GENESIS: Generation of E-Population Based on Statistical Information

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Abstract

Simulating virtual environments populated with virtual but realistic crowds requires dozens of different face and body geometries. We present GENESIS (GENeration of E-population based on Statistical Information), an application that allows automatic generation of desired population models. The aim of this application is to generate any population group that is statistically calculated to satisfy given properties.

We divide the population generation module into the face part and the body part. Each of them is based on a database, which is an organization of information collected and processed from the real population dataset. Upon the specification of the population parameters by the user, GENESIS transforms them onto a number of queries to the underlying databases, and process the results from the database in a statistical manner, allowing dynamic generation of desired number of individuals while satisfying the given properties of on the overall population.

1 Introduction

The necessity to model virtual population appears in many applications of computer animation and simulation. Such applications encompass several different domains – representative or autonomous agents in virtual environments, human factors analysis, training, education, simulation-based design, and entertainment. We note however that the majority of virtual population modeling methods can be classified as individual based - Most of these human figures come one by one, either from scratch or from modifying an existing model with interactive manual assistance. To avoid such limitations introduced when we model each individual to bring a population, we believe that the generation of population should be a single step process.

The importance of automatic modeling of population geometry has been recognized by a number of researchers in computer graphics. DeCarlo et al.[5] describe an optimization technique applied for generating varied face geometries based on anthropometric measurements. Blanz et al.[3] discuss a ‘morphable model’ for manipulating an existing model according to changes in certain facial attributes such as age, gender, hooked versus concave noses. They model new faces by forming linear combinations of the prototypes.

Azuola [1] and Grosso[6] have investigated the application of anthropometric data in creation of virtual human models. Their system creates a standardized human model based on a given statistically processed population data or alternatively, a given person’s dimension can be directly used in the creation of a virtual human model.

To our knowledge, no previously established work exists for automatic generation of population models that takes care of both faces and bodies. In this research, we attempt to develop an application to aid automatic construction of virtual population models that will be immediately usable in virtual environments simulating crowd. We divide the physical appearance into the face part and the body part. For the face part, individual face models are created, collected and constructed into a relational database, which is efficiently accessible by the application either for an immediate loading or for morphing in case the target population outnumbers the models in the database. The creation of population bodies is based on statistical data from anthropometric surveys to bring diversity and individuality among body models by differently scaling and shaping the geometric segments.

The remainder of the paper describes GENESIS in more detail. We begin in Section 2 by introducing the requirements, and the overview of the system in Section 3. In Section 4 and Section 5, we describe the two main modules that are responsible for the population face and body respectively. We finish in Section 6 with illustrations of the output models.

2 Contribution

Below we list the features of GENESIS and the resulting models.

- Automatic construction of unlimited number of population models: It offers a complete set of
functional modules to enable the user to create desired population in an automatic and easy-to-use way.

- **High-level population control**: A unique and high-level population control parameters have been defined to assist the user to work with the underlying databases. They include number of target population and distributions of age, gender, ethnic origin and optionally desired number of particular professionals among the population. The user decides the ratio of male and female in the population, or whether it is a homogenous or a multiracial group.

- **Individual control**: Physical characteristics of the human models are essentially derived from the input population parameters and the database, which is the compilation of the real measured population. Yet, interactive modification of the geometry and shape properties is considered to be useful.

- **Realistic models vs. performance**: By virtue of the photo images we use, physical appearance of an avatar is not only extremely realistic but also unique, making each individual within a population different from others. On the other hand, one of our main concern is the geometrical/computational optimization, due to the expected overload to the VR system simulating the crowds in real-time. Development of geometry simplification and real-time rendering technique is beyond the scope of this work. Instead, we adopt a number of heuristic ways and discrete LoD (Levels of Detail) representation to maximize the visual realism while maintaining as light as possible geometry.

- **Animation ready models**: The resulting models are immediately animatable. A standard way of representing humanoids in VRML, called H-Anim specification has been accepted. It is the only currently available international standard (fully adopted by MPEG-4) for animating avatars in virtual worlds.

### 3 Overview

Figure 1 shows the architecture of GENESIS. After various necessary settings on the target population through user interface, the **population manager** decomposes the input parameters into a number of queries to the underlying database and passes them to the face/body population managers. Upon retrieval of faces and bodies, it unifies them in a proper position to form a complete set of avatar geometry and locates them in the scene. It is also responsible for exchanging internal information between the face and the body part including: proper set of body/face selection, skin color calculation from the face texture to color the skin of the body.

**Figure 1: Architecture of Genesis**

**Face database** is essentially a collection of individual face models, constructed into a relational database. *Face population manager* has an access to the face database and it retrieves the desired face population from the face database upon receiving the queries from the population face manager. Whenever desirable, it executes the 3D morphing, allowing unlimited number of dynamic generation of new faces while satisfying the given properties on the overall population.

**Body database** is a condensed form of statistically processed anthropometric surveys. Based on the body database, *body population manager* processes the anthropometric information and carries out the distribution of different sizes, proportions and shapes.

### 4 Population faces

#### 4.1 Collecting individual faces and building a database

Based on our earlier work [10], a database of approximately 500 textured faces has been constructed using the photo-cloning software (Figure 2). The 3D model of each photo-cloned face is associated with information, which are mainly the name, date of birth, gender, ethnic group and the profession of the individual in question. The use of these data provides an essential solution to the face population generation. With an intention to maximize the exploitation of these data, a relational database is constructed.

Individual face models and associated textual data must be easily accessible for applications and should be structured in a way that enables the retrieval of the attributes related to the face model. From this, we
distinguish three concepts: the individual, the photo-cloned face model and the description of the face.

Figure 2: Photo-cloning process.

Figure 3: A collection of individual faces

In terms of DBMS (DataBase Management System), a relational table is assigned to each concept. We define relationships between the tables, and use the relationships to find associated information stored in the database. The separation of these three concepts namely Head, Clone and Individual is used in order to manage and to associate more than one cloned heads to an individual at different dates. We associate a Head description to each Clone, as we assume that the individual face changes through time.

Microsoft Access and SQL are used as the DBMS and the database interrogation language respectively, for accessing and modifying the information. The structure of the database is detailed in what follows:

- **Individual table** (individual_ID, first_name, last_name, birth_date, gender, morphology, vocation, address, fax_number, phone_number)
- **Clone model table** (clone_ID, clone_age, clone, location, cloning_date, flag, generic, texture)
- **Face description table** (head_ID, baldness, hair_color, hair_category, eye_color, skin_color)

4.2 On-line morphing

Apart from direct acquisition through reconstruction of real people, a morphing technique [10] is used for indirect acquisition of models through geometric morphing and texture blending of existing models. This is necessary because the majority of models in the database correspond to Caucasian men. Every face model generated from the generic model shares the same topology and has similar characteristic for texture coordinates. Thus a number of resulting 3D shapes are easily interpolated by a simple linear interpolation.

5 Population bodies

We notice that the difference among individual bodies resides in the variation of sizes, proportions and shapes. Anthropometry, a biological science of human body, systematically studies such human variability. Our approach, similarly to [1], makes use of the selected anthropometric data for automatic generation of varied human body geometries to produce most likely occurring individuals and population.

There are many human figure models currently available from different systems which provide the ability to produce human figures based on anthropometry. However our approach is different from others, in that we focus on kinematic properties (size, shapes, proportions, etc.) rather than kinetic properties joint limits(center of mass, strength, etc.) and also in that our aim is to create a believable population models in a single step process rather than calculating representative models, an average size of 50-year old German male, for instance, while our use of anthropometric data is rather aiming at generating population models.

5.1 Reference model

The reference body model we currently use is a segmented one, composed of 25~55 segments with a variable number of 800~5,000 triangles depending on the desired level of details.

5.2 Textured models

Some of the particular professionals wearing uniforms are represented by the textured body geometry. It was felt that combining the rigid body model with minimal use of texture image is a good compromise between the realism in appearance and faster manipulation of the geometry. Thus, we focus on getting texture coordinate information on only the torso part since it is visually effective enough to show their task.

In our current implementation, we support fireman, policeman and worker models that are defined in the scenario. The method to make a texture is separated into two parts: (1) silhouette extraction part that extracts human silhouettes from the front, side and back view to
crop human body shape and (2) texture generation part that uses silhouette information and calculates texture that fits to the model.

For making a texture, we take 2D photos from some viewpoints. It is possible to reconstruct the 3D object with reasonable precision with these photos. In most cases, the shape of 3D model and the silhouette of a human image do not have the same style. For example, while a 3D generic model is slim, the person in the input images may be fat. The silhouette in this case provides important information to deform the 3D generic model to fit to the target subject.

Silhouette is defined as a connection of edges that makes a border of a human body. However, a human wears many kinds of clothes. It makes automatic silhouette extraction a complicated problem. Our method is to reduce the working time of manual extraction. An operator can put some important points on the silhouette, and the silhouette is calculated from these points. This will be the efficient way to make the silhouette. From the silhouette, the texture region on the upper torso is calculated. This result is shown in Figure 4.

![Figure 4: Silhouette extraction and the texture fitting](image)

### 5.3 Anthropometric modeling

Anthropometric data for adult populations has been collected from various sources [4][11][12], from which a number of percentile measurement data based on a normal distribution is compiled. Stature, sitting height, chest circumference and head length are the chosen measurements for the first version of the system as they are considered as primary measurements in known facts and thus are important in correctly sizing the bodies for a population.

For each individual who belongs to the same group of the population, i.e. with the same ethnic group and the gender, a specific percentile of the measurement of the population is assigned, assuming a normal distribution of the group. Given with the number of bodies $N$ to be generated for the group, percentile information on the chosen measurements is processed. In our current implementation, the chosen measurements are the stature, sitting height, chest circumference, waist circumference, hip circumference, and the arm length. While the percentile and the standard deviation values directly compiled from [12] are used for the first three, hip circumference and arm length are handled by the measurement estimation driven by regression method using known correlation values.

The supported groups are the combination of different genders and ethnic groups. Each of the randomly selected individual is assigned with a percentile value $99 \times \frac{i}{N}$ ($i = 1, 2, \ldots N$) assuming that their measurements follow the normal distribution. Table 1, compiled from [9], shows the percentile information used for the stature.

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
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<tbody>
<tr>
<td>1 st percentile</td>
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<tr>
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<tr>
<td>99 th percentile</td>
<td>1710</td>
<td>1855</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>62</td>
<td>70</td>
</tr>
</tbody>
</table>

### 5.4 Individual deformation operators

In order to actually deform the reference model to satisfy the given measurement values of different part, a number of procedures and deformation operators are defined. First, the reference body model is measured at the selected part. Then a number of primary segments are processed by calculating appropriate scale factors and applying affine transformation to each correspondingly. Scale factor is calculated by dividing the desired measurement value by the measurement value of the generic body model. Note that whenever there is a dependency set for more than one segment, the transformation applied to the parent node will affect the child node.

So far we have described that physical characteristics of the body models are automatically derived from the input population parameters and the database of the real population dataset. Yet, interactive modification of the geometry and shape properties is considered to be useful. Apart from the automatic adjustment of the affine component of each segment, each instance of an avatar model is modifiable by local deformation operators provided.

### 6 Results and discussion

We have presented a novel framework for systematically generating virtual populations. It allows users to automatically generate animation-ready, realistic, yet geometrically optimized virtual population models. The resulting population models are realistic not only in that each individual model is unique and possesses photo-
realistic appearance but also in that they as a whole reflect the valuable statistical information from the domain of anthropometry and therefore comprise the visualization of the most likely population. Figure 5 shows an example of generated population models. When executed on a Windows PC with 1GHz, it takes about one minute to generate seventy models.

Figure 5: A population of 70 avatars

We envisage several further developments from our current results in the near future. Although the use of anthropometry data has proven to be effective in the generation of populations, further investigation should be carried out to enhance the number of supported measures. Different LoD (levels of detail) generation is left for future work as well, which will improve the rendering performance of the system. In conjunction with this, a simplification of the joint hierarchy such as LoA (levels of articulation)[7] is considered for an efficient animation control.

Finally, we are looking at loading and simulation of our population models in a virtual environment.

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References

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