Statement of Research
Fuhua (Frank) Cheng

1. Research Interests

My research interests are in graphics and geometric modeling, with special emphasis on computation techniques for rendering and geometric problems, and modeling of geometric shapes.

My work covers geometric/solid modeling, CAD/CAM, reverse engineering, finite-element mesh generation, biomedical imaging, and collaborative CAD.

2. Research Achievements

My major research achievements include:

- **Development of first hardware device for curve generation/rendering**


  A special hardware, based on parallel subdivision, supports fast and numerically stable generation/rendering of parametrically defined curves. This work won me the prestigious Dr. Sun Yat-Sen Technology Invention Award in 1985.

- **Development of a new spline scheme**


  Each degree $n$ spline basis function is composed of polynomials of degree $n - 1$ and $n$ alternately. A degree $n$ parametric alternate spline curve is composed of curve segments of degree $n - 1$ and $n$ alternately and, yet, the curve is $C^{n-1}$ continuous. Therefore, it provides the same kind of smoothness of a degree $n$ B-spline curve but with smaller construction and generation cost.

- **Initiated a new research area: Parallel B-Spline Algorithms**


  Publication of the above paper started a research area called Parallel B-Spline Algorithms. The area is still active today.

- **Discovering B-Splines are digital filters**


  By observing that B-Spline curves and surfaces can be viewed digital filters, it is now possible to use digital filter techniques to solve geometric problems such as curve and surface fitting.
• Development of a new shape design technique called INTERPROXIMATION

A new shape design technique by combining interpolation and approximation into a single process. It allows a user to design a curve using both points and regions, instead of just points.

• Best result in Parallel B-Spline Algorithms

The best result in Parallel B-Spline Algorithms is achieved by the above paper by showing that constant time performance is possible for surface fitting problem.

• Most efficient rendering technique for trimmed NURBS surfaces

A tessellation-based, rendering technique for trimmed NURBS surfaces. The new technique provides solutions to two major problems in trimmed NURBS surface rendering: Computational efficiency and numerical stability and crack problem. A version of this algorithm has been implemented in micro code in IBM's Risc machines.

• Constrained shape scaling techniques

A technique to hold significant features of a model unchanged while globally or locally alternating (scaling) it. This technique provides the design industry with the capability of globally or locally modifying an existing model in length, height, or width without affecting certain significant features and, consequently, avoiding expansive redesign process.
• **Error control for subdivision surfaces**
  - "Matrix based Subdivision Depth Computation for Extra-Ordinary Catmull-Clark Subdivision Surface Patches" (with G. Chen), Lecture Notes in Computer Science, Vol. 4077, Springer, 545-552.

With the above results, Catmull-Clark subdivision surfaces can be used for CAD/CAM applications now. This is important because Catmull-Clark subdivision surfaces include B-spline and NURBS surfaces as special cases. Therefore, if one can control the precision of a Catmull-Clark subdivision surface, then a universal representation for all CAD/CAM applications can be developed and a universal language for all CAD/CAM applications can be adopted.

• **Parametrization of Catmull-Clark subdivision surfaces**

The above work improves J. Stam’s SIGGRAPH paper by giving a representation with only half the basis functions. Besides, all the basis functions are explicitly given, not look-up tables are needed. So, a complete parametrization technique of Catmull-Clark subdivision surfaces is finally available.

My other contributions include:

- *Adaptive Rendering/Tessellation of Subdivision Surfaces*
- *Texture Mapping for Subdivision Surfaces*
- *Adaptive Subdivision of Subdivision Surfaces*
- *Streamline Modeling*
- *Collaborative CAD*
- *Label-driven subdivision*
- *Knot Reduction of NURBS Representation*
- *Bessel Interpolation*
- *Rate of Convergence*
- *Curve/surface fairing*
- *Shape Reproducing and Shape Preserving Interpolation*
- *Parametric blending*
• Shape generation on irregular mesh -
• Surface Connection -

3. Current Research Projects:

Three research projects are undergoing now. These include

(1) "Tessellation, Fairing, Shape Design, and Trimming Techniques for Subdivision Surface based Modeling", NSF (DMI-0422126), 9/1/04-8/31/08, $300,000.

(2) "Portable Digital Mouth and Occlusion Reproducing", KSTC (144-401-07-015), 4/1/07-3/31/09, $150,000.

(3) "On New Algorithms of Curve and Surface Modeling Based on Probabilistic Type Operators and Probability Distribution" (Co-PI), NSF of China (NSFC-10571145), 01/01/2006-12/31/2008, RMB$280,000 (US$35,000).