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Artículo original

Anatomy guided bottom up creature skinning

Generación de malla de piel a partir de la anatomía interna

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Abstract

It is possible to guide skin construction from the creature's inner anatomy. This paper introduces a method where is provided the system with bones, a set of muscles and a set of subsidiary organs in order to generate the mesh of the skin. The method generates a set of feature points from the inner anatomy. Then, it projects the feature points on a mirror plane which cuts the creature in the middle. Once in the plane, triangulate and reflect the points and adjust the skin's mesh inflating it and deflating it until all skin vertices are within some threshold of the underlying anatomy. Finally, fur is generated with offsets calculated from the skin's mesh. Feature point generation and automatic mesh generation strongly rely on the anatomical knowledge provided to the algorithm. However, it eliminates the need of a pre-existing skin mesh. The resulting mesh is consistent with the underlying anatomy.

Resumen

Es posible generar la malla de la piel a partir de la anatomía interna. Este artículo presenta un método que recibe huesos, un conjunto de músculos y un conjunto de órganos complementarios para generar la piel. El método inicia en el fondo de la anatomía y genera una serie de puntos clave que luego proyecta en un plano espejo que corta la criatura por la mitad. Una vez en el plano, los puntos son triangulados y reflejados. Posteriormente, la malla de la piel es ajustada expandiéndola y contrayéndola hasta que está a una distancia predeterminada de la anatomía. Finalmente, el pelo es generado con desplazamientos a partir de malla de la piel. El método depende del conocimiento anatómico para generar los puntos clave, pero elimina la necesidad de una malla de piel preexistente. La malla creada es anatómicamente consistente con la anatomía de la criatura.

I. Introduction

Modern creature design often relies on digitalisation or on the skills of a 3D artist who is responsible of providing a skin mesh. In contrast, it is possible to guide skin construction from the creature's inner anatomy. For example, our creature, Londra (Navarro Newball, 2010), proposes a dog head model where the skin was built from the underlying anatomy. Here, we provided the system with (Figure 1):

- » A skull with teeth.
- » Twenty three facial muscles.
- » Subsidiary organs such as the eyes, the nose and the tongue.

We had to decide between adjusting an existing mesh and generating a completely new one using the input. We tested barycentric interpolation to adjust a skin mesh to the underlying anatomy (for more information on barycentric coordinates refer to Hansford [2007]). Then, we implemented our approach which is guided by the underlying anatomy and obtained better results. Our method outputs a surface mesh that can be used as a surface representation for a creature's skin.

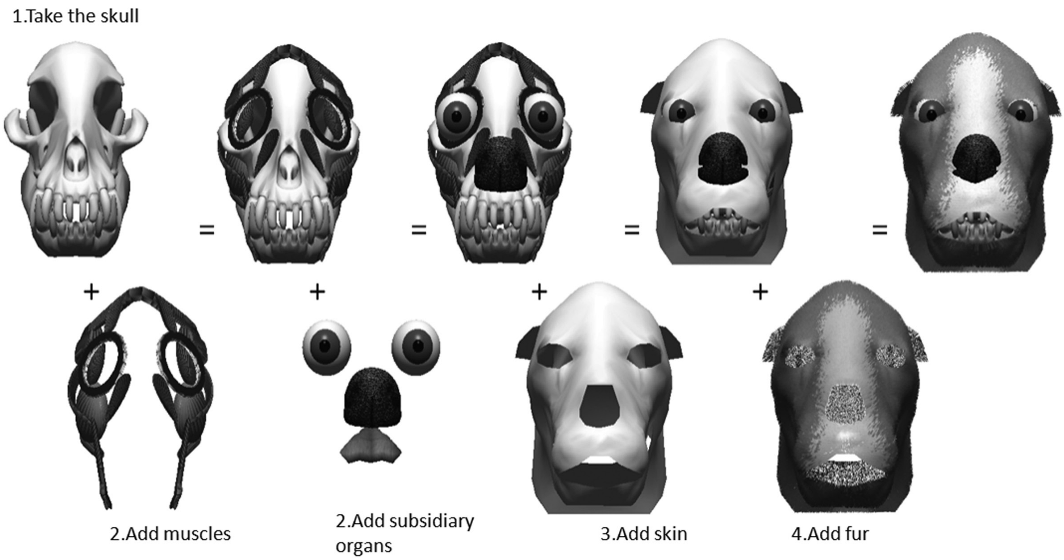

Figure 1. Underlying anatomy provided to the system. Using the skull, the muscles and the subsidiary organs we generate the skin and the fur.

2. Skinning approaches

In typical skinning (Mohr & Gleicher, 2003; James & Twigg, 2005; Kavan, Collins, Z'ara & O'Sullivan, 2007), vertices are weighted with respect to a skeleton. Frequently, a skin mesh is designed in a reference position and is bound to one or more joints. While this technique has been widely used, the addition of more detail relies on including fake anatomically incorrect joints or bones. Also, the technique can produce artefacts. In model reconstruction (Simmons, Wilhelms & Van Gelder, 2002; Kähler, Haber & Seidel, 2003), feature points are used to generate a reference skin mesh. Here, a skin reference model is interpolated using radial basis functions. However, feature points need to be defined interactively and generalised tissue must be used to represent bulks. In voxelization (Wilhelms & Van Gelder, 1997; Karabassi, Papaioannou & Theoharis, 1999), a body hierarchy in rest position is specified. Here, underlying components are voxelized in a 3D grid and an implicit surface for the skin is extracted. The skin is anchored to the nearest underlying component. However, some areas of the surface may not be visible and holes must be covered with generalised tissue. In marching cubes (Lorensen & Cline, 1987; Bourke, 1994), an implicit surface is extracted using lookup tables. It relies on the use of a regular grid. This technique, which uses a 3D grid or voxels, frequently generates more vertices than required and needs space partitioning. In Shrinkwrap (Bottino, Nuij & Overveld, 1996; Van Overveld & Wyvill, 2004), a technique adaptive to the local behaviour of the surface, a sphere shrinks iteratively to the final shape using Newton-Raphson and curvature is adjusted according to the gradient. The approach can be extended to account for topological changes. However, including topological changes requires reconnection; identification of type of change; and the curvature parameter for the adaptation has to be defined by the user. In active contours (Morse, Liu, Yoo & Subramanian, 2005) an initial estimate of the shape is adapted iteratively using radial basis functions and adapts naturally to complex surfaces. However, most of the work on adaptive contours has been done in 2D. Shrinkwrap could be considered an extension of the same idea to 3D. Both approaches rely on iterative processes that converge only under certain conditions and may affect the distribution of large and small triangles.

3. Skin Interpolation

We could use a big pre-existing reference shape (Figure 2A). Then, we could define feature points that would be used to fit the skin mesh to the underlying anatomy (Figure 2B). Next, we could start shrinking a triangulation of the characteristic points inspired in the idea by Bottino, Nuij and Overveld (1996); van Overveld and Wyvill (2004). However, shrinking a mesh that already has the desired topology should be simpler than shrinking a sphere that has to be adapted to the underlying topology. The idea is that every feature point in the facial mesh would have a counterpart in the

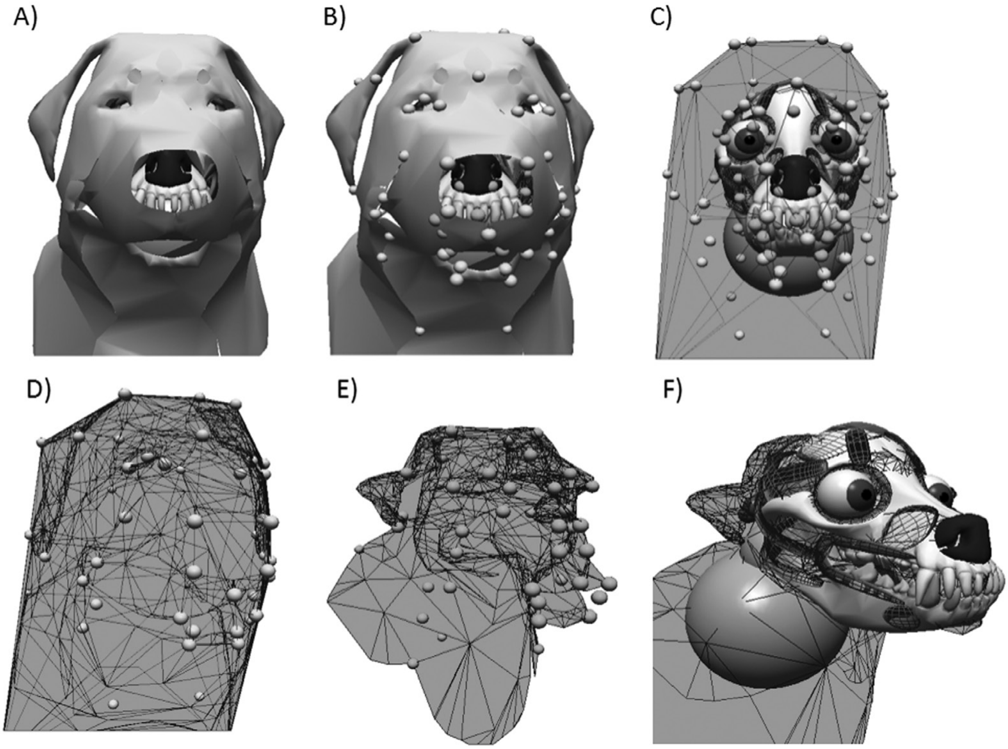

Figure 2. Skin interpolation. A) A big mesh inscribes the underlying anatomy. B) Feature points in the facial mesh. C) Blue points are counterparts of yellow feature points. D) Triangulation of feature points in the facial mesh. Remaining vertices are interpolated with barycentric coordinates. E) Facial mesh shrunk to make feature points coincide with their counterparts. Remaining vertices are interpolated with barycentric coordinates. F) Interpolated skin.

underlying layers (Figure 2C). This way, the feature points in the facial mesh would be interpolated to their counterparts and the remaining vertices would be adjusted through their barycentric coordinates (Figures 2D and 2E). Figure 2F shows the final result using this idea. The result looks promising but the fitting is not perfect. This approach has limitations such as:

- Better fitting requires the definition of more feature points and their counterparts. The interactive definition of these is tedious especially in the skin mesh
- If the skin mesh does not belong to the skull used (they were obtained from different sources), fitting becomes unnatural.
- This approach is not anatomically correct. We did not want to rely on a pre-

existing facial mesh. Instead, we decided to generate it. Moreover, we found that the semi automatic generation of feature points from the underlying anatomy was feasible. For instance, we decided to follow the bottom up approach explained next.

4. Bottom up generation of the skin

Bottom up skin generation was a major challenge. We simplified the problem and took advantage of the creature's symmetry as follows:

» Using the underlying anatomy (Figure 3A), we generate feature points on one side of the head semi-automatically (see section 4.2).

» Then, we project the feature points on a mirror plane which cuts the head in the middle. As the points representing the ear can cause topological distortions only the root of the ear is projected.

» Once on the plane, using 2D Delaunay (Cheng, Dey & Ramos, 2007) we triangulate the points (Figure 3B).

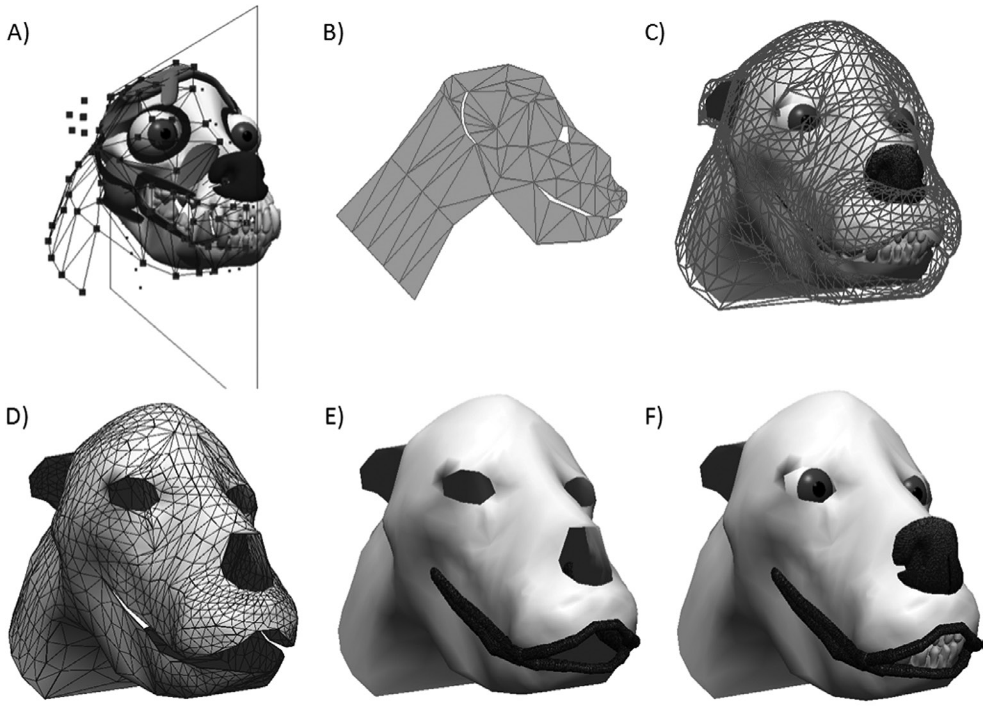

Figure 3. Skin generation. A) Feature point generation. B) 2D triangulation. C) Inflating the skin. D) Deflating the skin. E) Skin with lips. F) Underlying anatomy and the skin.

- To agree with the desired topology, resulting triangles are filtered using pre-programmed topological anatomical restrictions such as: more than two points belonging to a region with a hole cannot be connected in the same triangle (e.g. nose, ear root, and eye); points from the lower neck cannot connect with points not belonging to the neck.
- Once the one side of the mesh is generated, we mirror and smooth it with subdivision surfaces to obtain a skin mesh. At this stage, the underlying anatomy overlaps this mesh.
- Inspired by Bottino, Nuij and Overveld (1996) and by the way a warm towel is put on our face when we go to the barber, the skin mesh is inflated in the direction of the normal of each vertex so that every part of the underlying anatomy is inside it (Figure 3C). Then, the 'warm towel' algorithm starts deflating iteratively the skin mesh in direction opposite to each vertex normal. Deflation stops when all skin vertices are within some threshold of the underlying anatomy (Figure 3D).

4.1. Lips

In human models lips have to be shaped and coloured. For example, Kähler, Haber & Seidel (2003) determine the thickness of the lips by examining the upper and lower frontal teeth. Tarini, Yamauchi, Haber and Seidel (2002) identify the lip in a scanned facial mesh region and colour it. Breton, Bouville and Pel'e (2001) implements lips made of a single separate mesh which is moved by muscles. Lips convey the most information during speech (King, 2001). King (2001) introduces a separate and highly deformable lips models. He uses a B-spline surface which allows specifying most useful position and shapes. His model includes an advanced lighting model. In creatures, lips can be seen as an extension of the skin and are speechless. In some creatures, lips are firmer than in others. In our model, we generate lips from the skin´s mesh (Figure 3E). Using the 3D parametric line equation we generate textured spheres along the lines between boundary vertices in the mouth (lip region). We use different radii along different boundary regions of the mouth. For example, the lateral lower lips are thicker than the frontal upper lips. Figure 3F shows the skin generated covering the underlying anatomy.

4.2. About feature point generation

We state that our feature point generation is semi-automatic because it was programmed with our anatomical knowledge. However, once programmed, feature point generation is automatic. The points can be generated as follows:

- At a threshold along the path of some muscles.
- Sometimes, finding the leftmost, rightmost, lowest and upper most vertex of some muscle or bone and adding a threshold.

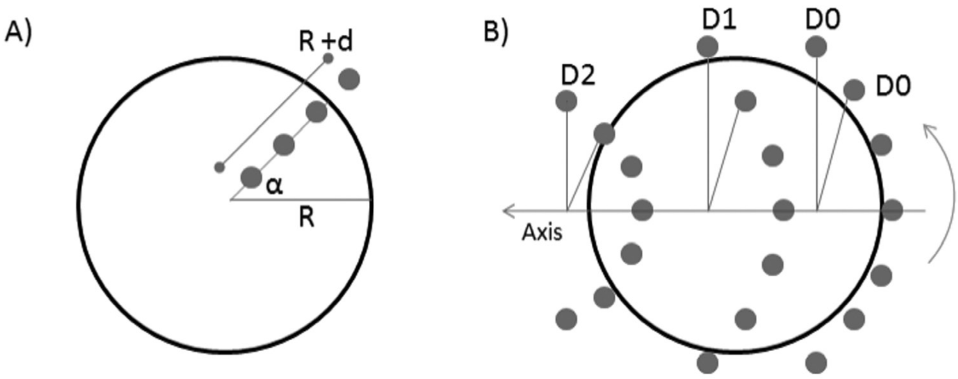

Figure 4. Feature points generation. A) Generating feature points at a distance R + d from the centre of a sphere at an angle α. R is the radius of the sphere. B) Generating points along the main axis of a sphere. D0 ≠D1 ≠D2 are distances from the main axis.

- Mirroring half of the points.
- For points around the nose, we detected the nose's boundary
- For the eyelids, we generate points around the centre of the spheres representing the eyeball at a distance slightly greater than the radius, using an inclination angle (α) (Figure 4A).
- For neck and ears we generate points along the main axis of the spheres used as markers. The radii (D0,D1,D2) are defined accordingly (Figure 4B). Cropped ears are simpler to generate. However, the idea can be extended by using more spheres as underlying ear markers.
- Some other points are obtained from displacements of others calculated with the above methods.

4.3. Thickness

We do not use a multi-layered skin. Thickness is related to the radii of the spheres used for the approximation with spheres and to the distance of the control points to the underlying layers. Additionally, the visible thickness of the skin is modelled with lips along the boundary vertices in the mouth.

5. Adding fur

Papaioannou (2002) uses multiple layers of concentric textures. This approach simplifies volume texture techniques to texture slices parallel to the surface. The

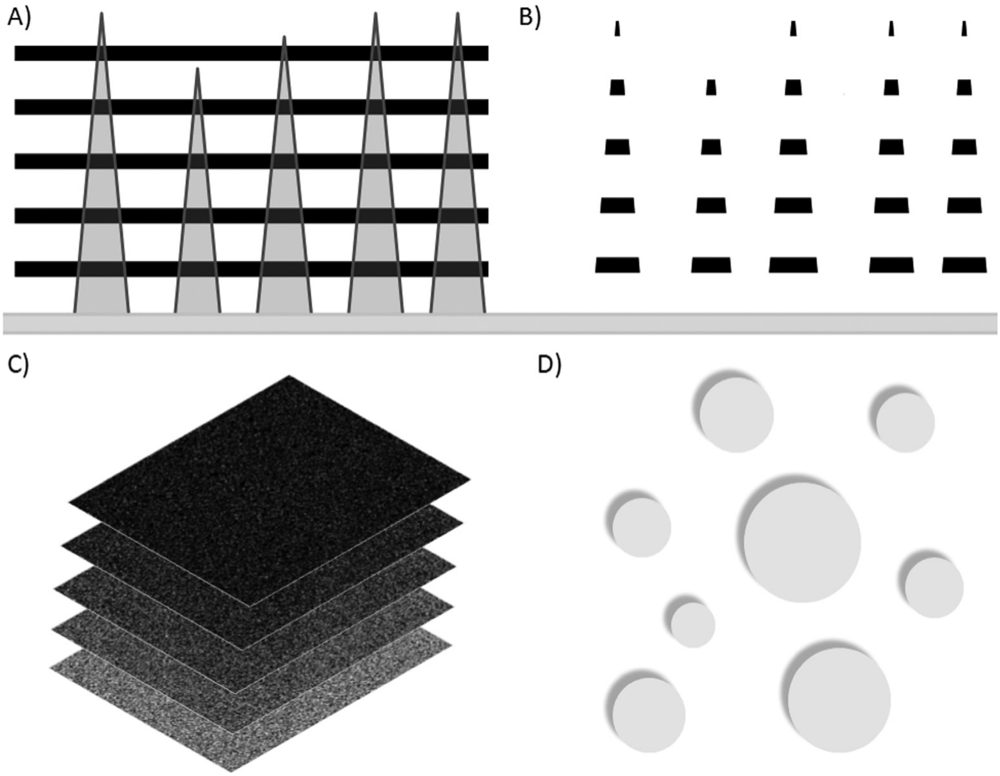

Figure 5. Fur Approximation. A) Fur model. B) Parallel displaced layers approximating fur. C) Opacity maps. D) Shadow approximation.

effect of volumetric fur is achieved by stacking one surface above the other (Figures 5A and 5B). Here, each fur layer, which is a displaced version of the previous one, is textured and mapped with an opacity map where high intensity pixels correspond to fur locations. Opacity maps are produced by thresholding. Here, maps further from the skin use a lower threshold (Figure 5C). For instance, fewer pixels pass the threshold near the tip of the hair creating the effect of a hair thinning. Hair over skin and hair over hair shadows are approximated by generating and displaying a displacement on the layer's texture map (Figure 5D).

Usually, the new layer of fur is obtained by displacing in the direction of the normal (Figures 5A and 5B). However, it is possible to displace in a slightly different direction to obtain a different fur orientation (Figure 6C). Fur length can also be changed (Figure 6D). The fewer layers the less resolution (Figure 6E). Figure 6B shows a complete creature with fur. Figure 6A shows the skin mesh using different textures.

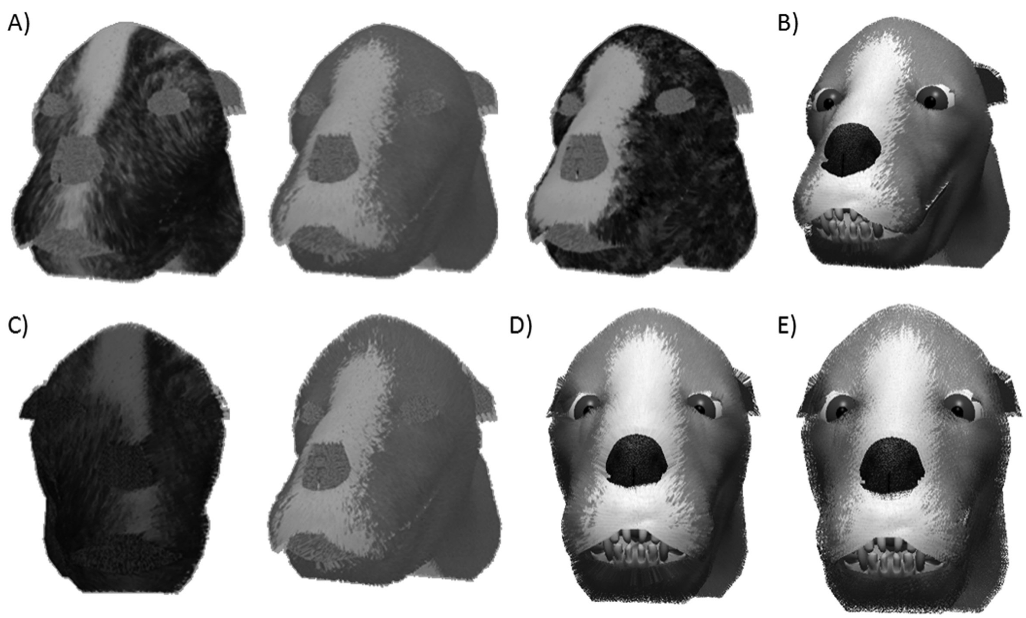

Figure 6. Londra's fur. A) Different texture maps. B) A complete creature. C) Fur orientation. D) Longer fur. E) Longer fur, fewer layers.

6. Model use in animation

Character animation involves building models from captured data and physical knowledge of the character. The first stage is model design. Here, the static model may be captured (e.g. from a range scan) or user specified (e.g. using a commercial model building package). However, captured models have to be further enhanced with different techniques and working on a 2D computer screen to create 3D characters requires expertise (Collins & Hilton, 2001). The process of manual shape construction can be time consuming. From interviews to three expert 3D artists, we found that the design of character can take from half day to a few months depending on the complexity of the character (Lazaro, 2011; Nicacio, 2011; Balciunas, 2011). Usually, artists gain understanding of the character's shape by drawing preliminary sketches (Lazaro, 2011).

When a skilled artist is ready to create the 3D model a skin mesh can be built in as little as one hour (Williamson, 2008; Ward, 2010). However, our model has the advantage that the underlying anatomy can be further used to control the animation (Navarro Newball, 2010). Our method does not require the artist to deduce the anatomy from a sketch. Instead, it generates the skin from a proposed anatomy. Thus, it saves time by giving the possibility to try several different anatomical configurations. It does not require an approximated rig, but uses the underlying muscles and bones as a more anatomically accurate animation rig. Moreover, the skin mesh in our model is generated almost instantly, given that the underlying anatomy is well defined. Deciding the parts of the anatomy that will generate feature points and placing the muscles takes between half to a couple of hours.

7. Discussion

Feature point generation and automatic facial mesh generation rely on the anatomical knowledge provided to the algorithm. Still, it is much easier than manual editing. One of the reasons for automatic point generation was that interactively placed feature points did not provide enough detail to make a good barycentric interpolation. Anatomical topology is implicit in the triangulation. Instead of using integration, we fix curvature by inflating and deflating at some step size. The existence of more feature points eliminated the need for interpolation of a pre-existing mesh. As a consequence, a new and more anatomically consistent mesh was generated. We believe the mesh is more consistent because it was produced from the underlying anatomy and used more points. In contrast, the pre-existing facial mesh did not belong to the original skull.

Our thickness approach simplifies the skin model. It can be enhanced by adding volume and more layers to the skin mesh.

Our skinning method relies on the underlying anatomy. When there was no anatomy in the model we decided to use an underlying and anatomically incorrect spherical skeleton. However, we believe that including the underlying cartilage for the ears and the bones and muscles for the neck can solve this problem and produce a more accurate model.

The conformational parameter for our skin generation method include: underlying feature points; topological restrictions (e.g. mouth hole), α orientation of eyelids, Lips' spheres radii and threshold skin-underlying anatomy.

The addition of fur layers enhanced Londra's look. However, it does not constitute an innovation. It is a simple method to achieve a decent level of realism and is not adequate for very close examination. It is mainly based on texture rendering and does not include fur geometry or dynamics. The use of several layers helped simulating fur strands from bottom to top and the effects of the animal undercoat and overcoat. Londra's fur contains three simple parameters: orientation, length and number of layers. Here, the more resolution desired, the more layers required. Further work could involve research on patterned fur generation which includes fur geometry and specialised illumination models.

Further work of automating muscle placement, skull reshaping and the creation of an animation plug in can make modelling more efficient. Our model requires more anatomical knowledge of the creature than artistic skills in order to generate a skin mesh. This knowledge is necessary in character animation anyway.

We believe the techniques proposed can be applied to the whole body of a creature. S&T

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