Summary of Research on Layered Manufacturing

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Overview

This research investigated the geometric underpinnings of Layered Manufacturing (LM), which is a technology that produces physical prototypes of complex 3D parts by orienting and slicing the corresponding digital models into thin layers and then printing these layers successively, each atop the previous one. The primary goal was to improve the speed, accuracy, and cost of LM by identifying and solving several key geometric optimization problems that arose in the process planning stage of LM, including generating appropriate tool-paths, minimizing the number of layers, optimizing surface roughness, optimizing the location of so-called support structures, and minimizing the quantity of support structures used. Most of the algorithms developed were implemented in software and tested on real-world geometric models. These results demonstrated that a systematic and rigorous approach, based on fundamental algorithmic methods from computational geometry coupled with rigorous experimentation and testing, could yield substantial improvements over the largely *ad hoc* methods used in commercial LM systems. Applications of LM to prototype design for surgical planning and training in urology were also explored. Rigid and flexible physical prototypes of the collecting system of a patient-specific human kidney were designed and built via LM and subjected to endoscopic manipulation for training purposes.

Publications and other work products resulting from this project can be found at
http://www-users.cs.umn.edu/∼janardan/layered.html

Impact

Some of this work was done in collaboration with Stratasys, Inc.—a Minnesota-based company specializing in LM technology—and resulted in transfer of technology in the form of software that was incorporated in the company's commercial process-planning tool *Quickslice/Insight*$^{\text{tm}}$. The surgical planning work was done in collaboration with urologists at the Univ. of Minnesota Medical School. The PI also co-organized a workshop, "Geometric and Algorithmic Aspects of Computer-Aided Design and Manufacturing", at DIMACS (an NSF Science and Technology Center at Rutgers). The workshop covered LM (in addition to other aspects of CAD/CAM) and an edited volume of refereed papers from the workshop was published by the American Mathematical Society.

Development of human resources in science and engineering

Two Ph.D. students and four M.S. students were advised to completion on this topic. They were: Dr. Jayanth Majhi (Ph.D., now at Synopsys), Dr. Ivaylo Ilinkin (Ph.D., Gettysburg College), Mr. Man Chung Hon (M.S., Intel), Mr. Paul Castillo (M.S., Univ. of Puerto Rico, Mayaguez), Mr. Eric Johnson (M.S., current employment unknown), and Mr. Vijay Rajagopal (M.S., Microsoft). Additionally, one student, Dr. Prosenjit Gupta (Ph.D., now at Heritage Institute of Tech., India), worked on initial phases of this project (but his Ph.D. thesis was on a different topic.)