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FINAL TECHNICAL REPORT

for

NASA GRANT NAG 3-395

INTERACTIVE COLOR DISPLAY OF 3-D ENGINEERING ANALYSIS RESULTS

(Originally Entitled INTERACTIVE GRAPHICAL COLOR DISPLAY OF 3-D SEAL-FLOW BEHAVIOR)

covering the period
1 March 1983 - 28 February 1987

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The principal technical findings and accomplishments of this project have been presented in three detailed technical reports submitted to the sponsoring agency. Each of these three reports also served as the anthor's M.S. thesis in Structural Engineering. The three reports are:

1. J. F. Hajjar, "General-Purpose Three-Dimensional Color Postprocessing for Engineering Analysis," Program of Computer Graphics Technical Report 84-1 to NASA Lewis Research Center, November, 1984.
2. B. C. Bailey, "Unification of Color Postprocessing Techniques for Three-Dimensional Computational Mechanics," Program of Computer Graphics Technical Report 85-1 to NASA Lewis Research Center, August, 1985.
3. M. J. Panthaki, "Color Postprocessing for Three-Dimensional Finite Element Mesh Quality Evaluation and Evolving Graphical Workstations," Program of Computer Graphics Technical Report 87-1 to NASA Lewis Research Center, March, 1987.

Copies of the abstracts of these three reports are appended to this report and these summarize the entire project.

In addition, a number of technical papers have emanated from this research. These include the following four completed papers, copies of which have been submitted separately to the sponsoring agency, and one manuscript in progress, which will be submitted upon completion:

1. J. F. Abel, A. R. Ingraffea, R. Perucchio, T.-Y. Han,and J. F. Hajjar, "Interactive Computer Graphics for Finite Element, Boundary Element, and Finite Difference Methods, "Unification of Finite Element Methods, North-Holland, 1984, pp. 47-63.
2. J. F. Abel, A. R. Ingraffea, W. McGuire, and D. P. Greenberg, "Interactive Color Graphical Postprocessing as a Unifying Influence in Numerical Analysis Research," Unification of Finite Element Software Systems, North-Holland, 1985, pp. 21-37. Also published in Finite Elements in Analysis and Design, Vol. 2, Nos. 1-2, April, 1986.
3. B. C. Bailey, J. F. Hajjar, and J. F. Abel, "Towards Effective Interactive Three-Dimensional Color Postprocessing," Engineering Computations, Vol. 3, No. 2, June, 1986, pp. 90-98.
4. J. F. Abel, M. J. Panthaki, and P. A. Wawrzynek, "Interactive Graphics and Analysis Accuracy," Reliability of Methods for Engineering Analysis, K. J. Bethe and D. R. J. Owen, editors, Pineridge Press, Swansea, Wales, 1986, pp. 305-318.
5. M. J. Panthaki, J. F. Abel, and P. A. Wawrzynek, "Graphical Postprocessing for 3-D Mesh Quality Evaluation," in preparation for submission to Engineering Computations.

GENERAL-PURPOSE THREE-DIMENSIONAL COLOR POSTPROCESSING FOR ENGINEERING ANALYSIS

by Jerome Frederick Hajjar

November 1984

ABSTRACT

A general approach to three-dimensional postprocessing of engineering analyses is presented. The approach is versatile and may handle the results from a wide range of engineering analysis methods which involve the discretization of continua. Examples of such analysis types are the finite element, finite difference, and boundary element methods. Interactive color postprocessing software using computer graphics techniques is developed to demonstrate this approach. The capabilities of advanced hardware are used, although an attempt is made to keep the software relatively flexible with respect to the type of device used.

A shaded image of the object or system being viewed is provided for the visualization of its three-dimensional geometry. Interactive manipulation and sectioning of the object is possible, and the response and attribute data may be inspected using a number of methods. A wide range of responses may be examined, including all types of scalars, vectors, and second rank tensors. The approach may be used both to provide a qualitative feel for the behavior of the continua or to obtain the detailed quantitative results of an analysis. The accuracy of the analysis or simulation may be assessed, and data necessary for redesign may be obtained.

UNIFICATION OF COLOR POSTPROCESSING TECHNIQUES FOR THREE-DIMENSIONAL COMPUTATIONAL MECHANICS

by Bruce Charles Bailey

August 1985

ABSTRACT

To facilitate the understanding of complex three-dimensional numerical models, advanced interactive color postprocessing techniques are introduced. These techniques are sufficiently flexible so that postprocessing difficulties arising from model size, geometric complexity, response variation, and analysis type can be adequately overcome. They have proven themselves through use in contemporaneous research efforts, and an exemplary user interface is provided to allow their easy use.

Finite element, finite difference, and boundary element models may be evaluated with the prototype postprocessor. Elements may be removed from parent models to be studied as independent "subobjects." Discontinuous responses may be contoured including responses which become singular, and nonlinear color scales may be input by the user for the enhancement of the contouring operation. Hit testing can be performed to extract precise geometric, response, mesh, or material information from the database. In addition, stress intensity factors may be "contoured" along the crack front of a fracture model. Stepwise analyses can be studied, and the user can recontour responses repeatedly, as if he were "paging" through the response sets. As a system, these tools allow effective interpretation of complex analysis results.

COLOR POSTPROCESSING FOR THREE-DIMENSIONAL FINITE ELEMENT MESH QUALITY EVALUATION AND EVOLVING GRAPHICAL WORKSTATIONS

by Malcolm J. Panthaki

March 1987

ABSTRACT

This research represents the third and final phase of a project on general-purpose, interactive color graphics postprocessing for three-dimensional computational mechanics. Three general tasks are accomplished. First, the existing program (POSTPRO3D) is ported to a high-resolution device. In the course of this transfer, numerous enhancements are implemented in the program. The performance of the new hardware is evaluated from the point of view of engineering postprocessing, and the characteristics of future hardware are discussed.

Second, interactive graphical tools are implemented to facilitate qualitative mesh evaluation from a single analysis. The literature is surveyed and a bibliography compiled in this area of research. Qualitative mesh sensors are examined, and the use of two-dimensional plots of unaveraged responses on the surface of three-dimensional continua is emphasized in an interactive color raster graphics environment.

Finally, a new postprocessing environment is designed for state-of-the-art workstation technology. Modularity, personalization of the environment, integration of the engineering design processes, and the development and use of high-level graphics tools are some of the features of the intended environment.