Statement of Research

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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*, *medical applications of CAD*, and *collaborative CAD*.

2 Research Achievements

My major research achievements include:

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

  "Bezier Curve Generator: A Hardware Approach to Curve Generation" (with K.R. Hsieh, R.R. Huang and Y.H. Chin), Proc. 1985 Int. Symp. VLSI Technology, systems and Applications, Taiwan, 278-281.

  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**

  "Alternate Spline: A Generalized B-Spline" (with A. P. Bien), J. Approximation Theory 1987, 51(2):138-159.

  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**

  "A Parallel B-Spline Surface Fitting Algorithm" (with A. Goshtasby), ACM Trans. on Graphics 1989, 8(1):41-50.

  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**

  "B-Spline Curves and Surfaces viewed as Digital Filters" (with A. Goshtasby and B. Barsky), Computer Vision, Graphics, and Image Processing 1990, 52(2):264-275.

  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**

  "Interproximation: Interpolation and Approximation using Cubic Spline Curves" (with B. Barsky), Computer Aided Design 1991, 23(10):700-706.

  "Interproximation using Cubic B-Spline Curves" (with B. Barsky), Modeling in Computer Graphics: Methods and Applications, ed. B. Falcidieno and T.L. Kunii, Springer-Verlag, Berlin (1993), 359-374.

  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**

  "Parallel B-Spline Surface Interpolation on a Mesh-Connected Processor Array" (with J. Wang, G. Wasilkowski et al), J. Parallel & Distributed Computing 1995, 24, 224-229.

  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**

  "Rendering Trimmed NURBS Surfaces" (with W.L. Luken), IBM Report RC18669, 1992.

  "Surface and Derivative Evaluation Methods for the Rendering of NURBS Surfaces" (with W.L. Luken), IBM Report RC18670, 1993.

  "Computing Step Sizes for the Tessellation of Trimmed NURBS Surfaces" (with W.L. Luken), IBM Report RC18499, 1993.

  "Comparison of Surface and Derivative Evaluation Methods for the Rendering of NURB Surfaces" (with W.L. Luken), ACM Trans. on Graphics 1996, 15(2):153-178.

  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**

  "Constrained Shape Scaling of Trimmed NURBS Surfaces using Fix-and-Stretch Approach" (with P. Zhang and C. Zhang), Computer Aided Design 2001, 33(1):103-112.

  "Constrained Shape Scaling of Multi-Surface Objects" (with P. Zhang and C. Zhang), Proc. Geometric Modeling & Processing 2000, Hong Kong, 398-407.

  "Constrained Scaling of Catmull-Clark Subdivision Surfaces" (with S. Lai and S. Zou), Computer-Aided Design & Applications 2004, 1(1-4):7-16.

  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**

  "Subdivision Depth Computation for Catmull-Clark Subdivision Surfaces" (with J. Yong), Computer Aided Design & Applications 2006, 3(1-4):485-494.

"Subdivision Depth Computation for Extra-Ordinary Catmull-Clark Subdivision Surface Patches" (with G. Chen and J. Yong), Lecture Notes in Computer Science Vol. 4035, Springer, 2006, 404-416.

"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**

  "Parametrization and Computation of Catmull-Clark Subdivision Surfaces" (with S. Lai), Computer Aided Design & Applications 2006, 3(1-4):513-522.

  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), NSFC (NSFC-10571145), 01/01/2006-12/31/2008, $35,000.

4 Future Research Plans:

Future research will focus in the following three areas:

1. **Non-Invasive Mouth Reproducing** : by working with people in vision and dental areas, novel data acquisition device and powerful subdivision surface based reverse engineering techniques will be developed so that a dentist can reproduce a patient's mouth without using the traditional impression-taking approach.

2. **Mesh Interpolation and Mesh Expansion** : to develop an ultimate solution for mesh interpolation problem and Fourier-transform-like expansion techniques for meshes (surfaces). A mesh expansion contains high frequency and low frequency information of the given mesh and hence can provide us with new or alternative solutions to problems in texture mapping, denoising, and morphing.

3. **Virtual 3D Plastic Surgery** : to work with people in plastic surgery area to develop a realistic 3D facial plastic surgery simulator. The technologies developed here would make outcome prediction of plastic surgery possible and, consequently, reduce the risk for any given patient. An imaging system developed in the first project will be used here for data acquisition.