NATIONAL MAPPING SYSTEM OF THE ARCHAEOLOGICAL AND HISTORICAL SITES IN INDONESIA: A Proposed Model of Spatial Data Integration

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Abstract: In Indonesia, archaeological and historical sites scattered throughout the territory with high diversity. The spatial distribution is also related to the diversity of forms, time and process. The study of material culture and historical archives can show the locations of past events that can be mapped. The difference is, Most of archaeological sites can be mapped directly according to their geographical context, although the possibility of a data and site transformation should not be ignored. On the other hand, most of historical events and a number of important toponymy still require interpretation to determine its location on the map. The abundance of data and material studies those related to the complexity of the past will not be able to contribute to the critical studies and cultural or historical resources management if not integrated through a GIS-based strategy. This paper offers a model of archaeological and historical data integration in accordance with Indonesia conditions through a GIS-based mapping system. The basic framework of this model using coordinate system UTM (*Universal Transverse Mercator*) as the main nomenclature of grid index, that can be subdivided into smaller grid units, appropriate to each detail study. A number of "field" need to be formulated as a basic information of site which contribute to the research and management purposes.

Keywords: Archaeological site, Historical site, Spatial data, GIS-based strategy, UTM, Grid index

1. Introduction

Indonesia is an archipelago with a high diversity in archaeological and historical sites. In detail, site diversity includes the differentiation on types, sizes, locations, period and duration of occupancies, scales, type of contexts, transformation processes, the quality and quantity of data, and many other differences, which have been tracked through thousands of sites. Retrieval processes of the most common sites are in three ways, namely field researches (survey and excavation), studying secondary sources (archive, manuscript, remote sensing data and old map), or through inadvertently events such as land preparation and construction project. Although, an remarkable progress in GIS application has opened up opportunity of site discovery through predictive modeling. One of which is modeling to predict the location of classic and cave sites in Yogyakarta (Yuwono 2015).

It is conceivable that the wealth of archaeological and historical data in Indonesia, with vast territory and long past history, are not restricted. It should be realized that they cannot be renewable, but can be interpreted continuously. Our ability to choose, use, re-check, and re-examine them, of course, highly dependent on our ease in accessing database. In fact, the acceleration of field researches in Indonesia have not been matched by adequate data management strategies.

Several obstacles that must be overcome include the number of archaeological agencies have not been commensurate with the area that should be addressed. The awareness of the benefits of GIS in Indonesia, especially to integrating and managing the archaeological resources, is still very low, as evidenced by the absence of a division in each archaeological agency which specifically managing spatial database. GIS practice at the beginner level is still done by individuals, while exploration activities continuously carried out at high speed. Consequently, more and more data accumulate and very difficult to be accessed for subsequent researches, especially by another researcher.

Due to the above conditions, the crucial problems to be solved are:

a) Whether spatial data accumulate until now can be optimized for scientific advancement and management purposes?
b) How the most appropriate strategy to realize the national mapping system in accordance with the conditions and the general problem of research and cultural - historical resources management in Indonesia?

2. Objectives

As part of spatial data, archaeological and historical sites in Indonesia face many problems that very crucial to be addressed.. The basic effort that needs to be done is integrate all data that have been collected into a spatial database system. So, the main objective of this article is to propose a grid index system of archaeological and historical sites into the nationwide map that can integrate all of GIS-based spatial data, which comprehensive, accessible and easily updated for various purposes. There is no doubt that the integrated data will be able to generate new information, new hypotheses and new paradigm rather than only partially managed.

Some advantages using this mapping system are:

a) Obtaining the spatial references for inventory, input, registration, and database processing correspond with an organized grid index and cartographic rules.
b) Obtaining mapping references in conceptual design, operational design, and cartographic design, through

the operating GIS that highly contribute in geo-database management, geo-processing, and geo-visualization.

c) The nomenclature of grid index can directly reflect the changing character of site and historical events that were affected by a shift in the degree of latitude and longitude along with their geographical implications. For example, the character of site diversity according to the climate regime and its natural consequences.
d) The grid index can be divided into smaller grids as needed, for inventory purposes at a national scale, survey on a regional or site scale and excavation on an intra-site scale.
e) In order to policy making, configuration of site distribution can be used to evaluate and improve various management aspects. Among others, necessary or not to add new archaeological authorities by calculating the ratio of total area that have not been explored? How many archaeologists are needed? How the most efficient organization for integrating and managing database at the national and regional levels? And the most important thing is how the budget should be allocated for these purposes?

3. Archaeology and History: GIS-based Studies

According to Ashmore and Sharer (2010: 62), archaeological site is: "*Spatial clusters of artifacts, features, and ecofacts. Some sites may consist solely of one form of data—a surface scatter of artifacts, for example. Others consist of combinations of all three forms of archaeological data. Site boundaries are sometimes well defined, especially if features such as walls or moats are present. Usually, however, a decline in density or frequency of the material remains is all that marks the limits of a site. However boundaries are defined, the site is usually a basic working unit of investigation*".

Unlike an archaeological site that can be identified through the one or several material remains contained on the surface or in the ground, so easily plotted, a historical site are not always associated with an object. A number of toponyms in most old maps often associated with historical events in the past. Therefore, the method to track a historical site also different, which is more reliant on some archives, manuscripts and old maps. In addition, it is more difficult to determine the boundaries of a historical site rather than an archaeological site. As a consequence, especially on a national and regional scale map, an archaeological site, which has a higher degree of accuracy, can be represented as a point with a variety of attributes; while a historical site, with a lower degree of accuracy, should be treated as a line or an area (or buffered point).

Although both disciplines deal with different objects, but the use of GIS equally be a fundamental demand. Various approaches in archaeology, such as spatial archaeology, regional archaeology, environmental archaeology, landscape archaeology, geoarchaeology, settlement archaeology and Cultural Resources Management (CRM), forcing archaeologists to be able to handle large amounts of spatial data and its attributes with GIS. On the other hand, the development of Historical GIS, also gives a challenge to historian not only to learn about the technical skills within GIS, but also learn the academic skills as geographer. The challenge for historical GIS is to take technologies and methodologies developed in GIS and apply them to historical research questions in a way that provides new insights into the geographical-based research questions (Gregory and Ell 2007: 11).

As argued by Ashmore and Sharer (2010: 13), "*Archaeology and history are related by their common concern with past human events. The major difference between the two disciplines is their sources of information. History works with written accounts and oral traditions about the past; archaeology works with material remains of the past*". The existence of material remains in soils surface or in its layers obtained through survey or excavation be the strong indicators of an archaeological site. Through which, a long history of archaeological research in Indonesia has been able to produce a long list of archaeological sites, though not yet integrated as a spatial database. On the other hand, the historical database that has not existed until now very crucial to be realized, since both are the materials of past studies which should complementary, though their sources of information are different.

Both archaeological and historical sites are spatial data that can be mapped. Each is an entity associated with a place or space, has a geographic reference (coordinates), which can provide information and knowledge about the place or space where it is located. Spatial data from the past formed and simultaneously reflect the spatial mindset of the past. In my opinion, spatial mindset can be defined as a mindset based on an understanding of spatial relationships among a number of entities, which consciously or unconsciously influence the decision of a person or people to consider and take attitude, action and strategy in addressing or adjusting to spatial complexity (Yuwono 2015).

The nature of spatial data covering six aspects, namely volume, multi-source, multi-scale, multi-type, imperfection and dynamic. Almost in each case, spatial data covering spatial and temporal dimensions, which the number of attributes characterizing certain phenomena can be in hundreds or even thousands (Leung 2010: 4-5).

The ability and power of GIS as a computer package designed to represent various forms of geographic information effectively, is to handle very large amounts of spatial and attribute data together. As a system, GIS allows us to handle information about the location of features or phenomena on the Earth's surface (Gregory and Ell 2007: 3, 33). GIS provide digital storage, processing and analysis functions of relevant geotopographic base (according to me, including all types of spatial data as the geographic entities) as well as attribute datasets of varied geographic and thematic resolution (Asche and Engemaier 2011: 149). While the spatial data is each entity associated with a place or space, as I mentioned above, the attribute data referred to non-spatial data which usually be stored in a certain database management system (Gregory and Ell 2007: 33). An attribute is a property which determines a trait and quality of an entity (Green 2001: 189). The amount of information, as a volume aspect, can be obtained from data with a lot of attributes, which provide opportunities for many ways of classification and aggregation.

In multi-source aspect, geo-referenced data can be obtained from a great variety of sources, such as satellite sensors, digital map scanning, radar devices, aircrafts, and global positioning systems (Leung 2010: 4). In archaeological and historical cases, a number of archives, manuscripts, and oral data can be sources of spatial data which should be interpreted sharply. The weakness of data accuracy for historical sites can be anticipated by prioritizing the presentation of events through lines or polygons rather than points.

In multi-scale aspect, In multi-scale aspect, presentation of data on analog or digital maps with different scales, or on remote sensing technologies with different resolutions, can show spatial structure differences. Diachronically, scale differences are typically used to show a trend and dynamic of a spatial process. The challenge for development of proper techniques in data mining is how to find a knowledge of the data in different spatial and temporal scales (Leung 2010: 4).

Archaeology recognize some scales in spatial analysis. The three most important are intra-site, site and region. In intra-site scale, researcher trying to find a spatial pattern of relationship between groups of context and feature obtained during excavation. More broadly, a site not must to be determined through excavation. Information can be obtained through various forms of non-invasive techniques, such as geophysical prospection, remote sensing, surface survey and predictive modeling. Although it is difficult to determine the limit, a site can represent the certain size, content, age, duration and complexity. The largest spatial unit in archaeology is a region, that could be delineated through the distribution of similar sites, ethnographic or ecological boundaries (Gamble 2001: 141-143)

In multi-type aspect, knowledge discovery from spatial data need to be carried out with raster-based data such as satellite imagery collected from various sensors; vector-based data such as point, line and polygon; or object-oriented data arranged in specific hierarchical structure. The challenge lies on whether appropriate method can be developed for outlining the knowledge from single-type or multi-type spatial data (Leung 2010: 5).

Generally, it is difficult to collect some perfect information about the complexity of a spatio-temporal system. Spatial data are generally imperfect. They might be incomplete though their attributes can still be measured accurately. Moreover, missing values and noises are generally exist in a spatial database. Such constraints become a fundamental problem in knowledge discovery through a spatial database (Leung 2010: 5).

Finally, a spatial system continues to change dynamically. Therefore, we need a set of data that can reflect the phenomenon or process from time to time. While the data can be in discrete time, as most time series data, or in continuous time. How to reveal a hidden process behind spatial data become important to be solved in order to find the spatial knowledge (Leung 2010: 5).

4. Methodology

The national mapping system for archaeological and historical sites contains grid index to integrate all sites in Indonesia. The proposed grid measuring 1° x 1° in geographic coordinate system combined with nomenclature according to the UTM coordinate system in the datum: WGS 1984. The projection used is transverse Mercator projection. This projection is used to transform 3D information of the region around the equator into 2D representations that can be printed or viewed on a computer screen (Cartwright 2011: 76) (Fig.1).

There can be no single projection system to the whole world without experiencing large distortions over most of the territory (Howard 2007: 83). In contrast, no one region in the world that can implement all projection systems accurately without distortions. Indonesian territory which crossed by the equator applying transverse Mercator projection with two coordinate/grid systems, geographic (latitude-longitude) are more commonly known and UTM plane grid system.

UTM coordinate system extending from 80° north to 80° south (avoiding the poles), using the 60 central meridians to create 60 vertical zones. Each zone includes 6° of longitude wide (from easting 200,000 m to 800,000 m) and each central meredian is assigned an easting of 500,000 m. In the northern hemisphere, the equator is zero, and coordinates increment northwards; in the southern hemisphere, the equator is assigned a value of 10,000,000 and coordinate values declining to the south (Howard 2007: 83-84; Heywood et al. 2006: 48).

The use of UTM as a metric coordinate is very advantageous in terms of measurement accuracy, but care is required especially in the areas of cross-border zone. Sometimes a further subdivision of each hemisphere is employed, into segments 8° of latitude wide, making a total of 20 "lanes". These "lanes" are designated by letters, beginning with C to M in the southernmost and continuing N to X in the north (avoiding I and O) (Howard 2007: 84). Indonesian territory lies in three lanes, namely L and M in the southern hemisphere and N in the northern hemisphere (Fig.1). Even though, I don't take into account the position of "lane" in the naming of grid index. The most important criterion is the hemisphere.

Some considerations in making the grid index in the national mapping system are as follows:

a) The division zone according to the UTM system, Datum: WGS 1984.
b) Does not use the map index (*Peta Rupa Bumi Indonesia* or topographic map) that produced by the government (Geospatial Information Agency), because of the scale differences between Java - Bali (1:25,000) and other islands (smaller than 1:25,000).

The procedures in this grid index creation are as follows:

a) Create grid index measuring 1° x 1°. Indonesian territory can be divided into 782 grids ranging from 95° - 141°E and 6°N - 11°S, with details as follows:
   - X axis : 46 grids
   - Y axis : 6 grids in the northern hemisphere
     11 grids in the southern hemisphere
b) Overlay between the grid index with base map (*Peta Rupa Bumi Indonesia*) produced by government (2006), resulting in 390 grids that intersect with islands in Indonesian territory.
c) Classify the grid index according to the UTM zone, ranging from Zone 46 to 54, the width of each zone is 6° longitude.
d) Naming of the grid index (390 grids) and preparing database. The nomenclature consists of four elements, namely:
   - UTM zone sequence: 46, 47, 48, and so on.
   - Hemisphere: N and S (the "lane" position not taken into account).
   - Latitude grid sequence: 1, 2, 3, and so on (starting from the equator).
   - Longitude grid sequence (each zone has a grid sequence: a, b, c, d, e, f, g, from left to right).

This proposed mapping system has some characters as follows:

a) Having a database system that is easily managed to input, store, classify, calculate, editing and display archaeological and historical data in Indonesia.

   Archaeological database contain the distribution of points (in national and regional scales), combination of points, lines and polygons (in site scale) and

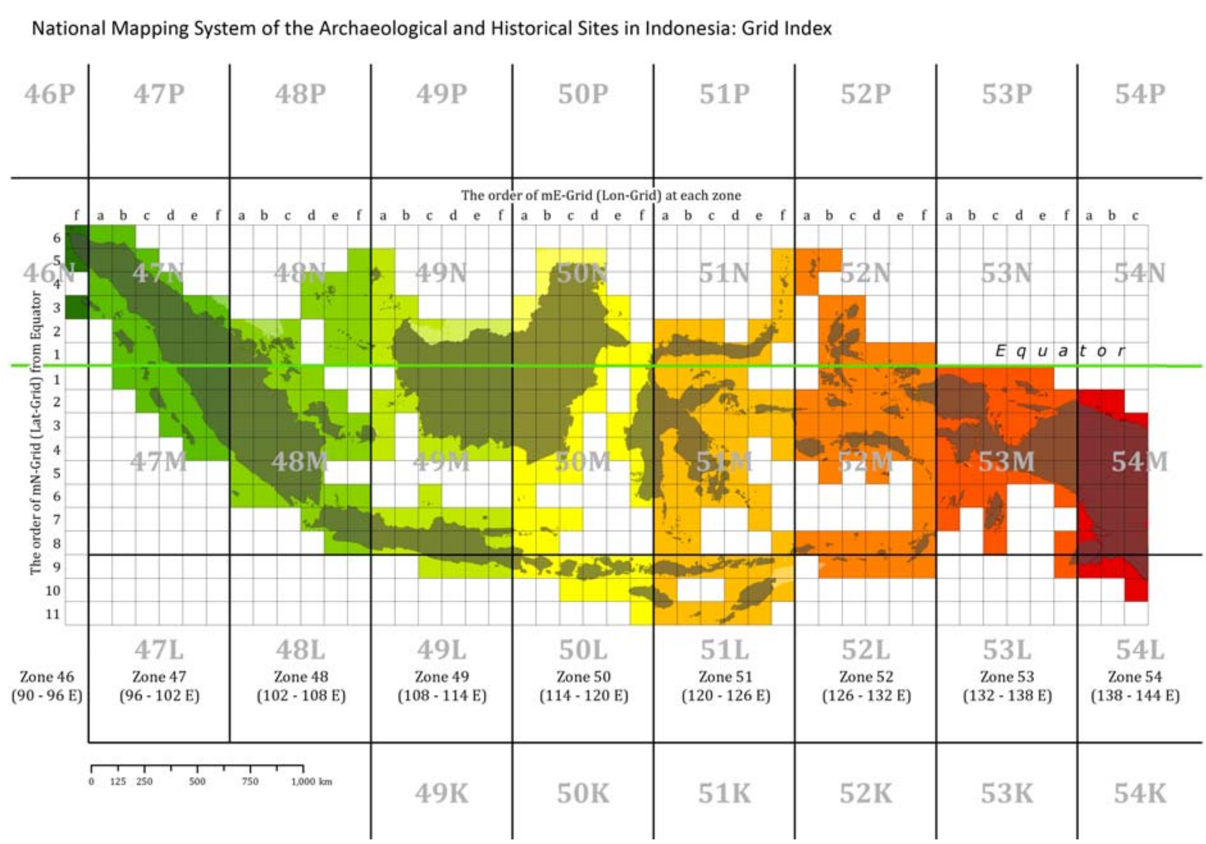

Fig. 1. Grid index of mapping system in national scale

polygons (specifically in intra-site scale) (Table 1).

Historical database contain the distribution of buffered points, lines and polygons, with a more limited scale variations (national, regional and site scale). In general, GIS has two main components of data: spatial and attributes, but some geographers and historical geographers argued that to understand a phenomenon fully requires a detailed understanding of three components: the attribute that says what the object is, the spatial that describes where it is located, and the third component is time (Gregory and Ell 2007: 7-8). The importance of time in historical study must be considered in the preparation of database. The task of historical GIS, therefore, is mapping the time in which an event took place and the actor had a role.

One of the most important spatial data more accessible by historians is old maps, which should be integrated through georeferencing. The aim is to define the coordinates by selecting the ground control points on modern maps as the references. This is a complicated operation, since the metric quality of old maps are often very low. Beside this, projection system of the old maps are sometimes unknown and the occurrence of cartographical deformation also unavoidable (Bitelli and Gatta 2011: 130).

b) The Nomenclature of the grid index is quite simple but contain sufficient information regarding to the site position (UTM zone, hemisphere, latitude and longitude position, both geographically and UTM).

c) The boundaries of each UTM zone become the grid index boundaries automatically, so there is no difficulty in separation each grid due to the differences of UTM zone.

d) Although each grid is still too wide (1° x 1° or an average of 12,000 km2), but easily shared into the maps with larger scales, by adding new code elements. These grid divisions are to accommodate some of the objective and scope of researches or other field activities that require varying map scales.

5. Concluding

It become clear that spatial data accumulate until now can be optimize for scientific advancement and management purposes. The map index is a fundamental requirement for the managers and users who needs a map-based information. Archaeological and historical sites scattered throughout Indonesia also require a special map index that can be integrated and managed as spatial information, which is important for stake holders and users engaged in cultural history.

Table 1. The character differences of archaeological database due to map scales

Scope	Scale	Major purpose	Attribute
National	≤ 1:12,000,000	Inventory	Site name
			Site type
			Site period
			Data autority
Regional	1:100,000 - 1:12,000,000	Inventory	Site name
		and Survey	Site type
			Site period
			Site chronology (oldest and youngest)
			Site elevation (absolute)
			Type of treatment
			Specific information by authority
			Data autority
Site	1:500 - 1:100.000	Detail survey	Site name
			Major finding (point, line, polygon)
			Range of elevation (absolute and relative)
			Site chronology (oldest and youngest)
			Single or multi-component
			Note of data tranformation
			Specific information by authority
			Data autority
Intra-site	>1:500	Excavation	Site name
			Sector name
			Grid name
			Datum point
			Major finding (artifact, ecofact, feature)
			Major matrix
			Chronology (oldest and youngest)
			Single or multi-component
			Context type
			Note of data tranformation
			Specific information by authority
			Data autority

It must be recognized that this proposal is very heavy to be realized, and requires a very long time to make it happen. An important conclusion should I put forward in this article is that, GIS-based national mapping system that can integrate all archaeological and historical sites is the most fundamental solution to overcome the weaknesses of research and management aspects that frequently occur in Indonesia. The mapping system also provides a very interesting display of cultural-historical configuration in Indonesia, which has become an important part of global history.

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