Based on a Master of Design thesis describing the workflow development for an authentic 3D digitalisation of large-scale heritage objects

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Workflow outline for an authentic 3D digitalisation of a real-world object

Basic Workflow (B/W) for small/medium objects
Advanced Workflow (A/W) for complex, large-scale objects

Target object: sea shell

Equipment: DSLR Camera (Nikon D850), lens (AF-S Nikkor 35 mm f/1.4 G), tripod, rotating platform, flat colour background

PREPARATION *(BW)*

Equipment

- DSLR Camera
- Fixed lens 35 mm to 50 mm. Locked if zoom lens
- Tripod
- Rotating platform (for small object in an indoor set-up

PREPARATION *(AW)*

Equipment

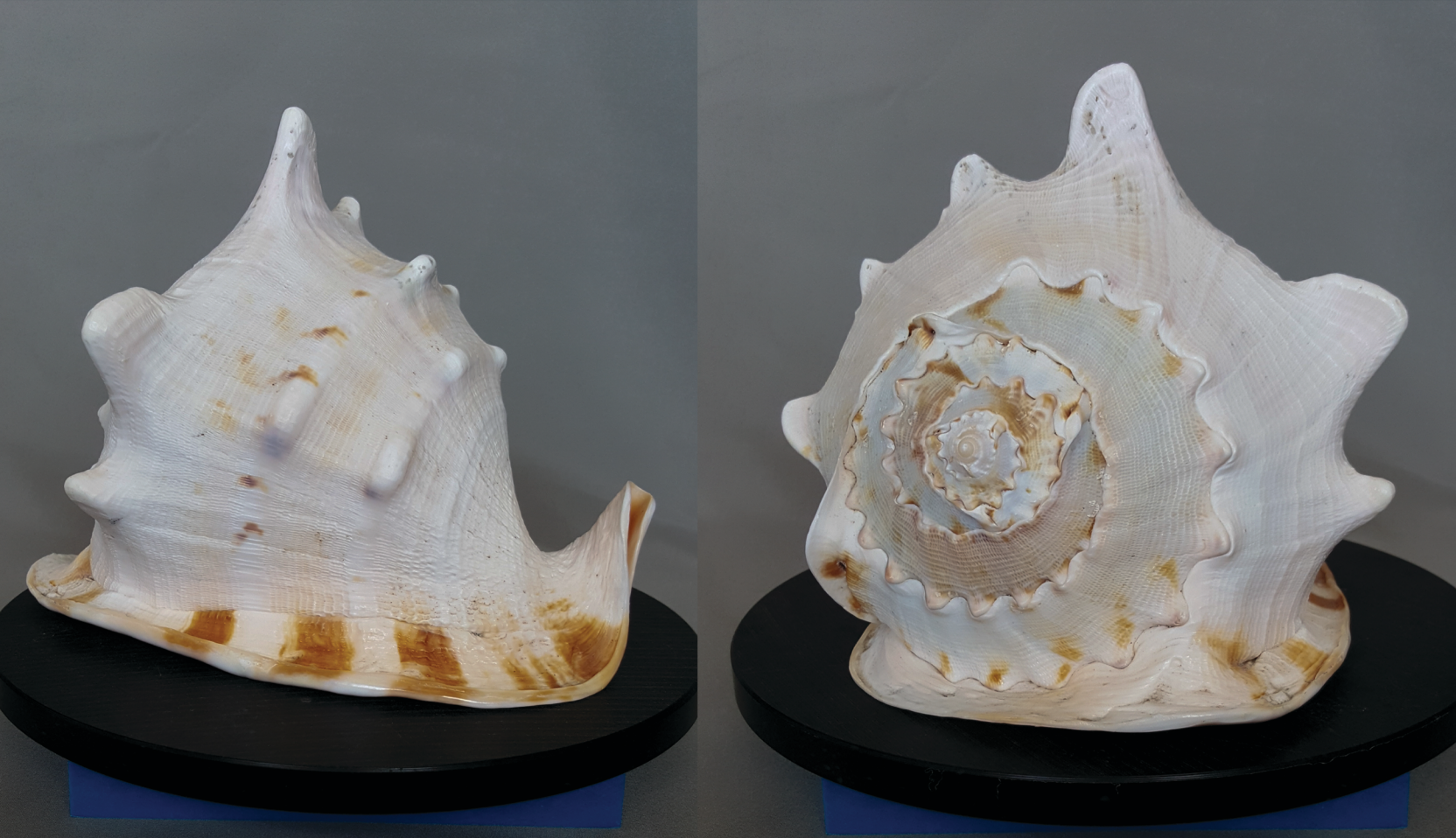
- 3D laser scanner
- Targets for laser scanner (checkerboard, spheres)
- DSLR Camera
- Fixed lens 35 mm to 50 mm. Locked if zoom lens
- Tripod
- Colour checker
- Chrome ball (HDRI lighting)

Lighting

- **Outdoor** - cloudy windless day
- **Indoor** - shadowless light set-up (strobe, diffused flash, softboxes)

Avoid Capturing

- Very thin self-occluding objects (hair, leaves)
- Objects featuring highly reflective, transparent or flat materials
- Objects with flat features or colours (particularly pure black or pure white)
- Repetitive patterns in either shape or material
- Non-stationary objects



Example of photographs from the image sequence obtained for digitalising the sea shell.

DATA ACQUISITION *(BW)*

Camera Set Up

- Manual mode
- Target object always in sharp focus
- Aperture f/11 onwards
- Native ISO or balance with aperture. No high values for clean results
- Even exposure across entire image sequence
- Image format .JPG

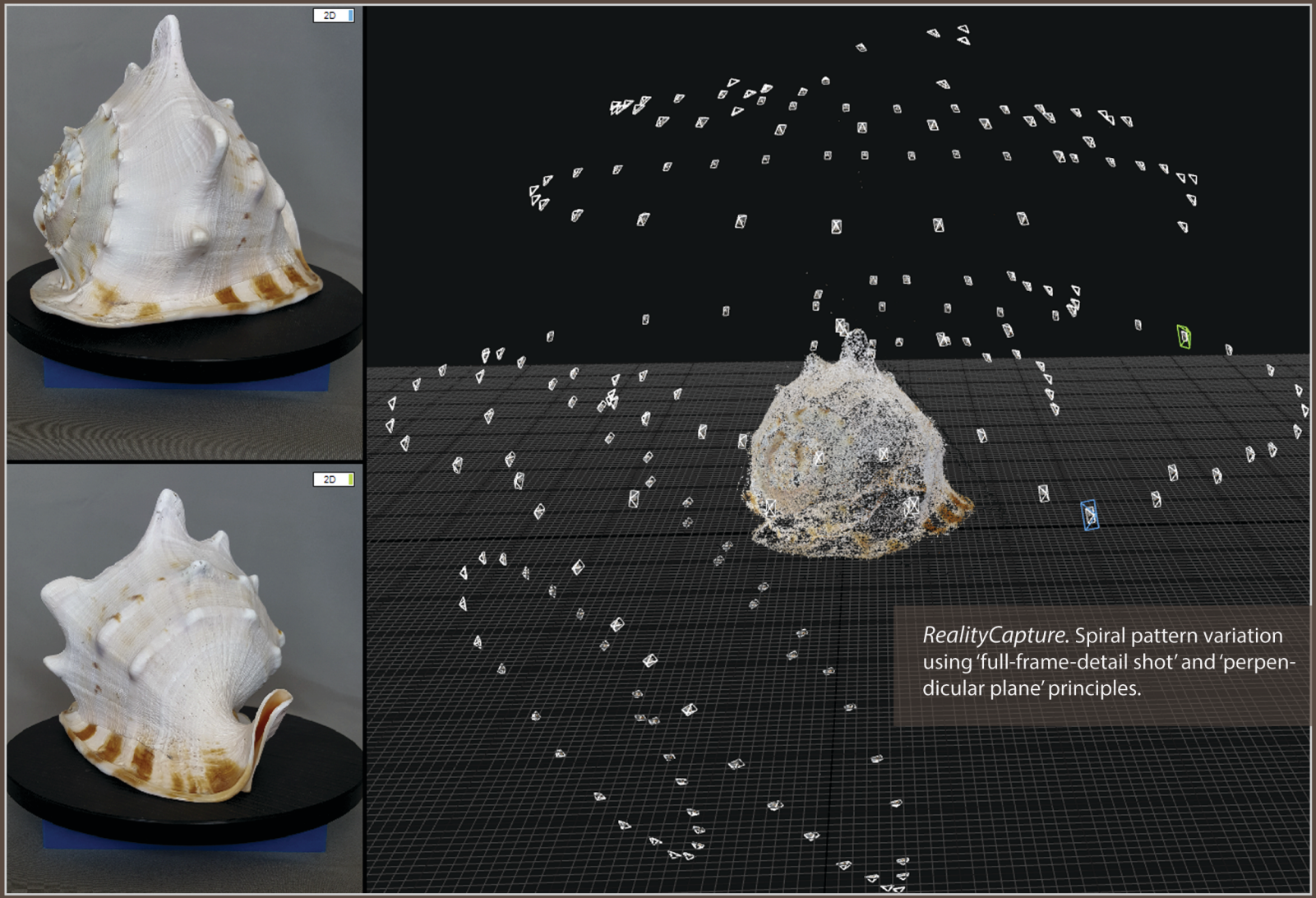
DATA ACQUISITION *(AW)*

Camera Set Up

- Manual mode
- Target object always in sharp focus
- Aperture f/11 onwards
- Native ISO or balance with aperture. No high values for clean results
- Even exposure across entire image sequence
- Image format .JPG, .RAW, .TIFF

Laser Scanner Set Up

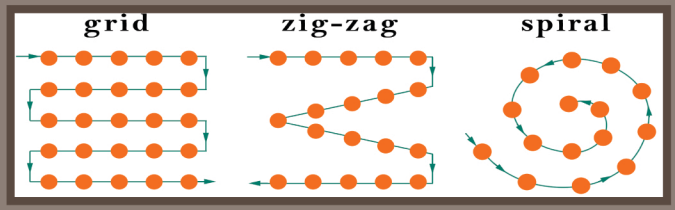
- Checkerboard targets - secured on flat surface, facing no less than 45° to the scanner position
- Spherical targets - attached to form a polygon around the scanner with varying height, distance and plane positions
- At least 3 targets per scan clearly seen
- Scanner resolution - depends on desired scale of the object and distance to it. The greater the distance the higher the resolution.
- Quality - controls amount of noise reduction and time per scan



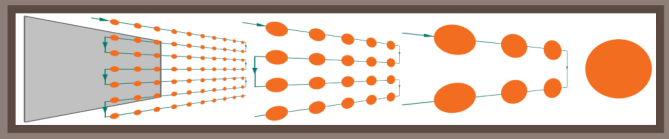
RealityCapture. Spiral pattern variation using 'full-frame-detail shot' and 'perpendicular plane' principles.

Shooting Patterns

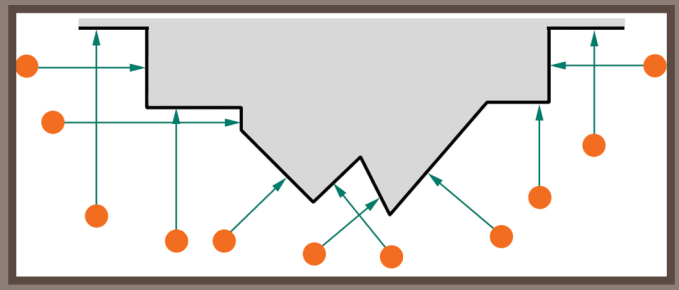
Planar objects can use any generic pattern from the three. For vertical planar objects it is best to use grid and zig-zag pattern. For horizontal ones, any pattern will suit. Encircled grid pattern or variations of a spiral pattern in combination with 'fullframe-detail shot' and 'perpendicular plane' principles are commonly used for volumetric object types.



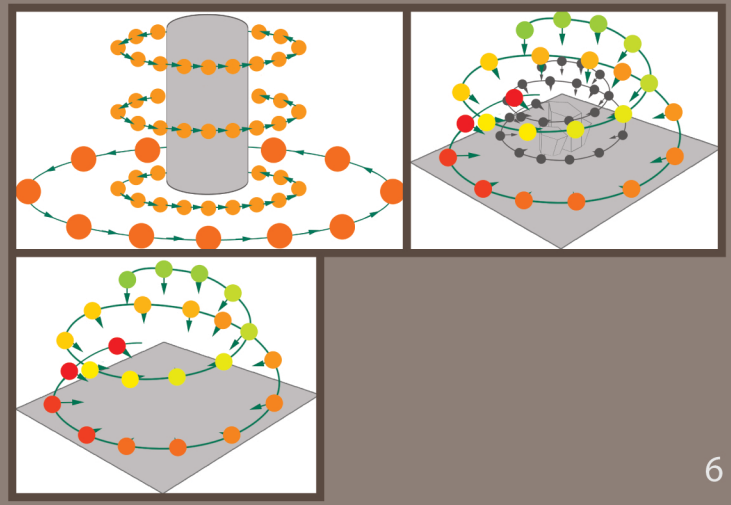
'Fullframe-detail shot' Principle. The orange circles represent camera positions for each image facing a target object, which is represented in grey colour. The stage close to the object should capture details and the stage further should have the object fitting in full-frame. This is done to capture as much detail as possible.

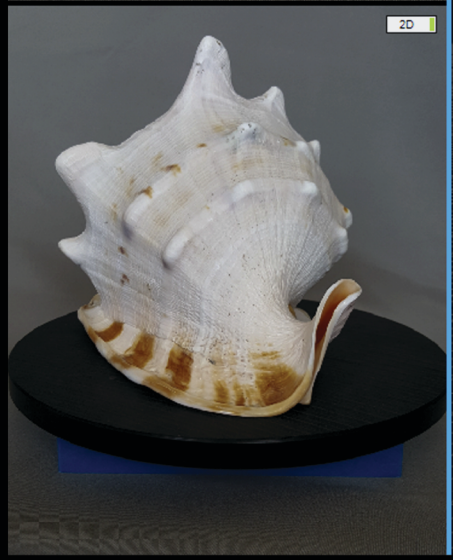


'Perpendicular Plane' Principle. An orthographic top view of a hypothetical target object represented symbolically in light grey. The orange dots represent a camera position for a single shot that must be present within the image sequence in order to capture all the data from the target object. If the object has a complex shape, then it has to be visually broken down into simpler forms that can serve as references for a 'perpendicular plane' principle. No panning during the shooting process, each image has to have its own position.



Pattern examples for volumetric and planar objects:





RealityCapture. Reconstructed and textured high-resolution model.

POINT CLOUD TO HIGH-RES MODEL *(BW)*

Software

- 123D Catch (free)
- Autodesk Recap
- Agisoft Photoscan
- RealityCapture

Each software has its own workflow. The general steps are:
Import image sequence-->Alignment--> Reconstruction of Polygonal Model--> Texturing-->Export Final Result

Restoration (if needed) Automatic

- MeshLab (free):
  -clean large polygons (selection per polygonal size)
  -close holes

POINT CLOUD TO HIGH-RES MODEL *(AW)*

Software

Photogrammetry:
- Agisoft Photoscan
- RealityCapture

Laser Scans (commonly provided with scanner):
- FARO SCENE 7.1

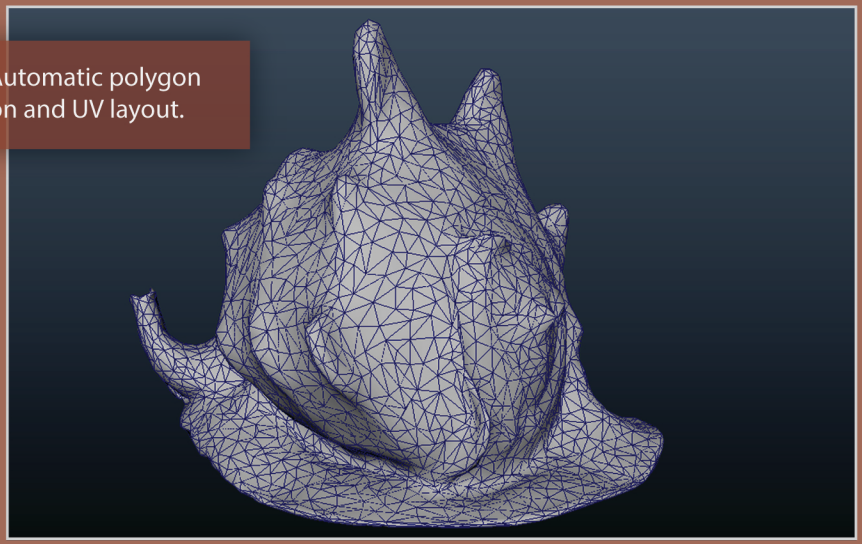
Each software has its own workflow. The general steps are:
Laser Scans Registration-->Combine registered scans with Image Sequence-->Alignment-->Reconstruction of Polygonal Model-->Texturing-->Export Final Result

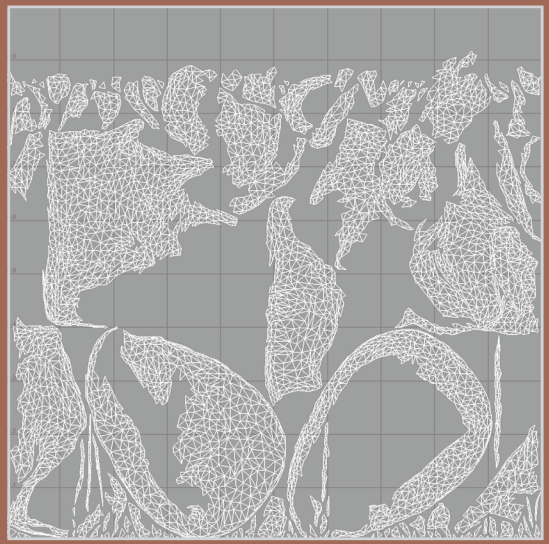
Restoration (if needed) Manual

- Pixologic ZBrush
- Blender (no more than 2-3 M polygons)
- Autodesk Maya (no more than 2-3 M polygons)
- Autodesk 3D Max (no more than 2-3 M polygons)
  -remove artefacts (Polygroups, Masking Tool)
  -close holes (Close Holes, Fill Holes)
  -manual modelling tools

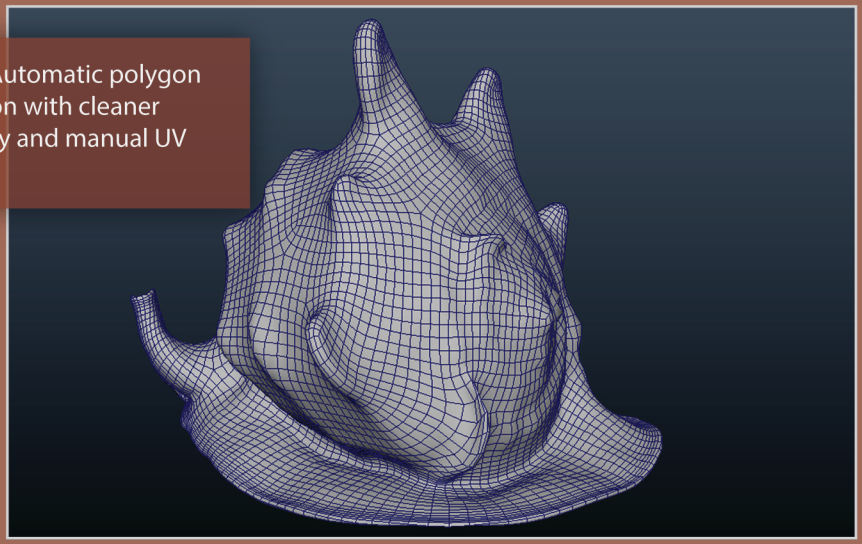
General principle for complex small/medium objects or large-scale objects - modular approach as per mesh continuity as well as material.

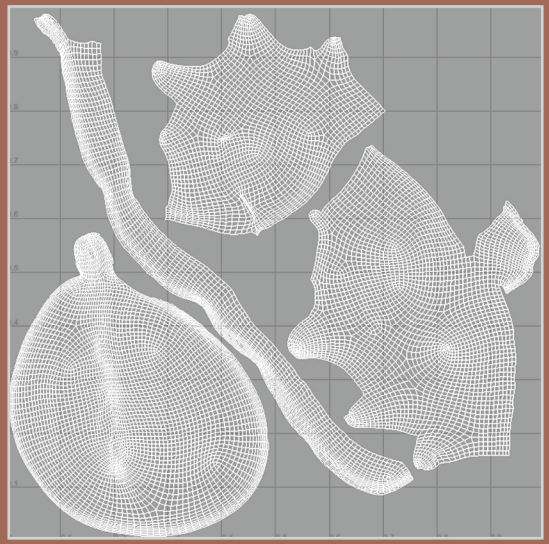
Maya. Automatic polygon reduction and UV layout.





Maya. Automatic polygon reduction with cleaner topology and manual UV layout.





OPTIMISATION *(BW)*

Low-Res Model

Automatic generation by reducing polygonal count using the high-resolution model.

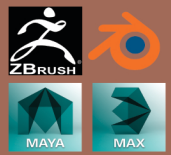
Software:

- MeshLab (free):
  - -automatic reduction through Quadratic Edge Collapse Decimation
- Autodesk Maya:
  - -automatic reduction through Reduce Tool

UV Layout

Commonly photogrammetry software generates its own UVs for the object during the texturing process. If UVs are lost through poly reduction process, they can be automatically generated.

Software:



- ZBrush
- Blender (free)
- Autodesk 3D Max
- Autodesk Maya

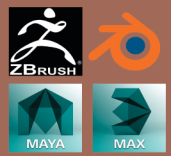
OPTIMISATION *(AW)*

Low-Res Model

Manual modelling from scratch to control the number of polygons, as well as areas, which require more or less poly distribution. The principle behind the distribution of the polygons is assigning more polygons to areas with finer details and fewer polygons to large planar areas.

Large-scale objects require a modular approach for easier modelling and texturing workflow.

Software:



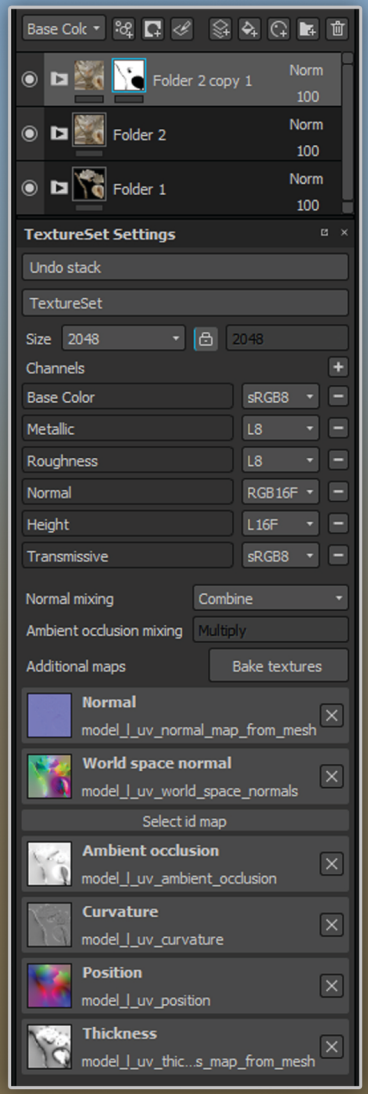
- ZBrush
- Blender (free)
- Autodesk 3D Max
- Autodesk Maya

UV Layout

Manual UV layout is recommended to ensure that seams between UV shells are hidden, as well as providing a proper use of UV space.

Software:

- ZBrush
- Blender (free)
- Autodesk 3D Max
- Autodesk Maya
- Headus UV Layout



SubstancePainter. Textured low-resolution model.

SubstancePainter. Baked maps: Colour, Normal, W/Space Normal, Occlusion, Curvature, Position, Thickness.

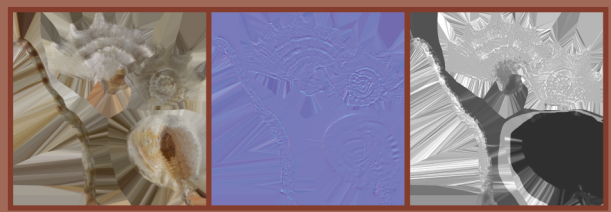
Texture Baking

Texture baking allows transfer of all the details from the high-resolution model to the low-resolution model. The details are baked into texture maps.

Software (baking for PBR material):

- xNormal (free):

Minimum number of baked texture maps:



Colour/Diffuse Normal Roughness

Occlusion

Texture Restoration (if needed)

Software:

- GIMP (free)
- Adobe Photoshop (Clone Tool)

Texture Baking

Texture baking allows transfer of all the details from the high-resolution model to the low-resolution model. The details are baked into texture maps.

Software (baking for PBR material):

- SubstancePainter
- SubstanceDesigner

Minimum number of baked texture maps:

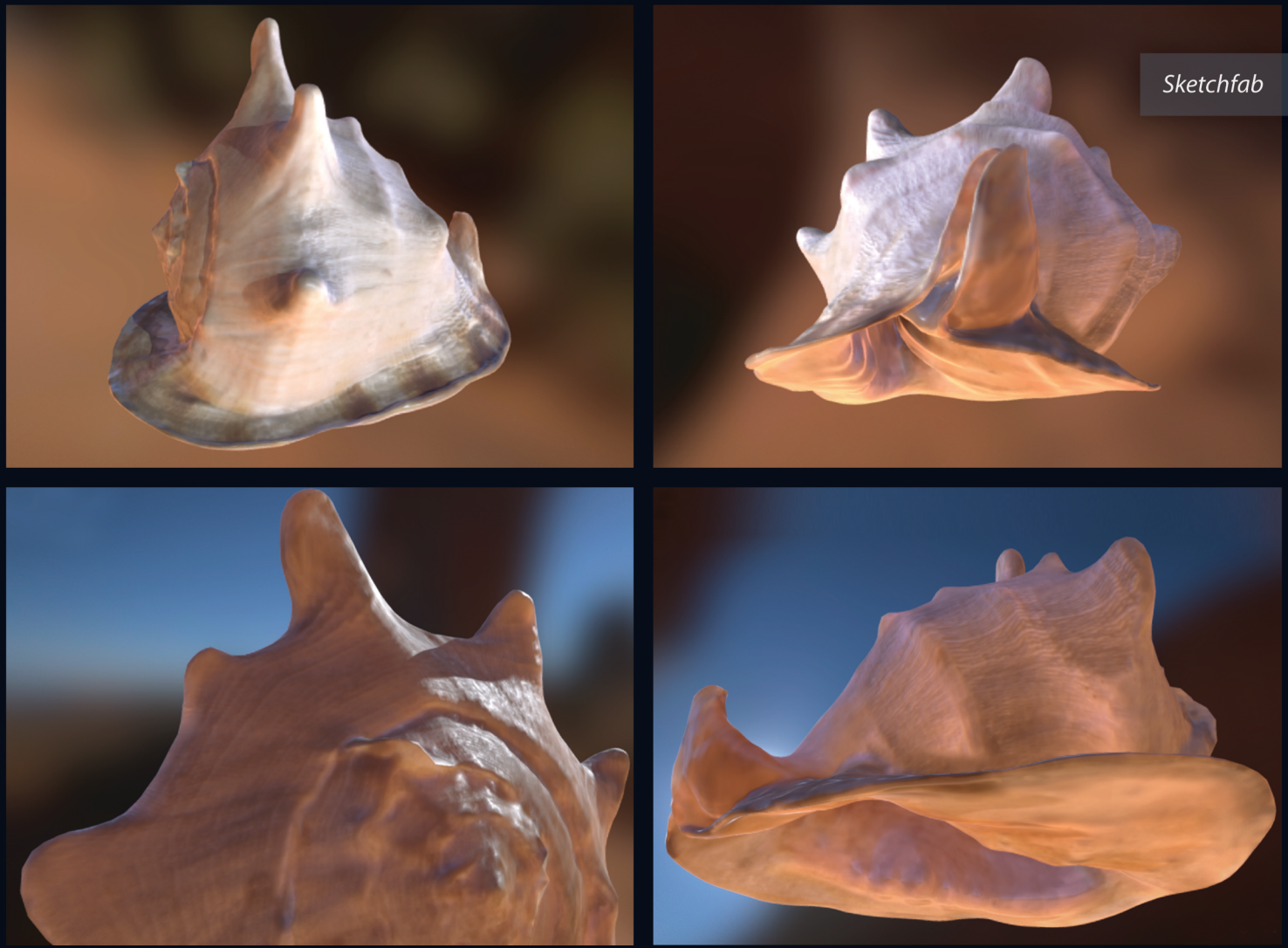
Colour/Diffuse Normal Roughness Occlusion

Thickness Curvature Position W/Space Normal

Texture Restoration (if needed)

Software:

- Adobe Photoshop (Clone Tool, HighPass for delighting)
- SubstancePainter (Clone Tool)
- Unreal Engine (Delighting)
- Unity Delighting Tool


Sketchfab

FINAL OUTPUT *(BW)*

.OBJ or .FBX + baked texture maps

Online Presentation

- Sketchfab
- Marmoset Toolbag Plug-in for personal web-site

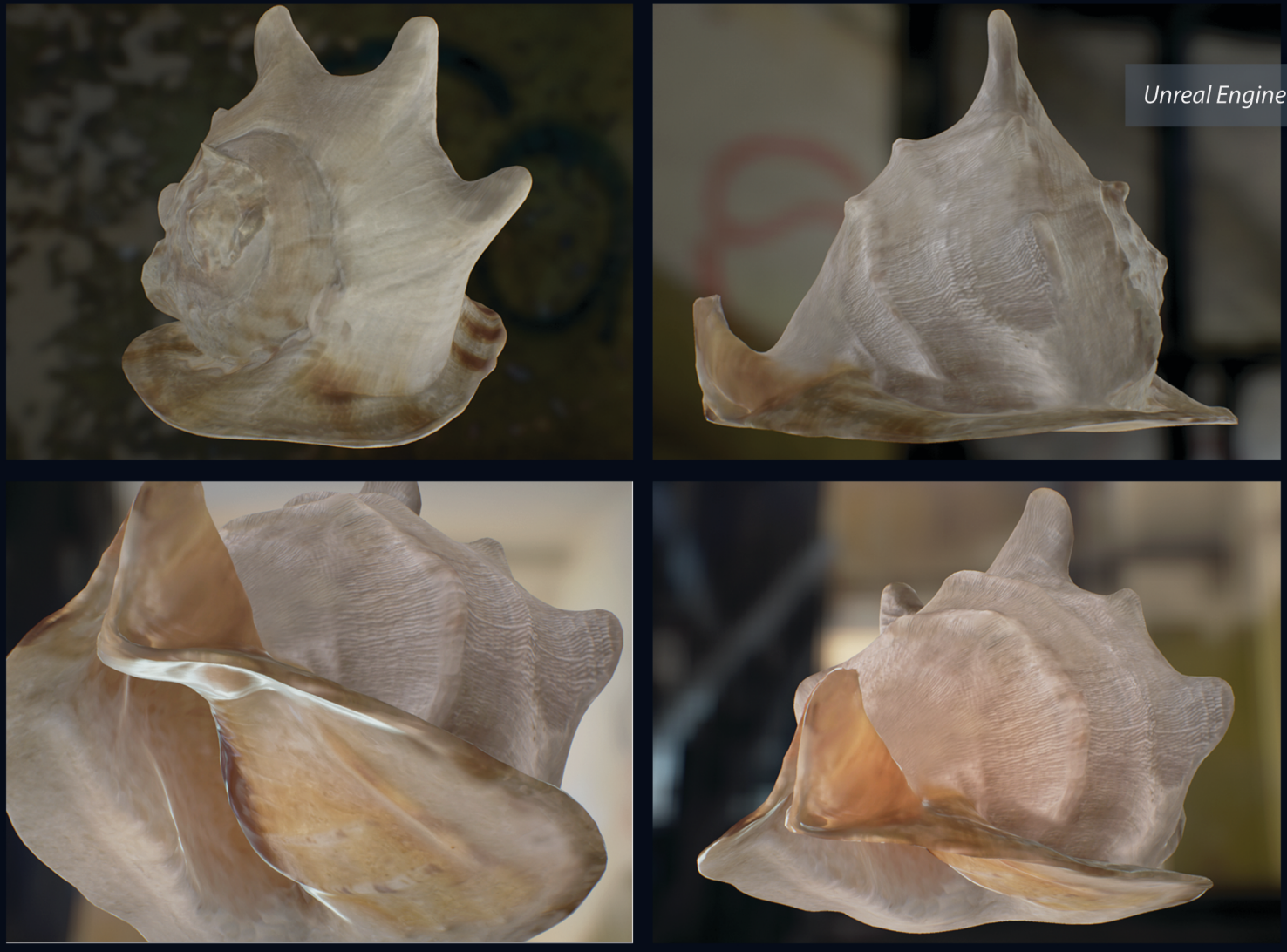
FINAL OUTPUT *(AW)*

Game Engine

Import the final optimised model for further interactivity development or integration into environment.

Software:

- Unity (VR or interactive visualisation)
- Unreal Engine (VR or interactive visualisation)


Unreal Engine 4

This outline is a brief summary of a reality-based 3D digitalisation workflow. More information, detailed examples and discussion of the workflow can be found in the Master of Design thesis "Authenticity in Digital Surrogates. Workflow Development for Generating an Authentic Digital Surrogate for Heritage Conservation" by Katarina Markovic.

A wide range of software packages can be used in the digitalisation workflow. Software packages mentioned in this outline are suggested because of their ease of access and common use in the digital design field.