MEP Technical Report 8701

TITLES AND ABSTRACTS OF TECHNICAL NOTES ON RESEARCH IN COMPUTER-AIDED DESIGN FOR 1987

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1. MEP Technical Report 8701
   Titles and abstracts of technical notes on research in computer-aided design for 1987
   Alan H. Bond
   December 1987

2. MEP Technical Report 8702
   An Intelligent CAD Model
   Alan H. Bond, S. Zia Ahmed, Basuki Soetarman and Dong H. Kim
   February 1987
   We have designed and implemented a CAD modelling system in Prolog-CADAM. This is built upon the CADAM 3D model, and extends it in three ways.

   (a) geometrically, to include surfaces, holes, volumes etc.
   (b) computationally, to include a dual model with corresponding model elements in the form of Prolog logical statements as well as Fortran numerical array elements.
   (c) representationally, to include predicates for geometric and manufacturing features.

3. MEP Technical Report 8703
   Rule-Based Automatic Dimensioning
   Alan H. Bond and S. Zia Ahmed
   January 1987
   Presented at IEEE 1987 WESTEX Conference on Expert System Applications

   The task considered is, given a 3d model of a part, to generate a set of dimensions for it in the three 2d views of the part. Good dimensioning of drawings is important for comprehension of designs, and is difficult to produce. Existing automatic dimensioning programs have limited capability compared to an experienced draftsman.

   Our approach was to use knowledge-based system, written in CADLOG, to express the task of dimensioning as a sequence of applications of rules. Rules embody the draftsman's knowledge of decomposition of the part into dimensionable 3d features, and of dimensioning choices, such as which views to use, which of many equal dimensions to express, and how to best layout the dimensioning information in the 2d views. Rules can also embody drafting policies of organizations to facilitate communication between different departments. We found that

   (a) dimensioning should be based upon manufacturing features which are sets of surfaces in specified 3d relationships
   (b) several different kinds of rules are needed
   (a) for each feature, rules for generation of dimensions onto sets of surfaces comprising it
   (b) for each surface, the generation of linear dimension forms
   (c) for each such form, the instantiation of the dimension onto an explicit 3d linear element
   (d) the selection of 3d linear elements to express in 2d views, and the selection of

views to use
(e) the layout of the 2d dimensions generated.

(c) a large amount of redundancy occurred, which had to be managed and retained until final expression decisions were made.

The system works by constructing a set of prioritized goals connected by a network of redundancy relationships. The rules construct, manipulate and are driven by this structure, which in some sense represents the experienced draftsman's awareness of the drawing.

4. MEP Technical Report 8704
Automatic Model Construction from Drawings
Alan H. Bond and Dong H. Kim
February 1987
We present a new approach to automatic model construction, which is knowledge-based. It constructs a 3D CAD model automatically given any number of possibly non-orthogonal views given as 2D drawings. The approach uses three phases:
Phase I. Basic construction of a 3D model by comparison of 3 2D views, including creating horizon and auxiliary lines of various kinds.
Phase II. Application of general geometric and physical wellformedness criteria. This includes the Preiss criteria as well as others currently being researched.
Phase III. For cases of more than one geometrically and physically correct solution, a model-driven selection program selects those solutions which are 3D structures of a given class. For example, we are interested in those solutions consisting of assemblies of uniform thickness sheets which are planar or circularly cylindrical, as well as including minimally deformed extrusions.

5. MEP Technical Report 8705
Integrating Prolog and CADAM to Produce an Intelligent CAD system
Alan H. Bond and Basuki Soetarman
February 1987
Presented at IEEE 1987 WESTEX Conference on Expert System Applications We discuss the system issues in integrating an artificial intelligence system like Prolog with a computer-aided design system like CADAM. These are totally different types of system, and both are interactive. An integrated intelligent CAD system was designed and implemented by combining VM/PROLOG and CADAM on an IBM 4341 mainframe. Integrating Prolog and CADAM involved solving a number of system programming problems. We had to deal with problems of combining two interactive systems, linking to CADAM, and of storage management in a VM virtual machine. Finally, we had to consider error recovery for errors at any point in our system.

The end result is an integrated intelligent CAD system, called CADLOG, which allows the user to interact through one screen to:
(i) work graphically in the conventional CADAM system
(ii) write application programs in Prolog, or a mixture of Prolog and Fortran
(iii) interact with his application program, setting Prolog goals and monitoring results in Prolog

(iv) produce modified drawings in Prolog and display them in CADAM We have started several engineering students who learned Prolog and wrote CAD application programs with very little difficulty.

We have built up a general CAD package, which provides facilities for reading in 2D drawings and automatically constructing an extended CAD model. This model provides a Prolog and Fortran interface, with a set of functions and predicates for accessing information contained in the model, which provides 3d wireframe, surfaces and volumes and manufacturing features.

The main application area is the design and manufacture of assemblies made of sheet metal and extrusions, as components of aircraft. We have implemented several application programs using the intelligent CAD system.

6. MEP Technical Report 8706
   Automatic partitioning of sheet metal assemblies
   Alan H. Bond and S. Zia Ahmed
   February 1987
   We present preliminary findings concerning the partitioning of 3D CAD models of sheet metal assemblies. A method of developing arbitrarily shaped sheets, by a specified recognition rule for elementary sheets and a growth rule for propagating the sheet across volume boundaries. A program was implemented easily in Prolog. It is hoped to generalize the system to other types of assembly and eventually to models of composites which are usually specified in directly in the form of assemblies.

7. MEP Technical Report 8707
   Automatic extraction of manufacturing features
   Alan H. Bond, S. Zia Ahmed and Dong H. Kim
   February 1987
   We present preliminary findings automatically extracting features of sheet metal assemblies and also machined parts.

   Several features found in sheet metal parts were defined as Prolog programs and implemented. This showed the usefulness of Prolog for writing features recognition programs, and also provided a tool for displaying all the features of a specified type that are present in a given 3D model.

8. MEP Technical Note 8709
   Outline of proposed approach to manufacturing features for Lockheed Missile and Space Division, Sunnyvale
   Alan H. Bond
   March 1987
   We describe an approach to the formal description and automatic extraction of manufacturing features from CAD solid models.

   (a) Extension of the modelling system to allow doubly curved surfaces.
   (b) Interfacing the chosen Sunnyvale 3D CAD modelling system to Prolog, thereby developing an intelligent CAD model based upon the chosen conventional CAD system.

(c) Developing formal descriptions in the form of Prolog expressions for all the features in the Sunnyvale classification scheme. This will involve writing further basic geometric functions in Prolog for the intelligent CAD modelling system.

Important issues in feature definition include

(a) That geometric features often overlap and interfere with each other, and hence may only be recognizable in a particular order.

(b) That the concept and form of features should probably be enhanced to include non-geometric information such as functionality, producibility and inspection information. This information can be comprehensive but need not cause problems. Indeed, the well-formedness constraints which use this additional information can give self-checking robustness in the representation.

9. MEP Technical Report 8710
The formal description of manufacturing features
Alan H. Bond
March 1987
We describe an approach to the formal description and automatic extraction of manufacturing features from CAD solid models.

We explore the potential of predicate calculus definitions in describing manufacturing features of 3D models.

We give many examples of features in machined prismatic parts as well as sheet parts.

We concluded that

(a) Definitions could naturally use sub-definitions

(b) Exceptional special cases often occur and can be accommodated in definitions

(c) Standard assertions with extracted parameter values could be defined for each feature.

(d) These form a self contained high level model, if combined with relations between features

The use of standard parametrizations is contrasted with the object-oriented approach.

10. MEP Technical Report 8712
Outline review of research of intelligent CAD/CAM group
Alan H. Bond
March 1987

(a) Artificial Intelligence and CAD/CAM

(b) The Prolog-CADAM Intelligent CAD/CAM system

(c) The Intelligent CAD model

(d) Automatic Model Construction

(e) A Rule-Based Design Checker

(f) Automatic Dimensioning

(g) Automatic partitioning of assemblies

(h) Defining features

(i) Other work in progress

11. MEP Technical Report 8713
Demonstrations of research of intelligent CAD/CAM group
Alan H. Bond
March 1987

    (a) Automatic Generation of GT codes from drawings
    Demonstrated by Nader Karimi

    (b) Automatic model construction form drawings
    Demonstrated by Dong H. Kim

    - (a) 2D − > 3D Basic construction
    - (b) finding the boundary surface representation

    (c) The Prolog-CADAM System
    Demonstrated by Basuki Soetarman

    - (i) The Integrated Interface
    - (ii) Applications
        - (a) Design Checker for Sheet Metal Parts
        - (b) Feature extraction
        - (c) Automatic partitioning of assemblies

    (d) Machined Parts
    Demonstrated by Peter Chen

    - (i) Representation in intelligent CAD system
    - (ii) Construction from process plan

12. MEP Technical Report 8714
Abstraction in FMS simulation
Alan H. Bond and Basuki Soetarman
August 1987
We discuss problems involved in describing FMS systems at different levels of abstraction. We describe the use of *approximations* which are needed at a given level of description in order to represent omitted detail at lower levels.

We discuss the problem of working with several different bases for abstraction at the same time, which we call *multiple abstraction dimensions*, which may interact. We describe two solutions:

(i) The *kernel abstraction method*, which defines a kernel of strongly interacting dimensions and describes one main abstraction hierarchy based upon this kernel. The abstraction hierarchies for other dimensions not in the kernel can be then described by adding to the kernel hierarchy.

(ii) The *flexible abstraction method*, which allows a new abstraction hierarchy to be defined from an existing one, by specifying whether approximate or exact forms are to be used in each object of the original hierarchy.

We also discuss an approach to the problem of *selective abstraction*, where different parts of the FMS system are used together but at different levels of abstraction.

13. MEP Technical Report 8715
User Manual for the Intelligent CAD Model
Alan H. Bond, S. Zia Ahmed, Dong H. Kim and Basuki Soetarman
April 1987
This is the user manual for the CAD modelling system developed in CADLOG. It describes standard data structures for each type of geometric construction, and gives definitions for the set of predicates available in the Prolog package. It also gives listings of some of the Prolog code.

14. MEP Technical Report 8716
Research at UCLA on intelligent CAD/CAM
Alan H. Bond and Basuki Soetarman
August 11 1987
Presented at Meeting of CAM-I Intelligent Manufacturing Systems Group
Radisson Plaza Hotel, El Segundo, Los Angeles, California, August 11-13 1987.

15. MEP Technical Report 8717
The formal definition and automatic extraction of group technology codes
Alan H. Bond and Rajanish Jain
September 1987
We discuss the use of the Prolog language to formally describe GT codes, and a case study of using this method in a program for automatically extracting a sheet metal GT code.

16. MEP Technical Report 8718
The formal definition and automatic extraction of group technology codes
Alan H. Bond and Rajanish Jain
September 1987
Presented at Users' Forum on "Group Technology Concepts and Applications" September 15-17, Los Angeles, California. Sponsored by the Society of Manufacturing Engineers and its Computer and Automated Systems Association We give a progress report in the use of the Prolog language to formally describe GT codes, and a case study of using this method in a program for automatically extracting a sheet metal GT code.

17. MEP Technical Report 8719
Automatic extraction of geometric features from CAD models
Alan H. Bond, Michel A. Melkanoff, S. Zia Ahmed,
Kang J. Chang, Dong H. Kim and Basuki Soetarman
June 1987
Presented at the
Second International Seminar on Intelligent Manufacturing Systems

August 24-29, 1987, Dubrovnik, Yugoslavia
(Proceedings to be published by Elsevier)

A CAD/CAM software methodology, developed at UCLA, is described. An industry standard CAD system, CADAM, has been interfaced to an artificial intelligence system, Prolog. The result is the ability to work with 3D CAD models, which are represented in symbolic as well as numerical form.

The symbolic form allows the formal specification of a wide range of features and situations, using the language of predicate logic. The Prolog system ensures that these specifications can run directly as programs to automatically extract features.

The use of this methodology, in implementing expert systems for design checking and for process planning, is described.

18. (Shortened form of MEP8724)

19. MEP Technical Report 8720
CAD/CAM knowledge utility and distributed knowledge
Alan H. Bond
May 1987
We discuss the use of knowledge in CAD/CAM systems. Design of large complex items such as aircraft is *institutionalized design*, in the sense that it is not the activity of a single individual or even a close knit group of designers, but rather a large group of people in a business organization.

20. MEP Technical Report 8721
Knowledge-based process planning for machining parts
Alan H. Bond and Kang J. Chang
June 1987
We describe a process planning system for machined parts, which uses an artificial intelligence approach. The knowledge of part geometry, of machining processes and of the activity of process planning, are represented as rules and frames using a uniform symbolic description method. The process planning system uses a blackboard software architecture, which uses explicit goals and hypotheses in the plan construction process. The system is written in Prolog and uses the UCLA CADLOG system.

21. MEP Technical Report 8722
Knowledge-based process planning for machining parts
Alan H. Bond and Kang J. Chang
August 1987
Submitted to the International Journal for Artificial Intelligence in Engineering, Special Issue on Planning.

We describe a process planning system for machining parts, which uses an artificial intelligence approach. The knowledge of part geometry, of machining processes and of the activity of process planning, are represented as rules and frames using an uniform symbolic description method. The process planning system uses a blackboard software architecture, which uses explicit goals and hypotheses in the plan construction process. The system is written in Prolog and uses the UCLA CADLOG system.

The input to the system is a 3D geometric description of the part. This is analyzed into machinable features and their spatial relationships. Rules make tooling decisions, concerning fixturing types and locating and holding surfaces. Rules generate constraint relationships among processing alternatives for the various machinable features. A hierarchical search process then finds an optimal temporal clustering of processes, which satisfies all the generated constraints. The result of this study provides a basis for a multi-agent process planning system.

22. MEP Technical Report 8723
Knowledge-based process planning using rule-generated constraints and hierarchical search
Alan H. Bond and Kang J. Chang
August 1987
Submitted to the Fourth IEEE Conference on Artificial Intelligence Applications, San Diego, California, March 14-18, 1988. We describe a process planning system for machining parts, which uses an artificial intelligence approach. The knowledge of part geometry, of machining processes and of the activity of process planning, are represented as rules and frames using an uniform symbolic description method. The process planning system uses a blackboard software architecture, which uses explicit goals and hypotheses in the plan construction process. The system is written in Prolog and uses the UCLA CADLOG system.

    The input to the system is a 3D geometric description of the part. This is analyzed into machinable features and their spatial relationships. Rules make tooling decisions, concerning fixturing types and locating and holding surfaces. Rules generate constraint relationships among processing alternatives for the various machinable features. A hierarchical search process then finds an optimal temporal clustering of processes, which satisfies all the generated constraints. The result of this study provides a basis for a multi-agent process planning system.

23. MEP Technical Report 8724
Automatic extraction of geometric features from CAD models
Alan H. Bond, Michel A. Melkanoff, S. Zia Ahmed,
Kang J. Chang, Dong H. Kim and Basuki Soetarman
June 1987
To be submitted to Journal of Manufacturing Systems A CAD/CAM software methodology, developed at UCLA, is described. An industry standard CAD system, CADAM has been interfaced to an artificial intelligence system, Prolog. The result is the ability to work with 3D CAD models, which are represented in symbolic as well as numerical form.

    The symbolic form allows the formal specification of a wide range of features and situations, using the language of predicate logic. The Prolog system ensures that these specifications can run directly as programs to automatically extract features.

    A number of expert systems which have been implemented at UCLA, using this methodology, are reviewed. These include systems for automatic dimensioning, design checking, process planning and automatic GT code generation.

24. MEP Technical Report 8725
Knowledge-Based Automatic Dimensioning
Alan H. Bond and S. Zia Ahmed
September 1987
To be submitted to the International Journal for Artificial Intelligence in Engineering. The task considered is, given a 3d model of a part, to generate a set of dimensions for it in the three 2d views of the part. Good dimensioning of drawings is important for comprehension of designs, and is difficult to produce. Existing automatic dimensioning programs have limited capability compared to an experienced draftsman.

    Our approach was to use knowledge-based system and to express the task of dimensioning as a sequence of applications of rules. Rules embody the draftsman's knowledge of decomposition of the part into dimensionable 3d features, and of dimensioning choices, such as which views to use, which of many equal dimensions to express, and how to best layout the dimensioning information in the 2d views. Rules can also embody drafting policies of organizations to facilitate communication between different departments.

    We found that

    (a) dimensioning should be based upon manufacturing features which are sets of surfaces in specified 3d relationships
    (b) several different kinds of rules are needed
        (a) for each feature, rules for generation of dimensions onto sets of surfaces comprising it
        (b) for each surface, the generation of linear dimension forms
        (c) for each such form, the instantiation of the dimension onto an explicit 3d linear element
        (d) the selection of 3d linear elements to express in 2d views, and the selection of views to use
        (e) the layout of the 2d dimensions generated.
    (c) a large amount of redundancy occurred, which had to be managed and retained until final expression decisions were made.

    The system works by constructing a set of prioritized goals connected by a network of redundancy relationships. The rules construct, manipulate and are driven by this structure, which in some sense represents the experienced draftsman's awareness of the drawing.

25. MEP Technical Report 8726
An Intelligent CAD-CAM System
Alan H. Bond, Basuki Soetarman, Dong H. Kim,
Zia Ahmed and Kang Chang.
To be presented at 5th DOE Workshop CAD/CAE, October 26-27, 1987, Lawrence Berkeley Laboratory, Berkeley, California.

    An integrated intelligent CAD system has been designed and implemented by combining VM/PROLOG and CADAM on an IBM 4341 mainframe. We discuss the system issues in integrating an artificial intelligence system like Prolog with a computer-aided design system like CADAM.

The end result is an integrated intelligent CAD system, called CADLOG, which allows the user to interact through one screen to
(i) work graphically in the conventional CADAM system
(ii) write application programs in Prolog, or a mixture of Prolog and Fortran
(iii) interact with his application program, setting Prolog goals and monitoring results in Prolog
(iv) produce modified drawings in Prolog and display them in CADAM

We have built up an intelligent CAD model The model provides 3D wireframe, surface and surface feature representations in both Prolog and Fortran, and higher level structures in Prolog which include volumes, manufacturing features and spatial relationships between faces.

The main application area is the design and manufacture of assemblies made of sheet metal and extrusions, as components of aircraft. The work is funded in part by a research collaboration with Lockheed Aircraft Company of Burbank, California.

We describe several CAD/CAM Expert System programs that we have designed and implemented using the CADLOG system. They include
(i) a design checker for sheet metal designs,
(ii) an automatic dimensioning program
(iii) an automatic 2D to 3D conversion program, and
(iv) a process planner for machined parts
Work in progress includes also (v) an intelligent simulation system for FMS systems, and (vi) a database for sheet metal assembly designs. (vii) a system for automatically generating GT codes for sheet metal parts.

26. MEP Technical Report 8727
    Structuring a CAD/CAM system as a set of cooperating experts
    Alan H. Bond
    October 1987
    A discussion.

27. OUTLINE DRAFT ONLY
    MEP Technical Report 8728
    The application of parallel logic programming to intelligent CAD/CAM systems
    Alan H. Bond
    December 1987
    Discussion.

28. MEP Technical Report 8729
    Multiple abstraction in knowledge-based simulation
    Alan H. Bond and Basuki Soetarman
    To be presented at the Simulation and Artificial Intelligence Conference
    of the Society for Computer Simulation, San Diego, February 3-5, 1988.
    We discuss issues and mechanisms in system abstraction arising in the design of a knowledge-based simulation system for studying flexible manufacturing systems.

We define the notion of abstraction and discuss its different conceptual uses. The notion of abstraction allows us to reason about the simulated system in different *abstraction dimensions* and at different *levels of abstraction.* We give an example of an analysis of a flexible manufacturing system into abstraction levels.

We then discuss the problem of using multiple abstraction dimensions, and describe a solution which is to define a *kernel abstraction*, from which abstractions in other dimensions can be found.

We then introduce the idea of an approximation and a method of stratifying approximations in which each level of abstraction has "approximate" and "exact" forms of functions.

A more general method of dealing with multiple abstraction dimensions is then described. This *flexible abstraction method* uses stratified approximation and allows abstraction dimensions which do not easily co-abstract, to be defined and used in simulations.

We describe the use of flexible abstraction to automatically configure a simulation so as to respond to a given set of queries, involving sets of variables with specified reporting accuracies.

29. MEP Technical Report 8730
An intelligent CAD-CAM system
Alan H. Bond, Basuki Soetarman, Dong H. Kim, S. Zia Ahmed and Kang J. Chang
October 1987
Presented at the Fifth DOE Workshop on Computer Aided Engineering, October 26-27, 1987, at Lawrence Berkeley Laboratory, University of California Berkeley.
An integrated intelligent CAD system has been designed and implemented by combining VM/PROLOG and CADAM on an IBM 4341 mainframe. We discuss the system issues in integrating an artificial intelligence system like Prolog with a computer-aided design system like CADAM.

The end result is an integrated intelligent CAD system, called CADLOG, which allows the user to interact through one screen to
(i) work graphically in the conventional CADAM system
(ii) write application programs in Prolog, or a mixture of Prolog and Fortran
(iii) interact with his application program, setting Prolog goals and monitoring results in Prolog
(iv) produce modified drawings in Prolog and display them in CADAM

We have built up an intelligent CAD model The model provides 3D wireframe, surface and surface feature representations in both Prolog and Fortran, and higher level structures in Prolog which include volumes, manufacturing features and spatial relationships between faces.

The main application area is the design and manufacture of assemblies made of sheet metal and extrusions, as components of aircraft. The work is funded in part by a research collaboration with Lockheed Aircraft Company of Burbank, California.

We describe several CAD/CAM Expert System programs that we have designed and implemented using the CADLOG system. They include
(i) a design checker for sheet metal designs,

(ii) an automatic dimensioning program
(iii) an automatic 2D to 3D conversion program, and
(iv) a process planner for machined parts
Work in progress includes also (v) an intelligent simulation system for FMS systems, and (vi) a database for sheet metal assembly designs. (vii) a system for automatically generating GT codes for sheet metal parts.

30. MEP Technical Report 8731
Parallelism in CAD/CAM
Alan H. Bond
November 1987
A talk prepared for the visit to UCLA of representatives of Hewlett Packard.
We first describe the approach to CAD/CAM taken by the UCLA Intelligent CAD/CAM group, which is a component of the Manufacturing Engineering Program. We have integrated the artificial intelligence language Prolog with the CAD system CADAM, to produce the CADLOG system. Then, using CADLOG, we have programmed several expert systems for different CAD/CAM areas. The group consists of a mixture of computer science and mechanical engineering PhD students, and is lead by Dr. Alan Bond, who has a computer science and AI background.

We then briefly discuss the two main kinds of parallelism in intelligent CAD/CAM systems. First, an intelligent CAD/CAM system should be a distributed set of cooperating intelligent agents, each of which is an expert system. Second, each agent should run on a parallel workstation, and we suggest a parallel logic programming methodology for implementation of agents.

31. MEP Technical Report 8733
Feature-based process planning for machined parts
Alan H. Bond and Kang J. Chang
November 1987
Submitted to the ASME Computers in Engineering Conference 1988. *Subject Categories*: Blackboard model, Process planning, Hierachical search, Constraints, Tooling, Prolog, CADLOG, CAD/CAM, Manufacturing, Engineering.
We describe a process planning system for machining parts, which uses an artificial intelligence approach. The knowledge of part geometry, of machining processes and of the activity of process planning, are represented as rules and frames using an uniform symbolic description method. The process planning system uses a blackboard software architecture, which uses explicit goals and hypotheses in the plan construction process. The system is written in Prolog and uses the UCLA CADLOG system.

The input to the system is a 3D geometric description of the part. This is analyzed into machinable features and their spatial relationships. Rules make tooling decisions, concerning fixturing types and locating and holding surfaces. Rules generate constraint relationships among processing alternatives for the various machinable features. A hierarchical search process then finds an optimal temporal clustering of processes, which satisfies all the generated constraints. The result of this study provides a basis for a multi-agent process planning system.

32. MEP Technical Report 8734
A feature-based design checker for producibility of sheet metal parts
Alan H. Bond and Chen-Chung Kao
November 1987
Submitted to the ASME Computers in Engineering Conference 1988.
A design checker for sheet metal designs is described. It embodies producibility rules for sheet metal forms such as cutouts, flanges, bends, joggles etc. which depend upon geometry, material and manufacturing process.

In this system, the producibility of a sheet metal assembly is interactively checked by

(i) representing the assembly in a 3d symbolic form in Prolog
(ii) analyzing it in terms of producibility-criticial situations.

These include

(a) well formed manufacturing features, such as round, bend, flange, hole, joggle etc., but whose size, relationship or proportion may be difficult to deal with or non-optimal in some way
(b) check situations, for example
   (a) bend relief situations, where two or more bends meet inside a part surface
   (b) almost-straight situations, where two 3-dimensional edges are almost, but not quite collinear in the corresponding flat pattern form
   (c) blank and cut-out situations, where there are many restrictions on producible configurations.

For each situation, producibility checks are performed. These may depend upon variables such as material, process etc. If a violation of a producibility rule occurs, and error message is generated, with suggested standard remedy if one exists, and the corresponding graphical elements are made more visible by a type change.

The system was written in Prolog, using the UCLA CADLOG Intelligent CAD system.

33. MEP Technical Report 8735
The formal definition and automatic extraction of group technology codes
Alan H. Bond and Rajanish Jain
November 1987
Submitted to the ASME Computers in Engineering Conference 1988.
We give a progress report in the use of the Prolog language to formally describe GT (Group Technology) codes, and a case study of using this method in a program for automatically extracting a sheet metal GT code.

The main goal of this research has been to investigate the use of Prolog as a formal specification language for specifying GT codes and, in general, complete descriptive systems for manufacturing parts.

As a subsidiary goal, we wanted to compare the efficiencies of Prolog and Fortran for the purposes of extracting GT codes automatically.

We used the UCLA CADLOG Intelligent CAD system, which provides a 3D CAD model in the form of symbolic expressions in Prolog.

We investigated the methodology of using formal definitions of features in Prolog. These definitions were found to have the following properties:

(a) Auxiliary definitions.
It may be necessary to define an auxiliary concept in order to define the main concept.

(b) All features can be defined as configurations of faces.
We found that not all features were volumes. Further, all features originally thought of as volumes could be defined in terms of face configurations just as naturally.

(c) Features may have a context.
Some definitions only accord with intuition if they are in a context of other face configurations, which however are not part of the feature as such.

(d) Special cases.
Special cases, which are often pathological cases, can occur which must be taken into account for rigour and completeness, but which tend to obscure the clarity of the main definition, which applies in 99 percent of the cases.

All of these properties can be handled naturally by formal definitions in Prolog.

Further, the Prolog expression

(a) Corresponds closely to an English language description
(b) Is a well defined and precise specification of a feature
(c) Is executable in Prolog to automatically extract all the instances of the feature that are present in a given model.

To determine whether this formal approach could be practical enough to use for a complete description scheme, we have shown the feasibility of the formal expression of the entire Lockheed sheet metal GT code in Prolog. We discuss the various features involved and their formal expression.

We give order-of-magnitude computing times, which show that automatic extraction of features using this formal approach needs only the same computing resources as a conventional approach using Fortran.

34. DRAFT
MEP Technical Report 8736
The specification and use of design checking configurations
Alan H. Bond and Chen-Chung Kao
December 1987
To be Submitted to the Journal of Manufacturing Systems
The problem is addressed of specifying and automatically recognizing those configurations in designs which may cause problems in manufacture.

The approach developed and reported here uses a predicate logic formal language to exactly specify producibility critical situations.

There are a number of problems in interpreting existing documented checking requirements, which are currently expressed in informal natural language and diagrammatic sketch form.

Formal predicate logic specifications can be directly run as computer programs by a Prolog system, to automatically recognize, in a three dimensional CAD/CAM model, the checking configurations specified.

An experimental computer system is described, which uses this technique to implement design checking for sheet metal parts.