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Active
Rev #: 0
OCA file #:
Work type : RES
Document : AGR
Contract entity: GTRC

Project #: E-24-605
Cost share #:
Rev #: 0
OCA file #:
Work type : RES
Document : AGR
Contract entity: GTRC

Center #: 10/24-6-R6898-0A1
Center shr #:

Contract#: PMS18539
Mod #:

Prime #:

Subprojects ? : N
Main project #: E-24-602

Project unit:  ISYE  Unit code: 02.010.124

Project director(s):
ZHOU C  ISYE  -  (404)894-2326

Sponsor/division names: GENERAL MOTORS CORP  /
Sponsor/division codes: 206  /  012

Award period:  900924  to  901214  (performance)  901214  (reports)

Sponsor amount
Contract value  17,941.00  17,941.00
Funded  17,941.00  17,941.00

Cost sharing amount

Does subcontracting plan apply ?: N

Title: DEVELOPMENT OF ISYE 6897 PRODUCT SYSTEMS MODELING AND SIMULATION

PROJECT ADMINISTRATION DATA

OCA contact: Don S. Hasty  894-4820

Sponsor technical contact
ED ALEF, DIR., TECH. EDUCATION PROG.  (000)000-0000

Sponsor issuing office
ELAINE H. HAGE, BUYER  (313)492-0048

GENERAL MOTORS CORPORATION  GENERAL MOTORS CORPORATION
GM TECH CTR/ADV ENG STAFF  GM STAFF PURCHASING
MANUFACTURING BUILDING A-MD04  GM TECHNICAL CENTER
30300 MOUND ROAD  7000 CHICAGO ROAD
WARREN, MI 48090-9040  WARREN, MI 48090-9035

Security class (U,C,S,TS) : U
Defense priority rating : N/A  N/A supplemental sheet

Equipment title vests with: Sponsor X  GIT

NONE PROPOSED

Administrative comments -
SUBPROJECT UNDER E-24-602/BANKS. GM REQUIRE SEPARATE INVOICING FOR THE MAIN PROJECT AND SUBPROJECT.
GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 03/25/91

Project No. E-24-605 Center No. 10/24-6-R6898-0A1
Project Director ZHOU C School/Lab ISYE
Sponsor GENERAL MOTORS CORP/
Contract/Grant No. PMS18539 Contract Entity GTRC
Prime Contract No.

Title DEVELOPMENT OF ISYE 6897 PRODUCT SYSTEMS MODELING AND SIMULATION

Effective Completion Date 901215 (Performance) 901215 (Reports)

Closeout Actions Required:  

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Comments: TO BE BILLED WITH SUBPROJECT E-25-M46; SEPARATELY FROM THE MAIN PROJECT.

Subproject Under Main Project No. E-24-602

Continues Project No.

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The Development of a Graduate Course

ADVANCED MODELING OF ENGINEERING SYSTEMS

The Final Report

by

Michael Ingrim
The George W. Woodruff School of Mechanical Engineering

Chen Zhou
The School of Industrial and Systems Engineering
The Georgia Institute of Technology
Atlanta, GA 30332

December 14, 1990
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Background

In Fall of 1989, the School of Industrial and Systems Engineering at the Georgia Institute of Technology learned that General Motors' Education Program needed a graduate product modeling course. Chen Zhou, an Assistant Professor of ISyE, went on to pursue this opportunity. General Motors provided partial funds for the development of the course (1/4 time for two academic quarters). Later, GM indicated the desirability of mechanical engineering focus and Michael Ingrim of the George W. Woodruff School of Mechanical Engineering has also been involved since then. The following is a brief description of the course.

Objectives of the Course

The principal course objective is to introduce the student to the development and use of mathematical models for predicting the dynamic response of engineering systems. Here, the focus is on energic systems, that is, on systems that involve the transmission, storage, and dissipation of energy. Many significant engineering systems fall into this category. Discrete event and information systems are not considered.

To achieve this principle objective, the student needs a set of basic modeling tools. Since the focus in this course is on energic systems, the bond graph modeling approach is adopted. This allows the student to produce physically meaningful models of multi-energy domain systems in a clear, uniform, and concise fashion. For completeness, block diagram, Laplace transform, and signal flow diagram approaches must also be understood.

In addition to a set of basic modeling tools, the student also requires an understanding and appreciation of the 'art' of modeling. Perhaps most significantly, the student must be able
to formulate clear modeling objectives, that is, to decide what information the model is to provide. The modeling objectives, in turn, determine the required complexity of the model and, to a large extent, the reticulation strategy needed to formulate a successful model.

Once the student can formulate a useful model, some form of simulation is usually required to extract the required information. This may consist of the direct derivation of state equations from the bond graph representation, the use of Laplace transform techniques in conjunction with block diagrams, or the use of specialized software to directly obtain the needed results. In addition, the student must be able to use simulation data in an intelligent and efficient manner for both design and analysis. This may include the introduction of certain approximations (e.g. linearization).

For these techniques to be of any use, the student must also have some practical competence in modeling actual engineering systems. This necessarily involves some knowledge of hardware, the ability to interpret performance data in the context of a dynamic model, and an understanding of the basic limitations built into any model.

Implementation

In achieving these results, two complementary approaches are used. First, a set of lectures and corresponding lecture notes are used to introduce basic modeling skills. These basic skills are then exercised through a series of modeling projects.

The lectures and lecture notes begin with an introduction to energy and power concepts in dynamic system modeling. Here, the notion of 'ported' subsystems is introduced. It is then a short step to the bond graph modeling technique. Bond graphs, like circuit diagrams, are
constructed from a small set of primitive elements. Unlike circuit diagrams, however, bond graphs are useful for modeling systems that are not purely electromagnetic in nature. Bond graphs combine energy and signal information to yield a complete description of a system's dynamic behavior and, in addition, provide a physically meaningful 'picture' of this behavior.

To gain proficiency in this method, basic modeling techniques are explored for mechanical, electromagnetic, thermal, fluid, and chemical systems. This is done with the aim of producing models for multi-energy domain systems, that is, systems containing components from more than one of these energy domain. A number of realistic examples are included to illustrate this process.

In addition, a major project will be assigned to student in GM to make up the difference between quarter credit and semester credit.

**Project Progress and Offering Schedule**

So far, the course syllabus and major parts of lecture notes have been developed. Several tentative course projects have been designed for the course. These may be modified during and after first time of offering. The lecture notes can be made available for students in General Motors. The course will be offered once every year during Spring Quarter starting from 1991.

**Tentative Projects**

A number of short projects are used to give the student experience in the development and use of dynamic models for system design and analysis. Each of these projects requires the specification of model objectives, the development of performance criteria, the generation of a
dynamic system model, and the intelligent use of simulation data for the purposes of design.

A brief description of these projects is given below:

1. **Analysis of a dissipative electrical oscillator.** Here, the student must model an electrical oscillator that includes 'real' components with non-ideal behavior. The student is asked to predict both the transient and frequency response of the system using bond graphs and block diagram formulations.

2. **Design of a dissipative mechanical oscillator.** This is the mechanical analog of the first project. Here, however, the student must choose components from a finite list to satisfy dynamic performance criteria in the form of transient, steady-state, and frequency response specifications.

3. **Flywheel and counterweight sizing for a reciprocating compressor.** In this project, the student must size a flywheel and counterweights to satisfy both transient and shaking load performance criteria.

4. **Design of an electrohydraulic transmission.** The objective of this project is to develop a simple controller for an electrohydraulic transmission to satisfy dynamic performance criteria.

5. **Design of a stearic acid recirculating system with heating.** Stearic acid solidifies at ambient temperature. Here, the student must size a recirculation pump and heat exchanger so that both steady-state and transient criteria are met.

6. **Design of a vibration suppression system for a ship drive.** Here, the system is continuous in nature. The student will select vibration reducing components to prevent transmission shaft failure.
Course Title: ME 8401 - Advanced Modeling of Engineering Systems

Credits: 3-0-3

Text: *Introduction to Physical System Dynamics* (Rosenberg and Karnopp), course notes

Prerequisites: Graduate standing in science or engineering

Course Description: An introduction to the modeling of multi-energy domain engineering systems. Hybrid linear and nonlinear mechanical, electromagnetic, fluid, thermal, and chemical systems are considered. Bond graph, state-space, impedance, phase-plane, and linearization techniques are introduced.

Grading: Two tests, project (larger project for semester credit).

Course Syllabus:

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<td>Introduction to distributed system modeling</td>
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<td>Impedance techniques *</td>
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<td>Bond graphs with block diagrams *</td>
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* as time permits
MODELING OF ENGINEERING SYSTEMS — ADVANCED

PRESENTER
Chen Zhou
Professor of Industrial and Systems Engineering
At Georgia Institute of Technology

COURSE DESCRIPTION
This video tape delayed course introduces systems engineering concepts to product modeling. Topics covered include:

- Mechanical and electrical systems elements
- Analogy with fluid and thermal elements
- Analysis of dynamics systems
- Concepts of modeling a physical system by system elements
- Modeling of complete systems and idealized models
- Development of models in terms of state equations and bond graphs
- Selected automobile product systems

PREREQUISITES
B.S. in Engineering or Science

CREDITS AVAILABLE
* 4 graduate credits at Georgia Institute of Technology (University Course #: ME 8401)
  3 credits toward the Certificate in Advanced Engineering
  3 credits toward the Certificate of Doctoral Studies in Engineering
  3 credits toward the Certificate in Management of Technology
  3 credits transferable to the Rensselaer Polytechnic Institute Master's Degree Program pending approval by the Plan of Study Committee
  3 credits. (Transferability to the Purdue Master's Degree Program currently under consideration by Purdue University)
  45 clock hours on the employe personnel file

TIME AND PLACE

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UNIVERSITY TUITION COST: $510.00
*Employes registering at this institution for the first time must submit a copy of their transcript(s) along with the registration form.

GM COURSE INFORMATION

GM Course No.: MECH 531
GM Course Name: Product Systems Modeling and Simulation

NOTE: Courses are one-half paid company time/one-half personal time