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Evaluation of Computer Aided Software as a Space Analysis Tool for Outfit Unit Design and Planning

Prepared by:

Patrick D. Cahill, Principal Investigator
Senior Engineering Research Associate
University of Michigan transportation Research Institute (UMTRI)
Marine Systems Division

for

Designers and Planners

in Support of

Generic Build Strategy
Midterm Sealift Project

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Executive Summary

During July, 1995, the University of Michigan Transportation Research Institute, Marine Systems Division, conducted an extensive literature search to identify and evaluate software currently commercially available that would support space analysis for outfit unit design and planning. The long term objective is to identify and evaluate specific software packages or combinations of packages that can be employed in the development of build strategies and the early stage design of shipboard spaces, particularly machinery spaces.

The entire University of Michigan library system was searched for pertinent literature about shipbuilding and other industries where spacial planning is a critical design element. Specific resources utilized included the NSRP documentation center, the UMTRI library, the Kresge Business Library, the Dow Engineering Library and the School of Art and Architecture library.

The overall conclusion of the research effort is that there is not a currently available commercial software package that will automate the spacial arrangements problem. However, there is current research that has resulted in working prototypes, and there are available commercial packages that, in combination with each other, will offer a viable solution.

The Architecture and Civil Engineering community has made the most progress in the development of a specific tool that appears to address the issues of concern. ABACUS (Architectural Case Based Design System) has been developed into a working prototype at the department of Architecture, Eidenossische Technische Hochschule, Zurich, Switzerland. It is a Case Based Design system implemented in LISP and AutoLISP and using Autocad as a graphic engine.

Other tools of interest include Case Based Design and Case Based Reasoning software prototypes, Artificial Intelligence and Knowledge Based systems without graphical engines, and parametric design packages that maintain topographical relationships.

Objective

This report represents the finding of Tasks 1.1 and 1.2 of a three part task statement. The specific task statements are:

Task 1.1 Literature search to obtain information on specific software currently commercially available.
Task 1.2 Comparative assessment of identified software with regard to state-of-the-art capabilities described in CAD/CAE literature.
Task 2 Demonstrations of selected software at vendor sites to assess capabilities to perform space arrangements, analysis and optimization for ERAM and to interface to ERAM product modeling efforts.
Task 31. Provide a report detailing the findings and providing recommendations.
Task 3.2 Provide administrative support for report preparation and task management.

It quickly became apparent during the literature search that there are no commercially available packages that meet the requirements of the ERAM and GBS portions of the Midterm Sealift Program. As a result, the focus of the search was shifted to identify research efforts that may result in the appropriate software packages, as well as software that may be used as a component of an Integrated, Automated, Intelligent Arrangements $(IA)^2$ program

Current Research and Development Focus

Current software research and development is focused in three areas that, if combined and integrated, have great potential to yield the desired $(IA)^2$ system. These three areas are product modeling, knowledge based systems and parametric design. The only area in which shipbuilding specific research is occurring and ongoing is in product modeling. Knowledge based systems development is prominent in the civil engineering and architectural design fields, and parametric design efforts are heavily focused on supporting the mechanical design and manufacturing field. An additional field in which these three areas are being combined is I electronics, specifically in the design and manufacture of Very Large Scale Integrated (VLSI) circuits. The literature pertaining to VLSI design is extensive, but may be technically beyond the scope of what can be readily implemented in the shipbuilding industry.

Product Modeling

Much of the current research in shipbuilding that may eventually result in a space planning system is in the area of product modeling. Research has been funded to implement a universal STEP translator based on the work by NIDDESC. A number of international organizations, both in Europe and in Japan, are focusing research efforts on the data structure and format of product model database that is independent of design software. Strong efforts are underway in both Japan and Europe to integrate product and process models.

A significant part of the focus of the product modeling efforts has been a consistent leaning towards the object oriented programming paradigm. As long as product and process model attributes can be defined as objects within a software system, they are more likely to be universally available for representation and implementation in both graphics engines and knowledge bases.

Knowledge Based Systems

Research within the civil engineering and architecture industry on knowledge based systems holds the most promise for near term implementation of an $(IA)^2$ design system. Knowledge based systems cover a number of different paradigms, and can be considered a subset of Artificial Intelligence or Expert Systems. They are rule based, often implemented in a tabular or spreadsheet format, and have significant amounts of software code, generally in either C or LISP, that make up the intelligence engine. Knowledge based systems research has resulted in a large number of prototypes, particularly in civil engineering and architectural design, that use existing designs as the knowledge base and integrate them with rules and additional user input to generate new designs. Some of the systems are purely specification based, some have graphics engines attached to the AI backplane.

Case Based Design, or CBD, is one of the most significant knowledge based paradigms. Case Based Design systems have the following properties:

- A CBD system does not require a complete domain model but can produce complete and complex designs based on a relatively small knowledge base.
- Design starts from complete cases, implicitly achieving tradeoffs between several functions. This avoids the problem of multi-criteria optimization.
- Applying the design history of existing cases can make design problem solving more efficient.
- Using cases as the source of knowledge allows learning by storing new cases.

The specific properties of case based systems make them very appealing for use in the shipbuilding industry. Each subsequent design becomes part of the knowledge base, and learning obtained in construction and operation of a specific design can be applied to enhance the knowledge base. It is likely that the software is object oriented, or can readily be adapted to object orientation, which will complement the product and process model outputs.

Parametric Modeling Systems

Parametric modeling systems represent the leading edge of design software. Research and development is continuing to enable better, smarter and faster parametric design, and a number of outstanding packages are already available. Parametric modeling allows a designer to quickly define part geometry, and changes in a specific portion of the geometry will result in a "ripple" effect in which all related parts will change in accordance with the design specifications. Leading edge parametric design maintains topographical relationships in assemblies, and changes in the parameters of part of an assembly result in the necessary changes within the rest of the assembly. Much of the code developed to support parametric design follows the object oriented paradigm, which supports the theory that the integration of parametric design, knowledge bases and product models may be well within the reach of near term technology.

Currently Available Software

Two of the three focus areas have software already available, although some is in the prototype stage and the commercial availability is unknown. Product and process modeling efforts will move forward regardless of the implementation of an $(IA)^2$ package. The product and process model will represent data rather than a specific software package. Several of the abstracts included in Appendix B address the product and process modeling efforts.

There are a number of Knowledge Based systems currently available as prototypes; however, the commercial availability and the levels of development are unknown. Case based design systems include ARCHIE, CADSYN, CADET, ABACUS, CASE, GOAL and SEED. A brief description of these systems is provided in Appendix B. An additional abstract on Allegro Common LISP is included in Appendix C as a potential programming tool to support knowledge based system development.

Parametric Design systems of note are currently available from Intergraph, including a two dimensional spacial planning system called project layout. Autodesk has released a new version of designer which provides parametric modeling that maintains topographical relationships of assemblies. An abstract on PASS by Data One is included in Appendix C as one of the few software tools that stood out during a review of over 1000 CAD/CAM software abstracts.

Conclusions and Recommendations

The overall conclusion of the project primary investigator is that there are no software packages currently commercially available that will meet the needs of the ERAM and GBS projects in terms of providing an $(IA)^2$ tool, with the possible exception of ABACUS. There appears to be significant promise in the concept of integrating a knowledge based system with a parametric design package. Even if the integration is not seamless, i.e. the design engineer runs the knowledge based system to achieve a set of parameters that are then used as input to the parametric design software, the end result may be a more intelligent and semi-automated design process. The core of the system is the knowledge base, which will allow a steady development of design starting points, and learning form construction and operational experiences.

Appendix A: Bibliography of U of M Library Research Results

GBS Arrangements Study Literature Search Bibliography: University of Michigan Library System

Title	Author	Publisher	Year	Location	Call#
A framework for case-based reasoning in engineering design	H. Shiva Kumar and C.S. Krishnamoorthy	Artificial Intelligence for Engineering Design, analysis and manufacturing (AIEDAM) Vol 9 Nbr 3 pp161-182	1995	Eng	
Advanced CAD/CAM systems : state-of-the-art and future trendsin feature technology	the International Federation for Information Processing (IFIP).	London ; New York : Chapman & Hall	1995	ENG	TS155.6.A35
Advances in design automation, 1994 : presented at the 1994ASME Design Technical Conferences, 20th Design AutomationConference, Minneapolis, Minnesota, September 11-14, 1994	Design Automation Conference (ASME) (20th : 1994 :Minneapolis, Minnesota)	New York : American Society of Mechanical Engineers	1994	ENG	TA174.D46511
Advances in feature based manufacturing	edited by Jami J.Shah, Martti Mantyla, Dana S. Nau	Amsterdam ; New York : Elsevier	1994	ENG	TS183.3.A381
Analog device-level layout automation		Boston : Kluwer Academic Publishers	1994	ENG	TK7874.A5491
Artificial intelligence in design '94		Dordrecht ; Boston : Kluwer Academic Publishers	1994	ENG	TA174.A79321
Artificial intelligence in optimal design and manufacturing	Zuomin Dong, editor	Englewood Cliffs, N.J. : Prentice Hall	1994	ENG	TS155.6.A771
Concurrent product design	1994 InternationalMechanical Engineering Congress and Exposition, Chicago,Illinois, November 6-11, 1994	New York, N.Y. : American Society of Mechanical Engineers	1994	ENG	TA174.C6611
Intelligent systems in design and manufacturing		New York : ASME Press	1994	ENG	TA174.I46881
Intelligent systems in design and manufacturing		New York : ASME Press	1994	ENG	TA174.I46881
Practical knowledge-based systems in conceptual design	Miles, John	London ; New York : Springer-Verlag	1994	ENG	TA345.M541
Advances in design automation, 1993 : presented at the 1993ASME Design Technical Conferences, 19th Design AutomationConference, Albuquerque, New Mexico, September 19-22, 1993	Design Automation Conference (ASME) (19th : 1993 :Albuquerque, N.M.)	New York, N.Y. : American Society of Mechanical Engineers	1993	ENG	TA174.D46511
Algorithmic aspects of VLSI layout		River Edge, N.J. : World Scientific	1993	ENG	TK7874.A4191
CAD geometry data exchange using STEP : realisation ofinterface processors		Berlin ; New York : Springer-Verlag	1993	ENG	TA174.C2541

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Title	Author	Publisher	Year	Location	Call#
A framework for case-based reasoning in engineering design	H. Shiva Kumar and C.S. Krishnamoorthy	Artificial Intelligence for Engineering Design, analysis	1995	Eng	
Advanced CAD/CAM systems : state-of-the-art and future trendsin feature technology	the International Federation for Information Processing (IFIP),	and manufacturing (AIEDAM) Vol 9 Nbr 3 pp161-182 London ; New York : Chapman & Hall	1995	ENG	TS155.6.A35
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Advances in feature based manufacturing	edited by Jami J.Shah, Martti Mantyla, Dana S. Nau	Amsterdam ; New York : Elsevier	1994	ENG	TS183.3.A381
Analog device-level layout automation		Boston : Kluwer Academic Publishers	1994	ENG	TK7874.A5491
Artificial intelligence in design '94		Dordrecht ; Boston : Kluwer Academic Publishers	1994	ENG	TA174.A79321
Artificial intelligence in optimal design and manufacturing	Zuomin Dong, editor	Englewood Cliffs, N.J. : Prentice Hall	1994	ENG	TS155.6.A771
Concurrent product design	1994 InternationalMechanical Engineering Congress and Exposition, Chicago,Illinois, November 6-11, 1994	New York, N.Y. : American Society of Mechanical Engineers	1994	ENG	TA174.C6611
Intelligent systems in design and manufacturing		New York : ASME Press	1994	ENG	TA174.I46881
Intelligent systems in design and manufacturing		New York : ASME Press	1994	ENG	TA174.I46881
Practical knowledge-based systems in conceptual design	Miles, John	London ; New York : Springer-Verlag	1994	ENG	TA345.M541
Advances in design automation, 1993 : presented at the 1993ASME Design Technical Conferences, 19th Design AutomationConference, Albuquerque, New Mexico, September 19-22, 1993	Design Automation Conference (ASME) (19th : 1993 :Albuquerque, N.M.)	New York, N.Y. : American Society of Mechanical Engineers	1993	ENG	TA174.D46511
Algorithmic aspects of VLSI layout		River Edge, N.J. : World Scientific	1993	ENG	TK7874.A4191
CAD geometry data exchange using STEP : realisation ofinterface processors		Berlin ; New York : Springer-Verlag	1993	ENG	TA174.C2541
CAD/CAM/CAE systems : justification, implementation,productivity measurement	Coticchia, Mark E.Title	New York : M. Dekker	1993	ENG	TS155.6.P741

GBS Arrangements Study Literature Search Bibliography: University of Michigan Library System

Title	**Author**	**Publisher**	**Year**	**Location**	**Call#**
CAD/CAM/CAE systems : justification, implementation,productivity measurement	Coticchia, Mark E.Title	New York : M. Dekker	1993	ENG	TS155.6.P741
Computer aided logical design with emphasis on VLSI 4th ed	Hill, Fredrick J	New York : Wiley	1993	ENG	TK7868.S9H65
Computer-aided design and manufacturing	:Amirouche, Farid ML	Englewood Cliffs, N.J. : Prentice Hall	1993	ENG	TA174.A481
Computer-aided design and manufacturing	Amirouche, Farid M. L	Englewood Cliffs, N.J. : Prentice Hall	1993	ENG	TA174.A481
Concurrent engineering : methodology and applications		Amsterdam ; New York : Elsevier	1993	ENG	TS176.C65
Design automation for timing-driven layout synthesis	Sapatnekar, Sachin S.,	Boston : Kluwer Academic Publishers	1993	ENG	TK7871.99.M44S3 71
Design to reduce technical risk		New York : McGraw-Hill	1993.	ENG	TA174.D4851
Intelligent concurrent design : fundamentals, methodology,modeling, and practice	American Society of Mechanical Engineers. Winter Meeting (1993: New Orleans, La.)	AmericanSociety of Mechanical Engineers,	1993	ENG	TS176.A44
Optimizing engineering designs	Krottmaier, J.,	London ; New York : McGraw-Hill	1993	ENG	TA174.K751
Algorithmic and knowledge based CAD for VLSI Published	Institution ofElectrical Engineers		1992	ENG	TK7874.A4161
Artificial intelligence in engineering design		Boston : Academic Press	1992	ENG	TA174.A791
Intelligent design and manufacturing		New York : Wiley	1992	ENG	TS176.I58
Knowledge aided design		London : Academic press	1992	ENG	TA174.K5711
Optimization-based computer-aided modelling and design :proceedings of the first working conference of the new IFIPTC 7.6 Working Group,The Hague, The Netherlands, 1991		Berlin ; New York : Springer-Verlag	1992	ENG	QA76.9.C65O651
Title:6th International Conference on CAD/CAM, Robotics, andFactories of the Future 1991 : held at South BankPolytechnic, 103 Borough Road, London SE1 0AA U.K., 19th-22nd August, 1991	International Conference on CAD/CAM, Robotics, and Factoriesof the Future (6th : 1991 : South Bank Polytechnic, London)	London ; South Bank Press,	1992	ENG	TS155.6.I58171
:Product modeling for computer-aided design and manufacturing :selected and expanded papers from the IFIP TC5/WG5.2 WorkingConference on	IFIP TC5/WG5.2 Working Conference on Geometric Modeling forProduct Engineering (1990 :	Amsterdam ; New York : North-Holland	1991	ENG	TS171.A11381

Title	Author	Publisher	Year	Location	Call#
Geometric Modeling for Product Engineering,Rensselaerville, U.S.A., 17-21 June 1990	Rensselaerville, N.Y.)				
Advanced modelling for CAD/CAM systems	H. Grabowski, R.Anderl, M.J. Pratt (Eds.).	Berlin ; New York : Springer-Verlag	1991	ENG	TS155.6.A3731
Advances in design automation, 1991 : presented at the 1991 ASME Design Automation Conferences--17th Design AutomationConference, Miami, FL , September 22-25, 1991	Design Automation Conference (ASME) (17th : 1991 : Miami, FL	New York, N.Y. : American Society of Mechanical Engineers	1991	ENG	TA171.A1D451991
An artificial intelligence approach to integrated circuitfloorplanning	Jabri, M. A. (Marwan A.)	Berlin ; New York : Springer-Verlag	1991	ENG	TK7874.J281
CAD/CAM, robotics, and factories of the future '90 : 5thInternational Conference on CAD/CAM, Robotics, and Factoriesof the Future (CARS and FOF'90) proceedings	International Conference on CAD/CAM, Robotics, and Factoriesof the Future (5th : 1990 : Norfolk, Va.)	Berlin ; New York : Springer-Verlag	1991	ENG	TS155.6.158171
Computer applications in production and engineering :proceedings of the Fourth International IFIP TC5 Conferenceon Computer Applications in Production and Engineering--Integration Aspects, CAPE '91, Bordeaux, France, 10-12September 1991	International IFIP TC5 Conference on Computer Applications inProduction and Engineering: Integration Aspects (4th : 1991: Bordeaux, France)	Amsterdam ; New York : North-Holland	1991	ENG	TS155.6.15861
Computer-integrated design and manufacturing	:Bedworth, David D	New York : McGraw-Hill	1991	ENG	TS155.6.B4391
Engineering optimization in design process : proceedings ofthe international conference	Karlsruhe Research Center	Berlin ; New York : Springer-Verlag	1991	ENG	TA658.8.E541
Mechatronics : electronics in products and processes		London : Chapman and Hall	1991	ENG	TS155.6.M42
Object-oriented databases with applications to CASE, networks,and VLSI CAD		Englwood Cliffs, NJ : Prentice Hall	1991	ENG	QA76.9.D3O261
Advances in computer-integrated manufacturing		Greenwich, Conn. : JAI Press	1990	ENG	TS155.6.A385
Advances in integrated product design and manufacturing		Winter Annual Meeting of the AmericanSociety of Mechanical Engineers, Dallas, Texas, November 25-30	1990	ENG	TS155.6.A386
Automatic programming applied to VLSI CAD software : a casestudy	Setliff, Dorothy E	Boston : Kluwer Academic Publishers	1990	ENG	QA76.6.S4681
Intelligent CAD; II : proceedings of the IFIP TC	IFIP TC 5/WG 5.2 Workshop on	Amsterdam ; New York : North-	1990	ENG	TA174.E871

Title	Author	Publisher	Year	Location	Call#
5/WG 5.2Second Workshop on Intelligent CAD, Cambridge, UnitedKingdom, 19-22 September, 1988	Intelligent CAD (2nd : 1990 :Cambridge, England)	Holland Elsevier SciencePub. Co			
Introduction to analog VLSI design automation		Boston : Kluwer Academic Publishers	1990	ENG	TK7874.I59551
Knowledge-based design systems		Reading, Mass. : Addison-Wesley	1990	ENG	TA174.K591
Advances in design automation, 1989 : presented at the 1989ASME Design Automation Conferences--15th Design AutomationConference, Montreal, Quebec, Canada, September 17-21, 1989	Design Automation Conference (ASME) (15th : 1989 : Montreal,Quebec	New York, N.Y. : American Society of Mechanical Engineers	1989	ENG	TA171.A1D451989
CAD systems in mechanical and production engineering	:Ingham, Peter	Oxford : Heinemann Newnes	1989	ENG	TS155.6.I58
CAD systems using AI techniques : proceedings of the IFIP TC10/WG 10.2 Working Conference on CAD Systems Using AITechniques, Tokyo, Japan, 6-7 June 1989	IFIP TC 10/WG 10.2 Working Conference on CAD Systems Using AITechniques	Amsterdam ; New York : North-Holland	1989	ENG	TA174.I1331
:Factory 2000 : integrating information and material flow	International Conference on Factory 2000	London : Institution of Electronic and Radio Engineers	1988	ENG	TS155.6.I57311
Automated modeling for design		New York, N.Y. : American Society of Mechanical Engineers	1988	ENG	TA174.A9211
Computer-aided systems engineering (CASE)	Eisner, Howard	Englewood Cliffs, NJ : Prentice-Hall	1988	ENG	TA168.E371
Design automation : automated full-custom VLSI layout usingthe ULYSSES design environment	Bushnell, Michael L. (Michael Lee),	Boston : Academic Press	1988	ENG	TA174.B871
Expert systems for engineering design		Boston : Academic Press	1988	ENG	TA174.E961
Physical design automation of VLSI systems		Menlo Park, Calif. : Benjamin/Cummings Pub. Co	1988	ENG	TK7874.P471
An expert systems approach to computer-aided design ofmultivariable systems	Pang, G. K. H. (Grantham K. H.)	Berlin ; New York : Springer-Verlag	1987	ENG	TJ213.P2651
Computer-aided engineering for manufacture	Milner, D. A. (Douglas A.)	New York : McGraw-Hill	1987	ENG	TS155.6.M551
Engineering productivity through CAD/CAM	Chorafas, Dimitris N	London ; Boston : Butterworths	1987	ENG	TS155.6.C4951
Intelligent and integrated manufacturing analysis andsynthesis	the Winter Annual Meeting of theAmerican Society of Mechanical	AmericanSociety of Mechanical Engineers,	1987	ENG	TS155.6.I561

Title	Author	Publisher	Year	Location	Call#
	Engineers, Boston,Massachusetts, December 13-18, 1987				
Knowledge based CAD and microelectronics	Holden, Tony	Amsterdam ; New York : North-Holland	1987	ENG	QA76.76.E95H651
CAD/CAM techniques	Hordeski, Michael F	Reston, Va. : Reston Pub. Co	1986	ENG	TS155.6.H671
Handbook of design automation	Sapiro, Steve	Englewood Cliffs, N.J. : Prentice Hall	1986	ENG	TK7874.S271
An introduction to automated process planning systems	Chang, Tien-Chien	Englewood Cliffs, N.J. : Prentice-Hall	1985	ENG	TS155.6.C491
Flexible manufacturing : recent developments in FMS, robotics,CAD/CAM, CIM		Amsterdam ; New York : Elsevier	1985	ENG	TS176.F591
International CAD/CAM software directory		Blue Ridge Summit, PA : TAB Books	1985	ENG	TS155.6.I571
An analysis of CAD/CAM applications : with an introduction toCIM	Stover, Richard N	Prentice-Hall Englewood Cliffs, N.J	1984	ENG	TS155.6.S761
CAD/CAM : computer-aided design and manufacturing	Groover, Mikell P	Englewood Cliffs, N.J. : Prentice-Hall	1984	ENG	TS155.6.G761
Elements of computer-aided design and manufacturing, CAD/CAM	Pao, Y. C.	New York : Wiley	1984	ENG	TS155.6.P361
Proceedings 1981-1992	ACM IEEE Design Automation Conference	New York, NY : Institute of Electrical and ElectronicsEngineers		ENG	TK5.I12
Automation based creative design : research and perspectives		Amsterdam ; New York : Elsevier Science B.V.,	1994	ARCH	NA2728.A881
Knowledge-based computer-aided architectural design		Amsterdam ; New York : Elsevier	1994	ARCH	NA2728.K641
Computer supported design in architecture : mission, method,madness		Charleston, S.C. : ACADIA	1992	ARCH	NA2728.C661
The logic of architecture : design, computation, and cognition	Mitchell, William J. (William John),	Cambridge, Mass. : MIT Press	1990	ARCH	NA2750.M581
ACADIA Workshop ... proceedings	Association for Computer-Aided Design in Architecture	Houston, Tex. : ACADIA	1988	ARCH	NA2728.A2611
Design by optimization in architecture, building, andconstruction	Radford, Antony	New York : Van Nostrand Reinhold	1988	ARCH	NA2728.R3441

Title	Author	Publisher	Year	Location	Call#
The architect's guide to computer-aided design	Crosley, Mark Lauden	New York : J. Wiley	1988	ARCH	NA2728.C751
Design computing		New York : Wiley	1986	ARCH	TS155.6.D45
Design tools monthly		Boulder, Colo. : The Nelson Group		ARCH	NA2728.D48
Designing the future : the computer in architecture and design	Baker, Robin	New York : Thames and Hudson	1993		
Advances in design automation, 1992 : presented at the 1992ASME Design Technical Conferences, 18th Design AutomationConference, Scottsdale, Arizona, September 13-16, 1992	Automation Conference (ASME) (18th : 1992 : Scottsdale,Ariz.)	New York, N.Y. : American Society of Mechanical Engineers	1992		
Design of marine and offshore structures : FourthInternational Conference on Computer Aided Design,Manufacture and Operation in the Marine and OffshoreIndustries	International Conference on Computer Aided Design,Manufacture, and Operation in the Marine and OffshoreIndustries (4th : 1992 : Madrid, Spain)	London ; New York : Elsevier Science Publishers	1992		
EURO-DAC ... : European Design Automation Conference	European Design Automation Conference (1992-)	Los Alamitos, Calif. : IEEE Computer Society Press	1992		
Simultaneous engineering : integrating manufacturing anddesign		Dearborn, Mich. : Society of Manufacturing Engineers,Publications Development Department, Reference PublicationsDivision	1990		
The C4 handbook : CAD, CAM, CAE, CIM	Machover, Carl	Blue Ridge Summit, PA Tab Professional and Reference Books	1989		
Intelligent suggestive CAD systems	Jakiela, Mark John	Ann Arbor, Mich. : Design Laboratory, College of Engineering,University of Michigan	1988		
Man-computer synergism for decision making in the systemdesign process	Allan, John J	University of Michigan Office of Research Administration	1968		

Appendix B: Selected Periodical Abstracts and References

Automation based creative design : research and perspectives	Amsterdam ; New York : Elsevier Science B.V.	1994

Case Based Design and Creativity

Gerhard Schmitt
Department of Architecture, Eidenossische Technische Hochschule, Zurich

Case Based Design, CBD, feature preserving but not necessarily geometry preserving. Combined with Case Based Reasoning CBR, relates the present situation to the closest experience in memory and uses that experience to solve a problem. Several case based design systems in use:

ARCHIE (Goel et al., 1991)
CADSYN (Maher and Zhang, 1991)
CADET (Sycara et al., 1991)

Case based design systems have the following properties:
- A CBD system does not require a complete domain model but can produce complete and complex designs based on a relatively small knowledge base
- Design starts from complete cases, implicitly achieving tradeoffs between several functions. This avoids the problem of multi-criteria optimization.
- Applying the design history of existing cases can make design problem solving more efficient.
- Using cases as the source of knowledge allows learning by storing new cases.

ACABAS - Architectural Case Based Design System - prototyped in 1990, implemented in LISP and AutoLISP and uses Autocad as the graphic engine. Results are tested and visualized on "Stalker" visualization software on Silicon Graphics machines.

Funded by the Swiss Nationalfond under the program NFP 23: Artificial Intelligence and Robotics.

Refs:

Faltings, Boi, Gerhard Schmitt, Kefeng Hua and Shen-Guan Shih, 1991. "Case Based Representation of Architectural Design Knowledge" in Proceedings of DARPA Workshop on Case based reasoning. Washington D.C. pp 307-316

Goel, A.K. and J.L. Kolodner, 1991. "Towards a case Based tool for aiding Conceptual Design Problem Solving" in Proceedings of DARPA Workshop on Case based reasoning. Washington D.C. pp 109-120

Advances in design automation, 1991 : presented at the 1991 ASME Design Automation Conferences--17th Design AutomationConference, Miami, FL , September 22-25, 1991	Design Automation Conference (ASME) (17th : 1991 : Miami, FL	New York, N.Y. : American Society of Mechanical Engineers	1991

Motion Planning in Plant CAD Systems
Koichi Kondo and Koichi Ohtomi
Mechanical Engineering laboratory
Research and Develoment Center
Toshiba Corporation
Kawasaki, Kanagawa, japan

“This paper discusses a general and efficient method for solving the motion planning problem defined as checking the existence of a collision free path among known stationary obstacles, and also presents it's application to a plant CAD system. The basic approach taken in this method is to restrict the free space referred to in path searching and to avoid executing unnecessary collision detection's. The configuration space is equally quantized into cell s by placing a rectangular grid, and two new search strategies which enumerate restricted cells are introduced for realizing this method. One is a local strategy which enumerates free space cells only along the boundary of the free space in the configuration space. Another is a global strategy which finds the outer boundary of the free space. This method has been actually implemented and has been applied to an example in a nuclear power plant.”

Rough example of a plant layout using solid primitives and a method of breaking the CAD model into a series of small cells, each of which either contains a solid member or does not. Separation between elements is calculated and routing for installation is determined based on moving a solid geometry part through the arrangement.

References:

Kameyama, K., Kondo, K. and Ohtomi, K., 1990. An Intelligent and Interactive CAD Layout CAD system for Industrial Plant, , Proceedings ASME DTM'90 DE-Vol 27. PP 33-38.

Lozano-Perez, T., 1983, “Spacial Planning: A Configuration Space Approach”, IEEE Trans. Comput Vol C-32, pp. 108-120.

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AUTOMATION IN CONSTRUCTION

Software design of maintainable knowledge-based systems for building design ☆

Tom Andersen *, Niels Vejrup Carlsen [1]

CABDU, Computer Aided Building Design Unit, c/o Department of Building Design, Building 118, Technical University of Denmark, DK2800 Lyngby, Denmark

Abstract

Identifying and establishing a basic structure for knowledge representation is one of the keys to successful design of knowledge-based computer systems. In Building Design and Construction, this initial knowledge structure can be achieved by utilizing a query driven approach to software engineering. As (user) queries reflect the user's demand for in/output, it is natural to link the overall user dialogue with key elements in the knowledge base. Direct connections between user screens and objects in the knowledge base support prototyping and testing the application during development. However, the price for pursuing this approach in its pure form can be high, as needs for later maintenance and augmentation of the system can be very hard to fulfil. To overcome these problems, a strict user interface software separation strategy must be introduced at early stages of software design, and implemented as a global control module as independent of the knowledge processing as possible.

Keywords: Knowledge-based; Query driven; Software design; User interface; Separation; Maintainable systems

1. Introduction

At the Computer Aided Building Design Unit (CABDU), our research efforts are directed towards the provison of an intelligent building design assistant (IBDA).

IBDA must be an integrated environment consisting of several computer tools working around a central model of the (building) artifact [7,12]. This system will employ a variety of information technologies spanning from logistics systems, traditional CAD systems and computational tools to knowledge-based design support systems. Some observations on the overall configuration of such an integrated environment are briefly presented in [3]. Issues like user dialogue and the diversity of design domains are outlined.

In this paper we focus on knowledge-based tools, and our aim here is to explore pertinent software engineering aspects for this category of computer applications.

In the following we will present and discuss the BYGSYS system which at this point is a stand-alone knowledge-based system supporting roof design. BYGSYS can be regarded as a tool

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possible links which must be reestablished according to the nature of the augmented functionality.

This also covers the introduction of *changed order of key screen*. The nature of the domain, the implications and rules etc. which can be derived by acquisition, cannot be neglected if one wants to pursue a sensible consultation process. In the example presented above, the selection of roof covering (Block2 in control function) do impact level 1 to a certain degree, thus reducing the choices of preferable roof shapes (which is controlled by Block1). This is simply augmented to the functional core by adding the relevant rules and functions. Test of the system has proven that it performs equally well in both scenarios, and that our distributed separation method formed a sound base for this augmentation of BYGSYS.

5. Conclusions

User (query) driven modelling and design does without doubt imply incremental prototyping. However, in the case of larger systems and/or complex knowledge domains, this is only feasible if care is taken to have optimal separation between the user interface and the functional core. An initial prototype can easily be developed without separation but later revisions will most likely be prohibitively complex.

So, user demands must be taken seriously when designing knowledge-based decision support systems. We do recommend user (query) driven knowledge acquisition and modelling but combined with an overall strategy for software separation as a minimum of effort.

It should be pointed out, that our findings and related proposed guidelines are based on research in the spectrum of technical building design. These can be classified as engineering domains, wherein a reductive problem solving approach can be applied.

If a domain satisfies these conditions, the query driven approach combined with a firm strategy of pursuing a high degree of independent user dialogue, is highly recommendable, and can form a basic software engineering strategy for a number of agents in an integrated software environment (IBDA) supporting building design.

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AUTOMATION IN CONSTRUCTION

Knowledge-based design research at the key centre of design computing [☆]

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Abstract

This report outlines the current focus of the research at the Key Centre of Design Computing (KCDC) in the field of knowledge-based design and its future directions. The research is classified into seven main areas as follows:
- Computer-Supported Synchronous Collaborative Design (CSSCD)
- Design Creativity
- Evolutionary Models of Design
- Shape Emergence
- Design Intent and Multiple Abstractions
- Integration of Specific and General Knowledge
- Concept Learning - Machine Learning

While each such area will be discussed separately, there are many interrelations between them. For example, the research on CSSCD includes the research into shape emergence, design intent and multiple abstractions and their integration in the one environment; design creativity includes research into shape emergence and evolutionary models; CSSCD, evolutionary models, design creativity, case-based design and design intent/multiple abstractions all deal with object-oriented or schema-based representations of design objects and classes, using the design prototype schema developed at the then Design Computing Unit (DCU). The work on memory organization for heterogenous design knowledge includes aspects of concept learning and machine learning. Evolutionary models are also seen as an approach to machine learning.

All the above areas of research are concerned with producing computable models of design processes based on integrating artificial intelligence approaches with CAD systems to provide better design support for designers using CAD systems. Other areas of research of the KCDC, not described in this paper are design theory and practice.

Key words: Knowledge-based design; CAD; Collaborative design; Design creativity; Evolutionary design; Shape emergence; Design intent; Case-based design; Concept learning; Multiple abstractions

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1. Computer-supported synchronous collaborative design

1.1. Aims

The aim of this research [1, 2] is to develop a computer-based design environment in which de-

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more concerned with the issue of knowledge representation, organization and access.

Further to the work related to the project on case-based design, on-going research is concerned with the organization of case memory with flexible indexing of cases for case retrieval and browsing using a multi-media approach [22, 23].

6.2. Concept learning – machine learning

6.2.1. Aims

The aim of this research is to examine the application of machine learning techniques in the generation of design concepts from design examples. More specifically, the research is aimed at learning empirical knowledge to assist preliminary design [24, 25].

6.2.2. Description

Existing machine learning techniques are insufficient in a number of ways. For example, much of the work on conceptual clustering builds upon Fisher's [26] COBWEB which provides a methodology for partitioning data spaces. However, Alem and Maher [27] show that this is insufficient in itself as it does not accommodate varied attributes across training examples nor learning associations among attributes within a cluster. In addition, associations between numerical and nominal data are not generated.

The work by Maher and Li [25] considers a target representation of design knowledge, called a design concept which is based on a group of design attributes and associations among these attributes and develops an approach to learning such concepts. The model for automatically learning design concepts from project data is an aggregation of machine learning and numerical analysis techniques and has two major components: concept aggregation and concept characterisation. Concept aggregation involves decisions about which entities or features are to be selected and grouped into a concept. In concept characterisation, the design concepts formed by the concept aggregation process are further defined by the empirical associations among the design attributes, in the form of empirical formulae and design patterns.

6.2.3. Summary

The proposed model has been tested using 72 bridge designs collected from the Roads and Traffic Authority (RTA) in Sydney. Four concept spaces were generated that, although unnamed by the system, could be recognized as representing four bridge design types: simply supported girder bridges; plank bridges; continuous bridges; and cable-stayed bridges. The empirical networks produced by the learning system represent a generalization of the examples from previous design projects. This generalised knowledge can be used to provide assistance in the preliminary design of new design problems by associating sets of attributes with concepts and providing initial values for the attributes.

7. Summary

This report has outlined some of the research areas in knowledge-based design in which the Key Centre of Design Computing is involved. All these areas have in common the aim of contributing to more useful CAD systems as design aids. All the areas have an effect on creative design and computer-supported collaborative design and their understanding and development are necessary for the understanding and development of creative design and computer-supported collaborative design.

Future research in knowledge-based design in the Key Centre of Design Computing has been outlined in each of the areas above, but in general, will concentrate strongly on creative design methods, emergence and computer-supported collaborative design. The latter area brings into focus the area of multi-media communication and research will also be directed in this area.

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AUTOMATION IN CONSTRUCTION

Central or distributed organization of design systems? [*]

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Abstract

The paper describes two design systems prototypes developed at the IMS Institute: GIMS-EXPERT, a centrally controlled system made in 1987, and GIMS-DDS, a distributed design system still under development. Both systems produce design sketches of the family houses to be built in "GIMS", a catalogue-based, prefabricated building system. Presented and discussed are the two systems gestations, basic concepts, and examples of output. The more rigid EXPERT produces the expected designs and is suited for the well-defined requirements and contexts, while the more flexible DDS produces satisficing answers in ill-defined contexts, and can even produce "unexpected" designs. It can also simulate the performance of GIMS-EXPERT.

Key words: CAAD; Design expert systems; Distributed design systems

1. Introduction

The paper describes two design systems prototypes developed at the IMS Institute: GIMS-EXPERT, a centrally controlled system, and GIMS-DDS, a distributed design system. Both systems produce design sketches of the family houses to be built in "GIMS", a catalogue-based, prefabricated building system [1]. The application domain suggests that all possible design solutions that can be produced (or "selected") from the system catalogued elements are determined in advance. If this is the case, a "Design object problem" relates to the question of which design to select and why, while a "Design methods problem" relates to the question of which design methods and tools to apply for the selection of the required designs, and eventual generation of the alternative designs from the existing elements.

Two design systems mentioned reflect two types of organization:

(i) a closed, "deterministic machine" (GIMS-EXPERT) and

(ii) an open, distributed, "almost self-organizing system" (GIMS-DDS).

How do these systems treat the aforementioned design problems? Which, of the two, should be selected for further development into the complete "GIMS Design System"? We shall firstly describe both systems' traits and after a limited discussion attempt some answers to these questions.

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the situation changes. Then, this tool becomes a fast and challenging interface, a full body contact between man and machine, where each partner can fool the other. The most important thing here is that every idea is represented as a 3-d object within seconds. As it happens, it is just possible that the PDP-AAM may be an undercover "agent-anarchist" [23]; when it enters the design process, anything can happen (even creative leaps?).

4.4. What kind of system is the GIMS-DDS?

The development of DDS tools started as an attempt to re-make the GIMS-EXPERT to be faster and more efficient. As the various tools appeared, doubts were risen as to what control, if any, to introduce. The pragmatic and empirical approach, "experiment first and propose and check a theory later" took its toll in sometimes unnecessary work (e.g. in making several very similar expert system shells), but the produced "kit of tools" proved to be an interesting simulating (and stimulating) device. GIMS-EXPERT was reincarnated, but we are still charting possible future paths of the DDS development. Obviously, the adapting organization of the DDS enables the formation of "static and dynamic frameworks" [5] but would it enable the creation of something that would perform like a "self-organizing system"? Why would anyone need such a system? Further development of DDS plus all sorts of new PDP-agents such as "analogists", "mutants" and others [24], point out to new directions of unpredictable methodological turns in CAAD theory and practice.

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AUTOMATION IN CONSTRUCTION

Knowledge-based design support ☆

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1. Historical perspective

In 1971 the Architects' Journal featured a paper entitled PACE 1: Computer Aided Building Appraisal [1]. The software known as PACE (Package for Architectural Computer Evaluation), initially developed on the Systemshare time-sharing system accessed on-line from a teletype terminal over the ordinary voice grade telephone network, has, in concept at least, survived the subsequent 22 years and remains to this day a crucial aid in the teaching of architectural design in the University of Strathclyde's Department of Architecture and Building Science.

The intention of PACE, subsequently known as GOAL (General Outline Appraisal of Layouts) was to make explicit to students and practitioners the "cause and effect" of decision-making at the early conceptual and formative stages of the design activity, i.e. how her/his design choices regarded form and fabric impacted on the range of cost and performance consequences which characterise the design (Fig. 1).

The user of GOAL created form by shaping and placing volumes, and chose fabric by selection from a constructional database. By naming volumes (e.g. classroom, store, stairway) the user ensured that the software found the relevant functional and environmental requirements of the space (e.g. air change rate, proportional limits, requirement for daylight, contiguity constraints). By choosing a particular construction, the user ensured that the software found the relevant physical properties of the building fabric (e.g. thermal transmissivity, and mass, acoustic attenuation transparency, colour).

The topographical and thermo-physical properties of the hypothesised design were available to a range of calculation routines some of which were well established (e.g. energy consumption algorithms) and some of which had to be invented (e.g. algorithms for the computation of planning efficiency).

The detailed output from GOAL, which was organised hierarchically to suit the needs of particular users, was also available as a summary of design and cost/performance variables, known as the "fingerprint" of the design (Fig. 2).

The fingerprint of all design hypotheses relating to a particular brief could be progressively saved and subsequently analysed. The analysis offered a variety of options:

– The cost/performance profile of any individual design could be displayed as a histogram in relation to a base line (or benchmark). The base against which a design was to be compared could be selected by the user and could be, for exam-

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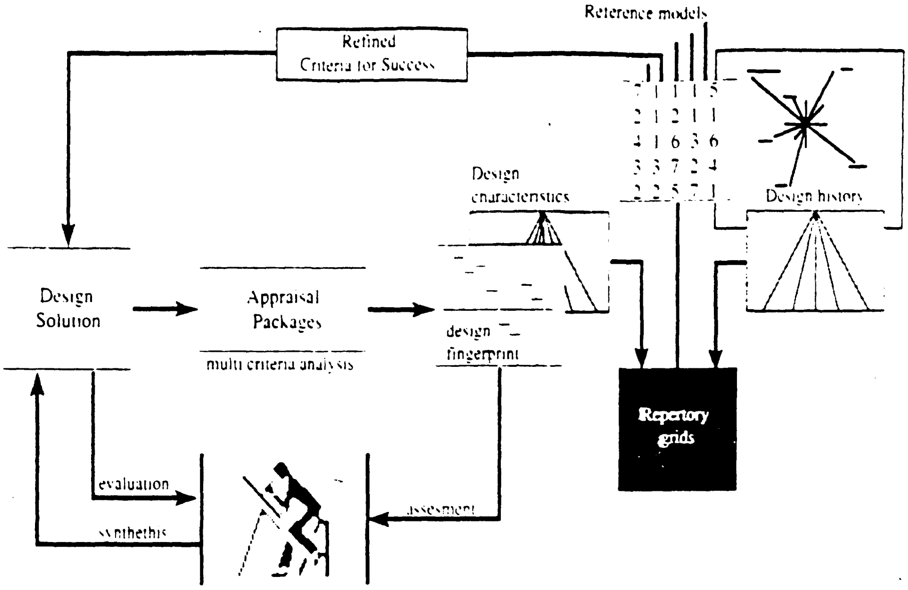

Fig. 17. Automated elicitation of a designer's belief structures and the derivation of models of the design process.

back-end of the framework would normally be used once a complete description of a building had been resolved. The use of sophisticated design tools of this form would therefore normally be used in a post hoc checking mode. The framework, adding contextually sensitive defaults, makes these applications accessible at an earlier stage of the design process, providing an opportunity to identify and resolve potential problems before the production drawing stage, thus saving valuable time and resources.

5.1. Future research

The KNODES environment blackboard, by monitoring and recording transactions between knowledge resources, provides a mechanism for recording and tracing design decisions.

This facility is to be used to provide on-line protocols of design activity. It is believed that where it is possible to enumerate designs by means of a classification or a diagnostic system (Fig. 17), design fingerprints, measured against known metrics, can be used to elicit a designer's belief structures and therefore provide some insights into the nature of design decision making.

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AUTOMATION IN
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Knowledge-based computational support for architectural design [☆]

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Abstract

The process of architectural design aims to define a physical form that will achieve certain functional and behavioral objectives in a particular context. It comprises three distinct, but highly interrelated, operations: (1) definition of the desired objectives; (2) production of alternative design solutions; (3) evaluation of the expected performances of the solutions and their comparison to the predefined objectives. Design can be viewed as a process of search for a solution that satisfies stated needs, while at the same time adapting the needs to the opportunities and limitations inherent in the emerging solution.

Computational techniques were developed to assist each one of the three operations, with varying degrees of success. We propose to integrate all three operations into one whole, by developing a computational model that will facilitate smooth transition from one operation to another. The role of computers in supporting this model will include providing a database of prototypical design objectives and solutions, storing project-specific design goals and solutions, and predicting their expected performances. This paper discusses the rationale and background for developing such a knowledge-based design system, and presents the parameters for implementing it as a computational tool to support architectural design. Examples from a prototype implementation serve to illustrate the discussion.

Key words: Design process; Knowledge base; Partnership paradigm; Design goals; Prototypes

1. Introduction

We consider architectural design a goal-directed search process which relies on prior experiences and knowledge. The purpose of the process is to define an object (or an environment) that achieves some desired behavioral and spatial characteristics, while conforming to and relying upon cultural, social, environmental, and other norms. We refer to the object that is being designed as the *solution*, and to the desired behavioral and spatial characteristics it strives to achieve as the *goals*. We view the process of design as a *dialogue* between the goals and the

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achieved outstanding results doing so without the aid of computers. It is our contention that it is not necessary to fully automate each and every one of the design process activities in order to significantly improve design productivity and quality. Rather, it is more prudent to develop a practical symbiosis between the capabilities of designers and machines.

The implementation of our approach is based on viewing architectural design as a process of search, which aims to reconcile the differences between a set of *requirements*, given by the client, and the expected behavior of a design solution, proposed by the architect. In the course of negotiating the differences between the two ends, tradeoffs must be made on both sides. The process also contributes to better understanding the problem itself, and informs both the architect and the client of initially hidden opportunities and irreconcilable conflicts.

The prototype we have developed forms a framework for implementing our proposed *design partnership* paradigm. In such partnership, the role of the computer can be shifted dynamically between passive representation/evaluation and active generation/evaluation of design solutions. Such dynamics would allow the designer and the system to respond to changing requirements, unforeseen problems, and emerging opportunities as they arise during the design process. The system demonstrates the feasibility of implementing this paradigm. Its utility for practicing architects is, nonetheless, yet to be tested.

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AUTOMATION IN
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Case-based design in the SEED system ☆

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Abstract

SEED is a software environment to support the early phases in building design currently under development. Among the capabilities intended for SEED is the automatic storage of solutions generated with the system as *cases* and their retrieval for reuse in a similar problem situation. SEED responds to practical demands requiring an approach to case-based design that differs from those known from the literature. The paper specifies the SEED requirements for case-based design, outlines an approach to satisfy the requirements, and presents technical details on the mechanisms under development.

1. Introduction

This paper outlines an approach toward the representation and reuse of past solutions in SEED, a *S*oftware *E*nvironment to support the *E*arly phases in building *D*esign. The project sponsors are particularly interested in capabilities that support work with *recurring building types*, that is, building types dealt with frequently in a design firm. Such firms, from housing manufacturers to government agencies, accumulate considerable experience with recurring building types. But this experience is located currently mainly in the memory of designers and in institutional records. Computational support for bringing this knowledge to bear on new projects remains dispersed and loosely coupled. SEED intends to provide systematic and broad support for both the creation and evaluation of new designs and their reuse in a new, but similar context.

This motivation aligns SEED with current work on *case*-based design systems [1] and, less closely, with *prototype*-based design systems [2]. But none of the approaches described in the literature matches exactly the requirements and application context of SEED. Section 2 introduces these requirements, starting with a brief overview of SEED. Section 3 outlines an approach toward the reuse of solutions in the SEED context that matches the requirements. Section 4 deals with technical issues that arise from this approach. Readers not familiar with the terminology and techniques of case-based reasoning and design, a subfield of Artificial Intelligence (AI), are referred to [1] for an introduction.

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operation can be used to eliminate functional units that do not exist in the problem specification or that are incorrectly allocated. The edit operations can be used to adapt the dimensioanl attributes of a design unit to satisfy certain constraints. At this point, the retrieved solution is more or less equivalent to an initial state with preplaced units, and the normal add and generate operators can be used to allocate or re-allocate functional units that are not yet or no longer allocated.

At any time, a design unit may have no functional unit associated with it, in which case all constraints on its shape and location are relaxed. This suggests an exciting extension of the retrieval procedure outlined in Section 4.2. If we allow functional units to be comparable — on an optional basis — not only with subclasses, but also with superclasses, we may be able to retrieve layouts based on size and dimensional constraints alone; for example, we may retrieve a narrow, linear scheme from a project dealing with building functions that differ from the ones currently under consideration.

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AUTOMATION IN CONSTRUCTION

Framework for development of CAD/CAC systems [☆]

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Abstract

This paper provides a framework for the development of Computer-Aided-Design/Computer-Aided-Construction (CAD/CAC) systems. A description of the proposed CAD/CAC systems is provided. The proposed system contains software tools related to (1) conceptual design, (2) structural and foundation analysis, (3) design of structural components, (4) routine geometric, mathematical, and optimization functions, (5) construction management, (6) Computer Aided Process Planning (CAPP), (7) process simulation, and (8) constructability analysis. On-going research work in areas related to CAD/CAC systems are highlighted. Incorporation of Group Technology (GT) paradigm for civil engineering structures to enhance the efficiency and effectiveness of the proposed systems is investigated. Issues related to algorithm development are also discussed. Possible extension of Automatically Programmed Tools (APT) language to include construction industry processes are examined. Specifically, the programming level syntax of APT can be extended by adding construction related vocabulary and features to only two out of five statement types and processor-level syntax can be extended by incorporating additional modular features.

Keywords: Construction process planning; Computer aided process planning; CAD/CAC; Rectangle adjacency graph (RAG); Automatically programmed tools (APT); Group technology (GT)

1. Introduction

There are three *main* participants in facility delivery process: (1) an owner, (2) a designer, and (3) a constructor. According to Miyatake, Managing Director of Shimizu, Computer Integrated Construction (CIC) includes not only design and construction issues, but also business-related functions such as marketing and financing of the three *main* project participants. Computer-Aided-Design/ Computer-Aided-Construction (CAD/CAC) systems proposed by Kunigahalli and Russell [17], is a subset of CIC and focuses upon design and construction issues within the facility delivery process.

The proposed design and construction integrating system requires multi-disciplinary research efforts in a variety of areas such as (1) Computer-Aided-Design (CAD) and geometric modeling, (2) algorithms and data structures, (3) Artificial Intelligence, (4) Computer Numerical Control (CNC) and robotics, (5) operations research in stochastic and deterministic processes, (6) data communication with Local Area and Wide Area Networks, (7) simulations, (8) Com-

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A constraint-system shell to support concurrent engineering approaches to design*

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This paper describes SATURN, a powerful constraint-system shell that provides knowledge integration and reasoning features ideally suited to supporting concurrent engineering approaches to design. SATURN is a logic-based constraint modeling system, tightly coupled with a relational database, and supported by a truth maintenance system. This paper presents SATURN's architecture and its modeling and manipulation techniques. An example application in automated-storage-and-retrieval-system design is provided to illustrate how a SATURN constraint-based model is constructed by a concurrent engineering design team, which then can be used by a product designer to create a feasible design. Unique features of this constraint-system shell include its rich knowledge representation facilities, its seamless integration of forward, backward and relational database inferencing, and its engineer-oriented user interface.

Key words: concurrent engineering, product design, constraint satisfaction, logic, logic programming, relational databases, automated storage and retrieval systems.

1 INTRODUCTION

Today's competitive market requires that engineering companies react quickly to volatile market demands and growing product complexity through efficient design processes that ensure a product's quality, competitive price and prompt availability to consumers. Success stories[1] have shown that this can be achieved by adopting a design philosophy termed concurrent engineering (CE). This philosophy encourages the simultaneous consideration of all aspects of a product's life cycle at the design stage. It stresses a parallel approach to design that is different from the more traditional approach where products are designed in isolation and only then considered in terms of their manufacturability, testability, quality, serviceability, etc.[2–4] Conceptually, the CE approach to design seems plain. Practically, however, when considering the life cycle of even the simplest product, the number of aspects to be considered at the design stage is quite formidable.

To counter this problem, companies usually set up design teams[5–7] whose members, drawn from all stages of the product's life-cycle, are responsible for ensuring that their design rules are satisfied (or at least considered) at the time of design. Design rules are derived from many sources including: tables found in manuals, standards established locally, nationally and internationally, equations found in textbooks, and heuristics based on experience and expertise. Still others are based on the results of techniques like simulation and process planning. Each of the various rules exerts a constraining influence on the evolving design (our interpretation of design rules is thus synonymous with that of constraints) and serves to guide a designer in making feasible design decisions. As new information surfaces during each step of the design the consequences of the design decision are checked against the design constraints to ensure conformity. If a decision results in some of the constraints not being met, the team members interactively collaborate to resolve or minimize the potential downstream manufacturing conflicts. This essentially results in an interactive constraint satisfaction process that is best performed if the team members themselves are responsible for building and maintaining the constraint-based models. As the design evolves, new design-rules, procedures and manuals are written so as to record new and/or updated

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using the cell references *b12=b10*b9*b8*). Using the Justification window, a designer or an application builder can trace through the complex interconnections among constraints and values.

Another window into the ATMS is the Violation window. Its purpose is to show which constraints are violated and which assumptions (designer assignments) caused the violation. For example, suppose a designer changes the value for the number of unit loads to store (cell *b13*, named *nuls*) from 15 360 to 16 000. This causes the constraint located in cell *k22* to be violated since the number of unit loads to store now exceeds the storage capacity (cell *h15*, named *maxnuls*) of 15 360 unit loads. The Violation window is shown at the bottom of Fig. 11. The violated constraint is shown as *k22* in the *Constraints* box and its form is shown in the *Constraint* box. The values that have caused the violation and the cells in which they are located are listed in the *Assumptions* box. A designer can use this information to 'fix' any occurring violations. A feasible design is obtained once all of the logic constraints have been satisfied. This is reflected in the constraint-sheet by the symbol, #TRUE.

7 CURRENT LIMITATIONS

Although SATURN was developed as a tool to support CE, its flexibility in knowledge representation and reasoning makes it quite generic in applicability (e.g. see Ref. 2). The largest application built in our laboratory to date has *c.* 500 constraints and is used for printed wiring board (PWB) design. In the current version of SATURN the total number of variables and constraints for a model is limited by the constraint-sheet size of 2500 constraint-sheet cells. SATURN, however, allows multiple constraint-sheets to be opened simultaneously and in the future, communication facilitated between the sheets will increase the number of allowable variables and constraints. Although the PWB application runs with good performance on a 486 machine, it is doubtful that significantly larger applications would execute in a reasonable amount of time on the same platform. Lastly, in this version of SATURN, the equation rewriting system in the Constraint Engine limits equations to a linear form.

8 CONCLUSIONS

A constraint-system shell, named SATURN, has been developed as a tool to support CE approaches to design. The architecture, the modeling and the manipulation techniques that form the basis of this tool have been reviewed. SATURN is a logic-based constraint modeling system, tightly coupled with a relational database, and supported by a truth maintenance system. SATURN incorporates rich representation formalisms that accommodate both the large volume and the wide variety of knowledge required for large scale CE systems. Its constraint engine is based on constraint propagation and constraint satisfaction algorithms that permit a designer to approach a design from any number of perspectives. Additionally, it provides support for interactive constraint satisfaction and constraint violation resolution during the design process. Integrating these features into the familiar spreadsheet-like user interface has significantly simplified model building, allowing developers to focus more on the model building process and less on AI-oriented, programming techniques. Together these qualities provide for powerful knowledge integration and the means with which to support the building and application of constraint-based models for CE. This makes SATURN an attractive support tool for engineers engaged in CE in design.

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A framework for case-based reasoning in engineering design

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Abstract

Although the case-based reasoning (CBR) process is domain dependent, certain aspects of it can readily be captured into a generic framework which in turn can be applied to various engineering domains. One such exercise that has been carried out is described here. In this paper, we present the notion that CBR can be formalized and applied in a specialized framework in an integrated knowledge-based environment. We first analyze the CBR process to abstract the steps involved in the development of a CBR system. We then propose a framework in which most of these steps are formalized so that they can be applied in a domain-independent manner. The salient features of this framework, called CASETOOL (CASE-based reasoning TOOL-kit), are then described. The highlight of this approach is the use of a concept called design criticism in the CBR process. The versatility of the tool is demonstrated through an application from the bridge engineering domain.

Keywords: Case-Based Reasoning; Engineering Design; KBS Development Tool; Bridge Design

1. INTRODUCTION

Engineering design involves wide usage of domain-specific knowledge and considerable problem solving skills to come up with a clear, concise, and unambiguous specification of the artifact being designed (Dym & Levitt, 1991). In engineering domains, the solution generation process is experience-based and highly iterative. Hence, design experts have recommended a study of similar cases for obtaining solutions at various stages (Heins & Lawrie, 1984). According to them, the study of similar cases gives an approximately good estimate of design parameter values to start with. Moreover, various feasible solutions can be generated at different stages of problem solving (Maher, 1987, 1990). To select a possible best solution, these feasible solutions are then critiqued from various aspects (Shiva Kumar et al., 1994). However, this process is time consuming and it is possible to avoid going through the same exercise if we know the history of past problem solving episodes. All these factors point toward the applicability of past cases in engineering design domains.

Analogical reasoning is a very efficient way to use past experience. Corbonell suggested that analogical reasoning is *a central inference method in human cognition*, and defined it as:

> transferring knowledge from past problem solving episodes to new problems that share significant aspects with corresponding past experience and using the transferred knowledge to construct solutions to the new problem (Corbonell, 1983).

Depending upon the problem definition of past and current situations, either *transformational analogy* (Corbonell, 1983) or *derivational analogy* (Corbonell, 1986) can be used for solving the current problem. Analogical reasoning and design dependent reasoning (Craig Howard et al., 1989) can be used in the models mentioned above to guide the search through short and appropriate paths in the search space. Reasoning based on a similar past problem-solving experience helps the designer to exploit the useful details specific to a particular similar case. This problem-solving strategy is termed as case-based reasoning (CBR) (Schank, 1982; Kolodner, 1985; Schank, 1986; Riesbeck & Schank, 1989) and is based on the premise that human reasoning processes are founded on specific experience rather than a set of general guidelines. It relates a current situation to the closest specific experience in memory and uses that experience to solve the problem at hand. Thus, the central idea of CBR technique in problem solving is

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A parametric design assistant for concurrent engineering

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Abstract

The Explorer parametric design assistant, an interactive tool that provides intelligent support for searching concurrent-engineering trade-spaces under multiple, conflicting objectives, is described. The system provides a convenient means for specifying multiple, cross-disciplinary constraints in terms of tables, formulas, and logical sentences. Based on these data, the system performs interactive constraint checking, computes feasible designs, and provides graphical analysis facilities, allowing users to compare designs based on multiple criteria. As a first application, Explorer has been used as a printed circuit board (PCB) construction design assistant. In initial tests, Explorer has helped users to find design configurations not previously considered that yield comparable performance and cost while offering better manufacturability and reliability. The capabilities and use of the Explorer system are described in detail, the underlying technologies are outlined, and an evaluation of the prototype system is presented.

Keywords: Concurrent Engineering; Constraint Satisfaction; Human Computer Interaction; Intelligent Assistant; Trade Spaces

1. INTRODUCTION

When the entire life cycle of a product is considered, many different, often conflicting, factors must be included in its design. Not only must the product satisfy typical design requirements such as being fast, small, and light, it must also be efficiently manufacturable, reliable, repairable, and disposable. Unfortunately, each of these factors is, in itself, an entire discipline, and typical design engineers simply cannot be expected to have all the required expertise. This has led to the advent of concurrent-engineering approaches such as Integrated Product Development (IPD) teams. These focus on bringing a sufficiently diverse set of engineers together early in the design phase so that all life-cycle issues can be considered.

Even though IPD is an important step in improving product development, there are many cases where it is neither possible nor sufficient. Engineers with specific knowledge are often not available when needed, and the interactions among the disciplines lead to a trade-space that no single engineer understands. Both of these problems can be addressed by creating a tool that captures aspects of each engineer's knowledge and combines that knowledge into a single trade-space search assistant.

We have created a tool, called Explorer, that supports intelligent, highly interactive searches of concurrent-engineering trade-spaces under conflicting objectives. Explorer combines the use of automated constraint satisfaction algorithms and a flexible graphical human interface to yield an intelligent assistant. Specifically, Explorer supports the following major capabilities:

- A declarative knowledge and data format in terms of which engineers from various disciplines can specify general constraints and metrics for their domain. This forms the static knowledge base of a specific Explorer application (e.g., for the domain of printed circuit board design).
- An interactive interface by which an individual designer can enter problem-specific requirements and properties (e.g., for the specific circuit board being

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ceptual design of satellites and bicycles have shown promise as Explorer applications. Moreover, since Explorer is, in effect, a generic spreadsheet tool, its applicability goes beyond engineering. However, the benefit to concurrent engineering is tangible and clear. Explorer permits designers to gain a better understanding of multidisciplinary trade-spaces, and it encodes aspects of each IPD team member knowledge so individual designers can benefit from the team's expertise even when separated by space and time. This allows the complex and often conflicting elements of multiple engineers' expertise to be integrated into a single, well-informed design decision.

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Knowledge based floor plan design by space partitioning: A logic programming approach

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This paper describes the incremental development of a knowledge based system for supporting floor plan design. A method of gradual space partitioning is developed which allows large flexibility in expressing demand, including highly incomplete descriptions. A simplified logic programming language is used to provide a readable and precise description of tasks, concepts, methods, regulations and other knowledge. A variety of architectural constraints are used to express demand, regulate solvability and improve efficiency of reasoning. A new lexicographic method is embedded in the system to increase time efficiency and convenience of use. The system is implemented in Prolog. Detailed experimentation with reasonably realistic design tasks are shown.

Key Words: logic programming, knowledge representation, concept modeling, demand modeling, space partitioning, lexicographic rules, combinatorial explosion, efficiency of reasoning, reasoning on constraints, rectangular design, architectural space planning.

1. INTRODUCTION

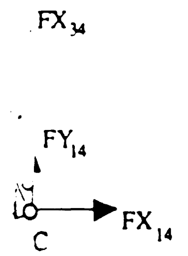
Recent advances in knowledge based systems technology promise new hopes of complex support in areas like architectural and engineering design, requiring deep knowledge and experience in a variety of subjects, high skills and strong reasoning with the – often inexact – conflicting goals. It is no more only the raw computer power, which can take over annoying routine parts of the job, but also an intelligent assistance in all kinds of human mental activities such as reasoning concept formation, knowledge interpretation, creation of completely new methods, modeling and solving ill-defined problems. The degree of automation of the design process however should be controlled by the human designer according to the task, the present phase and his/her confidence in the present system action. Open system, open minded human designer, good exchange of views (explanation) and learning from good results and mistakes both automatically and consciously are important assets of such a fruitful 'cooperation'.

Floor plan design is an architectural space planning activity determining subspaces of a given space according to various more or less defined or implicitly understood requirements and conflicting criteria. Typical problems of this category are, the floor plan of an apartment, a family house or one storey of an office building. A facility layout in an industrial environment may lead to a similar problem. The requirements may include bounds for the sizes or restrictions on the shapes and locations of rooms, adjacency of rooms, orientation of windows, lighting conditions, convenient internal traffic, etc. At first, the floor and the rooms will be considered as rectangles. This condition will be relaxed, the floor and the room will be compositions of adjacent rectangles.

The family of rectangular design problems is quite large. It includes various cutting or placement type of applications with specific constraints, such as the cutting of metal, glass, wood, textile sheets into smaller rectangles. Numerous Guillotine[6,42] and non-Guillotine cutting[4] algorithms have been developed, including one of a network type[7] and a general flexible tree search method[26]. There are many different approaches to the automatic generation of floor plans as well: cataloguing of small rectangular plans for further processing[1], various graph representation[3,39,40], exhaustive generation and abstraction[14,18], optimization in focus[37] and many others[22]. These systems have been implemented using imperative (procedural) languages like Fortran or Pascal.

Logic programming plays an important role in intelligent systems and also in the present paper. It can be viewed as a language, which can be used to reflect our meaning, intention, knowledge in a readable, yet sufficiently precise form to lay the basis of a computer system specification. Furthermore, the clear logic can support various algorithmic interpretations, and is thus very flexible in use. Fortunately the computer language Prolog inherits this double (logic and procedural) interpretation and contains additional features for controlling execution and other functions like internal and external communication. Many books have been written on logic programming and Prolog[8,24,29,33,41].

Floor plan design by logic programming has been carried out[34] using some rules for matching predefined rooms to form a floor. A series of papers by Gero and Coyne[10,11,20] also use predefined rooms and certain



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A METHOD FOR FORMULATION OF THE CONCEPTUAL DESIGN OF NON-FOSSIL FUEL FIRED POWER PLANTS

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In this paper, criteria for efficient and optimal design of thermal systems are presented. The main emphasis of the paper is in the problem set-up and in the structuring of the thermal system design information during the conceptual design phase. A two-level design structure (macro-level and micro-level) is introduced to enable the designer to adapt his design to the available (or required) technology level, type of application, economic factors, and O&M requirements. At the macro-level of design, economic feasibility (business) decisions are made, while at the micro-level of design, technical feasibility (engineering) decisions are made. A 50 MW wood burning power plant in Northern California is presented as an illustrative case study. All the information provided in the paper is from real world power plant design, and the problem is presented in a form to allow other researchers to try different optimization techniques to solve the problem.

KEY WORDS: Power plant, optimization, system design, conceptual design

1. BACKGROUND

Non-fossil renewable energy sources (e.g. wood, refuse, trash, wood residues, pulp, etc.) offer flexible, affordable, locally available, and sustainable alternatives to fossil fuels[1-8]. Wood, a renewable non-fossil fuel (commonly referred to as a bio-mass energy source), is one of the most widely used energy sources around the world. Throughout history, wood-based fuels have been the principal source of energy utilized by man[9]. In the past, most of the wood residues generated from the forest products industry have been either burned without energy recovery or disposed of as solid waste. However, in the recent past, there has been an increasing interest in utilizing these residues to generate power, especially in the Pacific Northwest where forest residues are abundant[9].

Globally, an average of 25 percent of the wood entering the timber industry is available for conversion to energy, for industrial, commercial and utility applications[10-13]. In the United States the percentage is higher at about 33 percent. Wood-fired electricity generating facilities can provide significant contributions to the power supply. Since 1983 four wood-burning power plants have been built in the U.S., with 121 MW installed capacity[8]. In the development of a wood (or any non-fossil fuel) fired small power plant (5 to 100 MW) using a "standardized" power plant design will not be appropriate, because of the uniqueness of the fuel, and the environmental effects of the fuel before and after processing. Moreover, plant location and system configuration are very much fuel dependent. Therefore, an efficient design method is needed for small power plant design and implementation.

sures as the basis. The following improvements to the model can make the design process more thorough:

- Including other subsystems (e.g. condenser) into the optimization; this will allow for studying a more complex interaction between the subsystems.
- Including a more sophisticated heat balance program (e.g. Ref. [34]) that can handle technical data for the subsystems, and the interactions between them.
- Incorporating electricity sales price, ROI models, and life cycle costing (LCC) into the economic analysis.

Work is underway at the San Diego State University (SDSU) Energy Engineering Institute, to implement these improvements as well as to increase the current knowledge of interactions, and couplings, among thermodynamic simulation, engineering decisions, and business decisions in power plant design.

SDSU's overall research effort is aimed at developing design/optimization methods for optimal design of thermal energy systems. In particular, methods combining thermal simulation models with mathematical optimization techniques, and a unified (generic) design/optimization perspective applicable to any thermal system, ranging from as small as a residential air conditioner to a large power plant, are being developed. The universal objective function is made up of maximum efficiency and minimum cost (initial, life-cycle, etc.).

Design trade-off studies for various types of thermal systems (e.g. cogeneration, thermal energy storage, HVAC, passive solar, parabolic trough concentrating collector, small power plants, etc.) are carried out in developing the universal (generic) thermal system design/optimization perspective.

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APPENDIX A: OPTIMIZATION STRATEGY: COMPROMISE THROUGH SELECTION DSP

A.1 Overview

In order to select the optimum cycle design, a selection DSP, which uses the quantitative (*hard*) information from Table 3, along with some qualitative (soft) information (e.g. reliability), must be developed. The formulation of such a DSP is presented below. Full details of a selection DSP can be found in Refs. [24, 29–31]. Only a brief overview of the particulars of the model are presented here.

A.2 Formulating a selection DSP

The steps for such a selection DSP are:

- Generating alternatives,
- Screening the alternatives,
- Identifying feasible alternatives,
- Weighing the attributes,
- Giving attribute ratings to the alternatives,
- Evaluating the merit function,
- Ranking the alternatives, and
- Post solution analysis.

Generating alternatives. The list of alternatives for the case study plant were based on altering the extraction pressures and temperatures at the turbine, and on the number of feedwater heaters in each configuration. As a result fifteen configurations of the power plant were evaluated. These are listed in Table 3.
Screening the alternatives. Any infeasible alternatives selected at the previous step, are deleted from evaluation.
Identifying feasible alternatives. This step involves furnishing information and specification to all alternatives. This step involves assigning weights to attributes in the order of their importance. The criteria (attributes) used in this model are shown in Table A.1, along with their relative importance. The four atributes are: initial cost, operation and maintenance cost, reliability and efficiency. The ranking is done from the most important to the least important in ascending order.
Assigning attribute ratings to alternatives. Rating values for each alternative can be derived using different types of scales, viz. ratio, to interval and ordinal scales. An ordinal scale can be used when the attributes are qualitative in nature.

Table A.1 Relative Importance of Attributes.

Attributes	*Ranking*	*Weights*	*Normalized Weights*
Initial Cost	2	3	0.3
O & M Cost	3	2	0.2
Reliability	4	1	0.1
Efficiency	1	4	0.4
Sum		10	1

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When using an ordinal scale, the attributes are normalized, so that all attributes are of the same magnitude. When a larger value of an attribute rating represents preference,

$$R_{ij} = (A_{ij} - A_j^{\min})/(A_j^{\max} - A_j^{\min}) \qquad \text{(A.1)}$$

When a smaller value of an attribute rating represents perference,

$$R_{ij} = 1 - ((A_{ij} - A_j^{\min})/(A_j^{\max} - A_j^{\min})) \qquad \text{(A.2)}$$

Tables A.2 and A.3, show the attribute ratings and normalized ratings for the five alternatives.

Evaluating the merit function. The next step in solving a selection DSP is to define and evaluate the merit function. A merit function combines all the individual ratings of attributes together using proper weights or importances defined earlier. The most frequently used model in evaluating the merit function is a linear model,

$$MF_i = I_j R_{ij} \quad i = 1, \ldots, m \quad j = 1, \ldots, n \qquad \text{(A.3)}$$

where, m = number of alternatives
n = number of attributes
I_j = relative importance of jth attribute
R_{ij} = rating for alternative i, attribute j
MF_i = value of merit function for alternative i

Ranking the alternatives. The alternatives, are ranked from highest value to the lowest, after the merit functions are evaluated. Ranking is shown in Table A.4. A merit score of one (1) corresponds to a perfect system and a score of zero (0) corresponds to an unsatifactory system. According to Table A.4, configuration B with low T & P is the optimal system design.

Post solution analysis[27]. Post solution analysis of the selection process consists of validation and sensitivity analysis. The latter involves sensitivity of the solution to

Table A.2 Attributes Rating for the Alternatives[1].

Alternative	*Captial Cost, MM$*	*O & M Cost, MM$*	*Reliability Rating*	*Efficiency %*
AHP	17.53	0.3506	5	29.72
BHP	18.01	0.3602	4	32.62
CHP	18.56	0.3712	3	32.90
DHP	19.04	0.3808	2	33.18
EHP	19.60	0.3920	1	33.44
AMP	16.61	0.3322	10	28.30
BMP	17.11	0.3422	9	31.00
CMP	17.63	0.3526	8	31.23
DMP	18.01	0.3602	7	31.46
EMP	18.62	0.3724	6	31.61
ALP	15.82	0.3164	15	27.37
BLP	16.25	0.3250	14	30.90
CLP	16.75	0.3350	13	30.13
DLP	17.18	0.3436	12	30.31
ELP	17.69	0.3538	11	30.36

[1] Reliability ratings are based on turbine throttle pressure and temperature of the cycle. Lower ratings indicate greater reliability. It is assumed that cycle operating at lower T & P will inherently be more reliable in its long term operation.

Table A.3 Normalized Attribute Ratings.

Alternative	*Captial Cost, MM$*	*O & M Cost, MM$*	*Reliability*	*Efficiency %*
AHP	0.55	0.55	0.29	0.39
BHP	0.42	0.42	0.21	0.87
CHP	0.28	0.28	0.14	0.91
DHP	0.15	0.15	0.07	0.96
EHP	0.00	0.00	0.00	1.00
AMP	0.79	0.79	0.64	0.15
BMP	0.66	0.66	0.57	0.60
CMP	0.52	0.52	0.50	0.64
DMP	0.42	0.42	0.43	0.67
EMP	0.26	0.26	0.36	0.70
ALP	1.00	1.00	1.00	0.00
BLP	0.89	0.89	0.93	0.58
CLP	0.75	0.75	0.86	0.46
DLP	0.64	0.64	0.79	0.48
ELP	0.51	0.51	0.71	0.49
Normalized Wieghts	0.3	0.2	0.1	0.4

Table A.4 Merit values for the Alternatives.

Alternative	*Merit*	*Rank*
AHP	0.502	12
BHP	0.579	6
CHP	0.518	11
DHP	0.466	13
EHP	0.4	15
AMP	0.519	10
BMP	0.627	3
CMP	0.566	7
DMP	0.521	9
EMP	0.446	14
ALP	0.600	4
BLP	0.770	1
CLP	0.645	2
DLP	0.591	5
ELP	0.522	8

changes in the attribute weights and sensitivity of the solution to change in the attribute ratings. Post solution analysis is described in detail in Refs. [29–31]. Post solution analysis is very important due to the nature and quality (hard and soft) of the information being used. This step involves two parts, namely, the validation of the solution and determining the effects on the solution of small changes in the relative importance attributes and also the changes in the attribute ratings. The goal of validation is to ensure that the designer feels comfortable with the computer solution. If there are any subjective misgivings these need to be resolved by modifying the ratings and/or altering the formulation.

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Ship Definition System in Computer Integrated Design and Manufacturing

T. Nomoto and K. Aoyama
Department of Naval Architecture and Ocean Engineering
Faculty of Engineering, University of Tokyo

Abstract

In order to make another remarkable progress in design and manufacturing, systems integration is the most important for all industries today. In our paper, ship definition system in computer integrated design and manufacturing is discussed. Object oriented concept is used to represent a ship model. Two types of objects are introduced One is part object which states geometrical properties and its attributes of the object. The other is connection object which states connection relation of part object A and B. Functions of cutting a designed structure into pieces and functions of assembling those pieces to a module are also introduced here. The system are called SODAS which means *System of Design and Assembly for Shipbuilding*.

1 Introduction

Even though CAD/CAM systems have made a remarkable progress in the stage of design and manufacturing in all industries, it is often said that elaborating engineering works are needed to manage CAD/CAM systems.

In recent years, the necessity of computer integrated manufacturing system has been recognized in Japanese shipyards. The Japanese shipbuilding industry organized a project to make feasibility study of computer integrated design and manufacturing in 1986. Product modeling and expert systems were taken as the most important themes in the project in order to integrate CAD/CAM system.

The aim of the paper is to propose one example of product definition system of a ship [1, 2, 3]. Object oriented concept is used to represent ship structures.

In the design stage, two types of objects are introduced. One is part object which states geometrical properties and its attributes. The other is connection object which states connection relation of part object A and B. Functions of cutting a designed structure into pieces and functions of assemling those pieces to amodule are also introduced here.

In the stage of assembling, two other objects are introduced. Facillity object is one of them. And operation object is the other. In facility object, lift-magnets to transfer a small structure, cranes and welding equipments are considered here. If the system has data on capacities of those facilities, the system shows us how many hours it takes to do the operation. In this stage, process planning and scheduling are also made at the same

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System Design of CIM for Shipbuilding

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Abstract

The Ship & Ocean Foundation has conducting feasibility studies on, and establishing a conceptual framework for CIM for shipbuilding. Now we have finished designing the concept to develop the pilot model which consists of product model system, data base system, expert systems and user interface, and have been prototyping them to study the key technologies in the requirements for the CIM for shipbuilding. This paper introduces the findings obtained through the processes to study them.

1. INTRODUCTION

In recent years, there is a growing demand for Computer Integrated Manufacturing for shipbuilding (CIM for shipbuilding) to enhance the productivity and to improve the labor-intensive industry [1].

Under the circumstances, the Shipbuilding Research Association of Japan made a fundamental survey on the method and possibility to construct the CIM for shipbuilding in its "Study on New Generation Technologies for Design, Production and Maintenance of Ships" (SR210), and proposed that it was effective to study the key technologies by developing a pilot model prior to the comprehensive development [2].

Based on the SR210 proposal, the Ship & Ocean Foundation organized "Technical Committee on CIM for Shipbuilding" in 1989 and is now promoting a three-year project on the research and development of a pilot model prior to the development of CIM for shipbuilding. By studying the following major technical subjects through the research and development of the pilot model, the Committee aims to offer fundamental materials to shipyards with which they can decide whether they should start the development of CIM for shipbuilding.

The Committee completed the design of the pilot model in 1989 [3], developed and evaluated a prototype of pilot model based on the design documents in 1990 [4], and is further promoting research and development to make a comprehensive evaluation this year. This paper introduces the findings obtained through the processes to study the subjects (product model system, data base system, expert system, user interface and object-oriented/prototyping) in the key technologies.

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Scheduling System of CIM for Shipbuilding Applied Product Model, Process-Equipment Model and Operation-Resource Model

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Abstract

It is very difficult to construct a computer system in the shipbuilding industry where all work commences upon the receipt of an order for a ship. In the pilot model of the Computer-Integrated Manufacturing System for shipbuilding, or CIMS, which is a focus of our recent project, we have constructed subsystems which generate parts information and determine work sequence. Combination of the product model in which the data developed by the subsystems is packed with a process-equipment model with an operation-resource model allows for timely scheduling with computer. The data from the scheduling system is integrated so that it can be utilized consistently down to the final process control in the workshop. The prototype scheduling and process control system which incorporates above functions is introduced here.

1. Introduction

At the present time, the manufacturers that produce a variety of products in small quantities have made in their possession all the relevant information (process planning, work load, etc.) before commencing to manufacture newly developed product. They can with ease make long-term schedules by estimating the number of the products, and make working schedule accordingly.

In the shipbuilding industry, however, where products are often tailor-made, almost no information exists at the initial stage of design because information is developed for each individual order. Even at the intermediate stage, the information available is still incomplete, so process scheduling has to be handled by veteran staffs. For these reasons, shipbuilders have encountered many obstacles in introducing the computer-aided scheduling method. 1)

The ship and Ocean Foundation has been engaged in a three-year project that started in fiscal year 1989 involving the research and development of a pilot model for CIMS.

For the pilot model of CIMS, the subsystems to determine the parts and work sequence were constructed. The data that is output from these subsystems, shows each individual operation and process as well as all operations in the process arranged in a hierarchy. Then by using the data the scheduling system enables one to establish the optimal work load and lead time for each unit, intermediate product and final product by process-equipment model. 2)

Moreover, the simulation using the operation-resource model which identifies detailed work throughput, the number of workers, and the equipment capacity in a process, including

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Process Planning System of CIM for Shipbuilding

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Abstract

The paper proposes the process planning system for shipbuilding. It carries out process planning design by use of both the design information dependent on the product and the factory information independent of it. Therefore integration of design and production information is necessary for generation of usable process planning.

The aim of this paper is to propose both how those information should be represented and how the knowledge for process planning design should be described systematically.

Regarding the proposed information representation as a model, the model including all information for the production (what is called *product model*) is proposed from the viewpoint of process planning. It can be flexibly applied to the revision of the product design (conceptual design, preliminary design, and detail design) even at process planning stage.

This paper describes the test run of the knowledge based process planning expert system with inference engine and verification of its effectiveness and practicability.

1. Introduction

Process planning means designing the entire production processes, such as production methods, production sequences, the types of machines to be used, quantity and procedures, based on the conceptual knowledge from the product design to production stage concerning products, parts, and materials.

In the manufacturing industries, in general, machining tools and application technologies have been significantly improving, while most process planning relies on the experience and perception of process planners and its evaluation items are various such as quality, cost, delivery, etc. Therefore, a study on process planning that allows comprehensive evaluation has been lagged behind. This is also true for the shipbuilding industry.

In the recent shipbuilding industry, CIM for shipbuilding (CIMS) has been expected as one of the approaches to be taken to tackle subjects such as reduction in lead time, productivity improvement, and quality assurance. CIMS is also expected as a means of solving various problems on the product stage such as a decrease in the number of skilled workers, and a relative decrease in labor force population. And a research on CIMS has been

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A NEW APPROACH TO DESIGN SYSTEM FOR SHIPBUILDING

- A Knowledge-Based Narai-Design System for Hull Structure -

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Key word : CIM for Shipbuilding, Narai-Design, easing constraints,
expert system

ABSTRACT

The Ship & Ocean Foundation has been conducting feasibility studies on, and establishing a conceptual framework for CIM for shipbuilding. Now our project has finished designing the concept to develop the pilot model which consists of its kernel systems functionally, and has been prototyping each kernels. The structural design system is one of kernels. This paper reports the sub-system having one function to be implemented on the structural design system. The system is, so called, the expert system and incorporates expert knowledge that a construction on ship is designed by tracing the design concept from the similar and typical construction. This system applied to the transverse section in hold part of oil tanker and the results indicate that this concept is applicable to generate the design information even earlier and output the information necessary to the production planning.

1. INTRODUCTION

In recent years, there is a growing demand for Computer Integrated Manufacturing for Shipbuilding (CIM for Shipbuilding) to achieve higher productivity and to improve the laber-intensive industry [1].

Under these circumstances, the Ship & Ocean Foundation formed the Technical Committee on CIM for shipbuilding, and is now constructing a pilot model for CIM for Shipbuilding to verify the applicable technical subjects and to establish the framework for this concept through a three-year research and development project [2].

One technical subject of this project is to determine the possibility of developing a structural design system that not only makes drawings and generates numeric data for NC cutting machines and/or welding robots on behalf of existing CAD/CAM systems, but also supports just designing and generates the design information even earlier than it is. The project will evaluate whether system network can be constructed to provide production planning information for scheduling, process planning, and Material Requirement Planning (MRP), which is not possible using conventional CAD/CAM systems, and to generate integrated information available for from design to production activity.

On the other side, when a designer will make a drawing of a part of hull construction, he makes it by referring the well-elaborated, similar and typical construction. The method is called narai-design, now widely used for hull structural design work. The system in which this method is incorporated can saves

SYSTEM INTEGRATION OF MANUFACTURING MANAGEMENT FOR SHIPBUILDING

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Key word : CIM for Shipbuilding, system integration,
process planning, scheduling, dispatching and monitoring

ABSTRACT

The Ship and Ocean Foundation has been conducting feasibility studies on, and establishing a conceptual framework for CIM for shipbuilding.

This paper discusses on integrating three systems concerning manufacturing in CIM for shipbuilding - Process Planning, Scheduling and Dispatching/Monitoring with efficiently communicating each other by the use of unique product model - to provide optimal and consistent information and detailed instructions for operation, and also to enable staff and workers to swiftly respond to unexpected disturbance by external reason.

1. INTRODUCTION

In shipbuilding industry, one ship should be built and delivered in no less than one year after specifically ordered. In addition, it includes many processes ranging from each new product designing, production planning, fabrication process from material, to the assembly of huge and enormous products. This aspect of shipbuilding industry makes it fairly difficult to improve the production planning and control, and forces shipbuilders to depend on skilled workers (their experiences and know-how) to supplement insufficient data.

Some elaborate and comprehensive manufacturing management, that is, production planning and control, however, is vital to further development of this industry if it should be accomplished without higher contribution from its skilled workers. Because the industry is characterized by its higher flexibility in detailed construction operations with broad restrictions imposed by large-scale facilities as docks and so on, the effective production planning and control must be worked out quite different from other industries such as automobile manufacturers where the production procedures are fairly divided into a number of special and apparent steps.

We must aim fine quality of production planning, more detailed instructions for operation in actual workplaces, its swift response with consistency to any update in design, which is unavoidable in parallel works of design and production planning or to the change of production planning

4TH INTERNATIONAL MARINE
SYSTEMS DESIGN CONFERENCE

A Proposal for the Next-Generation Shipbuilding Systems

- User-oriented system by intelligent user-interface -

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Key word : CIM for Shipbuilding, user-interface, product model,
model manipulation language, user-oriented system

ABSTRACT

The Ship & Ocean Foundation has been conducting feasibility studies on, and establishing a conceptual framework for CIM for shipbuilding. Now our project has finished designing the concept to develop the pilot model which consists of its kernel systems functionally, and has been prototyping each kernels. CIM for Shipbuilding, we call CIMS, is also a concept for next-generation shipbuilding systems, that have powerful functions to support users physically and mentally. This paper proposes a concept of user-oriented system for CIMS, and useful functions such a system need.

1. INTRODUCTION

Since April 1989, the Ship & Ocean Foundation has been promoting a feasibility study to implement the concept of CIMS (Computer Integrated Manufacturing for Shipbuilding), and is expected to submit a final proposal by March 1992.[1],[2]

CIMS refers to an automated design system used to efficiently build ships. This system integrates various information of design and production using computer networks to obtain the required quantity and quality of data whenever necessary.[1],[2]

To achieve automation and save labor in creating designs, devising plans and implementing management, the system incorporates initial data generating function and relies on various expert systems to generate design data and tooling instructions, as well as scheduling information. It, however, would be difficult to complete products without compiling work to the initial data by means of human creativity and overall judgement, because shipbuilders would still make designs and production plans for each ship for each order, even under the system in CIMS.

The shipbuilding systems, therefore, should be user-oriented by placing greater importance on improving productivity by fully considering overall ease of user interface and system operation. CIMS is ultimately designed for user-orientation, which is considered the most important criterion in constructing the next-generation shipbuilding systems.

AN EXAMPLE OF STEPS TO MODERN SHIP PRODUCTION BASED ON PRODUCT MODEL TECHNOLOGIES

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ABSTRACT

Recently highly advanced Computer Integrated Manufacturing(CIM) system has come to be regarded as essential, in order to establish competitive shipyard, integrated CIM environment is essential. Lack of integration of product information causes a lot of problems today. Considering current problems, authors discuss two practical solutions: integration of product information distributed in vertical and horizontal.

Vertical integration is integration of 3D CAD data throughout the process from a concept design phase to a production phase in order to eliminate double work between adjacent two phases. CAD/CAM are effective tools for this purpose.

Horizontal integration is integration of human activities in various departments, e.g. hull/outfitting designers, hull/outfitting planners. Communication between people is the main issue, especially between designers and production planners in order to eliminate re-work due to late arrival of the other people's request. Product information flow is in various ways like a network. Product Model is a most probable tool.

Authors definition of Product Model is a product information manager who can provide meaningful data for people in design and production departments. For the development of Product Model, object database, 3D graphics and expert system are key technologies.

Stepwise development or prototype development is more efficient than waterfall type development. Authors believe in prototyping with object-oriented paradigm. Modularity should be considered in system architecture. Application systems should be dependent on Product Model interface, but independent of database. Additional applications can be developed without giving serious influence on existing applications.

Inter-process communication is effective for development of application systems, but not yet confirmed in practical use.

AN IMPLEMENTATION OF A PRODUCT DEFINITION SYSTEM IN COMPUTER INTEGRATED DESIGN AND MANUFACTURING

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ABSTRACT

In the previous meeting which was held in Rio de Janeiro in 1991, the authors reported a paper "Ship Definition System in Computer Integrated Design and Manufacturing" . In that paper, a product definition system for shipbuilding is discussed from the stand point of three functions. These are design function, cutting function and assembling function.

In this paper, a deep consideration is mainly paid for design function. In order to make it possible to design any kinds of ship structures in three dimensional space, new concepts of "Room" and "Wall" is introduced. Room division function is also introduced just as cutting function was introduced for plates in the previous paper. And it can be applied to any types of room with surrounded walls. In addition to "Room" and "Wall" concept, design function of internal structures such as transverse rings, floors and girders are also considered. By using the above mentioned function, it is possible to design any kinds of ship.

Just like the previous paper, this system has also cutting function and assembling function for plates and plate structures. Therefore, a designed ship structure can be cut into smaller elements. By using assembling function, simulation of manufacturing of ship structures can be carried.

Some of results which are implemented as an application system will be shown. One of the most important thing is that these application systems are fully integrated with the product model which is described in this paper.

INTRODUCTION

Even though a great deal of efforts have been curried for implementing computer aided design and manufacturing systems in shipbuilding industries with advancement of computer technology, engineers in this field seem to be not satisfied with their existing

EXPERT PROCESS PLANNING SYSTEM OF CIM FOR SHIPBUILDING

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ABSTRACT

Process planning plays not only an integral role in a multi-application system of CIM; but also it serves as the active information link between the design department and the production department in shipbuilding. Embodying the properties of concurrent engineering, process planning supports such information-processing activities. On the one hand, this paper proposes knowledge based process planning system for determining the sequence of ship block assembly and pipe fitting. On the other hand, it synthesizes factory information utilizing Group Technology (GT) which is the underlying manufacturing concept. In this paper, factory information (production lines, workshops, work facilities etc.) is classified according to the similarities of design and production characteristics as well as similarities of specific parts. By using expert process knowledge and Group Technology, redundant process planning work can be eliminated which has been performed manually. Optimal sequence of production is determined, and production flow can be analyzed quickly. This paper describes the verification of its practicability and effectiveness by exemplifying the standard block assembly sequence, utilizing graphical user interface which enables the user to correct planning results interactively.

INTRODUCTION

Shipbuilding must abandon its traditional labor-intensive character, and also enhance the productivity with the reduction in lead time. The Ship & Ocean Foundation, Technical Committee on CIM for shipbuilding has also been developing and researching CIM. Shipbuilding is normally identified with "so-called" job-order production. The features of shipbuilding can be summarized as follows:

- enormous quantity of information for various products which we have termed intermediate products
- continual ongoing modification by customer from specific contract to delivery during design and production.
- simultaneous assembling for hull parts and outfitting parts
- accuracy assurance to be needed (which heat distortion by welding demands)
- concurrent engineering between the design department and the production department

SCHEDULING MODEL OF CIM FOR SHIPBUILDING

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ABSTRACT

The systematization of scheduling is essential to realize CIM for shipbuilding. However the scheduling work in shipbuilding largely relies on the personal experience of a planner that is not suitable for wide application. The systematization of scheduling can not be accurately executed. This paper introduces the analysis of the scheduling work in shipbuilding for realize the scheduling system in CIM for shipbuilding.

INTRODUCTION

CIM for shipbuilding consists of a product model and application systems. The application systems are intended to support design works, production works and others. Each system will generate information efficiently by its function of automatic information generation and that of usable graphical user interface [1-2]. On the other hand, the product model will quickly and accurately communicate and adjust information among the application systems. By introducing CIM, the following innovation on scheduling can be expected.

- Information necessary for design and process planning is likely to be acquired at the early stage. Therefore, the volume of work load can be grasped early.
- Possible differences among the scheduling for different terms, such as that between the long term scheduling and the middle term scheduling, can be adjusted.
- Schedulings can be more accurately executed by "Plan-Do-Check" cycle in controlling work performances.

CIM for shipbuilding requires (1) the systematization of scheduling and (2) the modeling of information for scheduling for the control in the product model.

The scheduling in shipbuilding, at present, rely on the expertise of the experienced planners in charge. However, most of the expertise of those planners are connected with some particular shipyards, and, therefore, not suitable for wide application. In this regard, the systematization of scheduling can not be accurately executed [3]. In addition, some problems including the followings can be also pointed out.

- The quality of the scheduling deeply depends on the skill of the planners.
- Upgrading the quality of the scheduling is difficult.

In order to improve these situations and realize CIM for shipbuilding, the scheduling

SYSTEMS DESIGN CONFERENCE

THE ROLE OF COMPUTER INTEGRATED MANUFACTURING FOR THE FUTURE SHIP BUILDING

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1952 [illegible]
1959 Dr.
[illegible]

[illegible]

Key words: CIM, Shipbuilding, CAD/CAM, Requirement

ABSTRUCT

The role of CIM for the future shipbuilding is reviewed. Ship and Ocean foundation is now conducting a 3 years joint project for the prototyping of shipbuilding CIM since 1989. The aim of the project is to figure out the features of the shipbuilding CIM and to review the recent software environment through prototyping from the view point of large system development. Review is made by full time members actually using the most advanced systems.

This paper introduces the experiences obtained from the project and point out the important aspects for the shipbuilding CIM.

1. What we expect for CIM?

CIM(Computer Integrated Manufacturing) is expected to be the key technology for any types of industry now. Many people believe that they cannot survive in the future industrial society without CIM. It is so much expected that even package programs for CIM are sold in the market with reasonable price. However, it may be too optimistic to believe that if you purchase a CIM package program, then you will survive happily in the global shipbuilding market in the future.

CIM is considered to be an integrated information processing system for the production activity and consisted of following four functions:

1. Business functions
2. Product design
3. Manufacturing planning
4. Manufacturing control

The most common CIM system, which is used in mass production type industries, mainly focuses on the integration of business functions and production control. In other word, the commonly used CIM is an integrated sales and production control system.

In mass production type industries, product design and manufacturing planning are made extremely in detail beforehand and the results are stored in a database. So that when they want to make a product, they can

Appendix C: Selected Software Abstracts

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Architectural Power Tools

Eclipse Software, Inc. (WA)
301 W. Holly, Ste. U4
Bellingham, WA 98225-4328
800-758-6779; 360-676-6175
FAX: 360-676-0921
Tech support: Use main no.

Category
Software, Applications
  Engineering/Scientific

Specifications
Mfr. suggested list price: $400
Number sold: 1,000
Release date: 1985
Application: Civil Engineering/Architecture
Compatible with: PC-MS/DOS; Apple Macintosh; Sun
  SPARCstation/SunOS
Disk storage required: 2 MB
Additional hardware/software required: AutoCAD
Source language: AutoLISP; C
Customer support: Free phone support
Site licensing available: Yes

Summary
AutoCAD architectural system. Provides parametric commands, integrated 3D routines, 3D symbol libraries, industry standard keynoting and flexible layering system. Includes hatch pattern and automatic elevation generators, movie generator, COGO routines, unlimited scheduling capabilities, full-screen text editor, source code and dynamic space reporting.

Other Terms
architecture; source code; computer-aided design (CAD); scheduling; editor

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Computer Select, June 1995

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PASS

Data One, Inc.
5420 Southern Ave., Ste. 106
Indianapolis, IN 46241
800-432-0664; 317-244-2999
FAX: 317-240-6255
Tech support: Use toll-free no.

Category
Software, Applications
  Engineering/Scientific

Specifications
Mfr. suggested list price: $5,400
Number sold: 300
Release date: 1987
Application: Civil Engineering/Architecture
Compatible with: PC-MS/DOS; Sun/SunOS
Minimum RAM required: 8 MB
Disk storage required: 15 MB
Additional hardware/software required: AutoCAD
Source language: C
Customer support: Maint. fee $1,350 per yr.; phone support
Site licensing available: No

Summary

Designing tool. Manages facilities layout, product specification, product re-order and physical assets. Generates and stores furniture and equipment configurations, automatically generates elevations, counts and prices components, compiles reports and compares project databases. Automatically generates 3D models.

Other Terms
comparison; computer-aided design (CAD)

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Allegro Common LISP (V.4.2)

Franz, Inc.
1995 University Ave.
Berkeley, CA 94704
800-333-7260; 510-548-3600
FAX: 510-548-8253
Tech support: Use main no.

Category
Software, Applications
  Artificial Intelligence/Expert Systems

Specifications
Mfr. suggested list price: $4,500
Release date: 1994
Application: Artificial Intelligence/Expert Systems
Compatible with: Sun SPARCstation/SunOS; Silicon Graphics;
  HP/HP-UX; IBM RS/6000/AIX; DEC DECstation/ULTRIX; AT&T UNIX
  System V
Minimum RAM required: 12 MB
Disk storage required: 50 MB
Source language: LISP
Source code price: $2,000 and up
Customer support: Maint. fee 25% of purchase price per yr. after
  first yr.
Site licensing available: Yes

Summary
Features CLOS for object-oriented programming. Implementation of Common LISP meeting all Common LISP specifications. Produces highly optimized code. Includes lexically scoped interpreter and compiler, debugging aids, bit/field manipulation, user-defined error handler, LISP library and parser/hash table facility.

Full Description
An implementation of draft ANSI standard Common Lisp. Offers X Windows support and integration with the UNIX operating system. Programmers work in an interactive environment with incremental compilation, automatic memory management and debugging tools. Code written in other languages, like C or Fortran, can be integrated with LISP programs using the foreign function interface. Includes the Allegro Presto delivery system for creating runtime applications, which can be used with Allegro Runtime for low-cost licensing.

Features a Common LISP Object System (CLOS), the object-oriented standard for LISP. Includes dynamic binding, method combination, generic functions and the meta-object protocol. Used to build artificial intelligence applications, such as language processing and expert systems, and to incorporate AI technology into other fields, such as computer-aided design and manufacturing.

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QuickEST/CAD for Windows

Constructive Computing Co., Inc.
5600 Inland Dr.
Kansas City, KS 66106
800-456-2113; 913-596-2113
FAX: 913-287-7652

Category
Software, Applications
  Engineering/Scientific

Specifications
Mfr. suggested list price: $1,495
Release date: 1986
Application: Civil Engineering/Architecture
Compatible with: Windows 3.X
Minimum RAM required: 512 KB
Additional hardware/software required: Windows 3.X
Source language: BASIC

Summary

System for extracting dimensions, areas and quantities from drawings prepared by AutoCAD or other CAD systems utilizing DXF files. Transferring this information to QuickEST systems to speed up process of preparing estimate from CAD drawings.

Other Terms
computer-aided design (CAD)

Record#
915 971 190 022 001 0

Attachment 3

Software Questionnaire Responses