports from all expedition team members are gratefully acknowledged.

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