

Web GIS Model and Implementation for Spatio-Temporal Shoreline Monitoring and Projection Based on Historical Data

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Article Info

Volume 83

Page Number: 5270 - 5277

Publication Issue:

March - April 2020

Article History

Article Received: 24 July 2019

Revised: 12 September 2019

Accepted: 15 February 2020

Publication: 27 March 2020

Abstract

This study is aimed to present a web GIS implementation for spatio-temporal shoreline monitoring and projection based on historical data from the Earth observation satellite images. In order to develop a spatio-temporal based application, readiness of spatio-temporal data such as time attribute on spatial data is needed. Thus, it can seemly integrate to the Web application functions. Three study areas in peninsular Malaysia has chosen as pilot study for this application. For Malaysia case, generally there is no GIS based application on sea level rise or shoreline monitoring and projection at this moment that readily available for the coastal practitioners or publics. Furthermore, most of coastal practitioners use standalone desktop GIS to do analysis. Alternatively, the system can be used by coastal expert or public interactively to monitor historical shoreline data visually and projected shoreline changes dynamically using web browser on desktop or mobile phone.

Keywords; *Web GIS, Spatio-Temporal, Shoreline Projection..*

I. INTRODUCTION

Coastal zones are constantly exposed to natural processes and anthropogenic activities are dynamically changing the coastlines or shorelines. Shorelines are important element to measure coastal zones because it acts an interface between land and water [1]. Coastal zones can be monitored through measuring the accretion or erosion of the shorelines that deal with the examination of historical records of climatic changes, detection of coastal changes, and management of coastal zones. Measuring shorelines thoroughly could be employed with geographical information system (GIS) based analysis. Hence, the results of the analysis could be

displayed visually so that messages can be delivered into quick fashion. To address visualization of shoreline analysis, a web GIS based application is implemented.

In order to implement a web GIS based application for shoreline monitoring and projection, we have to understand data that suit spatio-temporal format. According to Wu-jun et al. [2], there is needed to use time in space data model to form spatio-temporal data model. According to Schneider [3], a spatio-temporal data model is a data model representing the temporal evolution of spatial objects over time. There-fore, spatio-temporal data model includes spatio and temporal attributes. To

integrate the space dimension and temporal dimension effectively in spatio-temporal data model which consists spatio and temporal, there are two solutions: first, extend the temporal dimension based on space data model; second, extend the space dimension based on temporal dimension [2].

In order to model spatio-temporal data, understanding geographic phenomenon is important which composed of space, time attribution and topological relations that can be represented as in Equation 1.

$$E = f(S, T, A, TO) \quad (1)$$

Where, E is the geographic entity; S is the space relation of geographic entity, which is composed of spatial scale, spatial coordinate and spatial relation; T is the temporal; A is the attribution of geographic entity; TO is the relation between geographic entities.

Operations on spatio-temporal data types comprise, for instance, the spatio-temporal intersection, union, and difference of moving objects, the computation of the trajectory of a moving point as a line object, the determination of the location of a moving object at a particular time, the calculation of a moving object during a given set of intervals, and the test whether a moving point enters or crosses a moving region. Spatial and spatio-temporal query languages enable the user to query databases enhanced by these concepts.

Visualization of spatio-temporal data model is the visualization of multi-dimension information. The temporal dimension is a reference of geographic information in the dynamic simulation of geographic information process that permit multi-angle vision and can present the process [2].

There are a number of applications using Web based GIS for coastal studies. Kaewpoo et al.[4] developed web based GIS for coastal community's management in Trat province, located at Eastern part of Thailand. The system provided online spatial

data collecting, mapping and map display. It is ease of planning and decision making for managing marine and coastal spatial problem. Bradbury et al.[5] discussed coastal monitoring program for a large-scale regional in understanding of coastal process of environmental forcing factors, such as waves and tides that affect the shoreline. Moreover, they used GIS software, Shoreline and Nearshore Data System (SANDS) for the detailed analysis work such as monitoring and data storage GIS. SANDS was developed specifically for shoreline managers and coastal engineers, to analyze coastal data particularly for point analysis and time series of pro-file location.

For Malaysia case, National Hydraulic Research Institute of Malaysia (NAHRIM) carried out the study of the impact of climate change on sea level rise (SLR) in Malaysia to project SLR for the Malaysian coast of the year 2100 using satellite altimetry data from 30 stations around Malaysia [6]. Then, NAHRIM developed a mobile application for projecting future SLR. However, the projection value is in numbers only and cannot show the real affected regions involved. Therefore, the motivations of this work are to propose and implement a Web-based GIS system that show the real affected and projected regions involved on the map. Moreover, this work is focusing on shoreline projection and sea level rise that affected by changes of shoreline versus time. It is different from Kaewpoo et al. [4] that focused on management of spatial data for coastal communities while Bradbury et al. [5] provided coastal process data using hydrodynamic factors unlike this project focusing on changes of shoreline verses time.

II. METHODOLOGY

A. Study Area

In this study, three study areas are chosen which affected much by sea level rise according to National Hydraulic Research Institute of Malaysia (NAHRIM) located at the northern and southern

regions of Peninsular Malaysia namely Langkawi, Tumpat and Pontian coasts as shown in Fig. 1.

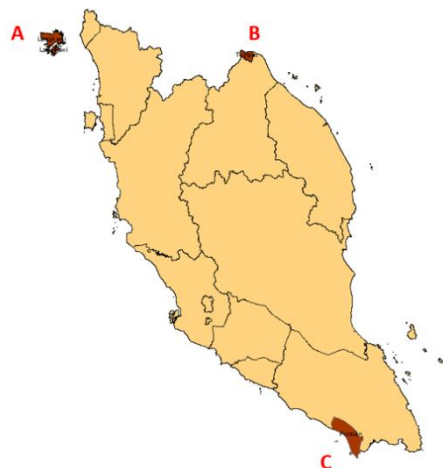


Fig. 1. Area of study for this project

B. Web GIS Model for Shoreline Monitoring and Projection

First and foremost, the earth observation satellite images were gathered according to the study area and with the minimal of clouds and shadows effects. In this study, minimum duration of 30 years' time chosen to store historical shorelines. After pre-processing the images of study area, image classification using machine learning technique was employed on multi temporal satellite images [7]. Then, shoreline was extracted from the classified images via post-processing tasks from raster images to GIS vector format. Then, the extracted shorelines data were merge into a single data and the temporal data attribute were added to the spatial shoreline data to make it ready for further spatio-temporal analysis stages. Then by using time series approach, the historical shoreline data was used to employ further processing tasks such as change analysis [8], prediction and projection [9]. The output of the processed data was converted to the spatio-temporal database (webgisdb) friendly. While digital terrain model (DTM) data in ASCII format was rasterized and mosaicked to be stored in webgisdb as shown in Fig. 2.

For the implementation, it is web based GIS application running on ArcGIS Server. In GIS Server, spatial data being published via www protocol to be viewed from web browser from Desktop computer or mobile phone. While Desktop GIS used for spatial data handling and map editing such as coloring shoreline data before exporting to the server. The main data for this system is historical shoreline and DTM data besides processed data such change analysis data and projection data. All the data have to be in the same coordinate system so that they can overlaid each other. In this case, Rectified Skew Orthomorphic (RSO) has been chosen as our coordinate system.

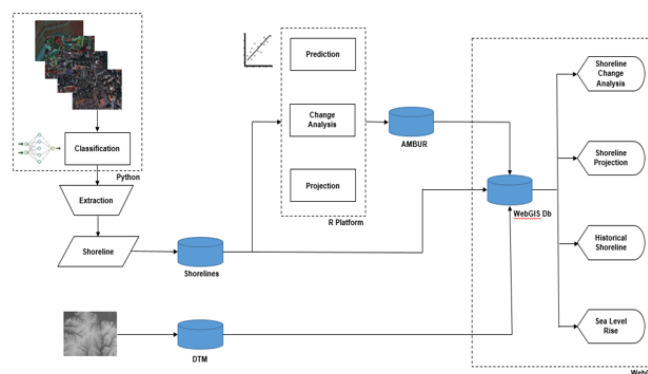


Fig. 2. Web GIS Model for Shoreline Monitoring and Projection

III. IMPLEMENTATION

The implementation of Web GIS for spatio-temporal shoreline data requires to understand data involved. Then, data needed to be prepared accordingly to suit the ArcGIS Server environment. In order to understand spatio-temporal data for this application, can refer to Equation 1. Space (S) is related to area of studies consisting of three regions in Peninsular Malaysia which consist of polygon for the area of studies while RSO projection system as coordinates and spatial relation.

A. Data Preparation

In preparing data for web based GIS, there is spatio-temporal data involved, specifically elevation data and shoreline data in this research. Spatio-temporal

data is needed to develop a web GIS based shoreline monitoring and projection system. In order to develop such system, understanding data type that suitable to run and display on Web GIS is essential. The important functionality in spatio-temporal application is it would be able to animate prediction and sea level rise. Besides that, historical shoreline and shoreline changes could also be displayed by choosing shoreline layers. For the Temporal (T) element, data is acquired from the earliest date in 1970s until 2017. The collection of data based on data availability and free from clouds and shadows effects. Attribution (A) data involved row of data elements covering the area of studies which relation between geographic entity (TO) is what distinguish between one entity with others. A and TO will be explained more details in the following subsection.

Digital Terrain Model. Digital Terrain Model (DTM) is an elevation data of the ground data above sea level was used to visualize the sea level rise as shown in Fig. 3. The data is gathered from Department of Survey and Mapping Malaysia originally in ASCII format. The spatial resolution of the DTM data is 30 m. For use in GIS, the data need to be rasterized. From the figure, the brighter tones represent the higher elevation while the darker tones represent the lower elevation.

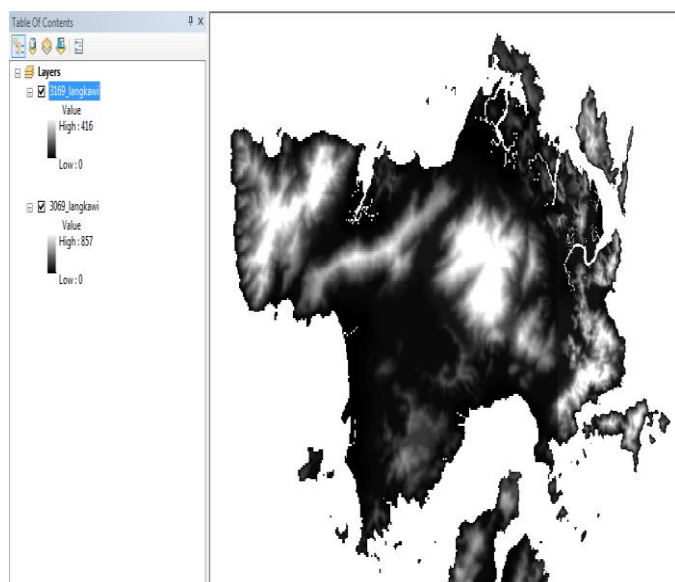


Fig. 3. Digital Terrain Model Data

Shoreline Data. Shoreline data could be categorized into three types of data, namely historical shoreline data, shoreline changes data and shoreline projection data. The historical shoreline data is the extracted data from satellite images while shoreline changes data is the process data after performing analysis such as change analysis.

FID	Shape	Class_Id	Parts	DATE	ACCURACY	SHORE_LOC	CLASS_1	CLASS_2	CLASS_3	GROUP	LEFT_FID	RIGHT_FID	Id
0	Polyline	1	323	10/01/1973 02:56:01 AM	1						0	0	1
1	Polyline	1	323	10/01/1973 02:56:01 AM	1						0	0	2
2	Polyline	1	323	10/01/1973 02:56:01 AM	1						0	0	3

Fig. 4. Historical Shoreline Data Attributes

Min_Date	Max_Date	Min_Chng	EPN	EPN_Error	EPN_MinDate	EPN_MaxDate	EPN_Er_L	EPN_Er_U	LRR
2015/10/04 01:12:59 AM	24/04/2003 01:46:32 AM	0.121651	0.674	0.154421	0.674	0	0.519579	0.820421	0.8204
2015/10/04 01:12:59 AM	24/04/2003 01:46:32 AM	0.647030	7.252311	0.154421	7.252311	0	7.809704	7.409704	7.252311
2015/10/04 01:12:59 AM	24/04/2003 01:46:32 AM	97.000562	10.592231	0.154421	1.420556	21.686366	-20.24101	23.594622	12.345046
2015/10/04 01:12:59 AM	17/05/2008 01:50:58 AM	97.000561	7.847297	0.113451	1.642013	13.646402	-12.004391	15.308415	0.854031
2015/10/04 01:12:59 AM	17/05/2008 01:50:58 AM	130.472241	10.46867	0.113451	4.677021	15.586403	-10.891372	20.245434	10.470937

Fig. 5. A Portion of Data Attributes for Shoreline Analysis

Fig. 4 is a spatio-temporal shoreline data ready for analysis. The most important attributes are date and id. Date must be in time format suitable to analysis need to be employed while id must be unique to differentiate each shoreline data records.

Meanwhile, analysis data consists of a large number of attributes. It is because it involves the many stages of processing the time series shoreline data as shown in Fig. 5. The differences between analysis data and pre-processing data is that analysis data have 2 dates attributes for change analysis stage. It can be used further for prediction in the later stage.

FID	Shape *	nYears	RateMeth	Date
0	Polyline	2	LRR	1/1/2018
1	Polyline	4	LRR	1/1/2020
2	Polyline	6	LRR	1/1/2022

Fig. 3. Shoreline Projection Data Attributes

After the difference of two dates (duration) and shoreline change data are used for prediction, it can use the same model for projection analysis. While projection data consist of very simple temporal part after retaining the necessary attributes for storing and display useful projection data as shown in Fig. 6.

From the Fig. 4 to Fig. 6, clearly visible that A covers all of row data for all columns separating by FID attribute. While, the Shape element stores polyline as geographical type, TO for each FID values. The difference between the FID attributes is how the geographical shape is.

B. Preparing Data for Web Based GIS

For web based GIS, ArcGIS Server is used for managing GIS Web services, applications, and data [10]. Generally, the basis of web application can be viewed on desktop applications, mobile devices and web browsers. When data in ArcMap document in MXD format is published on the server, the map is converted in map service as web service component. Once the map is published, the map service can be used to request a map image at any scale or extent. Additionally, the attribute of the features in the map also available such as geometry, etc.

For the detail data preparation procedure [4], first and foremost, all the shape file and images data needed to be added up using import function. Then, data needed to be shared to determine the access right for the layer data. The permission could be the combination of owner, group and others depending on how the data need to be shared. In our case, data is shared as all privileges for all users because we do not set any authorization setting since we do not provide login function. Then, map with a number of layers on a base map from a wide audience to a specific audience depending on the operations to be set up. First, base map needs to be customized from base map gallery. In this case, web map is chosen as default base map. Second, data layers need to be added to overlay on the base map. Third, style of the

map visualization can be customized to display in different format. Fourth, the map can be saved after finalizing base map, data layer and symbology customization. Finally, map is shared by map publishing a web map for further process in web application.

C. Web Based GIS on Shoreline Monitoring and Projection Modules

In this system, there are four main modules, namely historical shoreline, shoreline changes, shoreline projection and sea level rise as shown in Fig. 7. The main application is ArcGIS Server hosting web based application which developed in HTML and CSS for the static interface. The dynamic interface is developed using JavaScript.

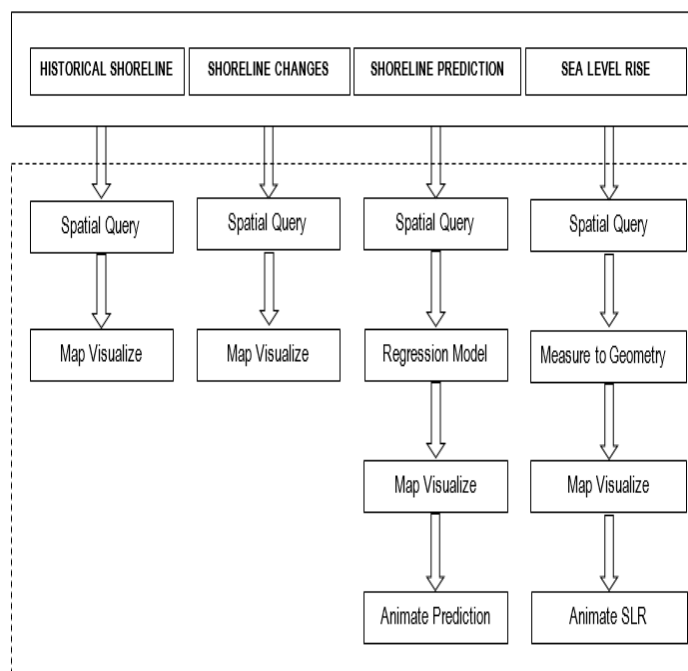


Fig. 7. Web GIS Modules

As in Fig. 7, there are four main modules consist of historical shoreline, shoreline changes, shoreline prediction/projection and sea level rise modules. Both historical shoreline and shoreline changes modules involve spatial query and map visualize functions only. Meanwhile in shoreline prediction/projection modules consists of regression model, map visualize and animate prediction modules beside spatial query model. Finally, sea

level rise consists of measure to geometry, map visualize and animate sea level rise modules besides spatial query module.

IV. RESULTS AND DISCUSSIONS

A. Historical Shoreline Module

Generally, the visualization function is used to display historical shoreline data as depicted in Fig. 8. Specifically, the data can be displayed one or more layers at one time by enabling the checkbox button. The year label will be used to differentiate with other layers. The historical data overlaid the map simultaneously after clicking the checkbox. Details information such as year, length and shape length will be displayed after clicking the shoreline on the map.

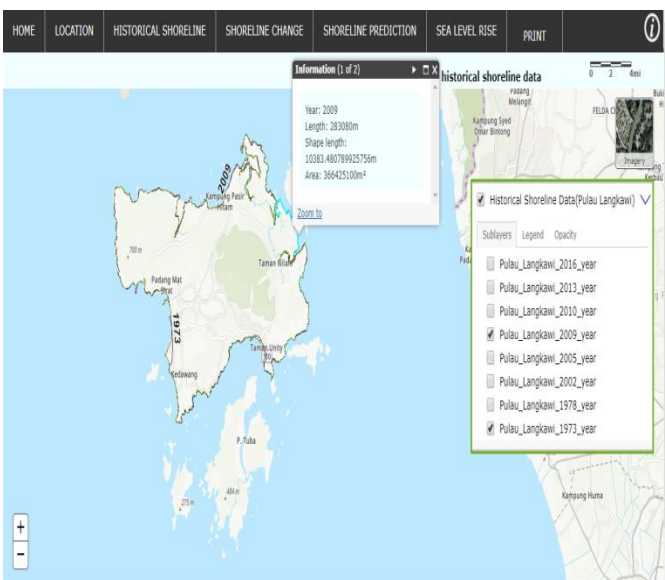


Fig. 8. Historical Shoreline Module

B. Shoreline Change Module

As in historical shoreline module, generally the visualization function is used. Specifically, shoreline change module also can be displayed by enabling the checkbox button. Along the shoreline, the condition of shoreline for duration of study can be noticed whether it accrete, erode or unaltered with help of the legend as depicted in Fig. 9.

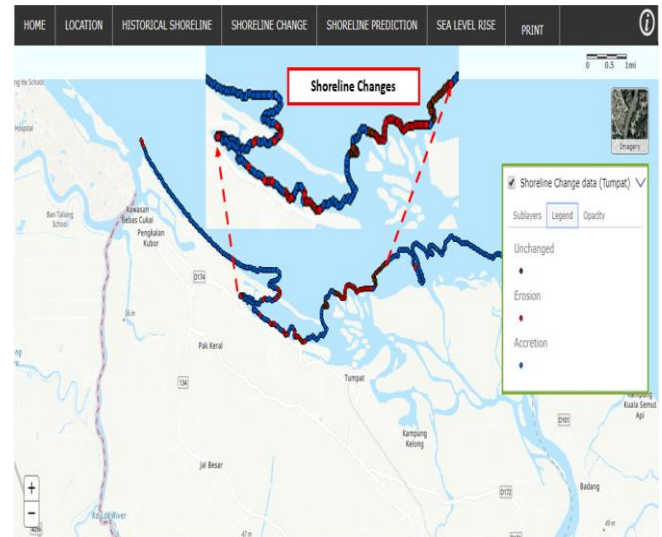


Fig. 9. Shoreline Change Module

C. Shoreline Projection Module

Generally, the visualization and time functions are used in shoreline projection module as shown in Fig. 10. Specifically, shoreline projection module will visualize the future shoreline positions from year 2020 to 2100. Using the time slider, shoreline positions can be visualized by clicking the play button. Besides that, the time slider has the functional buttons which are forward, backward and play buttons.

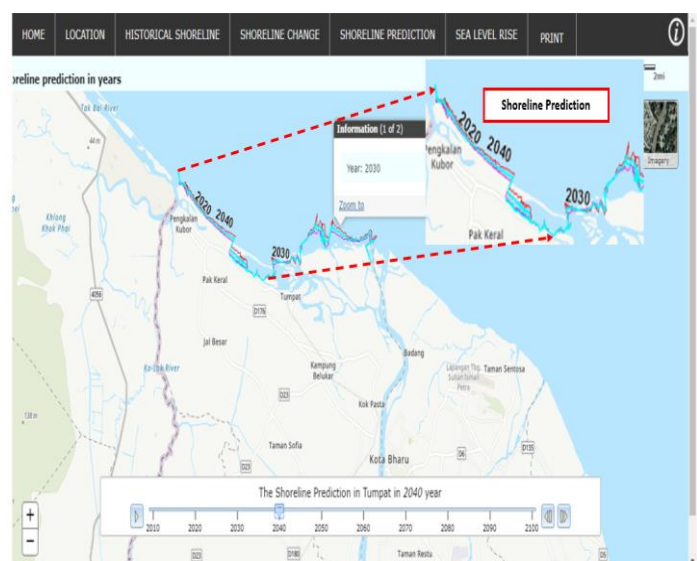


Fig. 10. Shoreline Projection Module

D. Sea Level Rise Module

Generally, the visualization, analysis and time functions are used in sea level rise module as depicted in Fig. 11. Specifically, this module consists of slider bar (in meter) below the map. Sea level rise will be displayed dynamically by clicking the play button. Like in shoreline projection module, sea level rise module also has similar functional buttons because of using time slider.

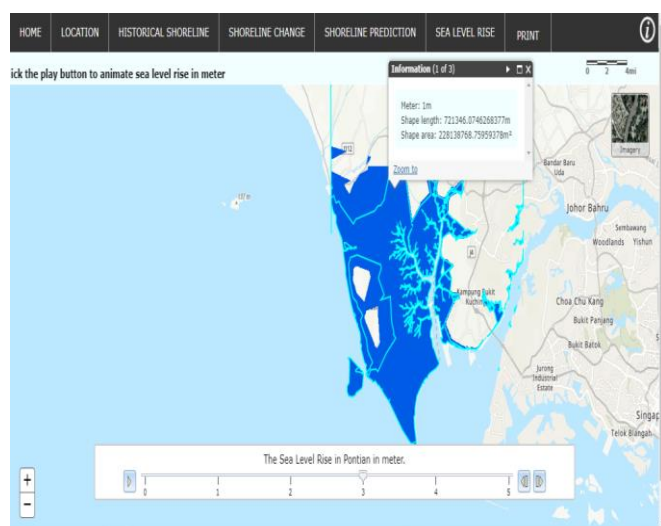


Fig. 11. Sea Level Rise Module

V. CONCLUSIONS AND FUTURE WORKS

The implementation of spatio-temporal shoreline monitoring, and projection is depending on the quality of data being extracted and predicted through a series of processes. Understanding spatio-temporal data is essential towards modeling the implementation of spatio-temporal shoreline monitoring and projection. Spatio-temporal application can be implemented using ArcGIS Server and a rich of supporting build-in features such as widgets, etc. For the future works, the system could predict, and project shoreline positions based on live data instead of displaying on processed data that retrieved from database.

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