Physical based Rigging

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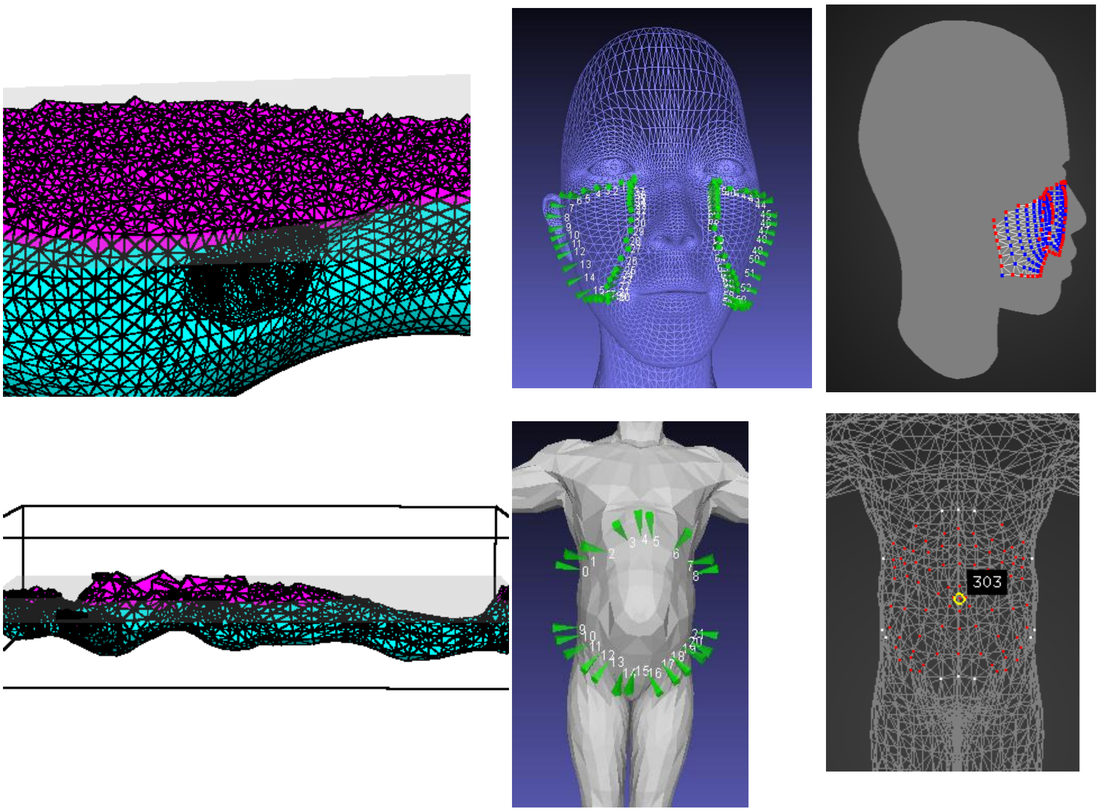
Introduction

Computer animation has been a popular research topic since 1970s, when the first parametric facial model is proposed[0]. In the recent few years, a lot of techniques are proposed to model and animate faces like physical modelling, motion capture, mesh deformation etc. However, most of them require burden work of artists and assistance of expensive model. Rigging is one kind of the most popular techniques used in facial animation, aims to generate expression models with more details. In order to simplify this process for users and yet generate satisfying results I propose a method with spring mesh and subspace constraints. I will introduce two methods, spring mesh and expression cloning. The first is used to deform face model, while the second one is used to restrain the deformed model from being weird.

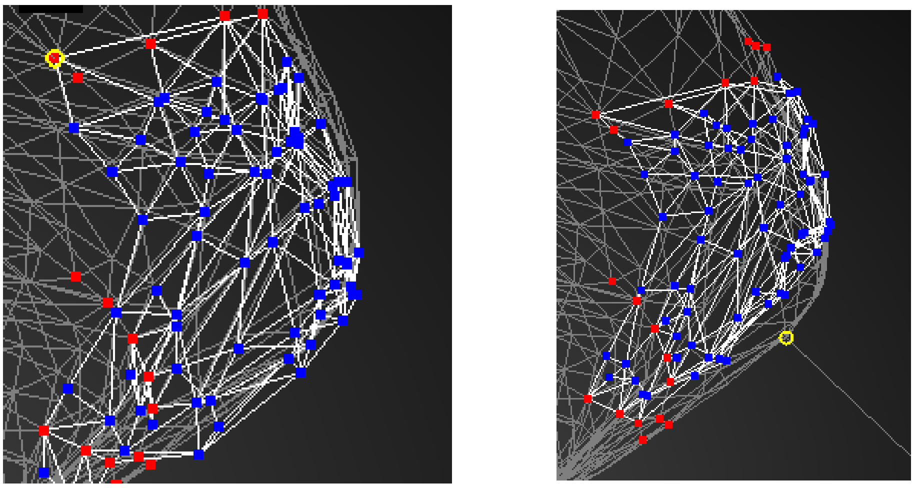
Spring mesh

Spring mesh[1] is first proposed by Platt et. Al based on FACS system, which was used to simulate bone, muscle fiber and skin. Forces are applied to elastic meshes through muscle arcs generate various facial expressions.
There are many ways to create a simulation mesh from a graphical mesh. We create the mass spring system from a tetrahedral mesh by turning each vertex into a particle and each tetrahedral edge into a spring[9]. What is missing are the masses of the particles and the stiffness and damping coefficients of the springs. Given a user specified density ρ, the mass of each tetrahedron can be computed as its volume multiplied by the density. Then, each tetrahedron distributes its mass evenly among its four adjacent vertices. This is a straight forward procedure.
However, the behavior of the mass spring system will always depend on the structure of the mesh while not on stiffness and damping coefficients. So I just assign a common stiffness and damping coefficient to all springs. The following image show the process to tetrahedralize the mesh and compute mass for nodes.

Tetrahedralize Boundary Apply Mass & Force



The following image show the result for using this method to generate a shaking belly.



Expression Cloning

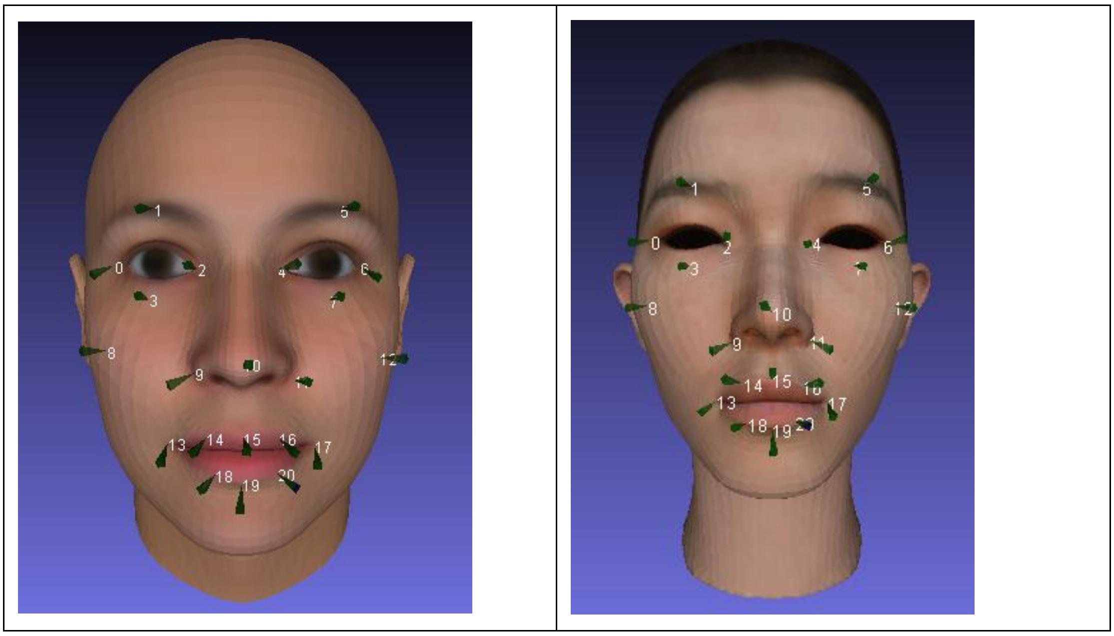
Expression cloning[2] is a technology to transfer expression from one model to another topologically different model. The main idea is transfer vertex motion vectors from a source face model to a target model which includes two steps: (1) Determine surface points Correspondence

(2) Transfer motion vectors.

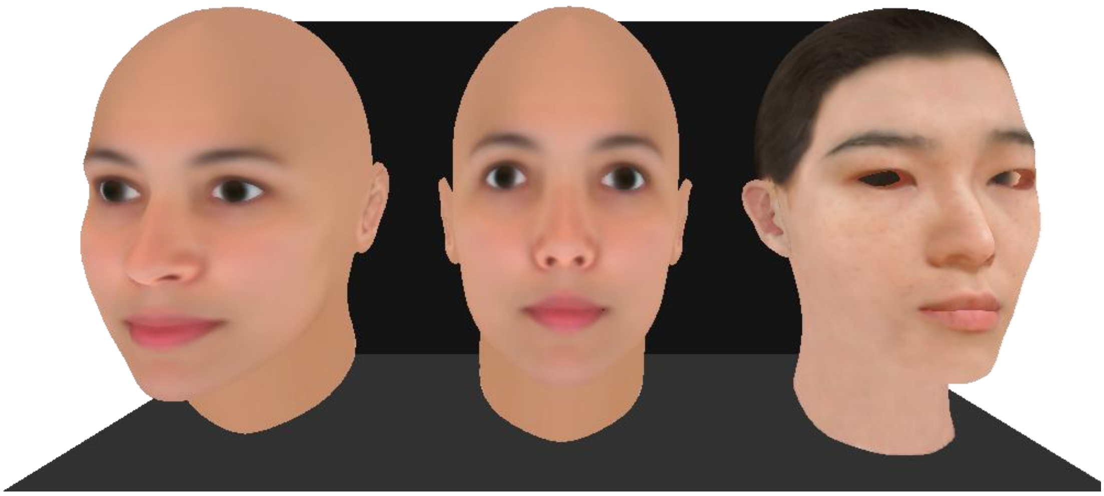
Dense Correspondence

RBF model is adopted to build correspondence relationship. The whole process is as follows:

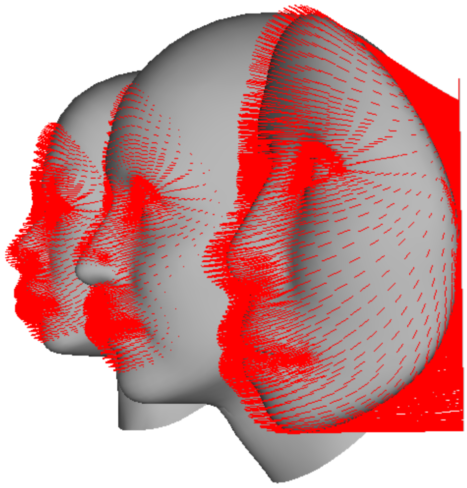
1. Manually label 20 or so correspondence for two models



2. Generate deformed model with RBF

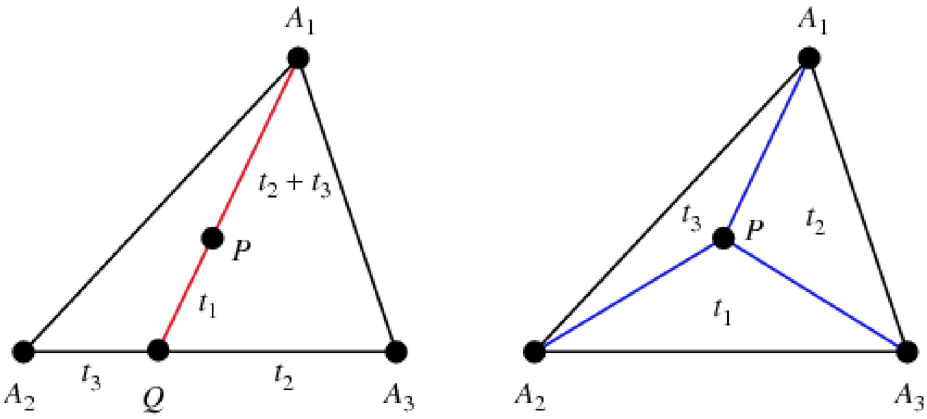


3. Using cylindrical projection to get vertices correspondence



4. Compute Barycentric coordinates to represent deformed model with source model.

$$\mathbf{P} = t_1\mathbf{A}_1 + t_2\mathbf{A}_2 + t_3\mathbf{A}_3$$



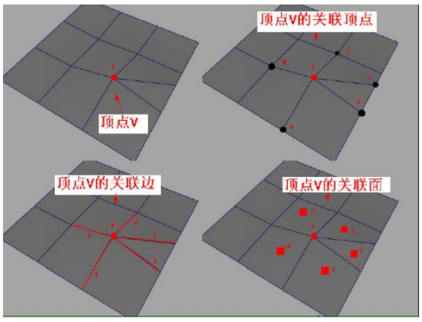
Transfer Motion Vector

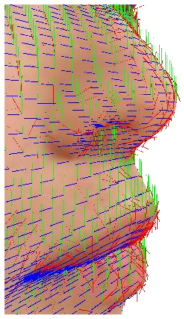
After deform the source model to target model and build correspondence between deformed model and target model, we need to transfer motion vector from target to deformed model through Barycentric coordinates, then to source model through direction and magnitude adjustment.

A. Direction Adjustment

In order to make direction adjustment, we need to follow the below steps:

- Build local axis for every vertex, because the topological structure is the same between deformed and source model, so a definite local axis could be built for each vertex.





- Build transformation between deformed local axis and source local axis with help of world space.

$$ {}^{O}_{W}R = \begin{bmatrix} x_w \cdot x_o & y_w \cdot x_o & z_w \cdot x_o \\ x_w \cdot y_o & y_w \cdot y_o & z_w \cdot y_o \\ x_w \cdot z_o & y_w \cdot z_o & z_w \cdot z_o \end{bmatrix} \quad {}^{W}_{D}R = \begin{bmatrix} x_w \cdot x_d & y_w \cdot x_d & z_w \cdot x_d \\ x_w \cdot y_d & y_w \cdot y_d & z_w \cdot y_d \\ x_w \cdot z_d & y_w \cdot z_d & z_w \cdot z_d \end{bmatrix} $$

$$ {}^{O}_{D}R = {}^{W}_{D}R\,{}^{O}_{W}R $$

B. Magnitude Adjustment

To adjust Magnitude between deformed local axis and source local axis, we need to build boundary box for each local axis, then obtain the ratio for each dimension.

$$ \mathbf{S}_{x,y,z} = \frac{size_{x,y,z}(DeformedSouceModelLocalBoundingBox)}{size_{x,y,z}(SouceModelLocalBoundingBox)} $$

C. Motion vector transfer

Assume the motion vector of i_{th} vertex on source model is $\mathbf{M}_i$, the motion vector of i_{th} vertex on deformed model is $\mathbf{M}_i^{'}$. Then the transformation between them is very simple:

$$ \mathbf{M}_i^{'} = \mathbf{S}_{x,y,z} \cdot {}^{O}_{D}\mathbf{R} \cdot \mathbf{M}_i = \mathbf{S}_{x,y,z} \cdot {}^{W}_{D}\mathbf{R} \cdot {}^{O}_{W}\mathbf{R} \cdot \mathbf{M}_i $$

Physical based Rigging

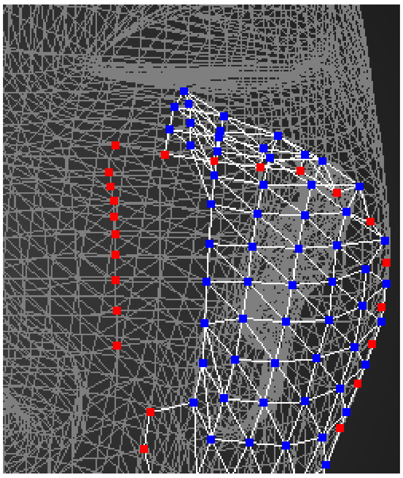
Rigging is a term used in facial animation area for generating facial expression with more details, it’s very important to generate realistic facial animation. In the film industry, usually this work is done by artists’ manual work. In the research community, physical based model[3][4], data driven method[5][6] and some specially designed devices[7][8] are adopted to generate more details (like wrinkles and pores)for face model. In order to facilitate common users more easily do facial rigging, I propose a parameter based Physical Rigging system.

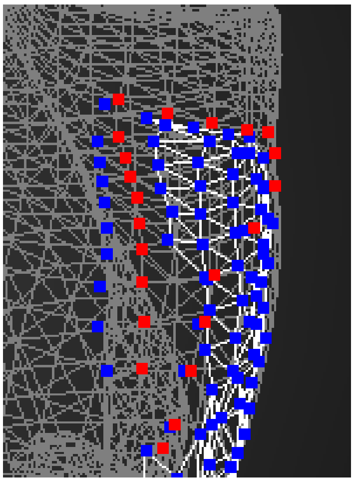
The principle is pretty simple, spring mesh is adopted to deformed mesh, while subspace constraints is added to restrain the mesh from being weird. Following is the whole formulation:

$$\underbrace{\|\mathbf{M}^S - (\mathbf{M}_0^B + \sum_{i=1}^{n} \alpha_i \mathbf{M}_i^B)\|^2}_{subspace} + \beta \underbrace{\|\mathbf{M}^S - \mathbf{M}^{S*}\|^2}_{physical}$$

- Where $\mathbf{M}^S$ is the expression generated by this method
- $\mathbf{M}_i^B$ is the ith blend shape generated by expression cloning
- $\mathbf{M}^{S*}$ is the expression generate by spring mesh

The parameter β could be adjusted to obtain different details.
Following images shows the result generated by this method. The red dots are boundary, the blue dots are spring mesh nodes. In the left image I didn't use subspace constraints, so the deformation is not natural at all. After I added subspace constraints, the deformation looks much better (shown in the right image).





In the near future, I will design an efficient Gui to facilitate users edit boundary and modify spring mesh attributes, hopefully this method will be used in a video driven facial animation system.

Reference

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