**3D Morphometry Toolbox – Instruction Guide**

*Gwyneth E. Rivers, Robert D. Storrar, Andrew H. Jones, Antti Ojala*

1. **Toolbox description**

A user-friendly, Python-based, ArcGIS toolbox that automatically extracts and calculates 3D morphometric data at user-set transect-segmented intervals along the profile of a given landscape feature. This allows for a highly detailed assessment of elongated features and provides users with a robust dataset in which to further manipulate and analyse as desired. It is intended that this open-access toolbox will be of value to both research and industry GIS users that are interested in the quantitative analyses of elongated landscape features.

1. **Toolbox utility**

This toolbox may be utilised for the measurement of any elongated landscape feature in which users require a detailed 3D morphometric assessment. As such, application is not limited by discipline area and may extend to a wide range of studies, including surveying of artificial landscape features in the built environment, such as railway embankments. Furthermore, this toolbox may be used to capture a single 3D morphometric assessment of a landscape feature, which may be useful for landform typology and/or to enhance feature diagnostic criteria. Alternatively, the toolbox may be applied as a repeated monitoring method in which to analyse evolutionary properties. This may be particularly useful in contemporary, fluvial settings, for example. The toolbox is currently established to calculate the 3D morphometric data of ‘positive-relief’ landscape features, however, it may also be applied to negative-relief landscape features (i.e. river channels) if numerical outputs are inverted.

1. **Script execution & software requirements**

*Script execution*

The tools are written in Python [v2.7] and incorporate Python libraries from ‘*ArcPy’* [ArcGIS 10.0-10.6]*, os, ‘Pandas’* [McKinney et al., 2010]*,* and embeds Python code for Tools, *‘Transect2.0’* [created by Mateus Vidotti Ferreira]*, and ‘Create Points on Lines’* [created by Ian Broad].

*Software requirements and availability*

The toolbox is intended to work within ArcGIS 10.1 and subsequent versions (*including ArcGIS Pro*). A ‘*3D Analyst*’ and ‘*Spatial Analyst*’ license is required. The toolbox can be downloaded from the public GitHub repository <https://github.com/gwynrivers/3D_Morphometry_Toolbox>.

1. **Installation**

The toolbox needs to be downloaded and imported into the general ArcGIS ‘ArcToolbox’ workspace prior to use. See steps below:

1. Import the *‘3D\_Morphometry\_Toolbox.tbx’* into the ArcGIS general toolbox (FIGURES 1 & 2).

**Graphical user interface, application

Description automatically generated**

*FIGURE 1. ArcMap 10.1.6 user interface. Screenshot demonstrating how to import the ‘3D Morphometry Toolbox’ into the general ArcGIS ArcToolbox. Right-click the top ‘ArcToolbox’ and select ‘Add Toobox…’, navigate to the saved ‘3D Morphometry Toolbox’ and select OK. The toolbox will then appear in the general ArcToolbox.*

1. Ensure that the script file path is linked to each tool.

**Graphical user interface, text, application

Description automatically generated**

*FIGURE 2. Continuation of FIGURE 1: ArcMap 10.1.6 user interface. Screenshot demonstrating how to import the ‘3D Morphometry Toolbox’ into the general ArcGIS ArcToolbox. Right-click each script within the ‘3D Morphometry Toolbox’, navigate to the ‘source’ tab and link to saved located of each script within the ‘3D Morphometry Toolbox’.*

1. **Tool operation & required inputs**

The toolbox comprises two tools, a primary ‘3D Morphometry Tool’ and a secondary ‘Average Feature Tool’. Specifically, the primary tool is intended to extract and calculate detailed 3D morphometry, at user-defined transect intervals, along the length of a target landscape feature. The secondary tool is then available to average calculated transect morphometrics per parent feature if desired.

***Primary tool: ‘3D-Morphometry-Tool’***

The primary tool requires: a polygon shapefile *(.shp)* containing digitised outlines of the identified target features, a polyline shapefile *(.shp)* containing digitised crestlines of the identified target features (FIGURE 3), a DEM of the study area *(.tif*), and a specified *‘Output\_Folder’* to store generated outputs. The file path to the *‘Output\_Folder’* must **not** contain any spaces. The *‘Output\_Folder’* should be refreshed after each tool has completed execution.

Graphical user interface, application

Description automatically generated

*FIGURE 3. Example of digitised landscape feature showing digitised outlines and crestlines. A) slope DEM rendering to identify central and lateral breaks in feature slope, B) hillshade DEM rendering used to identify target feature.*

The primary tool also requires two additional user-specified parameters; 1) transect intervals *(units; meters)*, which is the distance the user desires to set between each transect, and 2) transect length *(units; meters)*, which is the length of each individual transect *(NB: transect lengths should be set at a length which extends beyond the entire width of the digitised outlines as these will be clipped to the outline extent upon running the tool)*. Note: the run time of the tool is dependent on the size of the input dataset and the number of transects specified to be generated. Figure 4 provides an example of the user interface and required inputs.

***Graphical user interface, application

Description automatically generated***

*FIGURE 4. Screenshot of the ‘3D-Morphometry-Tool’ user interface as it appears when opened in ArcGIS. Required inputs as shown: ‘Feature Outlines’, ‘Feature Crestlines’, ‘DEM’, ‘Transect Intervals’ (units in Meters), ‘Transect Length’ (units in Meters) and ‘Output Folder’.*

***Secondary Tool: ‘Average-Feature-Morphometry’***

The secondary tool ‘Average Feature Morphometry’ requires: the generated ‘*Transect\_Morphometry.shp*’ file, the generated ‘*Feature\_Morphometry.shp*’ file, the original ‘*Feature Outline’* shapefile, and the file path to the specified *‘Output Folder’*.  Figure 5 provides an example of the user interface and required inputs.

Graphical user interface, text, application

Description automatically generated

*FIGURE 5. Screenshot of the ‘Average-Feature-Morphometry’ tool user interface as it appears when opened in ArcGIS. Required inputs as shown: ‘Transect\_Morphometry.shp file’ (amended as per quality control checks), ‘Feature\_Morphometry.shp file’, ‘Feature Outlines’ and ‘Output Folder’.*

1. **Generated outputs**

***Primary tool: 3D-Morphometry-Tool***

1. *‘Feature\_Morphometry.shp’*

Table

Description automatically generated with medium confidence

*FIGURE 6. Screenshot of attribute table of generated ‘Feature\_Morphometry.shp’ shapefile. Fields as shown include: Sinuosity, Length, Feature\_ID and Area.*

1. *‘Transect\_Morphometry.shp’*

Graphical user interface, table

Description automatically generated

*FIGURE 7. Screenshot of attribute table of generated ‘Transect\_Morphometry.shp’ shapefile. Fields as shown include: CL\_Z, AVG\_SLOPE, Feature\_ID, AV\_BASE\_TE, HEIGHT, CS\_AR, CS\_VOL, ASYMMETRY and WIDTH.*

*A picture containing text

Description automatically generated*

*FIGURE 8. Screenshot of feature and generated transects upon primary tool execution. Transects are spaced at 10 m intervals and orientated 90⁰ to the feature crestline.*

1. *Summative Histograms*

*Chart, waterfall chart

Description automatically generated*

*FIGURE 9. Example of produced summative histograms based on the initially generated transects, prior to any quality control checked and data refining.*

***Secondary tool: ‘Average\_Feature\_Morphometry’***

1. *‘Av\_Feature\_Morphometry.shp’*

*Table

Description automatically generated*

*FIGURE 10. Screenshot of attribute table of ‘Av\_Feature\_Morphometry.shp’ produced upon executing the secondary tool. Fields include: Feature\_ID, AREA, SINUOSITY, LENGTH, CL\_Z, AV\_BASE\_TE, AV\_HEIGHT, AV\_ASYMM, AV\_SLOPE, AV\_WIDTH and TOTAL\_VOL.*

1. **Additional comments**

*Feature digitisation*

Each identified target feature must have both a single crestline and outline. The accuracy of the output data is dependent on the quality of the input data. A duel rendering of the DEM is advised during the digitisation process (i.e., a hillshade rendering to accurately identify target features, and a slope rendering to accurately capture central and lateral slope breaks of each feature). Crestlines should be smooth and extend beyond the entire length of each identified feature as these will be clipped to the length of the outlines upon tool execution.

*Transect specifications*

Transect lengths should be set at a length that is sufficient to extend beyond the greatest width of identified features – these will be clipped to each feature width extent upon tool execution.

Transect intervals will be generated as the user specifies; the shorter the distance between each transect, the more detailed and larger dataset will be returned. It should be noted that the larger the initial dataset, and the smaller the intervals set between each transect will result in a longer execution time of the tool.

*Quality control checks*

Upon execution of the primary tool, some negative values may be returned due to inaccuracies during the digitisation process. As such, quality control checks should be undertaken and any anomalous values removed to mitigate any influential results. This can be done by opening the attribute table, sorting the ‘height’ column and removing any negative values. Transects are placed perpendicular (90⁰) to crestline orientation. In rare circumstances, highly sinuous features may produce some distorted transect placements. It is advised that, once the primary tool has been executed, the user undertakes a visual quality control assessment of the transect placements to ensure that outputs are within a reasonable range/placement. Erroneous transects may be either manually removed or modified as appropriate. It should be noted that if any transects are removed, the preliminary summary histograms will no longer be accurate.

*Outputs*

If a *.csv* file is required for further data manipulation, the attribute table of the *.shp* files may be converted to a *.csv* file using the ArcGIS ‘conversion’ toolbox. Updated summary statistics and histograms can then be produced manually from the *.csv* file.