

Virtual Body Morphing

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We discuss how to morph several different human shape data. The main idea is to create one human body structure from a given human body shape data either from photographs, designer's tool, Laser scanner or Infrared scanner. Then we use a rapid 3D-morphing system by using interpolation and 2D-image metamorphosis based on triangulation where the shared structure is inherited from the generic human. It is an integration of 3D shape and 2D skin information. This system enables a user to control the shape and skin color in a very intuitive way. Automatic texture clothing methods is also introduced with some examples. Here, we described H-Anim body data structure as our desired generic body structure.

1. Introduction

Here we are interested in intuitively controlling 3D-morphing among several virtual human. When we morph one person into another in 3D, we must deal with alteration in both shape and texture. Morphing technology has seen a great deal of development, either in only 2D [8][3] or 3D [7][1]. The main 2D-morphing methods have little been exploited in terms combining it with 3D-shape morphing. Nevertheless, this seems a natural approach to better results with less effort. In this paper, we vary aspects of both 2D and 3D representations in creating new virtual bodies as our previous job for virtual faces [12], showing how easy and fast the smooth morphing can be achieved.

There are various sources to get 3D human data. Most of them provide shape and texture and some of them do also animation structure inside. Homogeneous structure has been an important

topic in computer simulation. When we can convert to one structure from any structure for human shape, the virtual humans become morphable. Then every converted body shares the same topology, and it is relatively easy to vary body shapes in 3D between them just using a simple linear interpolation of 3D coordinates. Then we utilize 3D information to facilitate 2D morphing among texture images following triangle by triangle the entire 3D body. The resulting body manifests very smooth images without any gaps in the textured parts. This approach for two persons turns out to be very easily extended to several people.

2. Previous works

The body morphing methodology is based on two previous works. The first one is body cloning from photographs and the other is conversion of human shape to homogeneous data structure.

2.1. Face and body cloning from photographs

Photographs are one of the easiest and cheapest equipment to get feature points. The features on photographs are very visible most of time even under various circumstances. Our previous works [9][10] show the photo-cloning methods can approximate the person's shape quite well and the texture mapping has a high resolution.

The methodology is composed of two major components: face cloning and body-cloning to a given scanned model by different kinds of generic models. The face-cloning component uses feature point detection on the frontal and side images and then uses DFFD for shape

modification. Next a fully automatic seamless texture mapping is generated for 360° coloring on a 3D polygonal model. The body-cloning component has two steps: (i) feature points specification, which enables automatic silhouette detection in an arbitrary background (ii) two-stage body modification by using feature points and body silhouette respectively. The final integrated human model has photograph-realistic animatable face, hands, feet and body in H-Anim 1.1 format [5].

For our photo-cloning, we use snapshot to take five orthogonal photographs of the face and body parts either from commercial camera or

snapped after loading the scanned model as shown in Figure 2.

2.2. Making H-Anim bodies from various structure

The main idea is a combination of feature-based photo-cloning method and surface-based adaptation method as shown in Figure 1. The result from photo cloning is a good approximation of the 3D input human data. So it is possible that we adapt the cloned body to the 3D input data to remove the error, then the final body has the same shape from the 3D input data while it has the functional skin structure and skeleton for animation. More detailed description can be found in a literature [11].

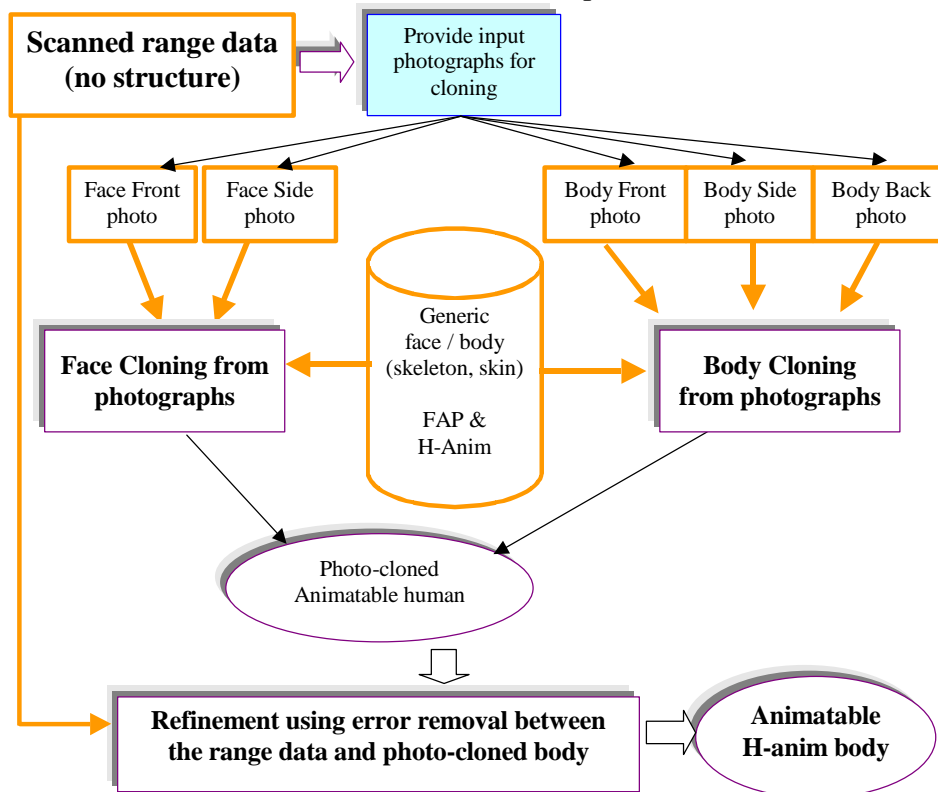


Figure 1: Overview of making H-Anim body cloning from various structured data.

3. Pre-process to make H-Anim bodies

Here we use four virtual humans from four different sources and therefore with four different structures. We pre-process them to get

H-Anim bodies using the methodology described in Section 2.

1. Photo-cloned body using face and body cloning methodology described in Section 2.1. The input photographs are shown in Figure 2.

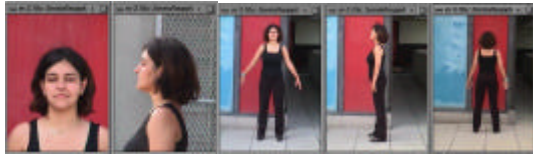


Figure 2: Five photographs as input for face and body cloning system

2. Designed body from commercial product *Curious Labs* Poser 4 [6] as shown in Figure 3.

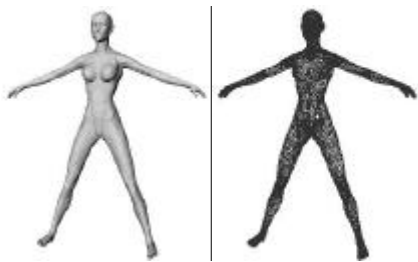


Figure 3: Designer's tool produces a woman's body in 3D. There is no texture data.

3. Laser-scanned body from a free website of *Cyberware* [4] as shown in Figure 4.

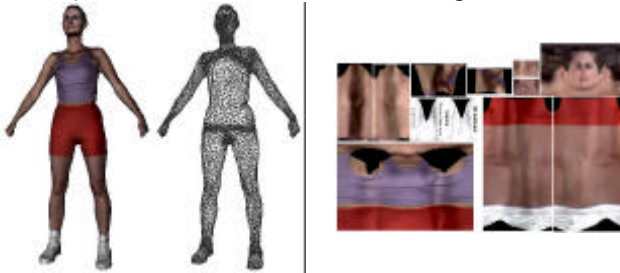


Figure 4: Laser scanner produces a body "Tammy" with many texture images. The data is collected from a free website [4]

4. Infrared-scanned body from *Hamamatsu* as shown in Figure 5.

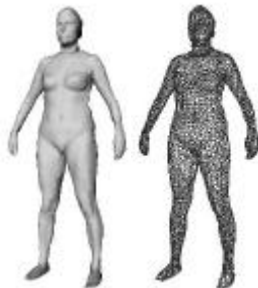


Figure 5: Infrared scanner produces 3D data without texture image.

As we can see from Figure 2, Figure 3, Figure 4 and Figure 5, each source to get 3D data produces different data structure, different number of points and different resolution. Some of them produce texture images and others do not. We use a methodology described in Section 2.2 to create homogeneous data structure with skeleton inside skin. As a homogeneous data format, we use H-Anim [5] format which is a standard for communication purpose.

Figure 6 shows the animatable virtual bodies with the same structure while the texture images used are shown in Figure 7 and Figure 8 for body and face region respectively.

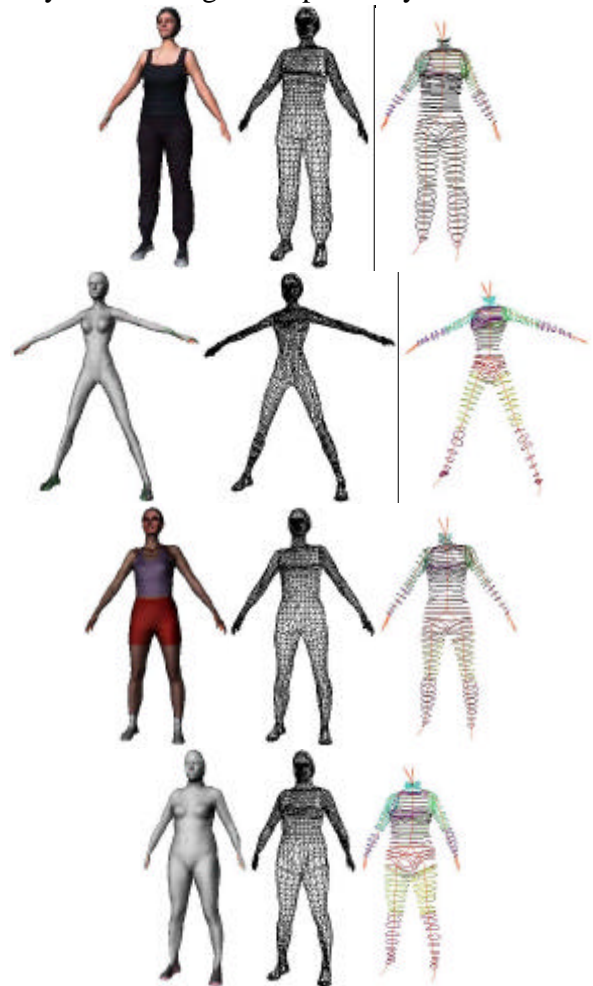


Figure 6: Every body is converted to the animatable homogeneous (H-Anim 1.1) structure.

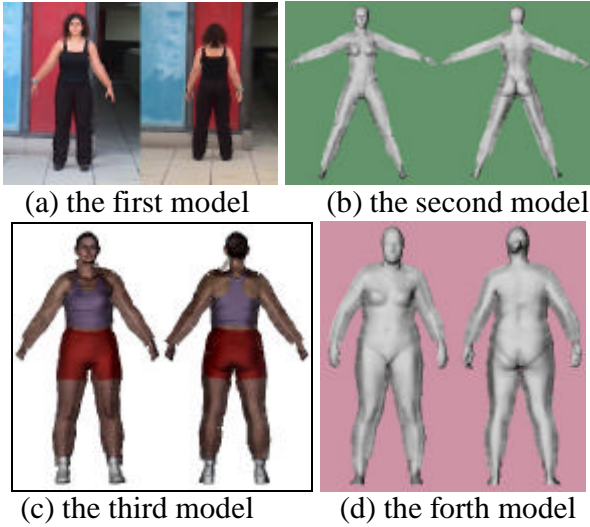


Figure 7: Body texture images created from H-Anim body conversion.



Figure 8: Face texture images created from H-Anim body conversion.

4. 3D Morphing

We explain 3D morphing between two virtual humans, but it is very easily extendable for several virtual humans. When we morph one person to another person in 3D, there are five items needed such as (i) skeleton morphing (ii) skin shape morphing (iii) skin texture coordinate morphing (iv) skin texture image morphing and (v) texture image morphing for extra-triangles on the border between front and back process.

4.1. 3D interpolation in skeleton and skin shape based on the same topology

After the pre-processing described in Section 3, every body shares the same topology and has the same characteristic for skeleton and skin surface coordinates. Then the coordinates of skeleton and skin surface are easily interpolated. An interpolated point P between P_L and P_R is found using a simple linear interpolation in 3D. Since the each sub skin part is connected to certain skeleton joint by 4x4 matrix, it requires an

interpolation between matrixes too. So we use the linear interpolation for each M_L^{ij} and M_R^{ij} of two matrixes M_L and M_R to get M^{ij} of M .

4.2. Texture morphing

Beside shape interpolation, we need two items to obtain intermediate texture mapping. First texture coordinate interpolation is performed and image morphing follows.

4.2.1. 2D interpolation of texture coordinate

It is straightforward as 3D-shape interpolation. An interpolated texture coordinate T between T_L and T_R is found using a simple linear interpolation in 2D.

4.2.2. 2D-image metamorphosis based on triangulation

We morph two images with a given ratio using texture coordinates and the triangular face information of the texture mapping. We first interpolate every 3D vertex of triangles on the two body skin surfaces. Since H-Anim 1.1 format support a body with several skin partition, we have to process the skin parts one by one. Then to generate new intermediate texture image, we morph triangle by triangle for every triangular face on a 3D body. Parts of image, which are used for the texture mapping, are triangulated by projection of triangular faces of 3D bodies since the generic body is a triangular mesh. With this information for triangles, Barycentric coordinate interpolation is employed for image morphing. Three vertexes of each triangle are interpolated and pixel values inside triangles are obtained from interpolation between two pixels in two triangles with the same Barycentric coordinate. To obtain smooth image pixels, bilinear interpolation among four neighboring pixels is processed.

Pixels in the background, which are not covered by triangles, are not calculated to get intermediate values, which creates problems on the border between the front and back views as shown in Figure 9 (a).



Figure 9: 3D morphed body and 2D texture image in two cases; (a) straight morphed texture for ratio (1.0, 0.0, 0.0, 0.0) which is the same as the photo cloned body (b) extra triangulation to remove the problem on the border between the front and back views.

4.3. Extra triangulation on border

There are two items to discuss to understand the texture image generation and texture coordinates. Then we discuss how to solve the texture problems on the border between the frontal and back views.

4.3.1. Number of texture coordinates ³ number of surface points

The number of texture coordinates of the 3D object can be different from the number of surface points. Figure 10 helps to understand the problem and solution.

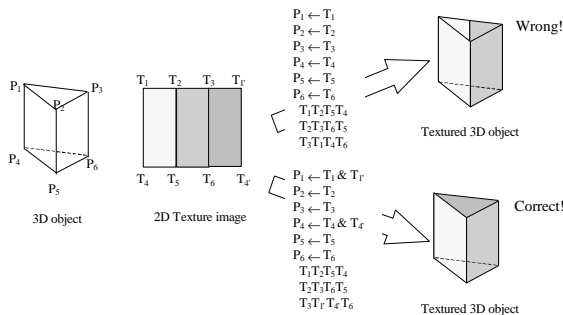


Figure 10: Why we need more texture coordinates than the surface point number?

When we assign only one texture coordinate for each point on the 3D surface, we may have problem in a certain region of the 3D object. To prevent this problem, we assign two coordinates for some points on the surface and give the polygon information using the texture coordinates, not using the point coordinate. For

the 3D-body model, we assign two texture coordinates on the border between the frontal and back views of the body.

4.3.2. Texture image generation with extension on the border

The body texture images in Figure 7 are generated from the frontal and back views. Since there are two images used, we have to make a partition of the skin envelope polygons, either to the frontal view or to the back view by checking the cross product of the vertex normal with the viewing vector. To get the texture coordinates we use a projection onto the XY plane in the image space. The process is as follows.

1. Get (or deform) the body with the back and side views;
2. Project back/frontal+back viewpoints onto the back view image plane to get the texture coordinates;
3. Get (or deform) the body with the frontal and side views;
4. Project frontal/frontal+back viewpoints onto the frontal view image plane to get the texture coordinates.

Then the proper texture mapping on both the frontal view and the back view are applied to the individualized body. However, there are some errors on the border between the frontal and back views caused by digitization process and different illumination between two images. We solve this problem in two steps as follows.

1. Extension of the interior pixels on frontal and back views within certain neighborhood with edge information obtained during photo cloning. This processing removes the noisy effect of the digitization process.
2. Blending between the frontal and back texture to remove the difference between the two images. This processing removes the illumination difference between the front and back views.

Figure 11 explains the texture image creation methods more clearly.

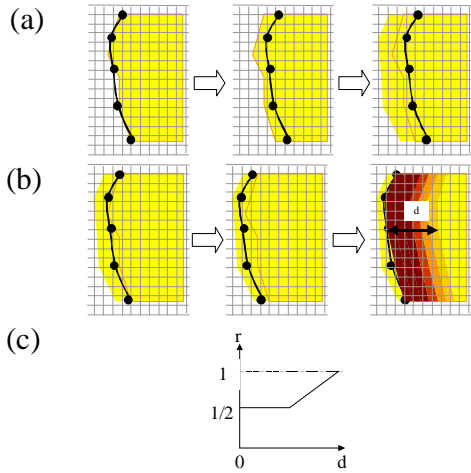


Figure 11: (a) extension of the interior region using edge information to remove digitalization error. (b) The texture blending between the frontal view and back view. (c) Piecewise linear mixing ratio of pixel color value where d is distance from the edge pixels and r is mixing ratio between the frontal and back views.

4.3.3. Generation of extra triangles

Every body texture image shown in Figure 7 has extended area on the boundaries between the frontal and back views, which means that the input images are ready for morphing. Since pixels on the boundaries are not calculated to get intermediate values during image metamorphosis based on triangulation, they are shown as the white pixels in the second image in Figure 9 (a). To solve this problem, we have to add extra triangulation for image morphing. Since we do not use edge information in this section, we generate extra triangles by looking for border edges of every triangular face on a 3D body. A textured 3D computer generated objects have four items as explained in Section 4.3.1; (i) 3D point coordinates (ii) 2D texture coordinates (iii) triangular face index for 3D coordinates (iv) triangular face index for 2D texture coordinates. So the different indexes between (iii) and (iv) indicate the edges of the triangular faces where the triangles for texture are separated. Boundaries of each sub skin part are also candidates as the border between the frontal and back views even though they have the same

index for (iii) and (iv). After collecting the candidate edges, we generate triangles by extending to the normal direction with the border edges. Since we do not have information which side is the interior, we generate in both normal direction of the edges. The resulted morphing with extra triangulation is shown in Figure 9 (b) where the border textures appear properly. Note that the texture morphing on the extra triangulation must be processed before the texture morphing on the body surface triangles.

4.3.4. Various morphing experiments

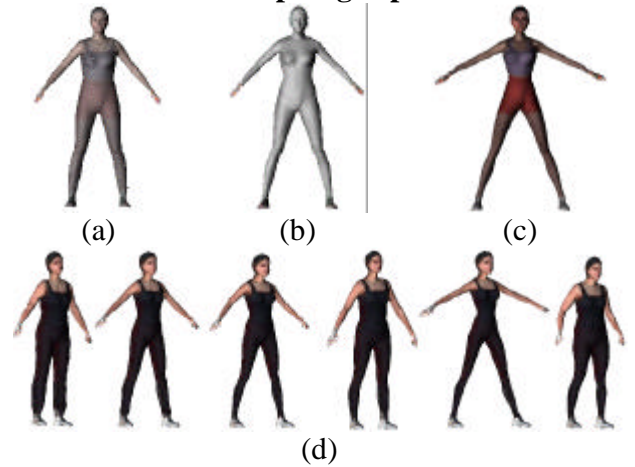


Figure 12: (a) the center person mixed by four virtual humans. (b) A center person between the second and fourth virtual humans. (c) A person with shape mainly from the second virtual human and the texture mainly from the third virtual human. (d) Various shapes with the same texture.

The resulting morphed body shows very smooth images without any hole in the textured parts. The four input virtual models in this paper have not only different data structure but also different character of the body shape and texture. It is possible to set different ratios for the interpolation of the 3D shapes and for morphing images. Figure 12 shows various ratios of morphing for shape and texture images.

5. Automatic textured clothing

3D Clothing [15] on 3D virtual body needs several items inside such as clothes

reconstruction and animation on moving body surface. The garment garments are created from 2D patterns and then seamed together. Conventional 3D garment simulator includes the modules for mechanical model, collision engine, rendering and animation. However when real-time simulation of virtual human is needed, only textured clothes are accepted in many cases [2][13][14] for the faster calculation. So we introduce easy textured clothing methods based on a databank of 2D textured clothes. We produce databank of textured clothes as shown in Figure 13. Every clothes design is based on a single body texture for the body shape and position. Here we use a body texture image of Tammy shown in Figure 7 (c).



Figure 13: Clothes images where the based body is 'Tammy'.

The idea for automatic textured clothing is the same as the morphing in previous sections. However for the clothes, the texture merging is treated differently. If the pixel for image morphing belongs to the background of the clothes, we use the pixel value from the virtual humans with given image-mixing ratio. Otherwise we use the clothes pixel value with 'Tammy' texture coordinates.

Figure 14 shows the texture image generated from the automatic clothing from a model of clothes. Note that the sizes of the texture images are the same since when it loads the texture images, it changes the sizes the same automatically and the size is decided depending on the number of virtual human loaded. IF the number of virtual human is big, we use smaller images for calculation speed. Figure 15 shows the virtual bodies with given texture clothes. It has well suited position fitting to any size of the bodies. So once we generate a large databank for clothes, we can choose any of them to any of

virtual model converted to the given H-Anim structure.



Figure 14: Four body texture images generated with given texture clothes.



Figure 15: Four bodies with textured clothes.

The other examples are also shown in Figure 16.



Figure 16: Five bodies with other textured clothes. The first body is morphed with strong character from the first and the third virtual humans.

6. Interface

We are more interested in intuitively controlling the creation of people about the shape and skin color using 3D-morphing system. Our approach for 3D morphing has the advantage of extending to several people in a natural way. Figure 17 illustrates a dynamic system for 3D morphing among a given number of people where the interface shows 3D morphing has two windows; the left one for controlling weights among several input bodies and the upper right one containing the resulting new body. Two options are provided, one-time morphing and continuous morphing. One-time morphing provides a convenient way to select an input ratio in an n -polygon in the left window for n given virtual

persons. The result appears immediately on the right window. For continuous morphing, the result varies according to the ratio points, which are chosen along a line or curve in the polygon. Since only a Barycentric calculation for texture image pixels is required, the calculation is fast,

which makes it possible to see real-time 3D morphing. There is also an option to have the shape and image variation separately to enable more various creations of new bodies.

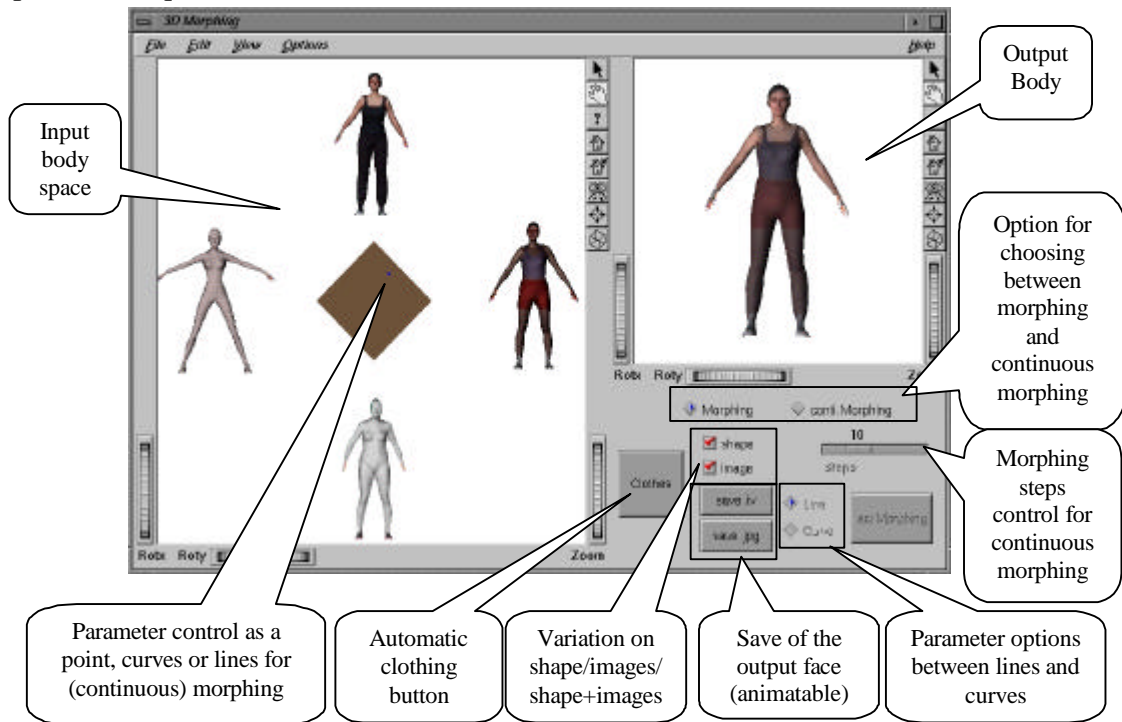


Figure 17: Graphical interface to control the morphing parameters and automatic clothing.

7. Conclusion

We have explained how to make 3D morphing to generate various mixing among several virtual humans, which are given from several different equipments. The idea shown here is to convert them into homogeneous structure as a pre-process and then use a rapid 3D morphing in real-time with intuitive user interaction to control mixing ratios. The idea of homogeneous structures and morphing also makes automatic texture clothing possible.

Automatic 3D clothing and animation in real-time using the generic (homogeneous) structure is ongoing topic.

8. Acknowledgment

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