

08:04:59

OCA PAD AMENDMENT - PROJECT HEADER INFORMATION

02/10/92

Active

Project #: E-20-G15

Cost share #: C-50-312

Rev #: 3

Center #: 10_24-6-R7014-1A0

Center shr #: 10/22-1-F-7014-1A1

OCA file #:

Contract#: MSM-9196186

Mod #: ADM REV

Work type : RES

Prime #:

Document : GRANT

Contract entity: GTRC

Subprojects ? : Y

CFDA: 47.041

Main project #:

PE #:

Project unit:

CIVIL ENGR

Unit code: 02.010.116

Project director(s):

RODRIGUEZ W E

CIVIL ENGR

(404)894-2390

Sponsor/division names: NATL SCIENCE FOUNDATION

/ GENERAL

Sponsor/division codes: 107

/ 000

Award period: 910515 to 920630 (performance) 920930 (reports)

| Sponsor amount | New this change | Total to date |
|---------------------|-----------------|---------------|
| Contract value | 0.00 | 119,200.00 |
| Funded | 0.00 | 119,200.00 |
| Cost sharing amount | | 0.00 |

Does subcontracting plan apply ? : N

Title: DEV& EVAL OF COMPUTER ANIMATION RES TESTBED FOR CONSTRUCTION SITE OPERATIONS

PROJECT ADMINISTRATION DATA

OCA contact: Mildred S. Heyser

894-4820

Sponsor technical contact

Sponsor issuing office

KEN CHONG

(202)357-9542

MARTIN V. GEARY

(202)357-9602

NSF

1800 G STREET, N.W.

WASHINGTON, D.C. 20550

NATIONAL SCIENCE FOUNDATION

1800 G STREET, N.W.

WASHINGTON, D.C. 20550

Security class (U,C,S,TS) : U

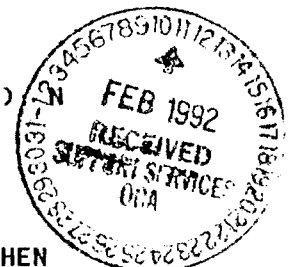
ONR resident rep. is ACO (Y/N)

Defense priority rating :

supplemental sheet

Equipment title vests with: Sponsor

GIT X



Administrative comments -

TO CORRECT GRANT NO., NOTE; THIS CORRECTED GRANT NO. SHOULD BE USED WHEN TRANSMITTING ANY REPORTS TO NSF.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 07/22/92

Project No. E-20-G15_____ Center No. 10_24-6-R7014-1A0_

Project Director RODRIGUEZ W E_____ School/Lab CIVIL ENGR_____

Sponsor NATL SCIENCE FOUNDATION/GENERAL_____

Contract/Grant No. MSM-9196186_____ Contract Entity GTRC

Prime Contract No. _____

Title DEV& EVAL OF COMPUTER ANIMATION RES TESTBED FOR CONSTRUCTION SITE OPERATI

Effective Completion Date 920630 (Performance) 920930 (Reports)

| Closeout Actions Required: | Y/N | Date Submitted |
|---|-----|----------------|
| Final Invoice or Copy of Final Invoice | N | _____ |
| Final Report of Inventions and/or Subcontracts | N | _____ |
| Government Property Inventory & Related Certificate | N | _____ |
| Classified Material Certificate | N | _____ |
| Release and Assignment | N | _____ |
| Other _____ | N | _____ |

Comments BILLING VIA LETTER OF CREDIT; 98A SATISFIES REQUIREMENT FOR PATENT_____
REPORT_____

Subproject Under Main Project No. _____

Continues Project No. E-20-683_____

Distribution Required:

| | |
|---------------------------------------|---|
| Project Director | Y |
| Administrative Network Representative | Y |
| GTRI Accounting/Grants and Contracts | Y |
| Procurement/Supply Services | Y |
| Research Property Management | Y |
| Research Security Services | N |
| Reports Coordinator (OCA) | Y |
| GTRC | Y |
| Project File | Y |
| Other _____ | N |
| _____ | N |

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEDOUT (SUBPROJECTS)

Closeout Notice Date 07/22/92

Project No. E-20-G15

Center No. 10_24-6-R7014-1A0_

Project Director RODRIGUEZ W E_____

School/Lab CIVIL ENGR_____

Sponsor NATL SCIENCE FOUNDATION/GENERAL_____

| | | | |
|------------------------------|----------------------|-----------------|-------------|
| Project # C-50-609 | PD GUENTER B K | Unit 02.010.300 | T |
| GRANT # MSM-9196186 | MOD# | BUD REV 5/12/92 | COMPUTING * |
| Ctr # 10/24-6-R-7014-1A1 | Main proj # E-20-G15 | OCA CO | MSH |
| Sponsor-NATL SCIENCE FOUNDAT | /GENERAL | | 107/000 |
| DEV& EVAL OF COMPUTE | | | |
| Start 910515 | End 920630 | Funded | 52,484.00 |
| | | Contract | 52,484.00 |

LEGEND

1. * indicates the project is a subproject.
 2. I indicates the project is active and being updated.
 3. A indicates the project is currently active.
 4. T indicates the project has been terminated.
 5. R indicates a terminated project that is being modified.
-

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National Science Foundation
Permit No. G-69

PI/PD Name and Address

Walter E. Rodriguez-Ramos
Civil Engineering
GA Tech Res Corp - GTRI
Atlanta GA 30332 -
0355

NATIONAL SCIENCE FOUNDATION FINAL PROJECT REPORT

| PART I - PROJECT IDENTIFICATION INFORMATION | |
|---|--|
| 1. Program Official/Org. | Ken Chong - MSS |
| 2. Program Name | STRUCTURES, GEOMECHANICS & BLDG SYSTEMS |
| 3. Award Dates (MM/YY) | From: 05/91 To: 12/91 |
| 4. Institution and Address | GA Tech Res Corp - GTRI Atlanta GA 30332 |
| 5. Award Number | 9196186 |
| 6. Project Title | Minority Research Initiation: Development and Evaluation of A Computer Animation Research Testbed for Construction Site Operations |

This Packet Contains
NSF Form 98A
And 1 Return Envelope

NSF Grant Conditions (Article 17, GC-1, and Article 9, FDP-II) require submission of a Final Project Report (NSF Form 98A) to the NSF program officer no later than 90 days after the expiration of the award. Final Project Reports for expired awards must be received before new awards can be made (NSF Grant Policy Manual Section 677).

Below, or on a separate page attached to this form, provide a summary of the completed project and technical information. Be sure to include your name and award number on each separate page. See below for more instructions.

PART II - SUMMARY OF COMPLETED PROJECT (for public use)

The summary (about 200 words) must be self-contained and intelligible to a scientifically literate reader. Without restating the project title, it should begin with a topic sentence stating the project's major thesis. The summary should include, if pertinent to the project being described, the following items:

- The primary objectives and scope of the project
- The techniques or approaches used only to the degree necessary for comprehension
- The findings and implications stated as concisely and informatively as possible

SEE ATTACHMENTS

PART III - TECHNICAL INFORMATION (for program management use)

List references to publications resulting from this award and briefly describe primary data, samples, physical collections, inventions, software, etc. created or gathered in the course of the research and, if appropriate, how they are being made available to the research community. Provide the NSF Invention Disclosure number for any invention.

SEE ATTACHMENTS

| | |
|---|---------|
|  | 3/12/92 |
| Principal Investigator/Project Director Signature | Date |

IMPORTANT:
MAILING INSTRUCTIONS
Return this *entire* packet plus all attachments in the envelope attached to the back of this form. Please copy the information from Part I, Block I to the *Attention block* on the envelope.

PART IV — FINAL PROJECT REPORT — SUMMARY DATA ON PROJECT PERSONNEL

(To be submitted to cognizant Program Officer upon completion of project)

The data requested below are important for the development of a statistical profile on the personnel supported by Federal grants. The information on this part is solicited in response to Public Law 99-383 and 42 USC 1885C. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. You should submit a single copy of this part with each final project report. However, submission of the requested information is not mandatory and is not a precondition of future award(s). Check the "Decline to Provide Information" box below if you do not wish to provide the information.

Please enter the numbers of individuals supported under this grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

| | Senior Staff | | Post-Doctorals | | Graduate Students | | Under-Graduates | | Other Participants ¹ | |
|---|--------------|------|----------------|------|-------------------|------|-----------------|------|---------------------------------|------|
| | Male | Fem. | Male | Fem. | Male | Fem. | Male | Fem. | Male | Fem. |
| A. Total, U.S. Citizens | | | | | | | | | | |
| B. Total, Permanent Residents | | | | | | | | | | |
| U.S. Citizens or Permanent Residents ² : | | | | | | | | | | |
| American Indian or Alaskan Native . . . | | | | | | | | | | |
| Asian | | | | | | | | | | |
| Black, Not of Hispanic Origin | | | | | | | 1 | | | |
| Hispanic | 1 | | | | | 1 | | | | |
| Pacific Islander | | | | | 1 | | | | | |
| White, Not of Hispanic Origin | | | | | 1 | | | | | |
| C. Total, Other Non-U.S. Citizens | | | | | | | | | | |
| Specify Country | | | | | | | | | | |
| 1. | | | | | | | | | | |
| 2. | | | | | | | | | | |
| 3. | | | | | | | | | | |
| D. Total, All participants (A + B + C) | 1 | | | | 2 | 1 | 1 | | | |
| Disabled ³ | | | | | | | | | | |

Decline to Provide Information: Check box if you do not wish to provide this information (you are still required to return this page along with Parts I-III).

¹Category includes, for example, college and precollege teachers, conference and workshop participants.

²Use the category that best describes the ethnic/racial status for all U.S. Citizens and Non-citizens with Permanent Residency. (If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)

³A person having a physical or mental impairment that substantially limits one or more major life activities; who has a record of such impairment; or who is regarded as having such impairment. (Disabled individuals also should be counted under the appropriate ethnic/racial group unless they are classified as "Other Non-U.S. Citizens.")

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintain cultural identification through tribal affiliation or community recognition.

ASIAN: A person having origins in any of the original peoples of East Asia, Southeast Asia and the Indian subcontinent. This area includes, for example, China, India, Indonesia, Japan, Korea and Vietnam.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

PACIFIC ISLANDER: A person having origins in any of the original peoples of Hawaii; the U.S. Pacific Territories of Guam, American Samoa, or the Northern Marianas; the U.S. Trust Territory of Palau; the islands of Micronesia or Melanesia; or the Philippines.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa, or the Middle East.

NSF Final Project Report (Award Number 9196186)

Development and Evaluation of A Computer Animation Research Testbed for Construction Site Operations

Walter Rodriguez
(Walter E. Rodríguez-Ramos)
School of Civil Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0355

PART II

□ SUMMARY OF COMPLETED PROJECT (for public use)

Although a myriad of design, simulation and construction (manufacturing) software systems are commercially available, they are not effective due to the dynamic nature of the design and construction communication processes. The principal investigator received a research award from National Science Foundation's Structures, Geomechanics and Building Systems division in May 1991 to December 1991 for research in visual simulation of construction processes. Under this Minority Research Initiation grant, both a functional "computing framework" and a "testbed" for design/construction operations simulation were developed.

Research was for the most part applied to the *creation of a construction visual simulation system* named the Construction Visualizer (CV) that was recently profiled on national television (CNN's World News, etc.) CV facilitates the design of construction operations at a particular site by providing dynamic 3-D primitives that represent machines, robots, people and materials. Each primitive has its own interactive animation capabilities, allowing the design/construction team to manipulate resources, edit the site, and evaluate construction operations alternatives, visually.

In addition, several visualization techniques were developed to improve the dynamic communication involved in the design and construction processes. The following visual-oriented methodologies were developed:

- (a) path algorithms for optimizing resource utilization,
- (b) kinematics for equipment (cranes, robots, etc.) simulations,
- (c) realistic rendering algorithms to represent the construction site, and an
- (d) animation/simulation language to allow procedural description of design and construction processes.

These experimental 3-D visualization techniques were used in assessing the value of computer animation/simulation in construction site activities; that is, quantitative visual reporting of user activities, resource utilization as well as evaluation of site design alternatives. Such visual reporting allows the scientific evaluation of computer animation/simulation functionality.

CV has opened a door that could potentially lead to new-visually-oriented process technologies and a more productive construction industry. CV is currently being used as an educational tool for pedagogical purposes as well as to identify future design and construction site research problems.

□ RESEARCH AND COMMUNITY IMPACT

As mentioned in the summary, several national and international companies (METRIC; CRSS; CSA; Wilson, Miller, Barton, Soll & Peek, Inc.; Charles Pankow Builders; and SHIMIZU-Japan) have expressed interest in the CV system. The CV system was recently profiled on national television (CNN's "Science and Technology", February, 1992) as well as on international magazines such as *Engineering News Record* (October 7, 1991) and *DesignNet*. (February, 1992).

It is anticipated that the new design and construction visual tools that have already been developed would eventually lead to software products that may be marketed nationally as well as internationally. Independent contractors would also benefit from the resulting productivity tools. Another positive outcome is that the integration of visualization tools in design and construction would assist in optimizing the use of the limited natural resources of our planet Earth.

A part of the NSF funding was used to support three (3) PhD students who expect to graduate in 1993. A list of publications that resulted - directly or indirectly - from this research is given below.

□ BOOKS

1. Rodriguez, W. (1992) The Modeling of Design Ideas 1/e, New York: McGraw-Hill Book Company, ISBN 0-07-053394-6, 272 pp. (\$29.95).

□ ARTICLES

1. Opendbosch, A. and Rodriguez, W., "Reverse Ray Tracing Technique for Complex Surface Visualization", Journal of Theoretical Graphics and Computing, STCG, Vol. 3, No. 1, August 1990, pp. 31-36.
2. Rodriguez, W.E., "Visualización Usando el Computador Gráfico", Jornadas de Expresión Gráfica, Huelva, Spain (Editor: Xoan Leicega Baltar, Congreso de Expresión Gráfica en la Ingeniería, Huelva, Spain, June 1-3, 1990, pp. 351-361).

PART III - TECHNICAL INFORMATION

Walter Rodriguez (Award # 9196186)

3. Rodriguez, W.E., "High-Level-Function Tests for Design Visualization", Fourth International Conference on Engineering Computer Graphics and Descriptive Geometry, Miami, FL., June 11-15, 1990.
4. Rodriguez, W.E. and Salthouse, T.A., "Spatial Visualization Research Survey On Third-Angle Orthogonal Projection Problems", 1990 ASEE Conference, Toronto, Canada, June 24-28, 1990.
5. Rodriguez, W.E., "The Engineering Design Process", Summerscape, July 9-13, 1990; and in Meet the Mentor Program, College of Sciences, December 7, 1991. Georgia Tech, Atlanta, Georgia (Mentoring activities for African-American and Hispanic-American minorities.)
6. Rodriguez, W.E., "Focusing on Design Visualization: A Variation to the Barr-Juricic Plan in the Quarter System", Proceedings Symposium on Modernization of the Engineering Design Graphics Curriculum, National Science Foundation & Univ. of Texas, Austin, Texas, August 5-7, 1990.
7. Weed, M. and Rodriguez, W.E., "Design-Prototyping for Ideation", Proceedings Engineering Design Graphics Division Conference, ASEE Tempe, Arizona, Nov. 18-20, 1990.
8. Leiceaga, X. and Rodriguez, W.E., "International Graphic Standards Issues", Proceedings Engineering Design Graphics Division Conference, ASEE Tempe, Arizona, Nov. 18-20, 1990.
9. Sinclair, M. Vitz, F., Otero, S. and Rodriguez, W.E., "Virtual-Reality System for Engineering Design Visualization", Proceedings Engineering Design Graphics Division Conference, ASEE Tempe, Arizona, Nov. 18-20, 1990.
10. Rodriguez, W., "Design as an ISI Process", Journal of Theoretical Graphics and Computing, STCG, Vol. 3, No. 2, December 1990, pp. 64-70.
11. Rodriguez, W.E., Hodges, L. and Leiceaga, X., "Graduate Graphics Programs", Proceedings Engineering Design Graphics Division Conference, ASEE, Tempe, Arizona, Nov. 18-20, 1990.
12. Hodges, L., Rodriguez, W.E., and McWhorter, S., "Evaluation of 3-D Display Techniques for Engineering Design Visualization", Proceedings Engineering Design Graphics Division Conference, ASEE Tempe, Arizona, Nov. 18-20, 1990.

PART III - TECHNICAL INFORMATION

Walter Rodriguez (Award # 9196186)

13. Hodges, L., McWhorter, S., and Rodriguez, W., "Comparison of 3-D Display Formats for CAD Applications", Proceedings Electronic Imaging Science and Technology Conference, SPIE/SPSE 1457, San Jose, California, Feb. 24 - March 1, 1991.
14. McWhorter, S., Rodriguez, and W., Hodges, L., "GUIs Performance in an Interactive Display Environment", Proceedings, ASEE Engineering Design Graphics Conference, Norfolk, Virginia, November, 2-6, 1991, pp. 29-36.
15. Opendbosch, A. and Rodriguez, W. "Visualizing Parametric Surfaces with the Enhanced Reverse Ray Tracing Technique", Proceedings, ASEE Engineering Design Graphics Conference, Norfolk, Virginia, November, 2-6, 1991, pp. 97-106.
16. Rodriguez, W., and Salthouse, T., "Spatial Visualization Research Survey", Journal of Theoretical Graphics and Computing, STCG, Vol. 3, No. 2, December 1990, pp. 78-83.
17. Opendbosch, A., Patterson, W., and Rodriguez, W., "Visual Simulation of Construction Hoisting Operations", Journal of Theoretical Graphics and Computing, STCG, Vol. 4, No. 1, pp. 59-68.
18. Rodriguez, W. and McWhorter, S., "A Simple Procedure to Import CAD Files into WP", MCN: Integrated Solutions for Design and Engineering, Vol. 6, No. 2, February 1991, pp. 45.
19. Rodriguez, W., "The Art of Design", MCN: Integrated Solutions for Design and Engineering, Vol. 6, No. 3, March 1991.
20. Rodriguez, W., "Checking Planarity of Faces", MCN: Integrated Solutions for Design and Engineering, Vol. 6, No. 5, May 1991.
21. Rodriguez, W., and Otero, S., "Junctions in CAD Solids", MCN: Integrated Solutions for Design and Engineering, Vol. 6, No. 7, July 1991, pp. 57.
22. Opendbosch, A. and Rodriguez, W., "Visualizing Parametric Surfaces with the Enhanced Reverse Ray Tracing Technique," Journal of Theoretical Graphics and Computing, STCG, Vol. 4, No. 2, December 1991, pp. 69-82.

CV has been featured in:

1. "Simulation provides Preview", Research Section, Engineering News Record, October 7, 1991.
2. Hurtado, Robert, "Visualiza la Construcción en Computadora", EL NUEVO DIA (newspaper with the largest circulation in Puerto Rico), Business Section, October 12, 1991, pp. 56.
3. McLees, Lea, "Site Simulation Could Improve Construction Facility Planning", Whistle, Vol. 17, No. 31, October 28, 1991, pp. 3.; and in Research News Release, September 9, 1991.
4. CNN's Prime News and World News, "Construction Visualizer," Thursday, February 6, 1992
5. CNN's Morning News, Friday, February 7, 1992
6. CNN's Science and Technology Week, Saturday, February 8, 1992 (Main feature: "Construction Visualizer"); ditto Sunday, February 9, 1992, 12:30 PM.
7. U.S.: MicroCAD News article posted in ARPANET by Dr. E.G. Wiggins, Dean of the Webb Institute of Naval Architecture in Glen Cove, N.Y., 1990
8. U.S.: DesignNet feature article "Construction Site Design" by Lea McLees, February 1992, pp.31-32. (Will also appear in the European version of the DesignNet magazine) .
9. U.S.: Architecture, article "New Frontiers in CAD" by B.J. Novitski, January 1992, pp.103-105.

Appendix: Background Information

Objectives

1. Review of current work on animation/simulation. Determination of the functional requirements (FRs) for the visualization and design of construction site operations.
2. Develop a visualization technique to facilitate construction site design and operations optimization.

Findings

A. First Phase:

Computer animation (simulation) integration in the construction site was categorized in five levels: (1) The system acts as a graphics editor for the design and optimization of construction site layouts (Rodriguez & Francis, 1983), (2) The system computes in-between scenes and construction equipment paths, (3) The system provides equipment operations such as translation and rotation, (4) The system provides facilities for defining construction objects which possess their own animation, (5) The system is extensive and can learn from a construction site manager expert. The system continually increases in power and intelligence. Existing key frame animation systems are currently at the level 2. Level 3 and 4 require extensive modeling capabilities. No level 5 systems are yet available. Animation toolbox testbeds were evaluated and tested with an in-house performance monitoring program (Rodriguez & Harrell, 1989). The potential use, FR's, and methods for the use of animation to simulate and visualize construction site operations have been identified (Rodriguez & Jones, 1988).

B. Second Phase:

1. We have researched some additional aspects of visual presentation such as detail resolution, realism, spatial accuracy and temporal accuracy which play an important role in understanding animation sequences. We researched computer languages and selected EIFFEL and C++ as the languages for the testbed development. We used the ICES kernel of solid primitives to model the construction objects (cranes, trucks, etc.) and import them into the construction visualizer editor.
2. We are currently working on refining the CV testbed.
 - a. The testbed design responds to the following functional requirements: (FR1) Minimize material handling cost (distance, time) between depots; FR2: Maximize safety (avoid interference between equipment). We comment that two widely accepted design principles have been satisfied: The independence of FRs, and the minimization of the information content (Suh, 1990).

b. The high level design of the system is finished and we are concurrently working on refining software coding. The prototype system present the user with a set of motion primitives which are used to generate the animations and visual simulations. Currently, we are providing the 3-D dynamic primitives that allow *moveto*, *grasp*, and *release*. For example, a simple animated optimal "path" involves a truck bringing material to a crane, and a crane picking the material up from the truck and putting it on top of the building structure. Path planning algorithms have been chosen and coded (Rodriguez & Francis, 1983; etc.). The testbed system automatically generates collision free paths.

c. An experimental prototype 3-D interface was developed based on a time-multiplexed stereoscopic display system - implemented with monitor calls. We have investigated the effectiveness of computer-generated realism cues for the visualization of construction site scenes (cues include motion, number of light sources, shading techniques, stereoscopic display, and hidden surface removal). This investigation uses a factorial experimental design to evaluate the effect of the type of computer graphics display provided for visual feedback on the user's performance on an object recognition and 3-D manipulation task (tower crane hook to site supply depots). The independent variables in the experiments are the presence of binocular cues, occlusion cues, surface shading cues, or any other factor, as yet undecided, that may affect user performance on this task. The dependent variables in this investigation measures task performance, such as the time for task completion or task error rates.

d. We have developed an enhanced reverse ray tracing technique to model and render the predefined geometry (topography) of construction sites. The topographical surface model is defined by control points using existing contour-data from the sites. The technique is based on the investigators' previous development work with the reverse ray tracing (RRT) technique (Opdenbosch & Rodriguez, 1990). In RRT, an object is drawn by intersecting vectors with the computer screen. These vectors are traced from points on the object surface to the observer location. RRT is very slow due to the necessity of super-sampling points on the object surface. The performance of this technique is being improved by defining a relationship between the actual area and the projected area on the object and use it to control the sampling of the points on the object surface.

e. We have developed a tool to simulate the real-time operations of a high-rise building hoist. This visual simulator is used to determine the performance of a personnel and material hoist (elevator) under different conditions. The simulation runs in real-time and allows the construction manager to take action in the process. The simulation creates its own people (and materials) and place them randomly at different building floors. The rate of arrival for the resources is controlled by an exponential random

generator which can be set and manipulated for each of the stories of the building. The time that takes the elevator to move from floor to floor is a variable defined in an input file along with other parameters such as unloading and loading times, capacity of the elevator, number of stories in the building, etc. Two files are generated: One contains the history of each resource, the other contains the data for the 3-D output interface to visualize the hoisting process. This simulation is currently being integrated into CV. The user can presently move material and people in a simulated construction site.

3. The suitability of the testbed for a specific test, particularly, the user interface for placement of stationary construction cranes and other construction equipment has been evaluated.
4. We have developed a video for the construction visualizer (cv) system. This video is currently being distributed to selected graduate construction schools and interested construction companies.
 - a. Three video and live presentations have already been done: Construction Dept., College of Architecture at Texas A&M University, "Visualizing Design and Construction Processes" (Feb. 1, 1991); College of Engineering, University of Puerto Rico at Mayaguez (December 12, 1991), and at the 1991 ASEE Conference in New Orleans.
 - b. The PI has presented the CV concept to various design and construction companies, including CRSS, Inc. in New York, HKS, Inc., R.S. Williams Construction Company, Inc. (Dallas), History Maker Homes, Inc. in Dallas, and Metric Constructors in Atlanta, among others.

Related M.S. and Ph.D. Theses

1. Opend Bosch, Augusto, "Reverse Ray Tracing Technique for Rendering the Topography of Construction Sites", M.S., Spring 1991. He will continue his Ph.D at Ga. Tech.
2. McWhorter, Shane, "User-Interface Design for Interactive Animation of Construction Site Operations", M.S., Spring 1991. He will continue his Ph.D. at Ga. Tech.
3. Ferrier, Adrian, "Visual Simulation of Water Flow", M.S., Fall 1991. He is acting EGR Lab Manager in the School of Civil Engineering at Georgia Tech.
4. Otero, Shelley, "Data Transfer for Simulators", Ph.D. at Ga. Tech. in progress. She was hired by Lockheed corporation.
5. Harrell, J., "Visual Programming Style Generator", Ph.D. in progress. He was hired by the Georgia Tech Research Institute.
6. Patterson, Walter, "Structural Visualization", Ph.D. in progress.
7. Mendez, Orlando, "Construction Simulation and Visualization", Ph.D. in progress.

References

1. Rodriguez, W., and Francis, R., "Single Crane Location Optimization", *Journal of Construction Engineering and Management*, ASCE, Vol. 109, No. 4, Dec. 1983, pp. 387-397.
2. Rodriguez, W., and Jones, B., ASCE, "Animation Tools for Extraterrestrial Construction", *Journal of Aerospace Engineering*, Vol. 1, No. 4, October, 1988, pp. 238-247.
3. Rodriguez, W., "Computer Graphics Tools and the Design of Microcomputer Graphics User-Interface to Improve the Information System Dialogue", *Microcomputers for Information Management*, Vol.4, No. 1, December, 1987, pp. 283-301.
4. Wilson, J. L., National Science Foundation Workshop on Construction Automation: Computer Integrated Construction, April, 1987.
5. Suh, N. P., *The Principles of Design*, Oxford, New York, N.Y., 1990.

About the Researchers

Dr. Walter Rodriguez was born December 28, 1948 in Aguadilla, Puerto Rico (USA). He is an associate professor and heads the EGR Program housed in the School of Civil Engineering at the Georgia Institute of Technology. He is also an associate director of the College of Engineering's CAE/CAD Laboratory. He co-founded and co-chaired the Computer Graphics and Visualization Program in the College of Computing at Georgia Tech. Professor Rodriguez received his bachelor's in civil engineering (construction), and master's in architecture from Universidad de Puerto Rico. His Ph.D. in Civil Engineering is from University of Florida, where he was elected to the Tau Beta Pi Engineering Honor Society. Dr. Rodriguez is a registered professional engineer in Georgia, Florida, and Puerto Rico; and a licensed general, building and residential contractor in Florida. He is author of over 60 articles, and four books published by McGraw-Hill. He has been awarded over one-million dollars worth of research grants. He has worked as an engineer, designer, and manager in projects totaling over 100-million dollars.

Ms. Shelley Otero (female, Hispanic) is a PhD student in the EGR program. She holds a B.S. (Aerospace Engineering) and M.S. (Engineering Computer Graphics) from Georgia Tech. Her research interest is in CAE/CAD database design and integration. She currently works for Lockheed in Marietta, and was formerly the EGR Lab Manager. **Mr. Shane McWhorter** is a PhD student in the EGR Program. He holds a B.S. (Physics) and M.S. (Engineering Computer Graphics) from Georgia Tech. His research interest is user-interface design. **Mr. Augusto Opdenbosch** (Hispanic) is a PhD student in the EGR Program. He holds B.S. (Mechanical Engineering) and M.S. (Engineering Computer Graphics) from Georgia Tech. His research interests are visual simulation and ray tracing. Recently, **Mr. Adrian Ferrier** and **Mr. Walter Patterson** joined the efforts. They created a "dynamic design editor" in cooperation with Mr. Opdenbosch.