Research - University of Victoria:
=====================================

P 1.

The title of this presentation is: "*Similarity based* ..."

P 2.

The purpose of this presentation is to show you a new technique in shape reconstruction:
"*mesh interpolation*"
i.e., given a set of points and the underlying topology from a given object, how would you faithfully reconstruct the original shape from these points through an interpolation process?

As the core technology of several important areas such as *reverse engineering*, *key-frame systems*, and *shape design*, it is critical that we have a powerful mesh interpolation technique that can handle meshes of any size, any shape and any topology. As far as I know, this problem has not been completely solved yet especailly for meshes of extremely large size and complicated shape.

We will present an algorithm in that direction. Before that, we need to define a term.

P 3.

The term "Catmull-Clark subdivision surface" will be used many times in this presentation.
To save energy, I use a short hand for it.
Subsequently, when you see "CCSS", you should understand it stands for "Catmull-Clark subdivision surface".

P 4.

The presentation is arranged as follows.
I will define the **task** and **objective** of this research first.

I then briefly review the background and previous work.

This is then followed by a description of our method, and a discussion of the implementation issues and test results.

Finally we give the concluding remarks.

P 5.

Given a 3D mesh, the task here is to construct a CCSS to interpolat the vertices of the given mesh.

The concept of interpolation can easily be explained with a curve example.
(here is an example of curve interpolation)

P 6.

But the surface case is what we are really interested at.

P 7.

The question is: among the infinitely many smooth CCSSs that interpolate the given data points, which one should we choose?

It may be difficult to imagine the situation in 3D, but it is easy to see the problem in the curve case.

In the following, sometime we will use curves to explain the concept. But you should understand the technique is aimed at 3D subdivision surfaces.

P 8.

If a reference surface is given, the task becomes easier. All we need to do is to find the interpolating surface that is most similar to the given reference surface.

P 9.

Usually, we would not be given such a reference surface. But with subdivision surfaces, the situation is different - we can construct a reference surface for ourselves.

Note that if we view the given mesh as the control mesh of a limit surface, then the shape of the limit surface should be close to the shape of the interpolating surface because both of them resemble the shape of the given mesh. Therefore, limit surface of the given mesh can play the role of a reference surface.

So we have a clear objective now: find an interpolating CCSS whose shape is similar to the limit surface of the given mesh.

P 10.

Before we proceed to our algorithm, I will briefly review of the background and previous work.

P 11.

Here is an example of the refining process.

P 12.

Another example.

P 13.

A major advantage of subdivision surfaces is it is possible to represent any complex shape with only **one surface**. Why? because there is no limit on the shape and topology of the control mesh of a CCSS. Therefore, it is possible for us to generate a surfac with any kind of topology and shape.

P 14.

Each of these objects is represented by one CCSS. This is not possible with traditional representation schemes, such as B-spline or NURBS surfaces, because domains of these traditional surface schemes must be rectangular and therefore can not even represent a closed object, not mentioning objects with holes.

P 15.

Subdivision surfaces did not get much attention from the CAD/CAM industries for almost 25 years because it was not known until 1998 that subdivision surfaces can be parametrized [Stam1998]. Without a parametric representation, it is essentially impossible for a CAD/CAM system to include subdivision surfaces as a free-form surface modeling tool because of problems with standard operations such as picking, rendering and texture mapping [Stam1998].

Jos Stam's 1998 parametrization technique was further improved in 2006 [Lai&Cheng2006]. With this new parametrization technique, we can compute the value of a CCSS at a given point with only one half of the cost.

P 16.

These are the definitions used for the parametrization equation.

P 17.

We can also easily compute the first and second directives at any given point, including the **extra-ordinary points**.

P 18.

There are two major ways to interpolate a given mesh with a subdivision surface: *interpolating subdivision* or *global optimization*.

In the first case, a subdivision scheme that interpolates the control vertices, such as the

Butterfly scheme, Zorin et al’s improved version, or Kobbelt’s scheme, is used to generate the interpolating surface. New vertices are defined as local affine combinations of nearby vertices. This approach is simple and easy to implement. It can handle meshes with large number of vertices. However, since no vertex is ever moved once it is computed, any distortion in the early stage of the subdivision will persist. This makes interpolating subdivision very sensitive to the irregularity in the given mesh, especially when the mesh vertices are not dense (see the example shown at the bottom of the slide). In addition, it is difficult for this approach to interpolate normals or derivatives.

P 19.

The second approach, global optimization, usually needs to build a global linear system with some constraints.

The solution to the global linear system is an interpolating mesh whose limit surface interpolates the control vertices in the given mesh.

This approach usually requires some fairness constraints in the interpolation process to avoid undesired oscillations. Although this approach seems more complicated, it results in a traditional subdivision surface. The problem with this approach is that a global linear system needs to be built and solved. Hence it is difficult to handle meshes with large number of vertices.

P 20.

P 21.

G satisfies the following property: each face of G is a quadrilateral and each face of G has at most one extra-ordinary vertex.

Q is then defined as a control mesh with the same number of vertices and the same topology as G.

P 22.

The vertices of G are divided into two categories: Type I and Type II. A vertex is called a Type I vertex is it corresponds to a vertex of P. Otherwise, it is Called a Type II vertex.

The vertices of Q are similarly divided into two groups as well. This way of setting up Q is to ensure the parametrization form developed for a CCSS patch can be used for the limit surface of Q and we have enough degree of freedom in our subsequent work.

The remaining job then is to determine the position of each vertex of Q.

P 23.

Since m-n is bigger than n, this setting leads to an over-determined system. W/o any freedom in adjusting the solution of the system, one has no control on the shape of the resulting interpolating surface S(Q) even if it carries undesirable undulations.

P 24.

In this paper, instead , the m-n Type II vertices are set as independent variables and the n Type I vertices are represented as linear combinations of the Type II vertices.

This approach provides us with enough freedom degree to adjust the solution of the resulting linear system and, consequently, more control On the shape of the interpolating surface S(Q).

This approach will be realized through the following construction process.

P 25.

P 26.

P 27.

P 28.

P 29.

P 30.

P 31.

P 32.

P 33.

P 34.

P 35.

P 36.

D could be very large if many sample points or constraints are used.

Fortunately, we do not need to calculate and store D and C.

P 37.

P 38.

P 39.

P 40.

P 41.

P 42.

P 43.

P 44.

P 45.

P 46.

A question that has been asked many times before is: Given a 3D shape, can you create a representation for it?

P 47.

P 48.

This interpolation technique gives us an one-piece represented control mesh, whose limit surface approximates the target model.
The development of the interpolation method is based on the assumption that the interpolating surface should be similar to the limit surface of the given mesh

By using information from the vertices of the given mesh as well as its limit surface, one has more control on the smoothness of the interpolating surface. Hence, a surface fairing process is not needed in our method.

There is no system solvability problem for the new method. The global linear system that the new method has to solve does not require an exact solution,

an approximate solution is sufficient.
The approximate solution can be provided by any fast iterative linear solver. Consequently the new method can process meshes with large number of vertices efficiently.

Our new method can handle both open and closed meshe
It can interpolate not only vertices, but normals and derivatives as well.

P 49.

This research work is supported by NSF.
Some of the data sets used in this work are downloaded from UIUC and Microsoft.

This ends my presentation of this work.
I will be glad to answer questions.