Final Technical Progress Report
(01 January 96 - 31 December 96)

Project Title: Modeling and Simulation in a Reconfigurable Distributed Virtual Environment PI Name (Last, First, MI): __Bajaj, Chandrajit, L.__ Institution: __Purdue University _____

Contract/Grant No. ___ N00014-94-1-0370

AASERT No. ___ N00014-95-1-1025

SUMMARY OF RESEARCH OBJECTIVES

Our research emphasizes modeling algorithms and data structures to support physical simulation and prototyping in a distributed and collaborative virtual environment. One new proposed thrust in geometric modeling algorithms is the use of algebraic splines (A-splines) in two, three and higher dimensions. The other main focus is to develop and demonstrate specific paradigms in our reconfigurable and interoperable distributed virtual environment SHASTRA, which would allow collaborating users to efficiently build three dimensional models from large measured point data sets (jet engines, automobiles, tanks, artificial implants, ...), generate surface and volume meshes coupled to these models and interactively modify the domain in response to the solution of physical phenomena (stress analysis, fluid dynamics). Furthermore, because of the SHASTRA software's distributed client-server nature, other modeling and simulation packages could be easily connected and interfaced for added functionality.

SUMMARY OF TECHNICAL PROGRESS

1. Developed efficient algorithms for the reconstruction of smooth surfaces from scattered scanned data (clouds of points) using A-patches (isocontours of trivariate A-splines). Preliminary results were obtained on detection and representation of sharp features using singular A-patches. This research is reported in publications [2] and [5]. below. Developed novel algorithms for reconstructing boundary and finite element meshes from cross-sectional data of arbitrary topology [3] and [11]. This has been a long studied problem and our solutions are both comprehensive and practical and shall prove to be very popular. Cross-sectional data is predominant in Computed Tomography/Magnetic Resonance Imaging. Reconstruction algorithms are used for populating synthetic environments.

2. Developed algorithms for generating rational spline approximations (trimmed NURBs) and low degree A-spline approximations of arbitrary algebraic curves and surfaces [1] and [4] . NURBs are non-uniform rational B-splines and have become an industry standard. Such conversion algorithms are necessary for data exchange of free-form boundary and solid models of industrial solid modelers.

3. Fast and robust isocontouring and data reduction algorithms were developed [6], [7] and [8], for unstructured meshes in any dimensions, to support the physics visualization of synthetic environments [9] and [10]. The time speedup obtained by preprocessing proves essential for the complex scene and interactive display requirements of synthetic environments.

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October 3, 1997

Dildree Ivery, Grant Specialist
Office of Naval Research
Resident Representative
Federal Building, Room 208
536 South Clark Street
Chicago, IL 60605-1588

Dear Ms. Ivery:

Subject: N00014-95-1-1025

Enclosed please find the Final Technical Report on the above referenced subject.

If you have questions, please feel free to call.

Sincerely,

Louis Pellegrino/rw

Louis Pellegrino, Director
Office of Sponsored Programs

LP:rw
Enclosure

cc: Defense Technical Information Center

4. Enhanced human -computer interaction were developed for collaboration in synthetic environments via brokering processes and constraint managers [12] ,[13]. Brokers are surrogate session managers and thereby enable hierarchical Session Managers for collaboration between multiple groups. Need for constraint management mechanisms (object-object, object-view and view-view constraints) arise in collaborative interactions with both shared data objects and displays. Models for the creation of object oriented constraints and

distributed service scheduling were developed and fully integrated into the existing Shastra substrate, allowing for developers to easily and quickly extend their existing applications to provide these facilities and presenting researchers with the opportunity to experiment with more sophisticated distributed, collaborative and cooperative multi-user applications.

5. New C++ interface libraries where also developed to make it easier to use the Shastra substrate within C++ applications. These interface libraries provided object oriented versions of the network, multimedia and collaboration libraries within the substrate. These new libraries where used in the implementation of an experimental synthetic environment called Networked Learning Spaces [14].

12. a. Number of ONR supported:

i. Papers published or accepted for publication in refereed journals: _4 ii. Papers published or accepted for publication in refereed conferences: _8 iii. Books or book chapters published or in press: __1

b. Trainee Data: Total 8 Female 2 Male 5
Minority 0 Non Us Citizen 3

i. No. of Grad Students 6
ii. No. of Postdoctorals 0
iii. No. of Undergraduates 1

d. Awards/Honors to PI and/or members of PI's research
group (please describe).

Awarded Visualization Chair, and Professor of Computer ScienceThe University of Texas at Austin, Austin, TX. Appointment effective September 1, 1997.

Appointed Director of the Visualization Research Center with the Texas Institute of Computational and Applied Mathematics (TICAM), The University of Texas at Austin. Appointment effective September 1, 1997.

e. Brief description of all transitions (or intended transitions) of your ideas or techniques to industry, to military laboratories or to military application.

Have had several discussions to transition Dynamic Mesh Simplification, Compression and Visualization Techniques to the Institute of Defense Analysis, Arlington, VA for their distributed interactive simulation work as well as wargaming.

g. Attach list of papers and other publications with full citation.

[1] ``Piecewise Rational Approximation of Real Algebraic Curves", (with G. Xu). {Journal of Computational Mathematics}, vol 17, no 1, (1997), 55 -- 71.

[2] ``Reconstruction of Surfaces and Surfaces-on-Surfaces from Unorganized Weighted Points" (with F. Bernardini, G. Xu). {Algorithmica}, 19, (1997), 243-261.

[3] ``Arbitrary Topology Shape Reconstruction from Planar Cross Sections", (with K. Lin, E. Coyle), {Graphical Models and Image Processing}, vol 58, no 6, (1996), 524 - 543.

[4] ``Spline Approximations of Real Algebraic Surfaces", (with G. Xu). {Journal of Symbolic Computation}, Special Isssue on Parametric Algebraic Curves and Applications, 23, (1997), 315 - 333.

[5] ``Splines and Geometric Modeling", (with S. Evans) {CRC Handbook of Discrete and Computational Geometry}, edited by J. Goodman and J. O'Rourke, CRC Series, {Discrete and Combinatorial Mathematics}, (1997), 833 - 849.

[6] ``Error Bounded Reduction of Triangle Meshes with Multivariate Data", (with D. Schikore), {Proc. of Visual Data Exploration and Analysis III}, SPIE vol 2656, (1996), 34 - 45.

[7] ``Splitting a Complex of Convex Polytopes in Any Dimension", (with V. Pascucci), {Proc. of the 12th Annual ACM Symposium on Computational Geometry}, ACM Press, (1996), Philadelphia, PA, 88 - 97.

[8] ``Fast Isocontouring for Improved Interactivity", (with V. Pascucci, D. Schikore), {Proc. of the ACM Siggraph/ IEEE Symposium on Volume Visualization}, ACM Press, (1996), San Francisco, CA, 39 -- 46.

[9] ``Physical Simulation of the Visible Human Joints" (with F. Bernardini, K. Lin, E. Sacks, D. Schikore), {Proc. of the Visible Human Project Conference}, NIH/NLIM, (1996), ed. Richard Banvard, Program chairman, Michael J. Ackerman Ph.D., Bethesda, MD..

[10] ``Interrogative Visualization of the Visible Human Datasets" (with F. Bernardini, V. Pascucci, D. Schikore), {Proc. of the Visible

Human Project Conference}, NIH/NLIM, (1996), ed. Richard Banvard, Program chairman, Michael J. Ackerman Ph.D., Bethesda, MD.

[11] `` Boundary and 3D Triangular Meshes from Planar Cross Sections", (with E. Coyle, K. Lin), {Proc. of the Fifth International Meshing Roundtable}, Sandia National Lab., Sandia Report SAND96-2301, UC-405, (1996), Pittsburgh, PA, 169 -- 178.

[12] C. Bajaj and Peinan Zhang. ``Object Based Constraint Management for Collaborative Systems". Technical report 96-039, Computer Sciences, Purdue University, 1996.

[13] C. Bajaj and S. Cutchin. Web Based Collaboration-Aware Synthetic Environments. Proceedings of the 1997 GVU/NIST TEAMCAD workshop, Atlanta, GA, 1997, 143 - 150 .

[14] N. Osumi, M. Shinya, T. Mori, T. Sunaga, C. Bajaj, S. Cutchin, and R. Merkert. ``NLS: Collaborative Virtual Environment to Promote Shared Awareness", Workshop on New Paradigms in Information Visualization and Manipulation, NPIV '96. In conjunction with Fifth ACM International Conference on Information and Knowledge Management (CIKM '96), pages 41 - 45, 1996.

h. List of Invited Presentations

1. ``Modeling and Visualization of Multivariate Data", ONR Workshop on Visualization, Phoenix, (February 1996)

2. ``Interrogative Visualization", University of Texas, Austin, Computer Science and TICAM center, (February 1996).

3. ``Collaborative CAD", IFIP Meeting on Geometric Modeling, Arlie, VA (May 1996).

4. ``Splitting a Complex of Convex Polytopes", ACM Computational Geometry Symposium, Philadelphia, (May 1996).

5. ``Modeling Surfaces and Associated Fields", Dagstuhl Seminar on Geometric Modeling, West Germany (May 1996).

6. ``Collaborative Shape Optimization in SHASTRA", and ``Interrogative Visualization", High Performance Scientific Computing, C3AD, Brazil, (July 1996).
7. ``Free-Form Modeling using Implicit Algebraic Splines" and ``Polynomial Surface Patch Representations", SIGGRAPH 96 Courses, New Orleans, (July 1996).

8. ``Computational Geometry for Interrogative Visualization", Canadian Computational Geometry, Ottawa, Canada, (August 1996).

9. ``Modeling and Visualizing Vector Fields",Mathematics of Surfaces, Dundee, U.K. (September 1996).

10. ``The Shastra Project", University of Texas, Austin, Computer Science, (November 1996).

11. ``Biomedical Modeling, Simulation, Visualization, Validation from 3D Scans", IMA Workshop on 3D Scanning, Minneapolis, MN (December 1996)

i. List of Program Committees Served

1. Pacific Graphics '96, Taiwan, 1996

2. Implicit Surfaces '96, Eurographics, Netherlands, 1996.

3. Computer Graphics International '96, Korea, 1996.

4. Fifth IEEE Workshop on Enabling Technologies for Concurrent Engineering, California, 1996.

5. Pacific Graphics '97, Korea, 1997

6. Computer Graphics International '97, Belgium, 1997.

7. Workshop on Algorithms and Data Structures '97, WADS, Halifax, Canada 1997.

j. List of Journal Editorial Board Service

1. ACM Transactions on Graphics.
2. International Journal of Computational Geometry and Applications.
3. Journal of Computer Aided Geometric Design, Special Issue on Medical
Volume Modeling and Visualization.