GOPI MEENAKSHISUNDARAM

Research Statement

My research work can be considered under the broad areas of **computer graphics and geometry**. Within these areas, during my graduate years, I have worked on various problems including collision detection, solid modeling, geometric simplification of models, surface reconstruction, efficient rendering of curved surfaces, texture mapping on curved surfaces, image mosaicing for teleconferencing application, and VLSI architectures.

The major goals driving my research are to obtain complete and usable solutions for those practical problems in geometry that arise in graphics applications. To achieve these goals, I work on developing fundamental theoretical concepts in geometry, which permit me, for example, to build efficient algorithms for graphics rendering. Such research also spins off a wide variety of inter-disciplinary research, ranging from graphics hardware design to structural biology.

Computer graphics research encompasses various areas that include model creation (like laser scan devices and model authoring tools), model representation (point sets, triangles, curved surfaces etc.), model manipulation (user interface), and model rendering (non-photorealistic rendering, stereo rendering etc.). In each of the above areas there are variety of problems based on geometry. For the sake of brevity, I list only a few problems stemming out of my dissertation in the areas of model creation, representation and manipulation.

Problems from Surface Reconstruction

Laser scans of objects yield large point sets with a normal vector at each point. These point sets sampled from the underlying objects are used to build computer models of these objects. Type of representation used to represent these computer models and manipulation of these models would depend on the requirements of the application. In my dissertation I chose to represent these models as sets of triangles, as my applications involve visualization using graphics hardware that is optimized for triangle rendering and physically based simulation which required surface representation. There exist robust but slow surface reconstruction algorithms that are theoretically proven correct for models without boundary. An important contribution of my work is the first theoretically proven correct reconstruction of models both with and without boundaries. This is one of the fastest algorithms known for surface reconstruction today. An implementation of this algorithm will be released soon for public use. Multiple laser scans of the same model from different view points are merged to get the point set of the complete model. Surface reconstruction algorithms have to be exceptionally robust to handle the noise due to device instabilities and the noise brought in by numerical errors in transforming points from one scan to be merged with the other. There exist robust algorithms to handle such input sets; but they are slow and assume models with no boundaries. Insufficient sampling is another kind of "noise" that would affect the identification of boundaries in the model. As most algorithms assume models with no boundaries, this kind of noise poses less problem to such methods. Robust and efficient algorithms for reconstructing models with boundaries from point sets is still a problem that holds a lot of promise for further research.

Related Work:
Surface Reconstruction based on Lower Dimensional Localized Delaunay Triangulation
M. Gopi, S. Krishnan, C. T. Silva,
EUROGRAPHICS 2000.
A Fast and Efficient Projection Based Approach for Surface Reconstruction
M. Gopi, S. Krishnan,
International Journal of High Performance Computer Graphics, Multimedia and Visualisation, Vol. 1, No.1, pp.1-12, 2000.

Resampling and Model Simplification: *(Short term project)*

In my dissertation I defined, for a given set of points, a distance function that captured the curvature variation in the model. I used this distance function in the sampling and reconstruction processes and this function has a potential to integrate various phases of model manipulation. For example, I would like to use this distance function to resample large point sets, even before the reconstruction process, for efficient storage and processing. Further, I successfully used this function in surface simplification also to reduce the complexity of the model for efficient rendering. Another graduate student, Deepak Bandyopadhyay implemented this idea for a class project, and the report is in http://www.cs.unc.edu/~debug/258/proposal.html. Pictures of the results can be seen in http://www.cs.unc.edu/~debug/258/final.html. I would like to supervise similar projects that might lead to good dissertation topics. Earlier, I worked in model simplification when I initiated a project to simplify spline models. As far as I know, this was the first attempt to simplify models in curved surface representation without converting them to any other intermediate representation like a polygonal representation. This experience, I am sure, will be useful in dealing with problems related to resampling and simplification.

Related Work:
Simplifying Spline Models
M. Gopi, D. Manocha,
Computational Geometry, Theory and Applications, Vol 14, Issue 1-3, pp 67-90, Nov. 1999.
A Unified Approach for Simplifying Polygonal and Spline Models
M. Gopi, D. Manocha,
Visualization '98.

Hierarchical Subdivision: *(Short term - Long term project)*

Many physically based modeling simulations, like collision detection, need surface representation. Efficiency of these simulations usually depends on good hierarchical representation of these reconstructed surfaces. Most of the present hierarchical subdivision methods assume an unorganized set of triangles without connectivity information. My work on ShellTrees is an example of such a subdivision method. But if the model is reconstructed and simplified using known techniques, we would have the connectivity information. Hierarchical subdivision of models with connectivity information is still an unexplored sub-field that I am excited to study.

For example, all the hierarchical subdivision methods used in collision detection applications invariably use bounding volumes, like bounding boxes and spheres, to enclose regions of the model. In these cases, spatial proximity is used as a guiding principle to subdivide the model, and connectivity information is not used even if it is available. Thus two unconnected regions of the model might lie in the same bounding geometry. But with the connectivity information given and used, two triangles being in the same bounding volume might mean not only spatial proximity but also "topological proximity". This kind of hierarchical subdivision has numerous applications. For example, this subdivision method can be used as a guide to approximate protein structure represented using thousands of spheres to be represented using fewer spheres without losing much of the underlying backbone information.

Relating different geometric processes with one another not only improves the understanding of these processes, but also leads to innovative solutions to various fundamental problems. I believe that there is a strong connection between the simplification process and the process of hierarchical subdivision in the presence of connectivity information. I am very eager to explore this relationship.

Related Work:
Rapid Accurate Contact Determination between Spline Models using ShellTrees
S. Krishnan, M. Gopi, M. Lin, D. Manocha, A. Pattekar,
EUROGRAPHICS '98.

Time varying triangulation: *(Long term project)*

I was looking into the problem of dynamic triangulation when I was in the telepresence group at UNC. Speed issues aside, the basic problem of triangulating dynamic surfaces itself is an exciting geometric problem. This has various applications in molecular modeling, morphing, and transmission of arbitrary animated models. For example, in molecular modeling, researchers are interested in visualizing protein folding or elastic movement of sub-molecular structures. Further, they also want to visualize the structural similarity of one protein molecule from the other using time varying molecular morphing. My research proposal document on dynamic triangulation problem for telepresence applications can be viewed at http://www.cs.unc.edu/~gopi/ResearchProposal.ps. In this document, I have proposed a time coherent surface reconstruction using the information of the "displacement vector" that is similar to the vector computed by MPEG systems for video compression and transmission. One of my immediate research plans is to embark on a project based on this proposal document.

Model Representation: *(Long term project)*

Explicit geometry, light field models, relief textures, normal meshes, distance fields, and surfels are examples of model representations developed over recent years. Representing models using geometry (e.g. triangle meshes) and image-based techniques (e.g. light fields) form opposite ends of the spectrum. The former is not dependent on the viewing direction but dependent on the scene complexity while the latter is dependent on the viewing direction but not dependent on the scene complexity. I am interested in parametrizable representations that span the spectrum from explicit geometry to image based representations.

Each of the above problems is a fundamental problem in computer graphics and many of its applications. Hence they have potential for starting long term and other projects requiring inter-disciplinary collaboration. My immediate research direction would be defined by these problems and few other exciting problems, both related and unrelated to the above topics.