Besök på Case Western Reserve University den 1-3 maj 1972

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1972

Document Version:
Förlagets slutgiltiga version

Link to publication

Citation for published version (APA):
Åström, K. J. (1972). *Besök på Case Western Reserve University den 1-3 maj 1972*. (Travel Reports TFRT-8002). Department of Automatic Control, Lund Institute of Technology (LTH).

Total number of authors:
1

BESÖK PÅ CASE WESTERN RESERVE UNIVERSITY DEN 1-3 MAJ 1972

K.J. ÅSTRÖM

REPORT (C) AUGUST 1972
LUND INSTITUTE OF TECHNOLOGY
DIVISION OF AUTOMATIC CONTROL

BESÖK PÅ CASE WESTERN RESERVE UNIVERSITY DEN 1 - 3 MAJ 1972

K.J. Åström

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BESÖK PÅ CASE WESTERN RESERVE UNIVERSITY DEN 1 - 3 MAJ 1972

1. INLEDNING

För en översiktlig beskrivning av verksamheten vid Case Western Reserve University (CWRU) hänvisas till en rapport från mitt studiebesök där 1970-05-20-21. Vi har också ett informellt samarbete med professor Schoeffler vid CWRU beträffande programvara och hårdvara för minidatorer. Professor Schoeffler har således besökt Lund vid två tillfällen och där givit kurser. Vi har också fått en s k Macro-Template-Assembler som är lämplig för att implementera högnivåspråk i utbyte mot delar av vårt programbibliotek. Vi skall eventuellt fortsätta samarbetet med gemensam utveckling av programvara för processreglering.

Mitt besök avsåg framförallt att diskutera dessa frågor, men jag passade också på att skaffa mig en förnyad överblick av verksamheten vid CWRU. Mitt besök sammanföll också med det 32:a sammanträdet med "Industrial Sponsors", vilket jag delvis deltog i. Vidare gav jag en föreläsning om identifiering och reglering.

2. INDUSTRIAL SPONSÖRS MEETING

Man har sedan 16 år tillbaka vid Case haft ett system med stöd från industrin för forskning inom processreglering. Denna verksamhet initierades av professor Donald Eckman. Verksamheten organiserades så att man skaffar sig stöd från industrin.Varje industrimedlem deltar med ett bidrag på cirka 10.000 $. Man har som mest haft 10 à 12 medverkande industriparter, men antalet är nu nere i 6. De faktorer som varit väsentliga för industrin vad beträffar att stöda denna verksamhet har varit

1. Rekrytering av forskare till industrin.

   Industrin har under många år haft mycket svårt att fylla sitt behov av kvalificierad personal inom processreglering. Man har därför sett en utmärkt möjlighet till att göra detta genom att hålla intim kontakt med ett universitet, t ex genom att stödja universitetsforskning. Vid vissa möten har det varit så många som 80 personer från industrin som deltagit. Man har deltagit för att studera studenternas insatser genom att lyssna till deras presentationer för att generera intresse hos studenterna för industriella problem. Med den ändrade situationen på USA:s arbetsmarknad är detta skäl nu ganska minimalt.

2. Intresse för forskningen.

Genom att industrin stöder forskningsprojekt på CWRU har man möjlighet att aktivt medverka i forskningen. Man får således Process Reports. Dessa delas endast ut till "Sponsors". Övriga rapporter är öppen information och delas ut till samtliga. Det viktiga är att industrin får resultaten på ett mycket tidigt stadium. Man har också möjlighet att i viss utsträckning genom diskussioner påverka projekten. Professor Lefkovitz påtalade dock att forskningsprogrammen hela tiden styrs av CASE.

Från universitetets sida motiveras verksamheten dels av finansiella skäl och dels för att få en feed-back från industrin. Man får alltså reaktion från olika "Sponsors" på forskningsprojekt, man får på ett tidigt stadium veta huruvida forskningen är relevant för dagens industriella problem. Studenter och fakultetens medlemmar blir på ett mycket tidigt stadium varse om väsentliga problemområden. Som ett exempel kan nämnas den verksamhet i programvara som startade för många år sedan. Den initierades vid universitetet och väckte sedan mycket stort intresse vid ett "Sponsors" meeting och man bestämde då att kraftigt öka denna aktivitet. Professor Lefkovitz påtalade också att det var ett ganska besvärligt sätt att skaffa pengar och att det egentligen var mycket enklare att få in pengar genom att söka dem från staten.

Organisation

Samarbetet med industrin organiseras således på detta sätt att man driver vissa forskningsprojekt. Dessa forskningsprojekt presenteras på "Sponsors" meetings. Presentationen görs i allmänhet av de studenter som genomförde arbetena. Programmet för Sponsors meeting denna gång framgår av appendix A i reserapporten. Vidare får vid varje möte Sponsors tillgång till Process Reports. Ett exempel på en sådan finns tillgänglig på institutionen för Regleringsteknik vid LTH.

3. INSTITUTE FOR COMPLEX SYSTEMS

Man har nyligen företagit en omorganisation och bildat ett Institutet för Komplexa System. Denna verksamhet leds av professor Mesarovic. Nio olika departments är inblandade i verksamheten. Målsättningen är att studera socialt signifikanta systemproblem. För närvarande har man varit starkt engagerad i att skriva forskningsförslag och att försöka finansiera verksamheten. Bland forskningsförslag som lämnats in kan nämnas

- o Effekt av tvättmedel i vattensystem
- o Informationssystem för bibliotek
- o Health Care Systems
- o Energisystem
- o Diskreta tillverkningsprocesser

Förslaget beträffande analys av effekten av tvättmedel i vattensystem har nu accepterats. Man har fått ett anslag på 0,5 M$ för ett tvåårsstudie från Rockefellerstiftelsen och denna betraktas som ett startanslag. Projektet koncentreras till sjön Erie och det är ett verkligt interdisiplinärt projekt. Man har således med experter från ekologi, ekonomi, sociologi och medicin. Avsikten är att behandla hela beslutssystemet. Gruppens medlemmar kommer från 8 à 9 olika avdelningar och man betonar de regionala aspekterna. Man tar även upp vissa legala synpunkter. Som ett exempel kan nämnas att staten Ohio inte har någon restriktiv lagstiftning vad beträffar utsläpp av fosfat trots att sjön Erie är mycket olämplig i detta hänseende. Den är grund och har ganska liten vattenföring. Som exempel kan nämnas att man i Florida har mycket kraftigare lagstiftning beträffande fosfat, trots att vattenreservoarerna som där är tillgängliga troligtvis tål mycket mer. Det var också intressant att notera att för att få projektet så hade universitetet lovat att inte debitera någon overhead på forskningsanslaget.

Projektet om energisystem avser att analysera energiproblemet för USA fram till slutet av detta århundrade. Man vill således analysera både efterfråge- och leveranssidan. Man vill uppställa en modell och göra de väsentliga avvägningarna, t ex mellan kärnkraft och kraft från fosila bränslen. Beträffande kärnkraft är man också intresserad av att analysera balanseringen mellan fusion och snabba breedreaktorer och när man lämpligen ska sätta in ansträngningar på de olika områdena. Man är också intresserad att gå delvis ganska djupt beträffande den teknologiska utformningen av systemet.

Romklubbsprojektet etapp 2

Inom institutet för komplexa system har man fått i uppdrag att utveckla fas två av världsmodellen. Man utgår då i första hand från Meadows modell och man avser att komplettera den i olika avseenden. Arbetet leds av Mesarovic. Professor Schoeffler hade också några studenter, undergraduates, som för närvarande simulerade modellen på olika sätt. En grupp använde ett CSMP liknande språk på GE 4060, en annan grupp använde ALGOL, och en tredje grupp gjorde det i FORTRAN.

4. DISKRETA TILLVERKNINGSPROCESSER

Vid tillverkning av styckegods finns en rad intressanta systemproblem. Det är också ett område som är relativt nytt vad beträffar tillämpning av informations- och reglersystem. Man var för närvarande intresserad att studera fem problemområden.

- Testning
- Maskinövervakning
- Skedulering och produktionsplanering
- Total processkontroll
- Utnyttjande av industriella robotar

Verksamheten leds av professor Schoeffler. Han var av den uppfattningen att det fanns många intressanta systemproblem och många intressanta tillämpningar av datorteknologi inom diskreta tillverkningsprocesser. Testningen är ofta en kritisk del av tillverkningsprocessen. Testning går ofta till så att man känner av på en hel rad olika givare. På basis av de primära signalerna gäller det att snabbt fatta beslut huruvida produkten skall accepteras eller om den ska ändras och skickas till tillbaka igen. Schoeffler ansåg att det fanna många tillämpningar för minidatorer som skulle få en mycket stor inverkan.

Maskinövervakning (produktionskontroll)

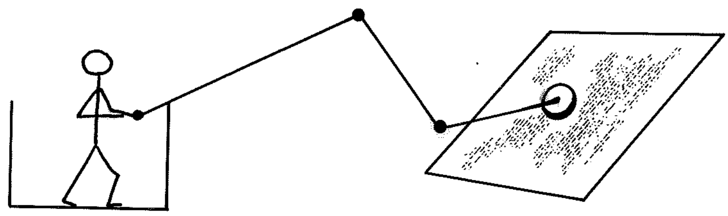
Arbete inom detta område omfattar flera olika faktorer. Målsättningen är att reducera tiden för stillastående hos maskinerna genom att göra bättre diagnos och övervakning av tillverkningsmaskinerna. Några enkla förstudier har visat att det ekonomiska incitamentet är mycket stort. Problemområdet omfattar utveckling av lämpliga givare. Detta betecknade Schoeffler som ett mycket svårt problem Det är t ex inte alls tillräckligt att bara mäta produktionshastigheten, det gäller också att ta reda på om man har tillverkat några enstaka element för att bara titta på hur de ser ut och maskinen kanske har gått i tomgång utan att det har funnits några tillverkningsämnen i den. En viktig faktor är utformning av operatörstationer och att operatören på ett förnuftigt sätt kan kommunicera med systemet. En annan viktig aspekt är att producera dokument som klart anger om hur produktionen har gått, liksom att göra diagnostiska prov på maskinerna och att göra förebyggande underhåll.

Produktionsplanering

Detta omfattar att kombinera inkommande order på lämpligt sätt och att bestämma i vilken ordning som de ska tillämpas. De problem som man för närvarande tittat på leder till heltalsprogrammering. Där hade man framförallt studerat heuristiska algoritmer och liknande. Man rekommenderade vidare en bok av Lasdon, en medarbetare vid Case Optimization in Large Systems. Totalstyrning av hela processen omfattar bland annat lagerstyrning.

Industrirobotar

Man hade vid Case också undersökt utnyttjandet av industriella robotar. En grundfråga som ställts var inte besvarad. Är det intressant att förse en industriell robot med mer intelligens, t ex i form av en minidator? Schoeffler påtalade att det var en mycket märkbar trend inom amerikans industri idag att utnyttja mer och mer industriella robotar. Han gav också exempel på en industrirobot från GE (Man-made) som bestod av en hydraulisk arm och ett reglersystem enligt figuren.



Genom att den hade ett hydrauliskt system så kunde man manipulera synnerligen stora krafter. Den användes bl a för att sortera glasskivor och Schoeffler nämnde som exempel att en man hade tappat en glasskiva och lyckats fånga upp den i luften med denna apparat. Han påtalade också likartad verksamhet vid Stanford (McCarty) och vid MIT (Minsky). Som nämns hade man gjort flera olika förstudier och man hade klara indikationer på att det fanns ordentliga vinster. Som exempel nämnde han en studie som hade visat att ett total - system skulle ge en vinst på 50.000 $ per år och systemet skulle kunna implementeras med en ansträngning av 6 manmånader. På fabriken har det hittills varit skeptiskt till att göra det, framförallt av det skälet att man var tvungen att sätta in manuella stationer där operatören skulle föra in all relevant information. Man var skeptisk till om detta skulle gå att göra på ett förnuftigt sätt. Schoeffler betonade också att en viktig del i kostnaden för sådana system är kabelkostnader. Den filosofi man hade på Case var för närvarande att prova marknaden genom att skicka ut olika forskningsförslag. Man tänkte sig bl a att gå vidare med den teoretiska analysen genom att titta på skeduleringsproblem och genom att undersöka lämpliga hårdvaru- och programvarukonfigurationer.

5. WATER RESOURCE MANAGEMENT

Man har för närvarande en grupp på Case som sysslar med Water Resource Management under Yakov Haimes. Man hade just fått ett forskningsanslag omfattande en summa av 70 K$ för en tvåårsstudie. I mycket stora drag ville man bygga upp en modell och analysera vattensystemet för nordöstra USA. Projektet var mycket brett upplagt och man avsåg att kartlägga tillgång och efterfrågan. Bland efterfrågan kan nämnas de krav som industrin och hushållen ställer och bland tillgångarna kan man nämna sjövatten, dammar, återanvändning. Man var också intresserad att undersöka vattenkvaliteten. Man hade där två motiv för att förbättra miljön, att öka den nationella inkomsten och för regional utveckling. Man baserade sig i stor utsträckning på en stor undersökning som just har genomförts på MIT. Man avsåg att bygga en modell i första hand en statisk Leonitieff modell som man sedan avsåg att utvidga till en dynamisk modell. Utbildningen ingick som ett viktigt moment i studien och som ett exempel bifogas i appendix B en kurs som man för närvarande har planerat att ge denna vår.

6. DISKUSSIONER MED PROFESSOR LEFKOWITZ

Professor Lefcowitz som var en av Eckmans medarbetare har framförallt varit verksam inom två områden.

- Hierarkiska strukturer
- Tillämpning av reglerteknik på industriell processreglering

Beträffande hierarkiska strukturer kom man in på detta på ett mycket tidigt stadium, redan i samband med en IFAC artikel år 1960. Man särskiljde här fyra nivåer

DDC
Optimering
Adaption
Självorganisation

Med DDC avser man bara att automatiskt exekvera givna beslut. Med optimering avsåg man att finna lämpliga börvärden för DDC-regulatorerna baserade på förenklade processmodeller. Med adaption avser man att uppdatera parametrarna i de förenklade processmodellerna och med självorganisationen avser man att uppdatera strukturen hos processmodellerna.

Man har arbetat på detta tema i många år, men man hade ännu ej en samlad presentation över området, utan resultaten fanns framförallt i form av doktorsavhandlingar och examensarbeten. Speciella problem som man för närvarande studerar, var möjligheten att ordna olika insignaler, t ex genom styrgreppens frekvens eller genom deras ekonomiska betydelse. Man var mycket intresserad av att undersöka hur man skall ta hänsyn till systemkostnaden. Bland de industriella tillämpningar som diskuterades nämnde professor Lefkowitz speciellt arbeten beträffande fetthydrering som man för tio år sedan var mycket aktiv med. Man hade således ställt upp matematiska modeller och diskuterat lämpliga styrstrategier. Dessa arbeten är inte fullständigt dokumenterade men jag fick två särtryck, D.P. Eckman och E. Lefkowitz "A Report on Optimization, Optimizing Control of a Chemical Process", Reprint Control Engineering, September 1957. Lefkowitz, Eckman "Application and Analysis of Computer Control System". Dessa rapporter är inte fullständiga men en mycket mer omfattande dokumentation finns i form av interna rapporter.

Katalytiska reaktioner nämndes som ett typiskt exempel på system där hierarkiska strukturer kunde vara lämpliga. Man tänkte sig således en kontinuerlig katalytisk reaktor där det i första hand gäller att reglera temperaturer och tryck baserat på ett ekonomiskt kriterium. Allteftersom reaktionen fortgår så kommer katalysatoraktiviteterna att sättas ner genom att det bildas kol på ytan och man är då tvungen att stänga av reaktorn och regenerera katalysatorn. För att driva processen optimalt krävs att man har god kontroll på denna process och att man kan bestämma regenereringstillfället optimalt. Vidare kommer katalysatorn i det långa loppet att förstöras så att så småningom så gäller det efter många cykler att bestämma sig för när man ska byta ut katalysatorn. Vid sådana system kan man således klart urskilja tre nivåer.

7. DISKUSSIONER MED GILL BLANKENSHIP

Gill Blankenship var en nytillkommen fakultetsmedlem från MIT. Han hade utfört sin doktorsavhandling under S. Mitter. Problemet var att finna stokastiska motsvarigheter till Popov-satserna. Han hade fått ett resultat i det fall då återkopplingskoefficienterna var vitt brus. För närvarande var Blankenship sysslesatt med flera olika problem, bl a att finna ett fall där olinjär filtrering kan lösas exakt. Han arbetade med de typer av bilinjära modeller som på sista tiden studerats av Roger Brocket och han försökte generallisera dessa genom att lägga till brus.

Vidare tittade han på ett linjärkvadratiskt problem där styringreppen var grupperade enligt reglerkostnad. Förutom det vanliga linjärkvadratiska kriteriet ville man också i varje steg minimera det antal komponenter av styrvariabeln som medverkar i reglering. Blankenship hade också tittat på distribuerade system. Ett ämne finns i en ugn, ovanför ugnen finns ett antal pyrometrar. Problemet var att bestämma huruvida man hade jämn temperatur inne i ämnet. Problemets lösning är känd om man känner yttertemperaturen på ämnet. Svårigheterna var här att man hade pyrometermätning och man var tveksam på vilka resultat de gav, bl a fanns det en gas mellan ämnet och pyrometrarna som starkt kunde påverka mätresultaten.

8. DISKUSSIONER MED PROFESSOR SCHOEFFLER

J. Wieslander projekt

Tillsammans med Jim Schoeffler diskuterade jag också Johan Wieslanders projekt. Frågan att snabba upp Macro Template Assemblern diskuterades och likaledes att implementera den på minidator. Det konstaterades att den stora andelen i minnesutrymmet var det fält på 3 x 8.000 ord som behövdes. Ordlängden måste vara minst 23 bitar, det behövs en pointer på 13 bitar för att adressera cirka 8 k, dessutom behövs en flagga på två bitar och man behöver ange ett värde med 6 à 8 bitar. Professor Schoeffler påpekade att man kanske inte behövde ha så långa fält som 8.000 utan att man kanske kunde nöja sig med hälften, men även så går det inte att implementera med ett enda ord på 16 bitsmaskin. Hastighetsreduktioner diskuterades också och professor Schoeffler bedömde det så att en förflyttning från UNIVAC 1108 till GE 4060 skulle reducera hastigheten med ungefär en faktor 10. Beträffande grundfrågan så bedömdes det inte vara så angeläget att snabba upp kombilatorn till ett pris av att göra den mindre flexibel, enligt de linjer som Johan hade skisserat. Vi diskuterade också nya språk. Jim berättade att han tänkte använda ett nytt språk som innehöll den gamla blockstrukturen i RTL plus vissa drag av BLISS där man dock eliminerade "DOT" notationen. Beträffande tidsplanerna så hade Jim förhoppningar att några faser skulle vara klara i slutet av sommaren. Ett alternativ till att använda detta språk skulle vara att använda C3 som dock inte lämpar sig direkt för reelltidsspråk. Preliminärt överenskom vi att en intressant möjlighet skulle vara att Johan åkte över till CASE på några månader när den nya kombilatorn är klar. Johan skulle sedan förse den med en slutdel som genererar kod för vår PDP 15 och han skulle sedan utnyttja kombilatorn till att generera monitorsystem för reelltidsstyrning på PDP maskinen. Professor Schoeffler påpekade också att arbetena med det virtuella minnet hade gjort mycket stora framsteg. Man kunde således läsa block om 64 ord med en hastighet om i medeltal 35 msek/ord.

Kurs i Systems Engineering

En kurs med denna titel har under många år givits vid CASE. Dess innehåll har kraftigt varierat från år till år. Föregående år behandlades t ex Water Resouces. Innevarande år hade Schoeffler givit kursen. Den handlade om Industrial Manufacturing in Control. Den innehöll bl a

Simulering
On-line datorer
Industriella processreglering- och tillverkningssystem
Organisation av programvara

Beträffande simulering hade man undervisat i simuleringsspråk såsom GPSS och Simula. Detta år hade man koncentrerat undervisningen till detta och man hade lagt mindre tonvikt på språk för simulering av kontinuerliga system av typ CSMP. Avsnittet om on-line datorer och programvara omfattade ungefär det som ingick i kursen Schoeffler presenterade i Lund, se appendix C. Beträffande industriell processreglering så gav man fundamenta, d v s karakterisering av insignal, utsignal och störningar. I kursen ingick också projektarbete omfattande analys av förhållandena vid en bensinstation, dimensionering av antalet tankar, etc. Organisation av ett exekutivprogram för reelltidsdatorer. Världsmodellen som angivits av Medows. Till nästa år kommer kursen att ändras och den kommer framförallt att ha stor tonvikt vid icketekniska system.

9. NYA KURSER

Man har under de senaste åren varit mycket aktiv med kursreformer, bl a har man infört kurser i systemteknik till icke-tekniker. Ett program som varit ganska svårt att få igenom men som numera funnit sin form är en utbildning för en bachelor examen i komplexa system. Ett preliminärt kursprogram finns bifogat i appendix E. Man hade även ett program på doktorsnivå i komplexa system. Detta program framgår av appendix D.

APPENDIX A

REVISED SCHEDULE

32ND SPONSORS' MEETING OF CONTROL OF COMPLEX SYSTEMS PROGRAM

Wednesday, May 3, 1972

9:15 - 10:00 a.m.	COFFEE AND DONUTS	Crawford 13
10:00 - 12:45 a.m.	SESSION I	Crawford 14
	Introduction	. . *I. Lefkowitz*
	Program Overview	. . *J. D. Schoeffler*
	Simulation Analysis of Large and Complex Systems	. . *J. P. Riley*
	On Self-Tuning Regulators	. . *K. J. Åström*
1:00 - 2:15 p.m.	LUNCH	Faculty Dining Room
2:15 - 4:45 p.m.		
SESSION II	*J. D. Schoeffler, Chairman*	Crawford 14
	Evaluation of Reliability of On-Line Mini-computer Systems	. . *S. Sunderland*
	On the Development of Discrete Event System Theory	. . *K. J. Chadha*
	A Virtual Memory Organization for Minicomputer Application Software	. . *L. Bronner*
	Computer-Aided Design for Large Scale System	. . *L. Bronner*
	DDC Software Organization for a Three Computer Hierarchical Control System	. . *V. Mileti*
	An Interactive Model of An Urban Wastewater Conveyance System	. . *I. Dear*
SESSION III	*D. Macko, Chairman*	Crawford 13
	On-Line Coordination of Interacting Systems	. . *C. Whitfield*
	A Study of Multilevel Control Applied to the Hot Strip Mill Process	. . *T. Fukuda*
	A Design Methodology for Automated Inspection Via Pattern Recognition	. . *D. Kylin*
	A Decision Structure for Making On-Line Support Tradeoffs for Large Complex Systems	. . *F. O'Neil*
3:20 - 3:35 p.m.	COFFEE BREAK	
8:30 - 10:30 p.m.	SOCIAL GET-TOGETHER	Howard Johnsons' Penthouse

Thursday, May 4, 1972

9:00 - 11:25 p.m.

SESSION IV	*G. Blankenship, Chairman*		Crawford 14
	Small Signal Models for Estimation of Input Variables from Secondary Process Measurements	. .	*D. Easterday*
	Some Simulation Models for One-Dimensional Distributed Systems	. .	*P. F. Salamon*
	Distributed System Identification Using Quasi-linearization	. .	*R. T. Schenke*
	Recent Developments in Stochastic Control and Filtering	. .	*G. Blankenship*
SESSION V	*Y. Y. Haimes, Chairman*		Crawford 13
	A Multilevel Approach to Planning for Capacity Expansion in Water Resource Systems	. .	*W. S. Nainis*
	Vector Optimization for Control with Performance and Parameter Sensitivity Indices	. .	*F. Gembicki*
	Regional Water Quality Management	. .	*S. Rosen*
	The Planning and Operation of a Regional Water Quality Management System: A Multilevel Approach	. .	*M. A. Kaplan*

10:10 - 10:25 a.m. COFFEE BREAK

11:30 - 12:30 p.m. LUNCH Faculty Dining Room

1:00 - 2:45 p.m.

SESSION VI	*L. S. Lasdon, Chairman*		Crawford 14
	Development of an LP Program for Ship Routing	. .	*L. S. Lasdon*
	Synthesis of a Crude Oil Supply System	. .	*S. J. Mathis, Jr.*
	Multilevel Techniques for Scheduling a Class of Integrated Industrial Systems	. .	*W. Driscoll*
SESSION VII	*I. Lefkowitz, Chairman*		Crawford 13
	Regulator Design with Consideration of Observation and Control Implementation	. .	*G. Blankenship*
	A Multilayer Control Hierarchy with an On-Demand Updating Policy	. .	*K. Tsuji*
	Application of LOGOS to Computer-Aided Design: an Example	. .	*C. Rose*

APPENDIX B

CASE INSTITUTE OF TECHNOLOGY

OF

CASE WESTERN RESERVE UNIVERSITY

PRESENTS

A One Week Short Course on

HIERARCHICAL APPROACH IN THE PLANNING, OPERATION AND MANAGEMENT OF WATER RESOURCES SYSTEMS

May 22-26, 1972

Co-sponsored by the

AMERICAN WATER RESOURCES ASSOCIATION

AMERICAN WATER RESOURCES ASSOCIATION

A ONE WEEK SHORT COURSE
for
Engineers and Public Officials Interested in
Water Resources Systems

May 22-26, 1972

HIERARCHICAL APPROACH IN THE PLANNING, OPERATION AND MANAGEMENT OF WATER RESOURCES SYSTEMS

Co-sponsored by the AMERICAN WATER RESOURCES ASSOCIATION

Devoted to understanding the hierarchical approach to model formulation and optimization of large complex water resources systems.

Designed for engineers and public officials concerned with the planning, operation and management of regional water resources systems.

Purpose

To present a comprehensive survey of the applications of the hierarchical approach to large complex water resources systems. In particular to discuss the applications of decomposition and multilevel optimization techniques to multiobjective functions in water resources, multiregional conjunctive use of ground and surface water resources, modeling and identification in water resources, regional management of complex multiple purpose water resource and hydrologic systems, regional water quality control and management, and recent research results and applications in current literature.

Format

There will be four 90 minute lectures given each day Monday through Friday. Two sessions in the morning: 8:30 - 10:00 and 10:30 - 12:00, followed by two sessions in the afternoon 1:00 - 2:30 and 3:00 - 4:30. Extensive use will be made of visual aids, and a complete set of all overhead projector transparencies will be provided to the participants prior to the lectures. New methods and theory introduced in lecture will be presented and explained via simple examples. Often, while a new method is discussed, it will be simultaneously developed and applied to a water resource example problem; thus the theory and its applications are discussed in parallel. This approach provides the participant with a close grasp of and comprehension of the material discussed. Separating the lectures will be a "coffee break" and opportunity for informal discussion of the lecture material. *Three out of the five 3:00 - 4:30 afternoon sessions will be devoted to "Workshop" and problem working.* In addition optional special evening tutorial sessions will be available to those participants who need a further review of systems engineering methodologies.

When:

May 22-26, 1972
Monday through Friday
8:30 am - 4:30 pm

Where:

Crawford Bldg. Room 13
Case Institute of Technology
Case Western Reserve University
Cleveland, Ohio

For:

Engineers and public officials interested in water resources systems

Course Notes:

A complete set of notes along with a complete set of all overhead projector transparencies are provided which cover the lectures in detail.

Prerequisite:

B.S. degree in Engineering, Science or equivalent experience.

Location:

Case Western Reserve University is in Cleveland, Ohio, easily accessible by air and road transportation. There is also public transportation from the airport to the university area. More detailed travel instructions are available upon request and will be supplied in response to registration.

Housing:

The University has reserved a block of rooms at the Howard Johnson Motor Lodge in University Circle (3 minutes walking distance from the campus). More detailed housing information will be supplied in response to registration.

HIERARCHICAL APPROACH IN THE PLANNING, OPERATION & MANAGEMENT OF WATER RESOURCES SYSTEMS

COURSE SCHEDULE

MONDAY, May 22

Morning — Haimes

Review of Fundamentals in Systems Engineering. Linear and dynamic programming, and Lagrange multipliers.

Afternoon — Haimes

Decomposition and Multilevel Optimization. Basics in the multilevel approach, different decomposition methods, and second-level coordinator techniques, saddle point and duality concepts.

Evening

"Get together" party

TUESDAY, May 23

Morning — Haimes

Modeling and Systems Identification in Water Resources. The identification of aquifer parameters, and other hydrologic characteristics via quasilinearization and multilevel approach.

Afternoon

1:00 - 2:30 — Rothenberg

"Data Management"--what data is necessary for water resources operation and management. How to obtain it, and techniques for processing it into useful information.

3:00 - 4:30 — Haimes

Multiobjective Functions in Water Resources. Model formulation and solution strategies via multilevel approach.

Evening — Staff

Optional Tutorial Session

WEDNESDAY, May 24

Morning — Haimes

Multiregional Conjunctive Use of Ground and Surface Water Resources. Joint consideration of the system modeling-identification problem with the system optimization problem.

Afternoon

1:00 - 2:30 — Dee

Joint Environmental Economic Models Used in Water Resources Planning

3:00 - 4:30 — Ricca

Application of the Stanford Streamflow Simulation Model to Ohio Watersheds. The Ohio State University version of the Stanford Streamflow Simulation Model. Presentation of the model's basic structure.

Evening

Optional Tutorial Session — Staff

THURSDAY, May 25

Morning — Hall

Optimum Operations for Planning of a Complex Water Resources System. The California Water Project.

Luncheon - Speaker: Dr. Ira Whitman, President of AWRA, Ohio Section

Afternoon — Hall

Optimum State Dynamic Programming. Project Planning and Investment Timing in Large Scale Water Resources Systems.

Evening

Social Hour

FRIDAY, May 26

Morning — Haimes

Regional Water Resources Management via Multilevel Approach. Multipurpose water resource systems, input-output and cost-effectiveness analyses.

Afternoon — Haimes

Regional Water Quality Control and Management via Multilevel Approach. System of Effluent charges and taxation.

Instructors:

Yacov Y. Haimes received his B.S. degree in Mathematics, Physics and Chemistry in 1964 from the Hebrew University, Jerusalem, Israel. He received a M.S. degree in Engineering (majoring in Systems Engineering) in 1967, and a Ph.D. in Engineering with distinction (majoring in Large Scale Systems Engineering, with a minor in Water Resources Systems Engineering) in 1970, both from the University of California at Los Angeles.

Dr. Haimes is an Associate Professor of Engineering in the Systems Engineering Division, School of Engineering, Case Western Reserve University. He was an Assistant Professor there from 1970 to 1971. His research and consulting activities are in the areas of modeling and optimization of large systems using decomposition and multilevel techniques; in particular, in application to water resources systems. He has participated in numerous short courses given by UCLA, Utah State Univ., University of Arizona, Colorado State Univ. and others.

Dr. Haimes is a member of AGU, ASCE, AWRA, IEEE, ORSA, ORSIS, Sigma Xi, and Tau Beta Pi. He is the author of numerous publications on system identification, optimization of large systems, water quality control, and regional water resource management.

Guest Lecturers:

Dr. Norbert Dee, Environmental Planner, Battelle Memorial Institute, Columbus, Ohio.

Dr. Warren A. Hall, Professor of Engineering, Department of Soil Science and Agricultural Engineering, University of California, Riverside, California.

Dr. Vincent T. Ricca, Assoc. Professor of Civil Engineering, Department of Civil Engineering, The Ohio State University, Columbus, Ohio.

Dr. Douglas Rothenberg, Asst. Professor of Engineering, Systems Engineering Division, Case Western Reserve Univ., Cleveland, Ohio.

ON THE HIERARCHICAL APPROACH

The hierarchical approach by decomposing the problem into subproblems at one level and coordinating the solution of the subproblems at a higher level and yet maintaining an overall optimum to the whole system, seems to be an excellent answer to the solution of large and complex water resource systems. By virtue of decomposing the problem into subproblems, a conceptual simplification of the more complex system is achieved, and a more accurate and representative mathematical model may become both feasible and computationally tractable. Furthermore, a reduction in dimensionality is achieved and the total solution effort is reduced, sometimes at the expense of more computational effort. None of the system model functions need be linear, thus more flexible models can be constructed to represent the real water resource problem at hand.

Format: There will be two 75 minute lectures given each morning Monday through Friday. Extensive use will be made of visual aids. New methods and theory introduced in lecture will be presented and explained via simple examples. Separating the lectures will be a "coffee break" and opportunity for informal discussion of the lecture material. A third 75 minute lecture will be given in the afternoon followed by informal sessions devoted to problem working, computer usage and laboratory. The class will be split up into several small groups for this purpose. In addition, provisions may be made for computer use during evenings for special projects.

Laboratory and Computer Facilities: The lectures are supplemented by laboratory experiments designed to provide familiarization and experience with the methods and techniques presented. The Systems Engineering Laboratory includes a GE 4060 digital computer system suitable for data acquisition and control of real-time systems, an EAI 580 analog computer which may be operated in real-time, in high-speed repetitive modes for iterative analog computations, or in conjunction with the digital computer as a hybrid system, and a Honeywell H21 digital control computer. Graphic communication with the computers is provided through a CDS 904 terminal. The laboratory includes several completely instrumented benchscale process units, and industrial control components to permit a wide range of research and experimentation on real-time data acquisition and control systems.

Course Notes: A complete set of notes is provided which cover the lectures in detail.

Faculty: Irving Lefkowitz, Douglas Rothenberg, and James D. Schoeffler are Professors of Engineering and members of the Systems Research Center where, for the past 15 years, extensive research and education effort in the field of data acquisition, computer control, software, and computer applications have been carried out.

Location: Case Western Reserve University is in Cleveland, Ohio, easily accessible by air and road transportation. There is also public transportation from the airport to the university area. More detailed travel instructions are available on request.

Housing: Accommodations are available at several hotel and dormitory facilities within easy walking distance from the University. We'll send you details on accommodations when you send in your Registration Form.

Registration and Fees: Course fee is $275 and includes complete course notes, laboratory and computer charges, and parking on the campus for the week.

Return Registration Form by May 1, 1972.
For further information write or phone:

Professor I. Lefkowitz
Systems Research Center
Case Western Reserve University
Cleveland, Ohio 44106

Phone: (216) 368-4078

APPENDIX C

Systems Research Center
Case Western Reserve University
Cleveland, Ohio 44106

Short Course for Industry:

REAL-TIME MINICOMPUTER SYSTEMS FOR DATA ACQUISITION, INFORMATION PROCESSING, AND CONTROL

May 22-26, 1972

INFORMATION PROCESSING, AND CONTROL

May 22-26, 1972

Devoted to detailed understanding of minicomputer hardware, software, and applications.

Designed for engineers concerned with the use of modern minicomputers.
Only limited familiarity with computers is assumed.

COURSE AND LABORATORY CONTENT

Organization of Minicomputer Hardware
Structural characteristics of modern minicomputers: memory, various registers, instruction sets.

Word Size and Memory Addressing in Minis
Modes of addressing memory and their utilization: problem of small word size tradeoffs in addressing, effects on choice of mini for various applications.

Input/Output Devices for Data Acquisition & Control
Analog and digital I/O devices: multiplexors, converters, actuators. Noise, speed, and interfacing problems.

Interrupt Structures and Control of I/O Devices
Software for control of I/O: drivers, I/O request subroutines, re-entrant software, dedication of I/O devices.

Real-Time Executive Programs for Minicomputers
Organizations for executive or monitor software: all core systems, overlay systems, core loads, partitions, dynamic memory allocation systems. Effect of application on choice of organization.

Dedicated Data Acquisition I/O Software
Organization of software for high volume critically fast response systems including extensive operator communication.

Fundamentals of Real-Time Systems
General structure of real-time systems for data acquisition, process monitoring, process control, operator communication, message switching, lab automation, and manufacturing control.

Background Theory for Direct Control
Review of basic principles and tools for direct, feedforward, interacting, and adaptive control.

Background Theory for Supervisory Control
Hierarchical computer control systems: on-line optimization, adaptive control, sequencing control, scheduling of manufacturing systems.

Data Acquisition and Control Packages
Characteristics of commercial packages and software systems for data acquisition, direct control, sequencing control, supervisory control.

Scheduled Lab Experiments:

1. Real-time data acquisition and control of a simple flow process.
2. Graphic operator console for communication with data acquisition and control systems.
3. Real-time Fortran programming for data acquisition and control.
4. Digital simulation for data analysis and system design.
5. Analysis based on Fast Fourier Transform.
6. Demonstration of computer aided-design system.

The laboratory facilities will be available also for students to carry on any additional experiments of their own choosing.

SYSTEMS RESEARCH CENTER
CASE INSTITUTE OF TECHNOLOGY
CASE WESTERN RESERVE UNIVERSITY

Registration Form (to be returned by May 1, 1972)

REAL-TIME MINICOMPUTER SYSTEMS FOR DATA ACQUISITION, INFORMATION PROCESSING, AND CONTROL

I am interested but I'd like further information ☐

Please register me in the course ☐

Check for $275 enclosed ☐
Check to be mailed by ______________

Make check out to: Case Western Reserve University

Mail to: Prof. I. Lefkowitz
Systems Research Center
Case Western Reserve University
Cleveland, Ohio 44106

Name: ______________

Mail Address: ______________

____

____
City State Zip Code

Company: ______________

Position: ______________

Phone: ______________

APPENDIX D

CASE INSTITUTE OF TECHNOLOGY

GRADUATE STUDY PROGRAMS

Leading to the M.S. and Ph.D. Degrees

in the

SYSTEMS ENGINEERING DIVISION

SCHOOL OF ENGINEERING

SYSTEMS & CONTROL ENGINEERING PROGRAM

Directed to problems of modeling, information processing and control of complex systems with major focus on technological systems.

Major Thesis Research Areas: Optimal control theory and design. Stochastic control and estimation. Direct digital control. Control of discrete processes. Real-time computer systems and software for control. Computer-aided design. Multi-layer control approach to complex systems.

J. Haimes

SYSTEMS ANALYSIS PROGRAM

(with Department of Operations Research)

Oriented to problems of simulation, data gathering and decision-making of large scale systems that are primarily non-technological in nature.

Major Thesis Research Areas: Modeling and management of urban systems. Health care delivery systems. Transportation systems. Environmental problems. Systems identification of large scale problems. Joint solution to system identification and optimization.

Richardson. Political

MATHEMATICAL SYSTEMS THEORY PROGRAM

(with Department of Mathematics)

Focuses on the characterization of systems, their structure and behavior, and on systems-oriented problems on a rigorous, mathematical level.

Major Thesis Research Areas: General systems theory. Coordination of interacting systems. Theory of multilevel hierarchical systems. Decision-making and control of systems.

J. Haimes

WATER RESOURCES SYSTEMS ENGINEERING PROGRAM

(with Chemical Engineering Division)

Directed to problems of planning, operation and management of large-scale water resources systems, with major focus on the hierarchical approach.

Major Thesis Research Areas: Systems identification of water resources systems. Regional water resources management and water quality control. Optimum planning of complex water resource systems. Multi-objective functions in water resources. Optimal allocation and scheduling of soil, water and financial resources for crop growth.

FACULTY

Banerji, R.B., Professor (Joint appointment with Computer & Information Sciences Department): Artificial intelligence, pattern recognition, learning systems.

Blankenship, G.L., Assistant Professor: Stochastic control and estimation, analysis of feedback systems, control applications.

Brosilow, C.B., Associate Professor (Joint appointment with Chemical Engineering Division): Process dynamics, computer simulation of distributed systems, control of industrial processes.

Haimes, Y.Y., Associate Professor: Modeling and optimization of large-scale systems, hierarchical approach, applications to water resources systems.

Katona, P.G., Associate Professor (Joint appointment with Biomedical Engineering): Modeling of physiological systems, bio-medical engineering.

Lefkowitz, I., Professor; Acting Head of Systems Engineering Division: Modeling and computer control of industrial processes, hierarchical approach to control of complex systems.

Macko, D., Associate Professor: Theory of hierarchical systems, decision-making and coordination in large-scale systems.

Mesarovic, M.D., Professor; Director of Systems Research Center: General systems theory, applications to bio-medical, urban and industrial systems.

Orner, P.A., Associate Professor: Control theory, modeling of physical systems, bio-medical engineering.

Rothenberg, D.H., Assistant Professor: System modeling, feedback control, systems simplification and decentralized control.

Schoeffler, J.D., Professor: Real-time computer systems and software, applications to control of industrial processes and manufacturing systems.

The above faculty are all members of the Systems Research Center. The Center provides staff, facilities and environment for interdisciplinary research on large-scale systems problems.

LABORATORY

The Systems Engineering Laboratory provides excellent experimental and computational facilities for real-time data acquisition, simulation, on-line process control, and interactive computer-aided design. There is also direct linkage to the Computing Center to provide additional capabilities for large-scale simulation and multi-computer systems studies. Several completely instrumented prototype processes are connected to the computer facilities for study of modeling and control problems in complex systems.

FINANCIAL AID

Various assistantships, traineeships and fellowships are available with stipends starting at $425 per month (less tuition).

INFORMATION

For further information and application forms write: Professor I. Lefkowitz, Systems Engineering Division, Case Western Reserve University, Cleveland, Ohio 44106.

APPENDIX E

Proposal for a Curriculum Leading to the

Degree of Bachelor of Science in Complex Systems

In 1969 CWRU embarked on a program of research and education in Complex Systems. As part of this program, the Committee on Systems Education, consisting of faculty members from many disciplines, has designed undergraduate curricula in complex systems. The B.A. program has been adopted by the faculty of Arts & Sciences. It is proposed that Case Institute adopt the B.S. curriculum described herein.

The educational need to which this new curriculum is directed is the education of students in the systems approach, its concepts, applications, and skills. In particular, the core courses that must be developed to implement the new curriculum are intended to teach the systems approach-- from application to theory and skills. The following statement defining the Systems approach provides the conceptual framework within which the curriculum has been planned.

A complex system may be classified as environmental, social, political, technical, medical, human, or combinations of these and other ways of categorizing complex situations that we want to understand and improve. It could, in principle, lie entirely within the domain of an existing discipline (the kidney, for example, can be regarded as a complex system) or fit no discipline (Lake Erie Pollution). Our program is oriented toward systems that involve several of the traditional disciplines and <u>precise</u> definition of a system will depend on the interests of the investigator and the purpose of the work. Some examples are: urban transport, population control, sewage treatment, etc. We shall emphasize what we call the "Systems Approach" to these problems.

The principles of the systems approach can be used as a means to improve our <u>understanding</u> of complex phenomena (in this role it may be called systems science), and an extension of these principles can be used to improve our <u>actions</u> and procedures (in this role it may be called systems engineering or systems management). The principles may be summarized this way. "The systems approach is a functional analysis of the system, treating the components, their interrelationships, and the context at the same time". Some of the most characteristic features of the Systems Approach are as follows:

1. <u>Function of Components</u>
   The phrase "functional analysis of components" means that each of the components of a system is examined in terms of its <u>function</u> as opposed to a detailed examination of, let us say, its physical characteristics. Thus, in an analysis of health care problems, a doctor is principally identified as a "component whose function is treatment of illness", an ambulance is a "means of transportation" and so on. A more detailed description (the precise skills of the doctor, the fittings of the ambulance) is deferred.

2. <u>Interrelations of Components</u>
   A systems description stresses the relations among components in terms of their functions. Thus various techniques of logical analysis and information theory play as large a role in the study of these relations as do the conventional disciplines.

3. Context Provides Objectives
   Functional analysis of the context means that the system under consideration is analyzed in terms of the function it serves in its larger context. Thus the function of health care delivery is "to improve the general health of the public". Analysis of the goals or purposes of a human system leads of course, to the problem of conflicting values and requires a broad outlook, some acquaintance with social philosophy, and some notions of how to approach resolutions of conflict in objectives and values.

4. Context Determines Feasibility
   We emphasize the improvement of actions and procedures. This means that examination of context must include some considerations that are very difficult to quantify such as political feasibility, popularity, etc.

5. The Balanced Approach
   It is not uncommon for a problem to be approached in terms of one or two of the points listed above. (One can cast almost any analysis into this form). The systems approach emphasizes a balance among all these considerations, calling upon other disciplines when a more detailed account of a component or of the context is needed. In this way the system under consideration always remains central to the analysis.

6. Modelling and Abstraction
   Frequently a system, or some of its important features, can be abstracted into a quantitative mathematical model. In this case, computer simulation techniques become very important. The goal of work on the problem may be either optimization or prediction. An illustration of the range of computer techniques can be found in meteorology. On the one hand, dynamical equations for the atmosphere can be used to study the weather (theoretical model). On the other hand, a preceptron or other "learning machine" can be "trained" to make weather forecasts from current meteorological data (adaptive simulation). Although most complex systems are not fully quantifiable, knowledge and mastery of computer techniques is an important tool in their analysis.

Proposed Degree Requirements:

Students majoring in Complex Systems are required to complete eight new systems courses, including Syst. 101, 102, 201, 202, 301, 332, 351, & 352. (Catalog course descriptions are attachment A).

In addition to the Case Core, other requirements include STAT 281, ENGR 112, & PHIL 360. Students are required to select a minor sequence of no less than 12 hours with the program committee. Typical minor programs are indicated in attachment C.

Attachment A

Courses in Complex Systems

SYST 101 Problems in Systems I. Introduction to systems approach to complex problems; introduction to systems concepts; multidisciplinary approach through emphasis on case problems; cases deal with wide range of issue, living to non-living, social to technical, quantitative to qualitative. Prerequisite: None. Corequisite: Calculus.

SYST 102 Problems in Systems II. Continuation of SYST 101. Emphasis on process of extracting analyzable systems problems from real world; measurement as a source of data; choice of goals for systems; issue of value judgements; introduction to disciplines and problem areas where systems approach is active. Prerequisite: SYST 101. Corequisite: Calculus.

SYST 201 Mathematical Models of Systems. Development, using examples, of mathematical models to describe systems, analyze their properties, and test appropriateness for specific problems. Topics include; Finite state systems, graphical and network descriptions, and difference equation descriptions. Term project to construct model of some real system. Prerequisite: SYST 102 (May be taken concurrently).

SYST 202 System Optimization. Formulation of specific decision problems in terms of optimization; examination of some mathematical techniques for solution. Topics include; extrema of differentiable functions of n variables, linear programming, non-linear programming, dynamic programming, statistical optimization. Term project to apply methodology to specific system. Prerequisite: SYST 201.

SYST 301 Systems Theory. Structures of systems models, methods of model building, and integration of material studied in SYST 101, 102, 201, and 202. Topics include: Interactions and integration of subsystems; feedback, regulation, control, and sensitivity; goal seeking; adaptation and learning. Prerequisite: SYST 202.

SYST 332 Computer Simulation. Development of insight into systems problems via simulation rather than manipulation of tractable mathematical models. Topics include: Simulation of continuous and discrete systems, probability concepts in simulation, and verification of simulation models. Case studies using computer. Prerequisite: ENGR 112.

SYST 351 Senior Project I. Integration by senior students of systems skills and knowledge through substantial involvement in a two-semester project that is large enough for real challenge and limited enough to permit significant accomplishment in two semesters. Prerequisite: SYST 301.

SYST 352 Senior Project II. Continuation of SYST 351. Problem areas such as environmental control, management of justice, and population control would provide the theme topic(s) for both the small project groups and regular seminar of a particular year. Prerequisite: SYST 351.

Attachment B

Proposed Case Institute of Technology
Undergraduate Curriculum in Complex Systems for the B.S. Degree

FALL SEMESTER

Freshman Year

	Regular Case Core	17-8-18

Sophomore Year

Syst. 101 -	Problems in Systems I	3-0-3
Syst. 201 -	Mathematical Models of Systems	3-0-3
Math. 223 -	Mathematics III	3-0-3
Engr. 112 -	Numerical Methods	2-2-3
Phys. 213 -	General Physics III	3-0-3
	Humanities or Social Science Sequence I	3-0-3
		17-2-18

Junior Year

Syst. 301 -	Systems Theory	3-0-3
Stat. 281 -	Intro. to Probability	3-0-3
	Minor Sequence I	3-0-3
	Humanities or Social Science Sequence II	3-0-3
	Open Elective	3-0-3
		15-0-15

Senior Year

Syst. 351 -	Senior Project I	3-0-3
	Minor Sequence III	3-0-3
	Social Science Elective	3-0-3
	Open Elective	3-0-3
Sids. 301 - or 302 -	Interdisciplinary Symposium	3-0-3
		15-0-15

SPRING SEMESTER

Freshman Year

	Regular Case Core	16-5-16

Sophomore Year

Syst. 102 -	Problems in Systems II	3-0-3
Syst. 202 -	System Optimization	3-0-3
Math. 224 -	Mathematics IV	3-0-3
Phys. 214 -	General Physics IV	3-0-3
Phys. 205 -	General Physics Lab	1-3-2
	Humanities or Social Science Sequence II	3-0-3
		16-3-17

Junior Year

Syst. 332 -	Computer Simulation	3-0-3
Phil. 360 -	Philosophy of Social Science	3-0-3
	Open Elective	3-0-3
	Minor Sequence II	3-0-3
	Humanities or Social Science Sequence IV	3-0-3
		15-0-15

Senior Year

Syst. 352 -	Senior Project II	3-0-3
	Minor Sequence IV	3-0-3
	Social Science Elective	3-0-3
	Open Elective	3-0-3
	Humanities or Social Science Elective	3-0-3
		15-0-1[illegible]

Credit Hour Distribution

Case Core	66
Complex Systems Major	39
Minor Sequence	12
Open Electives	12
TOTAL	129

Attachment C

Typical Minor Sequences

Environment

Geol. 114 & 115 (1)	Man & Environment
Geol. 240	Urban Geology
Physics 364	Physics of the Environment
Pol. Sc. 335	Politics & the Environment
Econ. 386	Urban Economics
URES. 318	Urban Sociology
Biol. 355	Ecology
URES. 201 & 202	Intro. to Urban & Environmental Studies
Engr. 262	Environmental Quality Criteria
Engr. 263	Environmental Problem & Engineering
Geo. 302	Natural Resources
Soc. 310	Soc. Environment & Personality

Derived Theme Minor

Phsyics 364	Physics of the Envioronment
Biology 355	Ecology
Pol. Sc. 335	Politics and the Environment
Engineering 262	Environmental Quality Criteria
Geography 302	Natural Resources: Environmental Use, Misuse & Conservation

Systems Theme

Math.	Linear Algebra
OR	Intro. to OR
Encon. 101	Economics
Engr.	Control Engineering I
Mang.	Management and Organization
Biol. 357	Environment Seminar
Engr. 416	Optimization
Engr.	Systems Engineering I
Engr. 410	Systems Theory I
Engr. 415	Decision Making and Control
Comp.	Computer Systems

Man and Society (Theme would be a selection of 12 - 18 hours).

Econ. 101 & 102	Principles of Econ.
Econ. 206 or 207	Intermediate Theory (micro & Macr.)
Econ. 385	Introd. Soc. Econ.
Econ. 364	Compet. & Public Policy
Pol. Sci. 337	Politics of Planning
Pol. Sci. 241	Political Behavior
SEEP 304	Sci., Technology, & Social Change
Soc. 350	Industrial Soc.
Soc. 390	Sociology of Organization
ORAD 310	Social Psych. & Personal Dynamic
ORAD 303	Group Dynamics & Interpersonal Dynamics

Personality and Society

PSCL 313	Psychology of Personality
SOCI 310	Social Environment and Personality
PSCL 253	Social Psychology
ANTH 371	Culture and Personality
SOCI 390	Sociology of Organizations

Public Policy in Industrialized Society

Posc 241	Political Behavior
ECON 207	Intermediate Macrotheory
POSC 343	Public Opinion and Citizen Politics
ECON 342	Public Finance
SCPP 344	Public Policy and Industrial Society

APPENDIX B

CASE INSTITUTE OF TECHNOLOGY

OF

CASE WESTERN RESERVE UNIVERSITY

PRESENTS

A One Week Short Course on

HIERARCHICAL APPROACH IN THE PLANNING, OPERATION AND MANAGEMENT OF WATER RESOURCES SYSTEMS

May 22-26, 1972

Co-sponsored by the

AMERICAN WATER RESOURCES ASSOCIATION

AMERICAN WATER RESOURCES ASSOCIATION

Case Institute of Technology of
Case Western Reserve University
and
The American Water Resources Association

HIERARCHICAL APPROACH IN THE
PLANNING, OPERATION AND MANAGEMENT
OF WATER RESOURCES SYSTEMS
May 1972

Nonprofit Organization
U. S. POSTAGE
PAID
Cleveland, Ohio
Permit No. 1402

WATER RESOURCES SYSTEMS - SHORT COURSE

A ONE WEEK SHORT COURSE
for
Engineers and Public Officials Interested in
Water Resources Systems

May 22-26, 1972

HIERARCHICAL APPROACH IN THE PLANNING, OPERATION AND MANAGEMENT OF WATER RESOURCES SYSTEMS

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Purpose

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Format

There will be four 90 minute lectures given each day Monday through Friday. Two sessions in the morning: 8:30 - 10:00 and 10:30 - 12:00, followed by two sessions in the afternoon 1:00 - 2:30 and 3:00 - 4:30. Extensive use will be made of visual aids, and a complete set of all overhead projector transparencies will be provided to the participants prior to the lectures. New methods and theory introduced in lecture will be presented and explained via simple examples. Often, while a new method is discussed, it will be simultaneously developed and applied to a water resource example problem; thus the theory and its applications are discussed in parallel. This approach provides the participant with a close grasp of and comprehension of the material discussed. Separating the lectures will be a "coffee break" and opportunity for informal discussion of the lecture material. *Three out of the five 3:00 - 4:30 afternoon sessions will be devoted to "Workshop" and problem working.* In addition optional special evening tutorial sessions will be available to those participants who need a further review of systems engineering methodologies.

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For:

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HIERARCHICAL APPROACH IN THE PLANNING, OPERATION & MANAGEMENT OF WATER RESOURCES SYSTEMS

COURSE SCHEDULE

MONDAY, May 22

Morning — Haimes

Review of Fundamentals in Systems Engineering. Linear and dynamic programming, and Lagrange multipliers.

Afternoon — Haimes

Decomposition and Multilevel Optimization. Basics in the multilevel approach, different decomposition methods, and second-level coordinator techniques, saddle point and duality concepts.

Evening

"Get together" party

TUESDAY, May 23

Morning — Haimes

Modeling and Systems Identification in Water Resources. The identification of aquifer parameters, and other hydrologic characteristics via quasilinearization and multilevel approach.

Afternoon

1:00 - 2:30 — Rothenberg

"Data Management"--what data is necessary for water resources operation and management. How to obtain it, and techniques for processing it into useful information.

3:00 - 4:30 — Haimes

Multiobjective Functions in Water Resources. Model formulation and solution strategies via multilevel approach.

Evening — Staff

Optional Tutorial Session

WEDNESDAY, May 24

Morning — Haimes

Multiregional Conjunctive Use of Ground and Surface Water Resources. Joint consideration of the system modeling-identification problem with the system optimization problem.

Afternoon

1:00 - 2:30 — Dee

Joint Environmental Economic Models Used in Water Resources Planning

3:00 - 4:30 — Ricca

Application of the Stanford Streamflow Simulation Model to Ohio Watersheds. The Ohio State University version of the Stanford Streamflow Simulation Model. Presentation of the model's basic structure.

Evening

Optional Tutorial Session — Staff

THURSDAY, May 25

Morning — Hall

Optimum Operations for Planning of a Complex Water Resources System. The California Water Project.

Luncheon - Speaker: Dr. Ira Whitman, President of AWRA, Ohio Section

Afternoon — Hall

Optimum State Dynamic Programming. Project Planning and Investment Timing in Large Scale Water Resources Systems.

Evening

Social Hour

FRIDAY, May 26

Morning — Haimes

Regional Water Resources Management via Multilevel Approach. Multipurpose water resource systems, input-output and cost-effectiveness analyses.

Afternoon — Haimes

Regional Water Quality Control and Management via Multilevel Approach. System of Effluent charges and taxation.

How to price   Plan and man [illegible]

Instructors:

Yacov Y. Haimes received his B.S. degree in Mathematics, Physics and Chemistry in 1964 from the Hebrew University, Jerusalem, Israel. He received a M.S. degree in Engineering (majoring in Systems Engineering) in 1967, and a Ph.D. in Engineering with distinction (majoring in Large Scale Systems Engineering, with a minor in Water Resources Systems Engineering) in 1970, both from the University of California at Los Angeles.

Dr. Haimes is an Associate Professor of Engineering in the Systems Engineering Division, School of Engineering, Case Western Reserve University. He was an Assistant Professor there from 1970 to 1971. His research and consulting activities are in the areas of modeling and optimization of large systems using decomposition and multilevel techniques; in particular, in application to water resources systems. He has participated in numerous short courses given by UCLA, Utah State Univ., University of Arizona, Colorado State Univ. and others.

Dr. Haimes is a member of AGU, ASCE, AWRA, IEEE, ORSA, ORSIS, Sigma Xi, and Tau Beta Pi. He is the author of numerous publications on system identification, optimization of large systems, water quality control, and regional water resource management.

Guest Lecturers:

Dr. Norbert Dee, Environmental Planner, Battelle Memorial Institute, Columbus, Ohio.

Dr. Warren A. Hall, Professor of Engineering, Department of Soil Science and Agricultural Engineering, University of California, Riverside, California.

Dr. Vincent T. Ricca, Assoc. Professor of Civil Engineering, Department of Civil Engineering, The Ohio State University, Columbus, Ohio.

Dr. Douglas Rothenberg, Asst. Professor of Engineering, Systems Engineering Division, Case Western Reserve Univ., Cleveland, Ohio.

ON THE HIERARCHICAL APPROACH

The hierarchical approach by decomposing the problem into subproblems at one level and coordinating the solution of the subproblems at a higher level and yet maintaining an overall optimum to the whole system, seems to be an excellent answer to the solution of large and complex water resource systems. By virtue of decomposing the problem into subproblems, a conceptual simplification of the more complex system is achieved, and a more accurate and representative mathematical model may become both feasible and computationally tractable. Furthermore, a reduction in dimensionality is achieved and the total solution effort is reduced, sometimes at the expense of more computational effort. None of the system model functions need be linear, thus more flexible models can be constructed to represent the real water resource problem at hand.

Registration and Fees:

Course fee is $200 which includes complete course notes and use of laboratory. A three-day registration fee (May 22-24) of $150 are also available for participants who cannot stay for the complete five-day course.

Enrollment may be made by individuals or companies. Any number of persons from a single company may enroll as long as there are vacancies. Reservations may be requested for industry and government employees requiring time to obtain authorization. Companies may enroll for a given number of individuals, supplying names later. To insure enrollment, **(class size is limited)**, individual names must be received by the university **before May 1, 1972.** For additional applications, please use separate sheet giving the information requested on the enrollment form.

REGISTRATION FORM FOR ENROLLMENT

Mail to: Mrs. Kathy Roberts, Systems Research Center, Case Western Reserve University, Cleveland, Ohio 44106

Enclosed is a check (payable to Case Institute of Technology) in the amount of $ ______ to cover enrollment(s) indicated: "Hierarchical Approach in the Planning, Operation and Management of Water Resources Systems," May 22-26, 1972.

☐ $200 Full Enrollment

☐ $150 Partial Enrollment, May 22-24, 1972

Do you wish hotel accommodations? ______ Yes ______ No

Arriving: ______ Date ______ Time Departure: ______ Date ______ Time

______ Last Name ______ First ______ I. ______ Position or Title

______ Business Address ______ Mailing Address for Course Correspondence

______ City ______ State ______ Zip ______ City ______ State ______ Zip

______ Daytime Phone ______ Signature

REAL-TIME MINICOMPUTER SYSTEMS FOR DATA ACQUISITION, INFORMATION PROCESSING, AND CONTROL

May 22-26, 1972

Devoted to detailed understanding of minicomputer hardware, software, and applications.

Designed for engineers concerned with the use of modern minicomputers.

Only limited familiarity with computers is assumed.

COURSE AND LABORATORY CONTENT

Organization of Minicomputer Hardware
Structural characteristics of modern minicomputers: memory, various registers, instruction sets.

Word Size and Memory Addressing in Minis
Modes of addressing memory and their utilization: problem of small word size tradeoffs in addressing, effects on choice of mini for various applications.

Input/Output Devices for Data Acquisition & Control
Analog and digital I/O devices: multiplexors, converters, actuators. Noise, speed, and interfacing problems.

Interrupt Structures and Control of I/O Devices
Software for control of I/O: drivers, I/O request subroutines, re-entrant software, dedication of I/O devices.

Real-Time Executive Programs for Minicomputers
Organizations for executive or monitor software: all core systems, overlay systems, core loads, partitions, dynamic memory allocation systems. Effect of application on choice of organization.

Dedicated Data Acquisition I/O Software
Organization of software for high volume critically fast response systems including extensive operator communication.

Fundamentals of Real-Time Systems
General structure of real-time systems for data acquisition, process monitoring, process control, operator communication, message switching, lab automation, and manufacturing control.

Background Theory for Direct Control
Review of basic principles and tools for direct, feedforward, interacting, and adaptive control.

Background Theory for Supervisory Control
Hierarchical computer control systems: on-line optimization, adaptive control, sequencing control, scheduling of manufacturing systems.

Data Acquisition and Control Packages
Characteristics of commercial packages and software systems for data acquisition, direct control, sequencing control, supervisory control.

Scheduled Lab Experiments:

1. Real-time data acquisition and control of a simple flow process.
2. Graphic operator console for communication with data acquisition and control systems.
3. Real-time Fortran programming for data acquisition and control.
4. Digital simulation for data analysis and system design.
5. Analysis based on Fast Fourier Transform.
6. Demonstration of computer aided-design system.

The laboratory facilities will be available also for students to carry on any additional experiments of their own choosing.

SYSTEMS RESEARCH CENTER
CASE INSTITUTE OF TECHNOLOGY
CASE WESTERN RESERVE UNIVERSITY

Format: There will be two 75 minute lectures given each morning Monday through Friday. Extensive use will be made of visual aids. New methods and theory introduced in lecture will be presented and explained via simple examples. Separating the lectures will be a "coffee break" and opportunity for informal discussion of the lecture material. A third 75 minute lecture will be given in the afternoon followed by informal sessions devoted to problem working, computer usage and laboratory. The class will be split up into several small groups for this purpose. In addition, provisions may be made for computer use during evenings for special projects.

Laboratory and Computer Facilities: The lectures are supplemented by laboratory experiments designed to provide familiarization and experience with the methods and techniques presented. The Systems Engineering Laboratory includes a GE 4060 digital computer system suitable for data acquisition and control of real-time systems, an EAI 580 analog computer which may be operated in real-time, in high-speed repetitive modes for iterative analog computations, or in conjunction with the digital computer as a hybrid system, and a Honeywell H21 digital control computer. Graphic communication with the computers is provided through a CDS 904 terminal. The laboratory includes several completely instrumented benchscale process units, and industrial control components to permit a wide range of research and experimentation on real-time data acquisition and control systems.

Course Notes: A complete set of notes is provided which cover the lectures in detail.

Faculty: Irving Lefkowitz, Douglas Rothenberg, and James D. Schoeffler are Professors of Engineering and members of the Systems Research Center where, for the past 15 years, extensive research and education effort in the field of data acquisition, computer control, software, and computer applications have been carried out.

Location: Case Western Reserve University is in Cleveland, Ohio, easily accessible by air and road transportation. There is also public transportation from the airport to the university area. More detailed travel instructions are available on request.

Housing: Accommodations are available at several hotel and dormitory facilities within easy walking distance from the University. We'll send you details on accommodations when you send in your Registration Form.

Registration and Fees: Course fee is $275 and includes complete course notes, laboratory and computer charges, and parking on the campus for the week.

Return Registration Form by May 1, 1972. For further information write or phone:

Professor I. Lefkowitz
Systems Research Center
Case Western Reserve University
Cleveland, Ohio 44106

Phone: (216) 368-4078

2800 3-72

REVISED SCHEDULE

32ND SPONSORS' MEETING OF CONTROL OF COMPLEX SYSTEMS PROGRAM

Wednesday, May 3, 1972

9:15 - 10:00 a.m.	COFFEE AND DONUTS	Crawford 13
10:00 - 12:45 a.m.	SESSION I	Crawford 14
Introduction		. . *I. Lefkowitz*
Program Overview		. . *J. D. Schoeffler*
Simulation Analysis of Large and Complex Systems		. . *J. P. Riley*
On Self-Tuning Regulators		. . *K. J. Åström*
1:00 - 2:15 p.m.	LUNCH	Faculty Dining Room
2:15 - 4:45 p.m.		
SESSION II	*J. D. Schoeffler, Chairman*	Crawford 14
Evaluation of Reliability of On-Line Mini-computer Systems		. . *S. Sunderland*
On the Development of Discrete Event System Theory		. . *K. J. Chadha*
A Virtual Memory Organization for Minicomputer Application Software		. . *L. Bronner*
Computer-Aided Design for Large Scale System		. . *L. Bronner*
DDC Software Organization for a Three Computer Hierarchical Control System		. . *V. Mileti*
An Interactive Model of An Urban Wastewater Conveyance System		. . *I. Dear*
SESSION III	*D. Macko, Chairman*	Crawford 13
On-Line Coordination of Interacting Systems		. . *C. Whitfield*
A Study of Multilevel Control Applied to the Hot Strip Mill Process		. . *T. Fukuda*
A Design Methodology for Automated Inspection Via Pattern Recognition		. . *D. Kylin*
A Decision Structure for Making On-Line Support Tradeoffs for Large Complex Systems		. . *F. O'Neil*
3:20 - 3:35 p.m.	COFFEE BREAK	
8:30 - 10:30 p.m.	SOCIAL GET-TOGETHER	Howard Johnsons' Penthouse

Thursday, May 4, 1972

9:00 - 11:25 p.m.

SESSION IV — *G. Blankenship, Chairman* — Crawford 14

Small Signal Models for Estimation of Input Variables from Secondary Process Measurements. . . *D. Easterday*

Some Simulation Models for One-Dimensional Distributed Systems . . *P. F. Salamon*

Distributed System Identification Using Quasi-linearization . . *R. T. Schenke*

Recent Developments in Stochastic Control and Filtering . . *G. Blankenship*

SESSION V — *Y. Y. Haimes, Chairman* — Crawford 13

A Multilevel Approach to Planning for Capacity Expansion in Water Resource Systems . . *W. S. Nainis*

Vector Optimization for Control with Performance and Parameter Sensitivity Indices . . *F. Gembicki*

Regional Water Quality Management . . *S. Rosen*

The Planning and Operation of a Regional Water Quality Management System: A Multilevel Approach . . *M. A. Kaplan*

10:10 - 10:25 a.m. COFFEE BREAK

11:30 - 12:30 p.m. LUNCH — Faculty Dining Room

1:00 - 2:45 p.m.

SESSION VI — *L. S. Lasdon, Chairman* — Crawford 14

Development of an LP Program for Ship Routing . . *L. S. Lasdon*

Synthesis of a Crude Oil Supply System . . *S. J. Mathis, Jr.*

Multilevel Techniques for Scheduling a Class of Integrated Industrial Systems . . *W. Driscoll*

SESSION VII — *I. Lefkowitz, Chairman* — Crawford 13

Regulator Design with Consideration of Observation and Control Implementation . . *G. Blankenship*

A Multilayer Control Hierarchy with an On-Demand Updating Policy . . *K. Tsuji*

Application of LOGOS to Computer-Aided Design: an Example . . *C. Rose*

R O S T E R

SPONSORS' MEETING NO. 32 - MAY 3, 4, 1972

I. INDUSTRIAL REPRESENTATIVES

BABCOCK & WILCOX/BAILEY METER CO.

J. Adams
R. Bilski
G. Carlo-Stella
L. Haberman
R. Klosky
R. Olmstead
T. Scheib

BETHLEHEM STEEL CORPORATION

J. G. Foulds
C. F. Long

ESSO RESEARCH & ENGINEERING

H. Mosler
J. D. Simon
J. L. Woodward

THE FOXBORO COMPANY

E. H. Bristol
P. Holst

GENERAL ELECTRIC COMPANY

R. Beauregard
A. S. Brower
D. Kampfer
J, M. Wexler

MARATHON OIL COMPANY

T. Deiro
J. Howell

MOBIL RESEARCH & DEVELOPMENT CORP.

P. Halbert
M. Tayyabkhan

VISITOR

R. Ash - Procter & Gamble

II. FACULTY

R. E. Bolz	Dean, School of Engineering
G. L. Blankenship	Assistant Professor, Engineering
Y. Y. Haimes	Associate Professor, Engineering
J. T. Koppenhaver	Assistant Director, Research Administration
L. S. Lasdon	Professor, Operations Research
I. Lefkowitz	Acting Head, Systems Engineering Division
D. Macko	Associate Professor, Engineering
M. D. Mesarovic	Director, Systems Research Center
H. R. Nara	Associate Dean, Engineering
P. A. Orner	Associate Professor Engineering
C. W. Rose	Assistant Professor, Information Sciences
D. H. Rothenberg	Assistant Professor, Engineering
J. D. Schoeffler	Professor, Engineering
S. Guberinic	Visiting Postdoctoral Fellow
O. Semenkov	Visiting Postdoctoral Fellow
J. P. Riley	Invited Lecturer, Utah State University
K. J. Aström	Invited Lecturer, Lund Institute of Technology

III. STUDENTS

M. Alpert
L. Bronner
K. Chadha
C. Conneighton
I. Dear
W. Driscoll
D. Easterday
J. Foley
T. Fukuda
F. Gembicki
B. Gunter
T. Harrington
R. Ishida
M. Kaplan
D. Kolo
D. Kylin
H. Lopez
H. Lycakis

S. Mathis
P. Merluzzi
V. Mileti
W. Nainis
F. O'Neil
E. Rechtschaffen
S. Rosen
P. Salamon
R. Schenke
R. Schmotzer
S. Sunderland
K. Tsuji
R. Walters
T. Weisman
C. Whitfield
S. Yoshii
W. Yu

Undergraduates

B. Alleshouse
J. Bendfeldt
K. Beracz
H. Jacobs
K. Mendelson
J. Milligan
D. Mumford
R. Sirow
E. Snyder
M. Stafford
T. Takacs
D. Wright

IV. STAFF

D. Brachi	Technical Secretary
G. Cadwallader	Administrative Assistant, Systems Research Ctr.
M. Cantini	Administrative Secretary
K. Roberts	Technical Secretary
T. Shook	Project Engineer, Systems Research Center
P. Worrell	Student Helper

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Wednesday, May 3, 1972

9:15 - 10:00 a.m.	COFFEE AND DONUTS		Crawford 13
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2:15 ~~2:00~~ - 4:~~30~~ p.m.			
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	Evaluation of Reliability of On-Line Mini-computer Systems	. . S. Sunderland	
	DDC Software Organization for a Three Computer Hierarchical Control System	. . V. Mileti	
	A Virtual Memory Organization for Minicomputer Application Software	. . L. Bronner	
	Computer-Aided Design for Large Scale System	. . L. Bronner → Urban → Industrial.	
	An Interactive Model of An Urban Wastewater Conveyance System	. . I. Dear	
SESSION III	D. Macko, Chairman		Crawford 107
	On-Line Coordination of Interacting Systems	. . C. Whitfield	
	A Study of Multilevel Control Applied to the Hot Strip Mill Process	. . . T. Fukuda	
	A Design Methodology forAutomated Inspection Via Pattern Recognition	. . D. Kylin	
	A Decision Structure for Making On-Line Support Tradeoffs for Large Complex Systems	. . F. O'Neil	
	Automatic Dipper Control forStripping Shovels	. . Takacs, et al.	
3:00 - 3:15 p.m.	COFFEE BREAK		
8:30 - 10:30 p.m.	SOCIAL GET-TOGETHER		Howard Johnsons' Penthouse

Thursday, May 4, 1972

9:00 - 12:00 noon

SESSION   *G. Blankenship, Chairman*   Crawford 14

Recent Developments in Stochastic Control and Filtering . . *G. Blankenship*

Small Signal Models for Estimation of Input Variables from Secondary Process Measurements. . *D. Easterday*

Eliminate gas chromatograph. Distillation. static.

Some Simulation Models for One-Dimensional Distributed Systems . . *P. F. Salamon*

Tuning Linear Quadratic Controls . . *V. Mileti*

SESSION V   *Y. Y. Haimes, Chairman*   Crawford 107

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Distributed System Identification Using Quasi-linearization . . *R. T. Schenke*

Vector Optimization for Control with Performance and Parameter Sensitivity Indices . . *F. Gembicki*

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The Planning and Operation of a Regional Water Quality Management System: A Multilevel Approach . . *M. A. Kaplan*

10:20 - 10:40 a.m.   COFFEE BREAK

12:00 - 1:15 p.m.   LUNCH   Crawford 13

1:15 - 2:45 p.m.

SESSION VI   *L. S. Lasdon, Chairman*   Crawford 14

Development of an LP Program for Ship Routing . . *L. S. Lasdon*

Synthesis of a Crude Oil Supply System . . ~~*S. J. Mathis, Jr.*~~

Multilevel Techniques for Scheduling a Class of Integrated Industrial Systems . . *W. Driscoll*

SESSION VII   *I. Lefkowitz, Chairman*   Crawford 107

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A Multilayer Control Hierarchy with an On-Demand Updating Policy . . *K. Tsuji*

Application of LOGOS to computer-aided Design: An Example . . *C. Rose*

(Computer engineering)