

Introduction

Animation has long been used to visualise concepts that are impossible to realise in real-life, and one such concept is that of morphing. In computer animation, the most frequently used method to transform a model from one form to another is to use blend-shapes. By taking a base mesh, and then duplicating it and moving around the vertices of the copy to create a new shape, it is possible to interpolate between the two shapes. This gives the impression that one mesh is morphing into another.

There is a problem with using blend-shapes to morph a character: The number and ordering of vertices needs to be identical in every shape. This means that if a very simple shape is going to morph into a more complicated one, then all the extra vertices needed to describe the details in the second mesh must be present in the first mesh, even though they have no purpose. This is not always a problem, but if you needed to animate, for example, spikes growing out of a character's skin, then blend-shapes may not be practical. The mesh would have to contain all the detail needed to describe the spikes, which would probably mean that there will be rings of vertices wherever a spike is due to appear. When a modeller makes a model of a character, it is standard practice to arrange the vertices so that edges create clean, flowing lines that describe the form and will deform in a predictable manner when animating. Having excess detail may make the mesh unusable to an animator.

Aims

I intend to produce a short animation in which a character morphs between a series of forms. I will choose forms which I believe would be impractical to morph into using blend-shapes. Instead I will look at using displacement maps that change over time to achieve the change in form. I will also look at creating animated colour textures to further aid the transition.

A displacement map is a greyscale image that is mapped to a mesh as a texture. It works similarly to a bump map in that light coloured areas of the texture make the area of the geometry it is mapped to be displaced away from the surface, while the dark areas cause the geometry to be displaced inwards. The difference between a bump map and a displacement map is that a bump map only changes the surface normals to make it appear that the geometry is displaced. A bump map cannot affect the profile of a surface. A displacement map actually changes the geometry so even the profile will be changed. A displacement map has the potential to create much greater changes to the mesh, but can produce a very dense piece of geometry which will lengthen render times much more than a bump map.

Research

My research into animated displacement maps turned up very little at first. I searched for academic papers on the library databases and looked through SIGGRAPH conference proceedings but found nothing that would help me with what I wanted to do. I couldn't be sure whether using animated displacement maps was so simple and commonplace that there was no reason for papers to be written on the subject, or because the techniques had not been used much and I was exploring new territory.

I started searching the internet for animated displacement maps and found a handful of results, but not as many as I would have expected if their use was common among CG artists. Examples of uses I found were using them to create the ripples on the surface of water, animating the billowing of a mushroom cloud, and flexing of muscles on a characters abdomen.

The most significant work my research turned up was that of Timor 'Taron' Baysal, a CG artist who has become well-known in the CG community for his use of animated displacement maps. He has produced several short animations to showcase the techniques he has developed, and he works to promote the software that has made it possible for him. I came across his work while searching CG forums on the internet where he has posted much of his work. In November 2004 he posted 'Frames of a Neckling' which created a lot of excitement among the other artists who populate the forum. It seemed that the work he was doing was different from anything that these people had seen before.

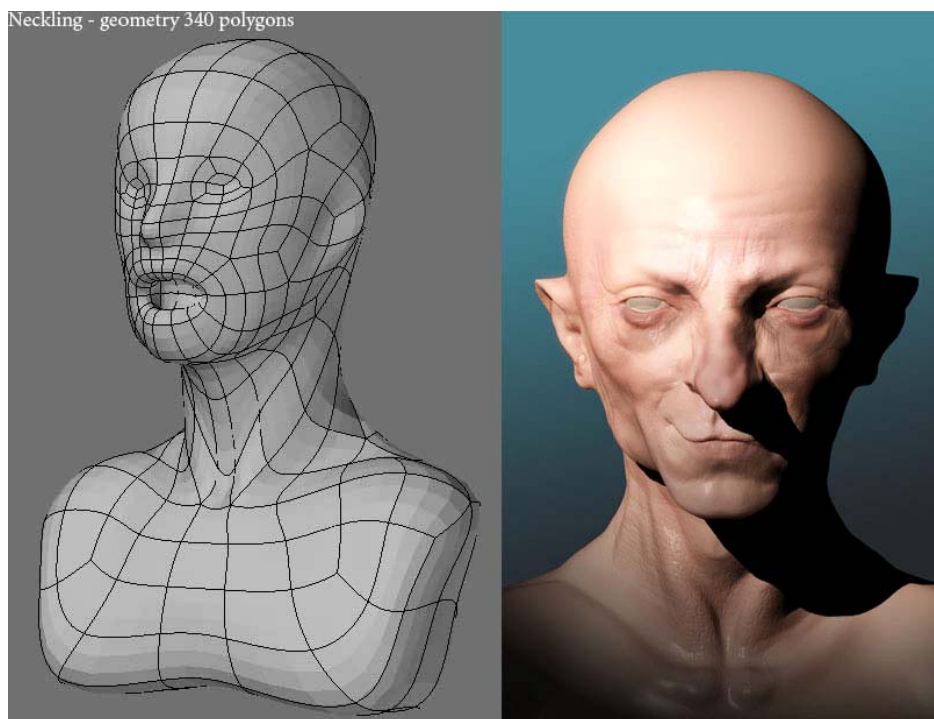


Figure 1: 'Neckling' by Taron

The image on the right is produced by applying a displacement map to the geometry on the left.

In works such as 'Neckling' the viewer is shown a very detailed head model. The head displays a variety of facial expressions, and as the face moves, the details in the face such as creases around the mouth and brow react in a realistic fashion. To achieve this level of detail using modelled geometry would require an incredibly detailed base mesh and a range of just as detailed blend-shapes to accompany it. This work becomes truly amazing when the viewer learns that the model of the character bust is made of a mere 340 polygons. All of the details from the shape of the ears to the creases on his forehead are achieved using displacement maps. The base mesh is animated using blend-shapes for the large movements such as the opening and closing of the mouth and turning of the

head, but all the smaller movements such as furrowing of the brow are done by blending between different displacement maps.

He has realised the enormous potential of his techniques, and has taken it further in works such as 'Neckling Change' in which the Neckling character morphs into a very different creature, and 'People' in which the human character continually changes into different people, changing both race and gender as it does so.



Figure 2: 'Neckling Changing' by Taron
This morph is achieved by blending between displacement maps.

I contacted Taron to ask him how long the techniques he used have been possible. He told me that he had been using animated displacement maps for more than 5 years, but it had become much simpler, due to recent software that he has started to use. The software he referred to was Pixologic ZBrush and pmG messiah:Studio. ZBrush is a revolutionary piece of software that allows the user to sculpt meshes with very high polygon counts. It can then export a displacement map that will transform a very simple mesh into the highly detailed one when the map is applied to the simple mesh in a 3D package such as Maya. Taron uses ZBrush to create his displacement maps and then uses messiah:Studio to animate and render the scene. Messiah:Studio is a 3D package that has support for animated displacement maps built into it. Unfortunately I am only able to use Alias Maya, but in Maya it is possible to use an image sequence as a displacement map, so it will still be possible for me to use animated maps, although probably not as easily as with the software Taron uses.

One thing I noticed from my research is that animated displacement maps seem to be used primarily to add realism to the work. Bearing this in mind, I intend to differentiate my

work from that I have looked at by using them to add fantastical elements to the work instead.

Approach

To begin with, I needed a character model to use as a basis for the morphs. Ideally I would have liked to have made one specifically for this project but due to time constraints this was never going to be practical. The character I decided to use is the Generi character by Andrew Silke. It's a simple cartoon character that is fully set-up for animation, and the creator has given permission for its use for non-commercial work.

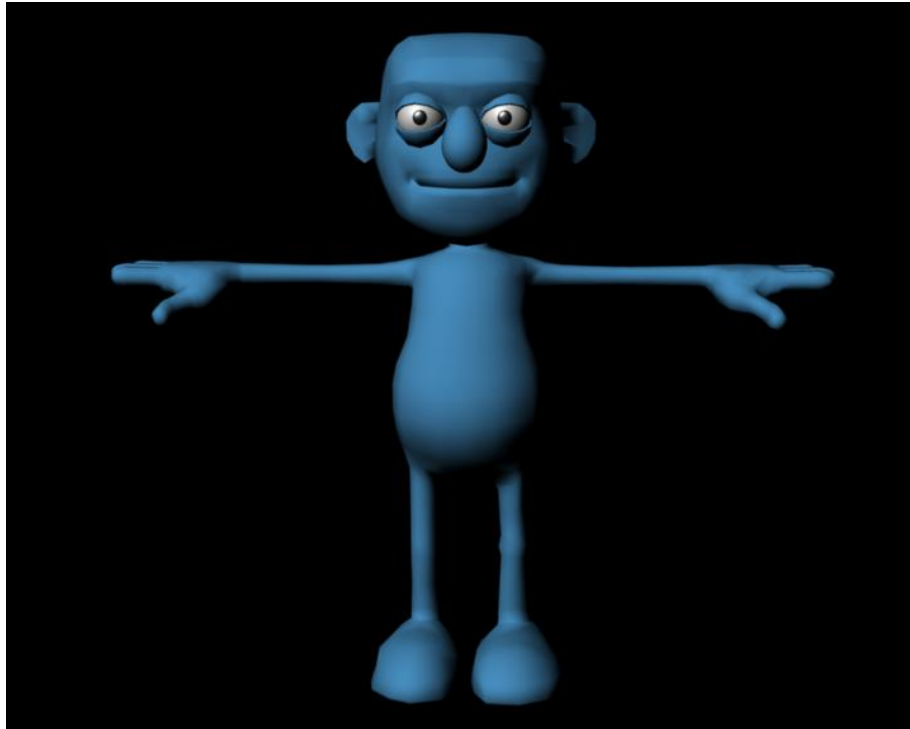


Figure 3: Generi
The Generi character by Andrew Silke.

The Generi character satisfied a number of criteria that I set myself when I looked for a suitable model. It has a low-polygon mesh, which will better illustrate one of the greatest advantages of displacement maps in that they can transform a very low-polygon model into one that looks incredibly detailed. It also has very little detail on it which provides me with a blank canvas to work on for the morph. It is fully set-up for animation, which not only meant that I could animate the character as it was morphing but it would illustrate another advantage as the morph could be applied after it had been set-up for animation or even after it had been animated. The Generi character has been used a lot by animators, especially for '10 Second Club' animations, and as a result many people will be familiar with it. I saw this as advantage because it will have more of an impact when the viewer sees the character transform into something else.

When I first started working with the Generi model I discovered that its UV texture coordinates had not been mapped. The model usually just has a blue shader applied to it, and so did not need the UV's to be mapped, but to apply texture maps for the morph (both colour and displacement) I would need to map them. After mapping the UV's I found that

when I moved a joint on the model, the UV coordinates would change positions in a seemingly random fashion. After asking a fellow student I was told this was because the geometry had already been skinned, and that a model needs to be UV mapped before it is skinned to avoid this. At this point it seemed like I would have to lose the fully set-up model and create maps for a duplicated version of the geometry that had not been rigged. This would have been a shame because I would have to set-up the character for animation again once I had mapped the UV's. Luckily I found a simple solution to this problem by mapping the UV's of a duplicated version of the character, and then transferring the UV set back to the original model.

With the character prepared for texturing, I started experimenting with displacement maps. I applied a simple procedural noise texture to the mesh as a displacement map so that I could adjust the controls to suitable settings for what I wanted to do. This was important because displacement maps are difficult to set up properly, and later on I would need to know whether the settings were causing problems or the textures themselves.

There are several reasons why displacement maps are difficult to set-up. Firstly, there are a number of settings that must be adjusted for the map to work correctly. The main one I had to adjust was the alpha gain of the displacement map which controlled the degree that the geometry was displaced to. The higher the alpha gain, the larger the displacement, which led to the character appearing swollen up if it was set too high. I had always thought that black areas on a displacement map would be displaced inwards, but I discovered that in Maya at least, black is interpreted as no displacement and anything lighter will be displaced outwards.



Figure 4: Early displacement test

In an early test, the character becomes bloated due to the alpha gain of the displacement being set too high.

Although it took a long time to find the right setting, I noted at this point that keying the alpha gain would be a good method of deliberately swelling the character. The other setting that needed tweaking was the sample rate, which controlled the precision of the

displacement. A higher sample rate meant that the displacement was accurate enough to show all the small details in the map, but also that the scene would take longer to render.

I found that when I rendered out a frame, there were strange creases in the surface of the mesh (see Figures 4 and 5). I was not able to find out what was causing this exactly, but I believe it may have been something to do with the tessellation of the surface at render-time. I found that sub-dividing the mesh removed these creases, although the cost was an increase in render times. Although I do not remember the source, I remember reading somewhere that displacement maps work better with subdivision surfaces than with polygon surfaces. Perhaps these creases were one of the reasons why polygons are not ideal.

Another problem with displacement maps is that you cannot view them in Maya's preview window, meaning that you must render a frame to see what effect the map has on the model. This slowed down the process when I had to repeatedly tweak settings and render the frames to set up the textures correctly. This was not helped by the fact that render times are greatly increased by the displacement maps, as new geometry is added to the scene.

After setting up the noise texture as a displacement map, I set key frames so that the displacement would increase over time, starting with no displacement at all. I also keyed the colour of the shader so that it changed from blue to green over time. I then rendered out this sequence over a length of 50 frames. At this early stage in the project I had achieved a very simple character morph using animated displacement maps. I was confident that what I wanted to do could be achieved to at least a basic level, and from now on I would be working towards creating a more challenging and aesthetically interesting morph.

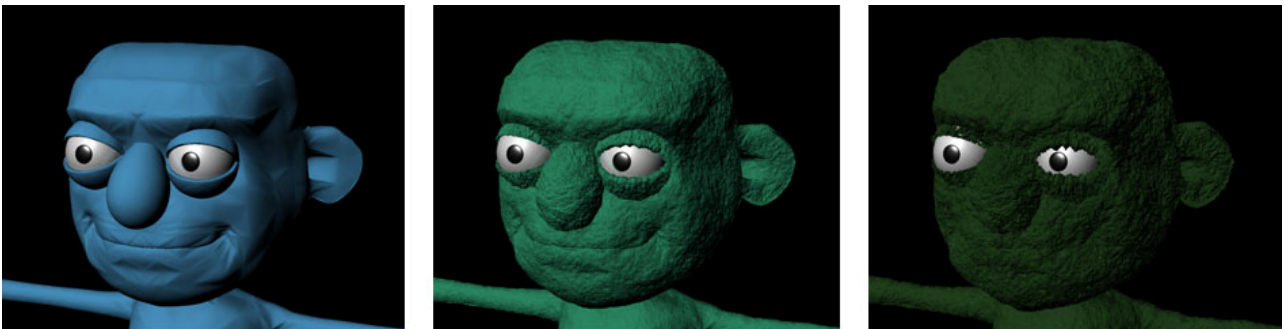


Figure 5: Animated displacement test

This test used a procedural noise texture as a displacement map. Note the artefacts on the skin in the image on the left. This was not present when the mesh was sub-divided.

Spike Morph

I needed to decide what I wanted the Generi character to morph into. It needed to be difficult to achieve using blend-shapes, but relatively simple to do with displacement maps. I decided to have Generi growing spikes out of his skin. Although it wouldn't be changing the geometry to any large degree, the spikes would greatly alter the apparent personality of the character, especially if combined with an appropriate animated colour texture. The two main problems I had were working out what was the best way to make the displacement look like spikes, and how to position them. I didn't think it would look good if

the spikes totally covered the characters body, and I suspected the spikes could behave strangely if they were positioned upon a seam in the texture.

I experimented with various methods of making the spikes using Photoshop, but the method I found worked best was selecting a small circular selection and filling it with a radial gradient from black on the outside to white in the middle. I then duplicated the circular selection many times and positioned each one where I wanted, using a UV snapshot of the model taken from Maya as a reference for where each part of the body lay on the texture. I used black as the base colour of the map. Many displacement maps use a mid-grey as the base colour which causes the model to become bloated when the alpha gain is increased. Using black, increasing the alpha gain only increases the length of the spikes, leaving the rest of the body where it is.

I ran Photoshop and Maya at the same time so that I could position the spikes on the 2D texture and then save it and do a render in Maya to see if the spikes were where I wanted them. This took quite a while but eventually I was happy with the placement. I wanted some of the spikes such as the ones on his chin and nose to be shorter, so I painted over them with black at 50% opacity to make them be displaced less.

I rendered out a turntable of the character with the displacement map applied, and the spikes looked like they were part of the geometry like I'd hoped. I also rendered out a sequence over 150 frames in which I key framed the alpha gain of the displacement map increasing from 0, and the spikes appeared to grow out of the character's skin as I'd hoped. I found that 150 frames was a good compromise between having enough time to see what was happening with the morph, and the time taken to render the sequence out.



Figure 6: Unfinished Spiky Generi
More spikes were later added on the back and around the face.

I thought it would be appropriate to have the version of Generi with spikes to be a red colour, and for him to change from his usual blue to red as he grows the spikes. This could be easily achieved simply by key-framing the colour of the shader, but I didn't want a linear transition. Instead I had the idea that small blobs of red could appear on his blue skin, which grow until they eventually cover the entire surface. I experimented with Shake, taking an image of some black blobs on a white background and keying blur, contrast and brightness nodes to make the blobs grow and shrink. The blur node changes the crisp edge between the black and white coloured areas into a gradient. This means that between the black and white is a range of tones of grey. Increasing the contrast pushes the lighter tones towards white, and the darker tones towards black. The brightness node can be used as a control. When it is set higher, more of the grey tones are pushed towards white by the contrast node, and when the brightness is at a low setting, more of the grey tones are pushed towards black. Therefore, by keying the brightness so that it decreases over time, the blobs of black appear to grow.

I then used this as a mask for a red texture that was layered over a blue texture. This created a sequence where the red blobs grow over time until the whole image is red. I also derived a colour texture of the spikes from the displacement map, giving them a bone colour. I keyed this so that the colour of the spikes would appear at around frame 50, the same time that the spike became visible on the displacement map. I then rendered out this image sequence and applied it as the colour of the shader.

I also made the colour of his eyes change from white to yellow over the course of the 150 frames. I felt that for this colour change a linear transition was adequate and so I simply keyed the colour of the shader.



Figure 7: Spiky Generi Morph
Stills from the finished morph sequence.

Rock Morph

I still wanted to see if I could take the technique further, and I had time to produce another morph. I recalled how the character became bloated when the alpha gain was set too high and I thought it would be interesting if I could use this to significantly increase the bulk of the character. I still needed to make a morph that would be impractical to do with blend-shapes, so I came up with the idea of morphing Generi into a large creature made of rock, with glowing cracks in the surface which looked like there was molten rock inside him. The

bulkiness could be achieved by increasing the alpha gain, and the complexity of the cracks would make it difficult to achieve without using displacement maps.

I applied a new colour texture to the model in Maya, and used the 3D paint tool to paint cracks all over his body. I then loaded the texture up in Photoshop and started making the displacement maps. As the cracks would have to be darker than most of the surface, I used a mid-grey as a base colour and on top of that I painted in white what would be rocky bumps when displaced. I layered the dark cracks over the top of this, so they would remain lower than any other part of the body. When I did a test render I found that the surface was too smooth so I added a bump map made from a stone texture. Using a bump map for the tiny details in the surface was better than including them in the displacement map because the sample rate would have to be very high for such small details to be displaced, and this would have greatly increased the render time.



Figure 8: Unfinished Rock Monster Geneti
Some of the cracks were later removed, especially on the face.

For the colour map I simply used a photograph of a rock surface. I used the same technique as the other morph to create the non-linear transition between the blue skin and the stone texture. To create the glowing cracks I used an incandescence map as it would look like it was giving off light due to the intense heat. As it was a separate texture I could also key it separately from the colour map which was an advantage because I wanted the glow to appear after he had finished changing colour. The incandescence map was created from the same crack texture that I had used on the displacement map, I simply used Photoshop to change the colour from black on a white background to yellow on a black background.



Figure 9: Finished Rock Monster Generi Morph
Stills from the finished morph sequence.

Appraisal

I feel that the targets I set myself were reached, although I would have liked to have created more forms for Generi to morph into, as well as try and make the two morphs I do have better. I think the spike morph works well, but there are a few things I would have liked to change. The most important is how the change in colour occurs. I still feel that a non-linear transition works better than a linear one, but I was unable to devise a good way to make this change occur. The technique I used worked, but not particularly well. After a certain point in the sequence the areas that have already changed colour cease to expand and instead the whole of the rest of the mesh fades into the new colour. I do not think I could have improved upon this using the technique I was using.

Also when the expanding areas of red reach a texture seam, they stop, making the seam visible. This is not obvious in the sequence I rendered out, as most of the seams are on the back, but it is visible on the left hand and ear. Also it would look better if the circles on the colour map that represent the spikes grew larger when they appear, rather than simply fade in. These circles are also slightly too small causing the lower part of the spikes to be coloured red, but I think this actually looks quite good.

The timing of the colour change and the spikes growing is not exactly how I would like it to be, but it would take a long time to fix as changes to the colour map would have to be rendered out of Shake and then the entire sequence rendered out in Maya just so any changes can be viewed. Rendering the sequence took around half-an-hour which is not unreasonable, but I still would have required more time to get the timing how I would have liked.

The rock morph was probably more successful in transforming the Generi character into something new, but there are still many problems with it. The bloating effect obviously caused parts of the body to be larger than they were designed to be, which meant that the geometry overlaps in some areas. The fingers are too close to each other, the mouth will close when the lips become bloated, and the shoulders are now situated within the torso. This may cause problems if the character was animated, but I did not have time to test it. I found that simply displacing the entire surface of a character is not the best way to increase its bulk, as it cannot be controlled as easily as by using blend-shapes. I feel that the character in the rock form looks very crude and could have benefited from being

sculpted in ZBrush There are also the same problems with the colour transition and timing as there was with the other morph.

Conclusion

Using animated displacement maps was fairly simple to set up, but difficult to use effectively. I still feel that animated displacement maps are a good way of morphing a character, but I did find some limitations to them. They are not ideal for large changes in the shape of the subject, as the new form cannot be viewed without rendering the scene and can cause problems if used to make the character change size. They were the best way to achieve the spikes on the first morph, and the cracks and bumps on the second, but these are relatively small details.

If I was to continue working on this project there are several areas that I would look into. I would try and combine the use of blend-shapes and displacement maps, as I believe that this would be the best way to create vast changes in the form of the character. The blend-shapes would be the best way to make large changes in the form of the character, such as the position of the limbs and mouth. The displacement maps would be the best to create the smaller, more complicated details such as bumps, spikes, wrinkles and cracks.

I would try to use procedural textures to change the colour of the character rather than use my current technique. I did not touch upon procedural methods in the project already because it is not a subject I know much about, but I believe it would allow me to start the colour change in one area and let it spread to the rest of the body. I would also need to find a way of not revealing the texture seams.

I would like to animate the characters during the morph; this would be easy to do as the textures were applied to an animation-ready version of the Generi character. The only reason I did not animate the characters for this projects was due to time constraints.

I would learn to use ZBrush to create much more accurate and detailed displacement maps than is possible for me painting them in 2D. I could also use it to paint the accompanying colour maps. ZBrush is becoming more and more popular with CG companies, and because of this I expect that more people will want to try and animate the displacement maps outputted from ZBrush. Currently it is possible to do this in 3D packages such as Maya, but as I found out it is not particularly easy. Perhaps there will an increase in popularity of software that has more support for animated displacement maps such as pmG messiah:Studio, or perhaps greater support for animated displacement maps or ZBrush integration will be present in the next version of Maya.

References

Websites last checked 9th March 2006

The Generi character was obtained from:
http://andrewsilke.com/generi_rig/generi_rig.html

Figures 1 &2 belong to Timur 'Taron' Baysal and were taken from his website:
<http://www.taron.de>

The animations 'Neckling', 'Neckling Change', and 'People' mentioned in the research section can also be downloaded from this website.

Information on the techniques used by Taron was taken from the following forum threads:

<http://forums.cgsociety.org/showthread.php?t=187263>

<http://forums.cgsociety.org/showthread.php?t=187770>

<http://forums.cgsociety.org/showthread.php?t=190944>

<http://206.145.80.239/zbc/showthread.php?t=022061>