Dr. Fatma Betul Atalay, Assistant Professor

Computational Geometry

B.S., Bilkent University
M.S., University of Maryland, College Park
Ph.D., University of Maryland, College Park

Research Statement

My research work is in the areas of computational geometry and computer graphics. I work on the design, analysis and implementation of geometric data structures and algorithms. My main interest is in issues related to simplicial meshes in high dimensions and quadrilateral meshes.

Hierarchical Simplicial Meshes

I utilize hierarchical simplicial meshes to design data structures to answer multidimensional interpolation queries. Hierarchical data structures based on repeated subdivision of space have been widely used in application areas such as finite element analysis, computer graphics, scientific visualization, geometric modeling, image processing and geographic information systems. In many such applications, the spatial decomposition serves as a discretization of the domain of a scalar or vector field. The field values are sampled at the vertices of the subdivision, and for any other query point the field value could be computed by an appropriate (often linear) interpolation of the field values at the vertices of the cell that contains it.

I work on theoretical and algorithmic issues involved in an efficient pointerless implementation of regular hierarchical simplicial mesh. My principal motivating factor involves space savings using a *pointerless* representation, and performance issues arising from modern memory hierarchies. An essential element of pointerless data structures is having a location code that enables efficient access and navigation of the data structure. For this purpose, I have developed a labeling scheme, which provides unique encoding of the simplices in the hierarchical mesh. Tree traversal, neighbor computation and point location can then be performed efficiently, through the use of these labels. Because of the regularity of the subdivision, given any point in space, it is possible to compute the location code of the node of a particular depth in the tree that contains this point. This can be done entirely in local memory, without accessing the data structure in global memory. Once the location code is computed, the actual node can be accessed through a small number of accesses to global memory (e.g., through hashing). Also, the space savings realized by not having to store pointers and simplex vertices is quite significant for large multidimensional meshes.

Related to the same simplicial mesh structure, I work on proving upper bounds on the cost of compatibly refining simplicial meshes. A simplicial mesh is called *compatible* if pairs of neighboring cells meet along a single common face. The compatibility condition is important since otherwise cracks may occur along the faces of the subdivision, which in turn causes discontinuities in the function and presents problems when using the mesh for interpolation. Refining a simplicial mesh to enforce compatibility requires refining additional simplices if they share split faces with their neighbors. The cost of compatible refinement is that a larger mesh will be generated. My goal is to show that when a simplicial mesh is refined to enforce compatibility, its size would grow by no more than a constant factor. I proved that when compatibly refined the size of a 2-dimensional simplex decomposition tree grows at most by a factor of 14 and this is tight. This is a worst-case bound, however, and preliminary experiments on randomly generated simplex decomposition trees suggest that, in practice the expansion factor is much smaller. For dimensions higher than two, I sketched an upper bound, but a more complete analysis would be needed to prove tight bounds. This is joint work with David Mount of University of Maryland.

Efficient Rendering through Multidimensional Interpolation

Ray-tracing has long been the most popular technique for generating high quality, physically accurate renderings of complex illumination effects such as reflection, refraction, and specular highlights. However, it remains a computationally very expensive technique. In traditional ray-tracing solutions, each ray is traced through the scene as needed to compute the intensity of a pixel in the image. By formulating ray-tracing as a sampling and reconstruction problem, I have designed and implemented a method to help accelerate this process by substituting accurate-but-slow computations by approximate-but-fast interpolations. Given objects defined by smooth curved surfaces, I can produce high-quality renderings faster than ray-tracing. I have applied a similar technique in another graphics application, that is rendering of atmospheric effects which arise from the absorption and scattering of light due to small particles such as smoke and dust. This is joint work with David Mount of University of Maryland.

Minimum Angle-bounded Quadrilateral Meshes

I work on quadrilateral meshes in 2-dimensions. A point set or a polygon is to be quadrangulated, with additional points (Steiner points) allowed into well-shaped quadrilaterals. When constructing such quadran- gulations, several optimization criteria may be considered. Our goal is to generate a quadrangulation where all quadrilaterals are strictly convex and has all angles larger than some constant—that is, the minimum angle is bounded. A simultaneous goal is to keep the number of the quadrilaterals (or, the number of the Steiner points) reasonably small. This is joint work with Dianna Xu of Bryn Mawr College and Suneeta Ramaswami of Rutgers University, Camden.

Interactive Probability Models with Applications

We are creating a set of supplementary learning modules for the probability and statistics course. These modules will include lab activities, interactive computer graphics and data sets from real applications. The goal is to enhance the learning process in probability and statistics courses by facilitating deeper understanding of each function through a hands on interactive visualization of what each function represents. This is joint work with Agnes Rash, Deborah Lurie and Susanna Wei of Saint Joseph's University.