System Design Document <BIZIAT: Broome Intertidal Zone Ichnofossil Access Tool>

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19/10/2019

Table of Contents

Table of Figures

Introduction

This System Design Document has been created to communicate the design of a suite of tools that will be used to facilitate access to dinosaur footprints in the intertidal zone near Broome. By designing and implementing this system I hope to provide tools that will aid in determining whether locations will be submerged or exposed depending on the (extreme in magnitude) local tidal movements. The system will also provide basic statistical measures on the users' datasets and may aid in the management of the record of known ichnofossils in the region. More detailed descriptions of the system architecture will be described in later sections.

Problem Objectives and Scope

The World Heritage listed place "The West Kimberley" has an extensive fossil record of dinosaur footprints (ichnofossils), which are mostly located in the intertidal zone close to the town of Broome. The area has very large tidal movements, and the location of the ichnofossils can present access challenges for researchers and enthusiasts (Romilio et al., 2017).

The system described in this design document is intended to provide a set of tools to assist with access to the ichnofossils. Described simply, it will use a publicly available digital elevation model of the intertidal zone to indicate which track locations will be accessible at any given tide height. It will allow a user to analyse which points will be exposed compared to the current (or future) tide height. Other basic tools are included that demonstrate other functionality possible with a custom toolbar. Importantly, part of the intention of the BIZIAT toolbar is to demonstrate what is possible with a customised ArcMap AddIn and is for the purpose of demonstrating to potential clients.

The dinosaur footprints are culturally and scientifically significant and sensitive. Important considerations stem from this context: the fossil record is irreplaceable and damageable, and footprints are known to have been cut out of the bedrock by independent parties (see Pockley 1996). The dinosaur tracks are also culturally significant to the local Aboriginal groups Yawuru and Goolarabooloo (Salisbury, Romilio, Herne, Tucker, & Nair, 2016). For these reasons, the actual spatial data describing dinosaur track locations is not publicly available, and for the sake of demonstration, a set of dummy data has been prepared.

Hardware and Software Requirements:

Hardware:

The BIZIAT tool is not hardware specific. Please see the next section entitled 'Software':

Software:

The BIZIAT tools have been developed using Python (version 2.7) making extensive use of the arcpy library, and also using pythonaddins, webbrowser, os, and threading libraries. The BIZIAT tools have been developed for and tested in ArcMap version 10.6. They can be installed on any system running ESRI's ArcMap 10.6, which should come with an installation of Python 2.7 and all required libraries.

System Overview

BIZIAT consists of two toolbars that are packaged as an AddIn for ESRI's ArcMap. The tools are as follows:

BIZIAT_Toolbar:

1. Zoom to Selected Features
2. Zoom to Full Extent
3. Clear Selected Features
4. Create Study Area
5. Help

BIZIAT_Statistics:

1. Enter Tide Height
2. Calculate Tide Extents
3. Choose Layer
4. Choose Field
5. Choose Value
6. Choose Analysis
7. Calculate Statistics
8. Print Results

Assumptions and Justifications

1. That locational height data has not been accurately recorded for the known track locations. This tool is only necessary if height has not been recorded for the known track locations. My assumption for this project is that locations exist as x,y coordinate data. If height data exists, then then DEM of the intertidal zone dataset would not be necessary to indicate whether a known point would be submerged or exposed at a given tide height. This could be computed directed from the z values of the points and the current tide height, without recourse to geospatial analysis.
2. That ‘access’ means that the point itself is exposed and nothing more. In reality, access means that there is an exposed and traversable pathway to the points. For example, a point may be ‘exposed’ but exist on an island surrounded by tidal water. This could be further developed in a more sophisticated version of the BIZIAT tool.
3. User_tracks data set is hard coded. In a future development a tool could be provided for users to enter their own set of points. It would be best to discuss this with the potential client to see what data entry format and schema suited their existing workflows.
4. Tide height datum is set at meters relative to Mean Sea Level. In reality people in Broome use a different datum when measuring tide height, meters above ‘Lowest Astronomical Tide’. This is common in areas where tides significantly affect water levels (Turner, Iliffe, Ziebart, & Jones, 2013). Further development could incorporate specification of tide datums by the user.

Data Layer

The NIDEM, or the National Intertidal Digital Elevation Model dataset, is critical to the BIZIAT tool. It is an elevation dataset for Australia's intertidal zone, with national coverage. Please refer to https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/123678 for the full metadata describing this dataset.

Layer Name	Description
known_tracks	Dummy data describing hypothetical x,y locations for dinosaur tracks. Most are located within the intertidal zone, but not all, to reflect the real spatial distribution. Attributes of relevance are - 'type' which is the genus of the dinosaur thought to have made the track, - 'certainty' which is a 'y' or 'n' value - 'preservation' which is an integer value between 0 – 2 inclusive The attributes have been populated at random to provide some test data for the statistical tools.
user_tracks	Identical schema to the known_tracks layer, but located in a different area to simulate the possibility of a user submitting data for a newly surveyed area.
exposed_extent	Describes the extent of the exposed part of the intertidal zone at a given tide height. Can be overwritten by the BIZIAT tool and is intended to be updated each time the 'Calculate Extents' tool is run.
submerged_extent	Describes the extent of the submerged part of the intertidal zone at a given tide height. Can be overwritten by the BIZIAT tool and is intended to be updated each time the 'Calculate Extents' tool is run.
zones	An intermediate data processing layer for the 'Calculate Extents' tool.
survey_area	A polygon describing a hypothetical survey area. This can be overwritten by the 'Create Study Area' tool.
intertidal_zone	The full extent of the intertidal zone (around Broome) as described by the NIDEM dataset.
NIDEM_reclass.tif	An intermediate data processing layer for the 'Calculate Extents' tool.
NIDEM.tif	An extract of the National Intertidal Digital Elevation Model, cropped to the case study extent. At 25m spatial resolution.

Figure 1: Data layers

Application Logic Layer

All data processing is done using python. The BIZIAT tool is written in python code, with a separate class for each tool or combo box. Each class is described below:

Class name	Type	Function
Zoom to Selected Features	Button	Zooms the map display extent to the extent of the selected features. This is useful as many of the other BIZIAT tools change which features are selected.
Zoom to Full Extent	Button	Zooms to the full extent of the data.
Clear Selected Features	Button	Clears the selected features. This is useful if confusion arises from the feature selections applied by the other BIZIAT tools and will reset the selection.
Create Study Area	Tool	Allows the user to 'draw' a rectangle on the map. This is then converted to a polygon feature class. The current 'study_area' layer is overwritten.
Help	Button with Dialog	Displays HTML formatted help document in the client's web browser.
Enter Tide Height	Combo Box	Allows the user to select from pre-determined tide height values, or to enter their own. Error checking is employed to ensure values are within the parameters required (see System Stability section in this document). **Please note: there is a problem here, the combo box is not accepting negative values. Please see System Stability section in this document.** Tide Height is stored as a global variable so that it can be shared with other classes.
Calculate Tide Extents	Button with Dialog	Takes the value from the 'Enter Tide Height' class and uses it to reclassify the NIDEM raster so that cells represent either submerged or exposed. I.e. if a cell value is <= tide height, then is it reclassified as submerged. This raster is then converted to a polygon feature class describing the submerged or exposed 'zones'. The 'zones' feature class is then separated into two feature classes, one describing the submerged extent, one describing the exposed extent. This separation enhances the clarity and simplicity of the data display for the user.
Choose Layer	Combo Box	Allows selection of the layer to be used for analysis. Whilst the combo box values were previously dynamically added, the values have now been limited to either 'user_points' or 'known_points' as this is in line with the design scope. 'selected_lyr' stored as global variable.

Choose Field	Combo Box	Allows the user to select a field for summary statistics processing. List is dynamically generated. 'selected_field' stored as global variable
Choose Value	Combo Box	Allows a user to select a field value to perform a selection. For example, if 'type' is selected in the Choose Field combo box, then the Choose Value combo box will be populated with dinosaur types. The user can then select only (for example) 'ornithopod' type dinosaur tracks.
Choose Analysis	Combo Box	Chooses between three intersection filters: Intersection with intertidal zone extent, exposed extent, or submerged extent. Applied this filter as a feature selection on the map.
Calculate Statistics	Button	Calculates statistics for **the selected features**. To calculate statistics on all features, the user should modify the selection. Given that the data point layers only contain nominal data, only basic statistics could be calculated. However, these basic measures are in line with the scope of this system. The statistics generated are entirely dependent on the user selection, and so many can be made. Examples are: 1) The user can see a proportional (percentage) breakdown of the types of dinosaur tracks that are currently located in the exposed part of the intertidal zone. 2) The user can see a percentage breakdown of the preservation status of the known dinosaur tracks that are currently submerged. 3) The user can see the total number of accessible dinosaur footprints of each type, given a user inputted tide value.

Figure 2: Tool classes

Relating to the Design Requirements:

Relating to the design requirements:

1. Control to: list the layers, initially displaying the default layer;
   It was decided to not make all layers available for selection, as this was not relevant to the requirements of the case study. It is possible to select between two layers, known_tracks or user_tracks, as these for an input to further analysis. It should be noted that this selection

choice is stored in a global variable so that it is accessible to other layers. Another method was tried, to store it as a property of the combo box (by defining '`self.sel = selection`') and then refer to that property with the other tools, but this method proved to be unstable.

2. Control to: list the fields that are available in the chosen layer, displaying the initial value in the textbox;
   This initial value is hardcoded to be 'type'. When focused, the combobox code obtains the complete list of field names that exist in the chosen layer. Some fields are more useful than others for analysis, and while in my specific case study it may have been more useful to only display the useful fields, I decided to use a dynamically generated list so that the tool could be used more generally. The most useful fields for analysis are: type (the type or genus of dinosaur that is thought to have made the track), condition (an hypothetical measure of preservation condition), and certainty (an hypothetical measure of the certainty with which the track was assigned a genus of dinosaur as its 'maker').

3. Control to: list the choices for filtering (see filter task information below);
   To maintain relevance to the case study, three filtering choices are available. To filter the full set of the chosen layer points with the full intertidal zone extent, the calculated submerged extent, or the calculated exposed extent. The assignment specifies a "Control to: use filtered or all features in statistics;". This has been modified to be clearer to the user and more in line with my case study. In my case 'all features' has been replaced with 'all features in the intertidal zone'.

4. Control to: display statistics;
   In this case there is just one button to display statistics. In my approach, many different statistics results can be generated **based on the user' selection of layer, field, and value, and filter**. In this way the output of the statistics tools is modified. No field names are hard coded into the statistics tools, all field are variables passed to the calculate_statistics Class.
5. Control to: use filtered or all features in statistics;
   As above, this is controlled by the user selection. The user can select a filter or not prior to pressing the Calculate Statistics button.
6. Print/save button: print/save the results; use element editing on the map to show statistics(after getting a filename).
   The Calculate Statistics tool displays the results in the Python window. This could be further developed, but this approach was in line with the scope of my design. At no point has the layout view been used in my design, and it seemed to me that to display results in a layout view would necessitate development of many other elements for little gain.

System Stability and Error Handling Controls

Relates to Standalone Python Script Section of Assignment

Multiple error checking and system integrity measures have been put in place. All user inputs take play within a ‘try/except’ clause so that errors will not cause the script to crash. For example:

```
try:
    mxd = raw_input("Please enter the full path to your .mxd
file:")
    mapdoc = arcpy.mapping.MapDocument(mxd)
except SyntaxError as error_details:
    print('SyntaxError, Goodbye!\n', error_details)
except IOError as error_details:
    print('IOError, Goodbye!\n', error_details)
except ValueError as error_details:
    print('ValueError, Goodbye!\n', error_details)
except TypeError as error_details:
    print('TypeError, Goodbye!\n', error_details)
```

Buffer analysis also takes place within a ‘try/except’ clause, so that if a layer is not bufferable, it will be excluded from geoprocessing. Layer groups are filtered out first with the following code:

```
for lyr in lyrList:
    # Find out if the layer represents a feature class
    try:
        desc = arcpy.Describe(lyr)
        print lyr.name + " is a valid layer."

    except:
        print lyr.name + "Not a regular feature class, excluded
from layer list."
        lyrList.remove(lyr)
```

Layers that cannot be buffered, such as WMS, are then excluded with the following code:

```
try:
    arcpy.Buffer_analysis(in_features=lyr,
                          out_feature_class=outputPath,
                          buffer_distance_or_field=buffer_dist,
line_side="FULL", line_end_type="ROUND",
                          dissolve_option="NONE",
```

```
dissolve_field="", method="PLANAR")

    # create layer in TOC and reference it in a variable for
possible other actions

    newLyrName = arcpy.mapping.Layer(outputPath)
    # Adds layer to mxd
    # arcpy.mapping.AddLayer(df, newLyrName, "BOTTOM")
    arcpy.mapping.InsertLayer(df, lyr, newLyrName, "AFTER")

except:
    print lyr.name + " cannot be buffered. Moving on to next
layer..."
```

The result is as follows:

```
bss_clip is a valid layer.
submergence_MSL is a valid layer.
intertidal_zone is a valid layer.
study_area is a valid layer.
Digital Earth Australia - OGC Web ServicesNot a regular feature
class, excluded from layer list.
GA Surface Geology of AustraliaNot a regular feature class,
excluded from layer list.
National Intertidal Digital Elevation Model nidem_v1.0.0 grid
(NIDEM 25m) cannot be buffered. Moving on to next layer...
AUS GA 1M GUPoly Lithology cannot be buffered. Moving on to next
layer...
Buffering completed
```

Relates to the AddIn Project

Try and Except clauses have also been implemented in the Python AddIn code. For example:

```
try:
    temp_tide_height = float(text)

except:
    pythonaddins.MessageBox("Tide value must be numeric, between
-2.601 and 2.772\n Tide value has been set to 0.", "ERROR IN
ENTERED VALUE")
```

Opening help.html in browser from the AddIn Toolbar. There is a stability concern here that was encountered during my testing, and research indicated that is has been identified by other developers (please refer to https://gis.stackexchange.com/questions/49724/code-to-open-web-browser-crashes-arcmap-when-run-from-a-python-add-in). A suggested workaround is to run the process in a separate thread. The other issue with this process is that I could not get the script to successfully open a html file references by a relative filepath relative to the python script. I could get it to open a web-accessible html file, or an html file specified by an absolute path on my machine. The ideal situation would be for the help.html to be bundled with the AddIn and further work is required to find a stable way to achieve this.

Use of Global variables: It could be more stable in future to employ a different method for communication of parameters between classes.

Definition of default values for variables used in calculations: The use of global variables does have one advantage, in that a value can be assigned to them prior to a particular class being run.

Further Improvements

The tide height input is range controlled. But the range values are hard coded, taken from the value range of the NIDEM layer. It would be better to have these range values extracted from whichever DEM the user was using. This also allows for reclassification of the DEM values to a different datum, such as relative to Lowest Astronomical Tide (see https://tidesandcurrents.noaa.gov/datum_options.html for more options and explanation).

Create Survey Area could be used to further limit the selection prior to statistical analysis. This could be done using the SelectLayerByAttribute_management tool, with the selection type set to 'SUBSET_SELECTION'.

Statistics at this stage are only based on nominal data. If numeric data is included, then this could be used for more complex statistics.

Comparison of Approaches – Open Source vs Proprietary

In a previous development stage (Assignment 1) much of the BIZIAT system was designed to be carried out using open source geospatial libraries. Whilst is was not implemented in its entirety, it was demonstrated to be possible. I will present pros and cons for each method:

ESRI AddIn		**Open Source**	
Pro	**Con**	**Pro**	**Con**
	Expensive, especially at Advanced license level.	Free for developer and end user.	
	Distribution of a third-party tool that is dependent on a certain data structure could be difficult.	Can be packaged with all dependencies as an executable.	
Standard and professional looking GUI.			GUI is less visually appealing or requires more work to develop.
	GUI (ArcMap), while pleasing and professional looking requires a level of GIS literacy not possessed by my intended end users.	GUI could be developed in Tkinter with more work, or alternatively pairing the solution with OpenLayers and GeoServer to run in a web browser.	
Powerful geoprocessing tools.		Powerful geoprocessing tools.	
	Difficult development workflow, as must close ArcMap and reinstall (compile?) the AddIn every time changes are made. In practise, this cost a lot of development time.	Code can be tested on the fly as it is interpreted and does not require compiling.	
Industry standard software.			Open source tools have always been present in the GIS world, and can also be said to be industry standard.

Figure 3: Comparison of Approaches

In summary, my preference would be to further develop the key parts of the BIZIAT system as an open source tool. The main reason lies in distribution and accessibility. As an open source software package, the BIZIAT tool could be packaged as an executable program, with all dependencies and required data. The tool could be provided free of charge. The ArcGIS AddIn version requires too high a level of knowledge for installation and setup of data layers. Each of which would have to be set up separately. Many of the tools also require the highest ArcGIS license level (Advanced) which can be a huge cost. As such, my preference for further development is the Open Source route using python and third-party geospatial libraries.

Conclusion

In conclusion, the BIZIAT tools require further development, but fulfil the scope in that they demonstrate how a Python AddIn can help to solve access issues for the ichnology of Broome. So if the tide is going to be very low tomorrow, how many ornithopod footprints could we see? The answer can be provided by the BIZIAT tools.

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