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Quarterly Progress Report for Contract N00014-90-J-1599

"Modeling Physical Objects"

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Period of May through July of 1990

1 Summary of Activities

The Newton work completed the collision support for arbitrary polyhedral geometries and began working on the temporary contact problem. The implementation was carried out by Bill Bouma and Dr. George Vaněček. For technical details see Section 2.1. The geometry research continued developing the basic theory and infrastructure for constraint-based surface design using the dimensionality paradigm. For technical details see Section 2.2.

The reports and papers completed during the reporting period are listed below in Section 2.4. I formally joined the editorial board of the journal "Computer-Aided Geometric Design." I taught a course on geometric modeling and robotics, in Trento, Italy, in June-July 1990. In May I gave an invited presentation at the third conference on topics in CAGD, in Monte Erice, Sicily. See also Section 2.3

2 Technical Details of the Work

2.1 Mechanical Simulation

During the reporting period, the collision support for Newton was completed. This involved perfecting the B-rep index, a generalization of the binary space partitioning tree that allows efficient testing of collisions between polyhedral solids in motion. In principle, the same geometric analysis also serves for tracking the contacts between two moving bodies that touch. First experiments showed, however, that there are robustness problems for contacts that persist over a longer period of time. The accuracy/robustness problems were studied, and we began discussions of how best to address them.

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2.2 Geometry Research

Work continues to develop the dimensionality paradigm. Together with Jung-Hong Chuang I completed the uniform surface evaluation algorithm discussed in the previous report. Moreover, we found a direct method for computing differential geometry properties of projected surfaces without actually performing the symbolic computation that determines a closed-form representation of the projection. This computation can be exploited in devising local implicit approximations to surfaces defined with the dimensionality paradigm. Jung-Hong Chuang completed his PhD under my supervision, and has accepted a job at the National Chiao Tung University in Taiwan, offered to him after a highly competitive selection from among seventy applicants.

Together with Ching-Shoei Chiang I continued the work on the initial-points problem. We found techniques for limiting the exponential growth of the number of control points needed to represent the constituting equations in the Bernstein-Bézier representation. However, it was found that the domain-shrinking criteria are not very strong, and experiments with an implementation of the method are not of encouraging efficiency. It was therefore decided to suspend the general approach and look for specialized approaches for specific surface classes.

Together with Pamela Vermeer I worked on the faithfulness problem. Briefly, the constraint equations comprising the surface representation in n -space may become dependent along special curves or at exceptional points. These dependencies give rise to spurious solutions. While the presence of these spurious solutions is locally irrelevant, global algorithms can run into difficulties in their vicinity. The objective of this work is to develop generic techniques to exclude such extraneous solutions from the problem formulation, but without resorting to expensive techniques such as factoring polynomials. We developed a method to exclude the effect of singularities by employing techniques from geometric theorem proving. This work continues. At the end of the reporting period we learned that Pamela Vermeer won a fellowship from the AT&T foundation that will support her during the coming years and includes a stipend for books and professional travel.

2.3 Talks, Workshops and Conferences

At the third international conference on topics in CAGD, at the center for scientific culture in Monte Erice, Sicily, I spoke on applications of the dimensionality paradigm, and demonstrated that certain auxiliary surfaces used for blending parametric surfaces with methods developed by Hoschek and by Pogna can be precisely defined. I then presented the theorem on how to compute efficiently differential geometric properties from this definition.

During June-July I directed the course on geometric modeling and robotics, held at the Fibonacci Institute in Trento, Italy. The course was given by three

main lecturers. Michel Bercovier (Hebrew University) taught physical analysis by the finite-element method. Matt Mason (CMU) taught robot manipulation and task planning. I taught geometric and solid modeling. There were also in residence two experts, namely Mike Erdmann (CMU) and Eugene Allgower (Colorado State). After a week of intense lectures attended by approximately 20 participants from North America, Europe, and Israel, a select group of five students stayed behind with the lecturers for a three-week period of research. During this time, we worked on topics including the dimensionality paradigm, parts orientation algorithm for robotic assembly, spatial index structure for collision support in mechanical simulation, finite-element simulations to interpret certain collision experiments, and surface reconstruction from dynamic observation data.

During the stay in Italy, I also visited the Ispra research establishment, a facility of EURATOM working on reactor design and safety. I presented to them my work on Newton, and discussed how it might relate to their objectives. Also, I spoke on the geometry research at Genova, Italy, to an audience of mathematicians.

2.4 Reports and Publications

1. "Algebraic and Numerical Techniques for CAGD," in *Computations of Curves and Surfaces*, W. Dahmen, M. Gasca, C. Micchelli, eds., NATO ASI Series C, Vol. 307, Kluwer Academic, London 1990, 499-528.
2. "Curvature Computations on Surfaces in n -Space," Report CAPO-90-34, Comp. Sci., Purdue Univ; (with J.-H. Chuang).



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