Mesh Parameterisation for Texture Mapping

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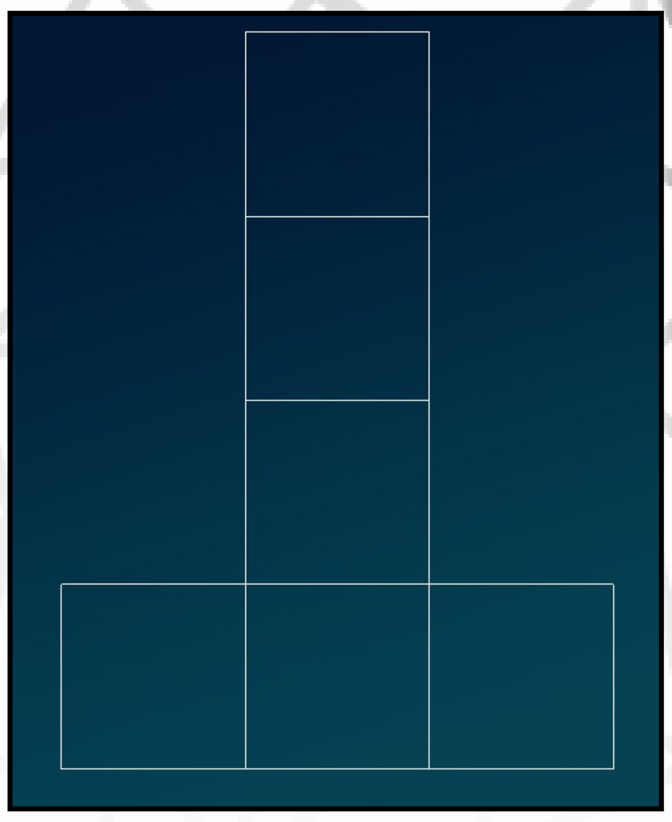
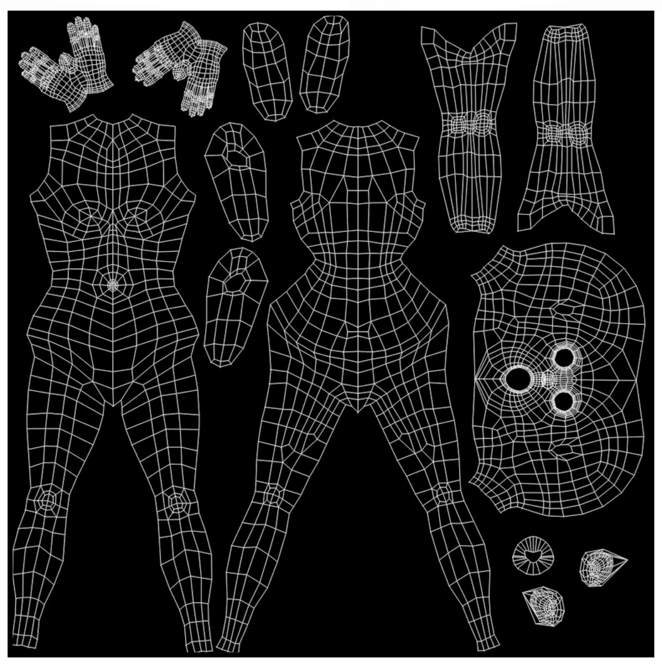
1. Introduction



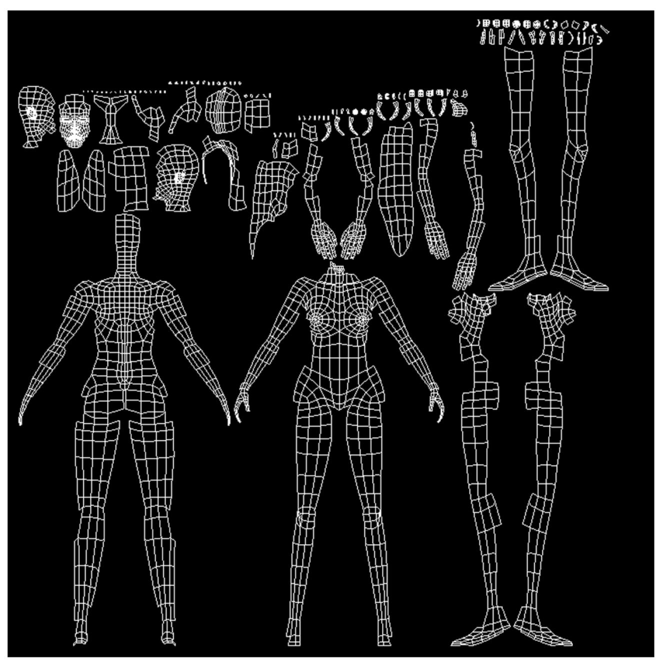
In many 3d applications, models are defined as a triangular mesh. These meshes are then textured by assigning a pixel of colour from a 2d picture onto a region of a 3d model and as such, a mapping of texture coordinates to mesh coordinates is required.

Mesh Parameterisation (also known as UV Mapping) is the process of mapping a 3d mesh to a 2d plane. The allows two 2d coordinates, U and V, to be used to reference every point on the surface of the 3d mesh. However, the creation of such a mapping is not trivial; angular distortion and distance distortion must be minimised in order to ensure that the 2d graph bears as much

2. The Problem



For texture mapping purposes, the layout of the UV map is important. Since the map is essentially a canvas, human intervention is often required to tweak the map layout, presenting a bottleneck in 3d model production. I intend to reduce the amount of adjustment required before a UV map is ready to paint on.



There is some previous work in the area of mesh parameterisation, but academic research has not yet made its way to industry use. My aim is to implement a plugin for Maya which utilises an existing parameterisation method, and then supplement this implementation with algorithms designed to enhance the layout of the UV map for an artist's use.

3. Characteristics of a Good Mesh Parameterisation

- Minimise Angular Distortion
- Hide Seams / Place Seams Logically
- Allow salient mesh features more map resolution
- Divide resulting map into UV islands appropriately

4. Project Objectives and Progress

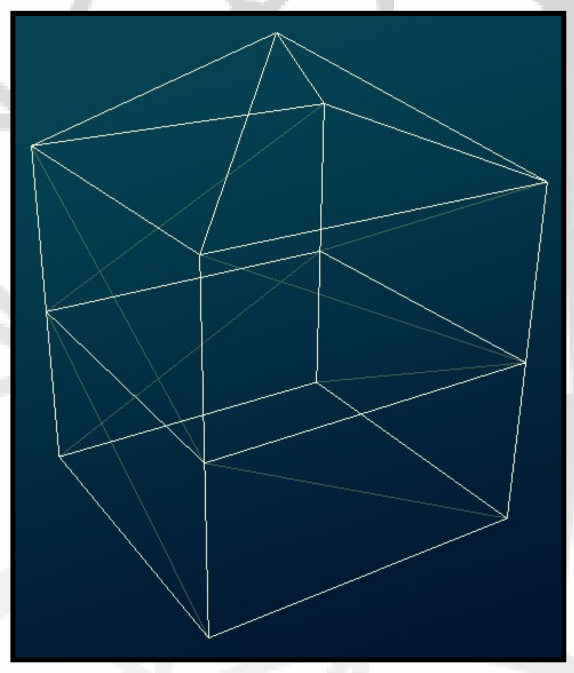
- Implement planar UV projection: **DONE**
- Implement cylindrical UV projection: **DONE**
- Implement a pelting algorithm: **70%**
  - Implement Seamster: **90%**
  - Implement ABF++: **50%**

Core Goals

- Implement Saliency map adjuster
- Implement UV Island layout optimiser
- Implement seam selection tool
- Implement parameterisation symmetry detector

New Research

5. Seam Selection Process (Seamster)

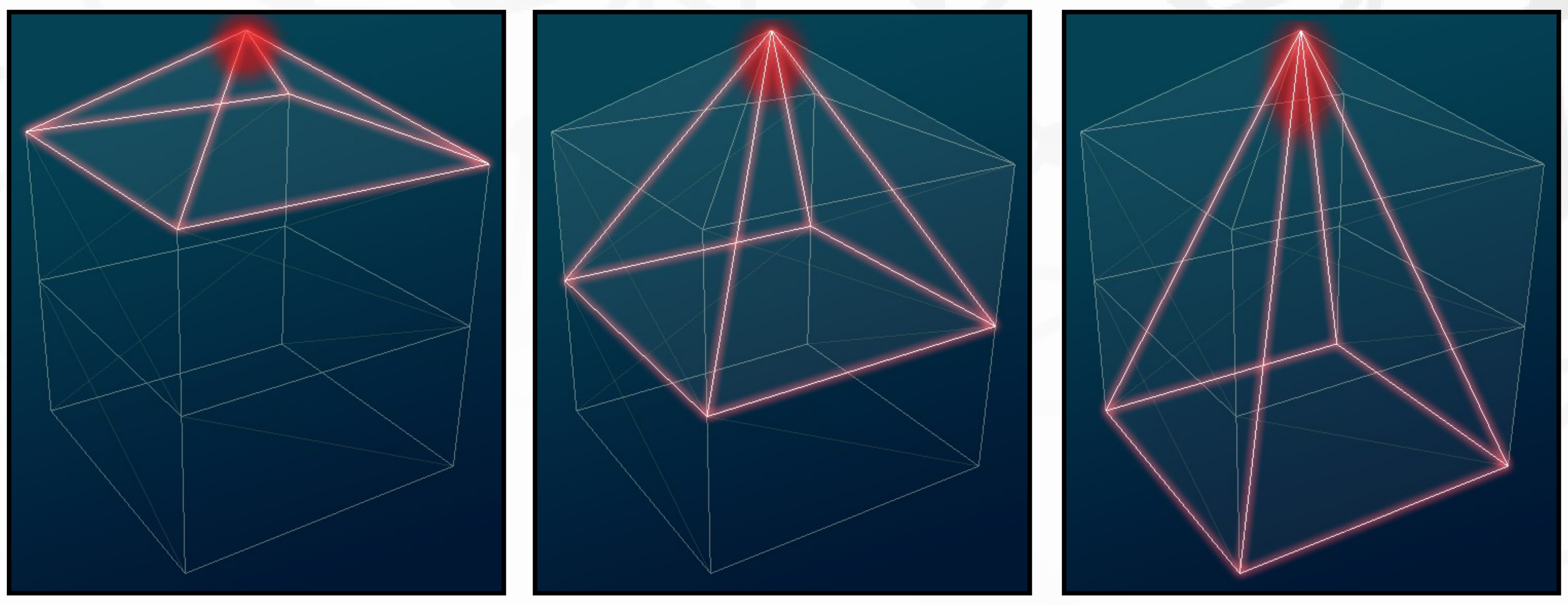


Calculate distortion at every vertex over several radii. Vertex distortion $D_r(n)$ at radius r is defined as:

$$D_r(n) = \max_{0 \leq i \leq r} (D'_i(n))$$

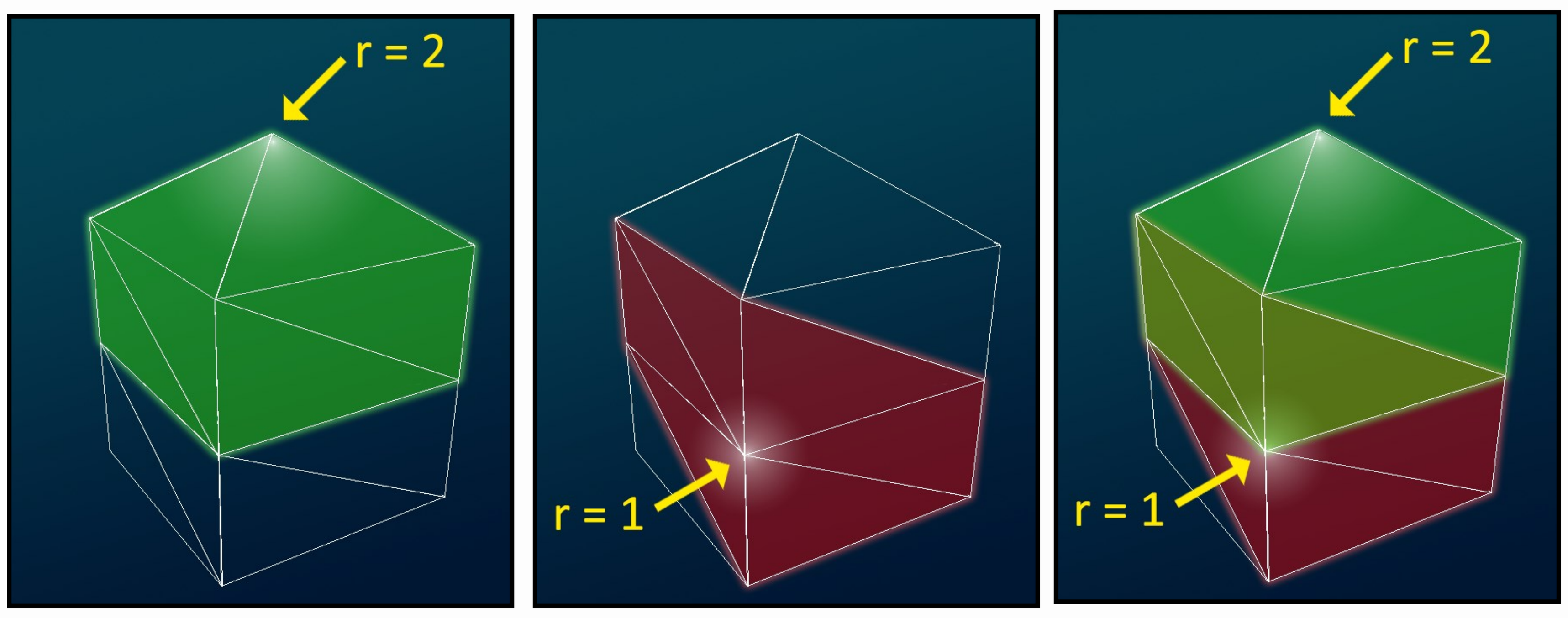
$$D'_r(n) = \frac{2\pi - \sum_j \tau_j}{2\pi},$$

Where τ_j is the set of angles between the vertex and the border edges in the radius Submesh.

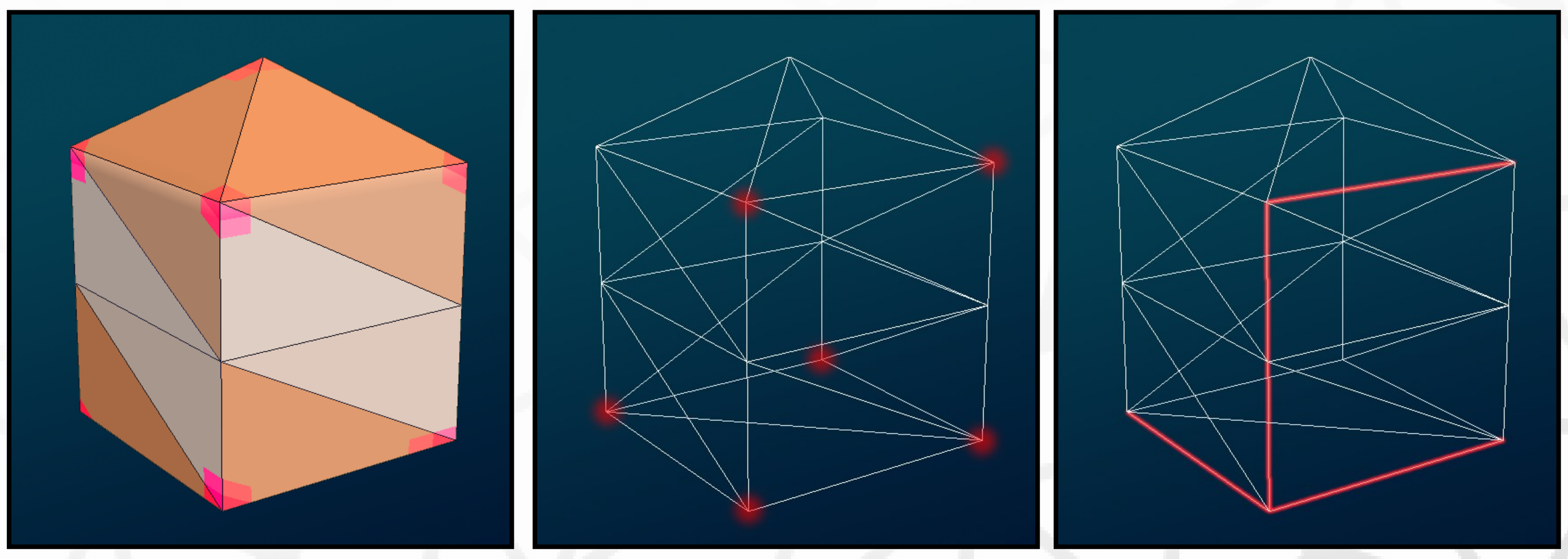


Submesh at r =0 | vSubmesh at r =2 | Submesh at r =3

- Filters distortion to eliminate clusters of high distortion vertices



- Place seams through the highest distortion vertices thus reducing their distortion to 0.
- Calculate a Steiner Minimum Spanning Tree to link the highest distortion vertices together
- NP Hard, Hence, use an approximation to a minimum Steiner tree:
  => Floyd-Warshall's followed by Kruskal's
- This minimum spanning tree forms the seams



6. Flattening Process (ABF++)

- Represents 3d mesh using only angles and connectivity
- Presents 3D-2D transformation as a Langrange Multiplier minimisation problem with the following objective function and constraints:

$$F(x) = F(\alpha, \lambda_{Tri}, \lambda_{Plan}, \lambda_{Len}) = E + \sum_t \lambda^t_{Tri} C_{Tri}(t) + \sum_v \lambda^v_{Plan} C_{Plan}(v) + \sum_v \lambda^v_{Len} C_{Len}(v).$$

$$E(\alpha) = \sum_{t \in T} \sum_{k=1}^{3} \frac{1}{w_k^t} (\alpha_k^t - \beta_k^t)^2,$$

$$\forall t \in T, \quad C_{Tri}(t) = \alpha_1^t + \alpha_2^t + \alpha_3^t - \pi = 0;$$

$$\forall v \in V_{int}, \quad C_{Plan}(v) = \sum_{(t,k) \in v^*} \alpha_k^t - 2\pi = 0,$$

$$\forall v \in V_{int}, \quad C_{Len}(v) = \prod_{(t,k) \in v^*} \sin \alpha^t_{k \oplus 1} - \prod_{(t,k) \in v^*} \sin \alpha^t_{k \ominus 1} = 0.$$