(54) Title: COMPUTER-AIDED SOFTWARE ENGINEERING FACILITY

(57) Abstract

A computer-aided software engineering facility (CASE) for providing a method for generating source code and executable computer programs in a language supported by various hardware entities in the multiprocess system, using the entity-relationship model and the high level Rules Language models that are distributable across multiple hardware environment or platforms. An object oriented modeling system is complied with linked rules of the Rules Language (59) as well as other system components to quickly and efficiently design computer source code and executable computer modules that have a high degree of precision as stored in a Repository (52).
requires many man-hours. Experience in the programming language used to develop the program is necessary.

With the code written, the design team's next problem is to debug the program for syntax errors, and then test the program to determine whether the application performs the desired function. Typically, the debugging and testing phase requires the programmer to evaluate a program at the code level.

The programmer's development tasks become more challenging with the use of multiprocessing systems architecture.

Traditionally, there have been two basic hardware configurations employed in the design of computer systems for multiple users. In one configuration all of a system's processing is performed by one large "mainframe" computer. Each user accesses that system through non-processing terminals.

A network system is the second traditional hardware configuration. A network is comprised of a number of individual processing units that are interconnected to allow the sharing of data and software. There may be additional processors to maintain a group's centralized database and additional processors may be dedicated to the maintenance of the system's operation. The use of a network of processors each dedicated to specific aspects of a computer system is the essence of multiprocessing.

The growth of the use of multiprocessing systems can be traced to the proliferation and development of powerful "micro" or "personal" computers (PC's). Within certain constraints, a PC can perform many of the same processing tasks that mainframe or mini computers do. However, a PC can perform these tasks with substantial savings of instructions executed by the
COMPUTER-AIDED SOFTWARE ENGINEERING FACILITY

Field of Invention

The invention relates to multiprocessor computer systems and in particular to facilities that aid in the development of computer programs for those systems.

Background of the Invention

Computer-Aided Software Engineering (CASE) software or "facilities" assist computer programmers or system developers in the design, development and testing of a computer program.

Traditionally, the steps necessary to implement a computer program were performed manually.

Design teams follow a number of discrete steps to create a useful application program from a nascent idea.

The analysis begins by manually developing a model in which a problem can be solved by computer. Design teams evaluate the needs of the prospective users and the properties that the computer system should possess to meet those needs.

In the technical design phase of development, developers begin to define how the application program will be built on a given system. They manually determine the procedural and data elements needed and how the data and procedures will be assembled to form the software solution. At this phase the two major tasks are data-modeling and process-modeling.

With the basic design of the program modeled, developers then begin the task of coding the program. Computer programs are generally written in high-level programming language such as BASIC, C, COBOL, FORTRAN or PL/I. The task of reducing the theoretical design of an application to working code is an arduous task that
various distributed programs in the language supported by that environment. For example, if the PC processors support only programs written in C language, those parts of the program must be in C. Whereas the other parts of the program, such as those on the mainframe, may have to be written in another programming language.

Programming in a multiprocessor environment is very complex and time consuming. Staffing requirements for designing an application in a multiprocessor environment alone can make the task cost prohibitive. CASE facilities were created to alleviate some of the burden multiprocessing architecture placed on the programmer.

Traditionally, CASE facilities allow a user to input a high-level logical design of a program which is then translated into code in a particular computer language. However, the CASE facilities currently available do not give the system developer a completely integrated system for the design, implementation and maintenance of a software application. The current facilities do not support the development of a program in a centralized location and where translated code is created and distributed to various environments. The current CASE tools also do not provide a method for reusing parts of a previously developed application that may be usable in an application under development. The current CASE facilities do not provide adequate testing and debugging tools.

One of the dilemmas in designing a CASE tool is that the output one is required to provide the user for the planning phases of the project is different from the output required later on, during implementation. Early CASE tools tended to emphasize support for one of these two categories of activity, and scrimp on the
computer, measured in millions of instructions per second, "MIPS". Moreover, unlike a mainframe system, a PC is dedicated to a single user. An efficient multiprocessing system encourages data sharing and the use of dedicated PC's for as many tasks as possible.

In multiprocessor systems, an application may be executed on more than one processor. When various parts of an application program are executed on separate processors, the application is "distributed."

Distributed processing can be executed either in a serial sequence or in parallel.

The simultaneous execution of a program on many processors is parallel processing. Sequential execution of a program across different hardware environments is serial or "cooperative" processing.

Multiprocessing capability brings new challenges to computer system designers. Whereas in a mainframe environment all parts of the program were programmed for a single environment, in multiprocessing systems designers can choose the particular environment where specific aspects of a program will run.

Although this freedom to distribute the program results in a highly efficient application, the programmers must now construct programs designed to execute in many hardware environments.

The task of programming multiprocessing systems involves difficult problems of swapping data across different, and incompatible environments. For example, a file containing data stored in a PL/I format is not readable by a program written in a different language such as C or COBOL. A programmer must design special software to handle the communication problems inherent in multiprocessing systems.

In addition, a programmer must code the
program through an entity-relationship modeling technique.

Another aspect is a relational database, where data is stored according to the entity-relationship model.

Another aspect is the high-level Rules Language in which the logic of a program can be specified in a highly modular form, promoting ease of re-usability.

The invention provides the capability for generating source-code for the program in a language supported by various hardware entities in the multiprocessing system, using the entity-relationship model and the high-level Rules Language modules.

To generate the program's source-code the invention provides basic program elements to execute the program in a multiprocessing environment. These program components and low-level routines are combined with the Rules Language modules and data type entities to create the program.

The invention further provides facilities to distribute, assemble and compile the program developed using the CASE facility of the present invention, as well as test and modify the program.

**Brief Description of the Drawings**

FIG. 1 is an illustration of a three-tiered computer system.

FIG. 2 is a diagrammatic representation of the program elements according to the present invention.

FIG. 2A is a diagrammatic representation of sample developmental workbench modules placed in a PC hardware environment.

FIG. 3 is a diagrammatic representation of a
other.

With prior design-oriented CASE tools, the output of a designer's work with the tool was a picture. What a designer would end up with is documentation that could be used to actually create a system, but not the actual system itself. In addition, if during the implementation phase, a user discovered a reason to change any aspect of the program, the designer had to go back and manually identify the change and update the documentation -- the documentation was useless unless it was compulsively updated. The actual implementation of the system, as well as any changes, were done using traditional methods. The only advantage of using a design-oriented CASE tool was that it produced friendly, complete documentation that really helped in design at the early stages.

The second family of CASE tools were implementation-oriented. They allowed a designer to draw a diagram of an entire model, but not of a piece of a module. Essentially, the designer could get a picture of whatever model the designer was working on. When the designer unloaded the model to the mainframe repository, the model replaced whatever model was already stored there. The actual documentation of these systems was primitive and inflexible.

Summary of the Invention

The present invention is a CASE facility providing a method and apparatus for designing, implementing and maintaining software that runs in multiple hardware environments -- a distribution that is transparent to the end-user.

One aspect of the invention is a method of modeling the program structure and the data used by the
the maintenance of a centralized database and the use of a rules-based language used in conjunction with other development tools presented by this invention are the same regardless of a particular hardware configuration.

Flexibility in hardware configuration is one advantage of the CASE facility according to the present invention over those CASE facilities currently available. The CASE facility of the present invention allows flexible architectural designs by creating a centralized database called a Repository where the design and the logic of the program module is stored, and translated code is distributed from the repository automatically to the different hardware environments.

Typical processors preferred for each of the tiers in the exemplary three-tiered hardware configuration are the IBM mainframe sold under the trademark "Model 3090", running the IBM MVS/XA operating system; the Stratus mini-computer sold under the trademark "Model XA2000", running the Stratus Computer, Inc. VOS operating system, and the IBM micro-computer sold under the trademark "PS2", executing the Microsoft Corporation operating system sold under the trademark "MS-DOS." (For further information on these processors or their operating systems, the reader is referred to the following publications that are hereby expressly incorporated by reference: "IBM System/370 Bibliography", document number 6024448; and "Introduction to VOS", by Stratus Computer, Inc., document number R0001.)

B. CASE Facility Elements

The CASE facility of the present invention comprises a number of programmed elements, as depicted in FIG. 2: a Repository 4; a Rules Language 6; a
sample entity-relationship according to the present invention.

FIG. 4 is a diagrammatic representation of a sample entity decomposition according to the present invention.

FIGS. 5 and 6 are diagrammatic representations of the entity-relationship model for application programs according to the present invention.

FIG. 7 is a diagrammatic representation of the Process Flow for a sample program using entity-relationship modeling techniques according to the presented invention.

Detailed Description of the Invention

A. Hardware

A typical hardware configuration for a computer system using the CASE facility of the present invention is shown in FIG. 1. The figure describes a "three tiered" computer system, named for the three distinct types of processors networked: the mainframe computer 1, as for example, an IBM 3090, a mini or supermini computer 2, as for example an IBM S/88 or Stratus, and a plurality of micro-computer workstations 3, as for example IBM PC workstations. A system using the CASE facility of the present invention is not limited to only this hardware configuration. For example, a similar CASE facility can be constructed to develop code distributed in a two-tiered environment, such as a system employing only a mainframe and PC workstations or a two-tiered environment comprising a mainframe computer and a minicomputer with both accessible by non-intelligent terminals. The CASE facility can be tailored to fit any hardware configuration. The basic principles of code generation,
(document number SC34-2089); "Interactive System Productivity Facility/ Program Development Facility of MVS: Dialog Management Services" (document number SC34-2137) and "DB2 Application Programming Guide for TSO and Batch Users.")

The information stored in the Repository 4 includes models provided by the present invention to form the basis for an application program and high-level logic modules defined by the present invention for use in the generation of an executable program, as will appear. For each program, a data-model and a process-model are developed through the use of an entity-relationship modeling system and stored in the Repository 4. The high-level logic modules stored in the Repository 4 are written in a Rules Language defined by the present invention as described below. The information is environment independent and is structured to provide a high degree of re-use.

Programmers input information to the Repository 4, using a standard database language supported by the hardware. For example where the Repository 4 is constructed from an IBM DB2 database, a programmer would use the DB2 Structured Query Language, SQL, to model the application. In another example described below, graphic interface modules could be provided to the user to input the information.

The Rules Language 6 is a high-level language that permits users to specify the logic of a program, independent of the hardware devices used by the system. Program modules written in the Rules Language 6 are translated by the Code Generator 24 into computer code suitable for execution in an environment where the modules are to run. The Rules Language is described more fully below.
Communications Manager 8; a Testing/Debugging Facility 10; a PC User-Interface Facility 2, including a Rules Painter 30; a Work Station Utility comprising a Work Station Manager 14, a Window Painter 16, a Workstation Converse 18; a Documentation Facility 20; and a Systems Generator 22 including a Code Generator 20, a Data Access Generator 16, and Systems Assembler 28. Although the programs created by the CASE facility are centrally-stored, the CASE system program elements may be located in any of the hardware environments used in a configuration.

The Repository 4 is a central database used to store all information about all of the application programs created with the CASE facility of the present invention. The Repository 4 could exist in any hardware environment supporting a standard relational database. For example on the three-tiered environment shown in FIG. 1, the Repository 4 could exist on the mainframe computer 1, using the IBM relational database management system DB2.

For purposes of a preferred embodiment of this invention, it is preferred that Central Repository be located in the mainframe environment and that the IBM relational database sold under the trademark "DB2" be employed. (For background information on DB2, the reader is referred to the following IBM publications which are hereby expressly incorporated by reference: "IBM DATABASE 2 Introduction to SQL" (document number GC26-4082); "IBM DATABASE 2 Reference" (document number SC26-4078); "OS/VS2 TSO Command Language Reference" (document number GC28-0646); "TSO Extensions Command Language Reference" (document number SC28-1307); "Interactive System Productivity Facility/Program Development Facility for MBS: Program Reference"
that the Microsoft Corporation's operating system, sold under the trademark "MICROSOFT WINDOWS," be used. (For more background information on MICROSOFT WINDOWS, the reader is referred to the following Microsoft

The Documentation Facility 20 generates all technical documentation for a program under development. Documentation includes functional decomposition of the system and hierarchy listings of the Rule Language modules.

The System Generator 22 includes the Code Generator 12, the System Assembler 28, and the Data Access Generator 26. The Code Generator 24 translates the Rules Language modules into code in an appropriate programming language. The System Assembler 28 brings the various coded program elements together to form an application program. The Data Access Generator 26 allows the program to access data across hardware environments. Code generation and program execution is discussed more fully below.

The PC-front-end 12, the Workstation Manager 14 and Communication Manager 8, together form a set of Development Workbench Modules 34 that enable the user to design the data and process models of an application, and rules language modules, and combine them to create a fully functioning application program.

On the development platform in the exemplary configuration described above, access to all the environments is through the PC Front End 5. There developers can code their applications using the Rules
The Communications Manager 8 performs the run-time transfer of information between hardware environments. For example the Communications Manager 8 would use routers and protocols to handle data transfers between a mainframe, a mini computer and PC Workstations.

The Testing Facility 10, comprising a Rule View Module enables programmers to step through and debug program code. The Rule View Module can create test data as well as provide regression and stress testing upon an application. The Rule View Module is explained more fully below.

The PC Front-End 12 allows PC based graphic interface to be used for all CASE tool functions. The Rules Painter 30 permits programmers to construct program modules by manipulating graphic representations of the Rules Language statements. The PC Front-End 13 eliminates the need for the programmer to know an operating system language, such as DOS, by offering all PC functions as menus.

The Workstation Manager 14 aids in managing user interface in a PC environment. The Window Painter Module 16 is a tool that helps the developer to create user-interface screens for applications. The Workstation Converse 9 manages the display and validation of screen information.

The Workstation Manager Module 14 works in combination with commercialized programs to design user-interface, such as, for example, Microsoft Windows. All of the complexities of using a commercial design tool, like Microsoft Windows, are managed by the Workstation Manager 14.

In designing an application or portions thereof for execution on an "IBM PC," it is preferred
Defined generally, an entity is something real or abstract about which information is recorded. The information is organized into a set of characteristics, known as attributes. For example, collected information about employees of a company could be placed in an entity type called Employee. The attributes for that entity could be a name, social security number, home address, age, birth date, department, etc. An entity called organization would include attributes such as organization name, address, type of organization (such as partnership or corporation), etc. This data is stored in a file in the Repository 4 (see FIG. 2).

An association between entities is known as a relationship. For example in FIG. 3 the entity, Organization 64, is now linked to the entity, Employee 58, by the relationship, Employs 66. Relationships are also defined by attributes.

2. Functional Design

The functional design phase begins the modeling task -- there are two tasks to perform: data-modeling and process-modeling.

Data-modeling is the method of creating an entity-relationship model for the real-world data to be used by an application program. The method involves identifying an entity, such as a corporation, and decomposing that entity into subentities and attributes. In FIG. 4, the example entity, Corporation 70, is made up of the sub-entities: Product 72, Staff 74, and Customer 76. Customer consists of the attributes: Name 78, Address 80, and the Entity Order 82. The Order entity 82 is composed of the attributes: Number 84, Date 86, and Status 88.

Once the programmer has modeled the real-world data elements, he or she links them using the
Language and the CASE facility will automatically generate native code for each environment, as appropriate.

However, for the last phases of development for compiling and testing the applications, it is necessary to switch to a front-end module for the appropriate execution environment of each one. With respect to those application development activities, each environment is accessed via an environment-specific front end. The environment specific activity is described more fully below.

The Software Distribution System 32 automates and controls migration of an application. The system manages the release of software to targeted computers. The Software Distribution System 32 solves the problem of synchronizing distribution of software located, for example, on hundreds of personal computers. For a more detailed description of a Software Distribution System see International Application No. PCT/US90/____, entitled "Software Distribution System;" filed on even date herewith in the name of Norman Shing et al., which is hereby expressly incorporated by reference.

C. Entity-Relationship Modeling

1. Entities and Relationships

A feature of the CASE facility of the present invention is the systems model. To design any application using the CASE facility, a developer must decompose the application into specified logical parts, and assemble them into a program. The data used by a program are stored in Repository 4, FIG. 2, according to an entity-relationship model of the present invention. The different parts of an application are expressed as entities and are linked by relationships.
all programs developed with the CASE facility presented by this invention use the same entity types and relationships it is likely that many of the program elements can be re-used.

D. Application Model Entities and Relationships

As an example of the present invention, programs built using the CASE facility are broken into ten entity-types and eleven relationships as shown in FIGS. 5 and 6. For each entity and relationship that defines an application a list of attributes and information is kept.

1. Entities

The Function Entity 90, FIG. 5, is a listing of all the application programs currently on the system. A Function 90 is defined by the following attributes: Function Name, Test Description and Application Identification.

A Process 92, FIG. 5, is a logical subdivision of a Function 90. A Function 90 typically is decomposed into two or more Processes 92. Processes 92 can be decomposed into lower level Processes 90 (sub-processes). When a Process 90 is related to another Process 92, the relationship is always hierarchical. There are three Process types: Root, Leaf and Node. Such relationships define the decomposition of one sub-system into others. The Process Entity 92 is defined by the attributes: Process Name, Description, Menu Description, Sub-Process Menu-Type and Sequence Number.

At runtime, a process 92 runs either as a foreground or background process. A Foreground Process is one that executes interactive communication with the end-user. For example, a Foreground Process may comprise the graphics functions, resident on a PC
relationships such as the Employs Relationship 3 illustrated in FIG. 3.

In model format, the data are stored in the Repository 4, (See FIG. 2). Using the entity-relationship modeling technique, data for any application can be stored and readily re-used in subsequent applications.

Process-modeling is the method of constructing a model of an application program, using an entity-relationship model. The CASE facility of the present invention requires that all applications be first reduced to an entity-relationship model, before a program's logic is specified. The entity-relationship model is not the actual program. It is separate from the program modules written in the Rules Language. However, the CASE facility uses the entity-relationship model to link the various program modules together as well as to construct and distribute the program through a multiprocessor system. Entities store information on the flow of a program, the data structures used, the user interface, the environments used by the modules and the multiprocessing needs of the program.

In addition the entity-relationship model provides a representation of the high-level design of the programs from the entities. The CASE facility can produce technical documentation from the process model. For a given application, the entity-relationship model implicitly represents an amalgamation of a high-level structure-chart and a detailed description of the logic and data requirements necessary to make a program run.

The process-modeling method allows users of the CASE facility to maximize efficiency by re-using program elements. The program resulting from the entity-relationship model is highly modular. Because
As with processes there are three categories of Rules: Root, Frontier and Node Rules. A Root Rule is invoked by a Process 92. Root Rules do not have user I/O capability. A Node Rule is any rule that is not a Root or Frontier Rule.

Frontier Rules lie on the boundary of a new computing environment. Those Rules are grouped in a special category because Communication Manager 8, FIG. 2, must execute all Frontier Rules and their input/output data has to be converted to accommodate changes in environment.

The Rule Relationships are modeled using Rule Entities 94 and the Uses Relationship 108.

Components are modules of code written in any third generation programming language known to the CASE development system such as C, PL/I or COBOL. Components are used to perform functions not handled by the Rules Language such as calculations, database access, and calls to operating systems. The CASE facility assumes a "black box" structure for Components. A black box has fixed inputs and outputs. Given a specific input, there is always a predetermined output. The same analogy applies to Components. Components have explicitly defined inputs and outputs.

The Component Entity 96, FIG. 5, FIG. 6 distinct from the component module described above contains the following attributes: Component Name; Component Description; Language Name (programming language that source code of the component is written in); and Execution Environment.

Windows define user interface. They specify what data are to be accepted from a user, how it is to be displayed, and how it is to be accepted. The Window Entity 98 is used to store all information about the
workstation environment 3, FIG. 1. This is the typical on-line/realtime process. In addition, the foreground processes can communicate synchronously with modules on other environments, and they can receive unsolicited data, asynchronously.

A Background Process, once started, will process its input, then stop, or wait for further input. This may be a batch process for example running on the mainframe, that receives input from a file, or it may be a continuous process that runs on-line, for example due that reads from a queue.

Rules are the procedural specifications of the logic of a Process. This logic is specified in a high-level language called the Rules Language. The Rules Language is based on the principles of structured design and programming. The syntax of the language along with restrictions built into the architecture ensure a highly modular and concise system specification process. The Rules Language is described in detail below.

Using Rules Language statements, the CASE facility generates source code for the various environments. The CASE facility of the present invention generates all code necessary to perform inter-system communication (for example, when a rule in one environment calls a rule in another), inter-process communication (for example, between different processes or regions on the same machine), program-to-program linkage, and user interface.

In the entity-relationship model only information about the Rule is stored in a Rule entity 94 -- not the Rule language statements. The Rule Entity 94, FIG. 5, FIG. 6, is defined by its attributes: Rule Name, Rule Description, Execution Environment; and Mode of Execution (for example, synchronous or asynchronous).
constants. Value Entities 118 provide the ability or refer to specific data values by symbolic or English names. This eliminates the need to hard-code specific literal values in Rules.

Data are stored in files. In a entity-relationship model information concerning data files is stored in the File Entity 120, FIG. 6.

2. Relationships

The ten entities representing a program are linked together by one of eleven relationships.

The Refines Relationship 104, FIG. 5, describes the decomposition of Functions 90 to Processes 92. Its attributes are: Function Name (first participant); Process Name (second participant); and Sequence Number (for menu display). Processes also refine into further subprocesses.

The Defines Relationship 106, FIG. 5, is used to describe the relation between an abstract Process 92 and the Rule Entities 94. Its attributes are: Process Name and Rule Name. Processes can also depend upon other processes.

The Uses Relationship 108, FIG. 5, is used to describe the link between one executable module and another: (e.g. Rule Uses Rule, Rule Uses Component and Component Uses Component). The attributes of a Uses Relationship are: Module Name and Sub-Module Name.

The Converse Relationship 110, FIG. 5, describes the link between a Module and a Window Entity.

The attributes of the Converse 110 relation are: Rule Name (first participant) and Window Name (second participant). The function of the converse relationship is explained more fully below.

The Relationship Owns 112, FIG. 5, connects
user interface. The window information is used by the Code Generator Module 24, FIG. 2, and Workstation Converse Module 18, FIG. 2.

A Window Entity 98, FIG. 5 in the entity-relationship model has the following attributes: Window Name, Description. The Window Name contains the name of a Panel File also stored in the Repository which contains the information necessary to produce graphic interface using a graphic interface program such as Microsoft Windows.

The View Entity 100, FIG. 5, FIG. 6, is a convenient grouping mechanism for storing data type variables that are used by the Rules Language. The View 100 is a hierarchical set of named scalar or aggregate values.

Views 100 are is used in three different ways throughout a typical system. A File View 100A represents a template of the data constructs saved in a data file. The data constructs used to describe the input and output to Rules and Components are Modular Views 100. The data structures used to handle user interface are called Window Views 100.

Field Entities 102, FIG. 5, FIG. 6, are the basic data elements that comprise the variables used in a program. The Field Entity 102 stores all information about data elements, independently of the environment in which the data element is used. The Attributes of this entity define the format, editing specifications, report and screen headings, and any other generic information about a particular data element.

A Set 116, FIG. 6 like a View 100, FIG. 5, FIG. 6, is a convenient grouping mechanism that is used to store related literals or constants. Value Entities 118, FIG. 6 are symbolic representations of literals or
relationships: A File Entity 120, FIG. 6, is Keyed 132 by a Field Entity 122; File Entity 120 also Forwards 130 information to another File 120; and a File View Entity 100A Describes 128 a File Entity 120.

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E. Process-Modeling Reduction Technique

All Applications developed with the CASE facility can be reduced to a set of pre-selected entities and relationships such as the above described entities and relationships. The method begins by defining the Function Entity 90, FIG. 5. A Function is equivalent to any application program to perform any task or function. The Function Entity 1 contains a generalized description of the Application. A Function is decomposed into processes. The processes represent general functions that the program must perform.

For example, one of the Process Entities 92 in an application to perform stock market trading could be entitled "Futures Trade Entry." A Process Entity 92, FIG. 5, stores information describing the process. Processes can be decomposed into further processes. On each decomposition the information about the new process is stored in a Process Entity 92.

The Function Entity 90 and the Process Entities 92 create a high-level overview of an application. During the modeling phase the CASE facility presented by this invention provides tools to aid development. The programmer can use CASE provided graphics to specify the Process 92 and Function 90 Entities and Refine Relationships 104. The user sees functions and processes listed on menus. The CASE facility also assists the analyst and user in process modeling by allowing this Function/Process decomposition to be prototyped interactively, as for example with an
entities to the Views Entities 100 which describe their logical data interfaces. The Rule 94, Component 96, Window 98 and File 120, FIG. 6, entities may own View Entities 100. The attributes of the Owns relationship are: Rule/Component/Window or File name; Entity type (either Rule/Component/Window/or file); View Name and View Usage (either In, Out or Inout for user interface I/O).

The Includes Relationship 114, FIG. 5 connects data items together to form structures. View Entities 100 can include sub-Views 100 and Fields 102. The Attributes of the Includes Relationship 114 are: View Name (first participant higher-level view); View/Field Name (second participant); Entity Type (second participant's entity type: either view or field); Sequence Number (used to order Sub-Views and Fields); Occurs Number of Times (used to create arrays in structures).

The Owns Set Relationship 124, FIG. 6, links executable modules to the literal set values they refer to. A Rule may Own a Set by making a local declaration using the Rules Language DCL statement discussed below. The literal values will then automatically be included in the Rule Module when the code is generated. A Component Entity 96 may also Own Sets 124. The Own Set Relationship Attributes are: Module Name; Module Entity Type (i.e. Rule or Component); Set Name.

The Contains Relationship 126, FIG. 6, link literal data items to a common Set Entity 116. A Set Entity 116 Contains, for example, 18 member Values in the Value Entity 118. The attributes of the Contains Relationship 126 are: Set Name; Value; Symbol Name; Sequence Number.

Finally, the CASE system has file
rules programming language. Everything that a user designs using the Development Workbench Modules 34 will be stored in a Local Repository 60 in the PC Environment 3. Eventually, the data in the Local Repository 60 are used to populate the Central Repository 4, which resides on the mainframe 1 environment. Everything that constitutes documentation or implementation of a system must be defined to the Central Repository 4, during the development cycle. Ultimately, the application is distributed, for example, to end-user PC workstation environments 3 (and other environments as appropriate) from the Central Repository 4.

However, use of the Development Workbench Modules 34 need not be connected to the Central Repository 4 at all times. For performance reasons, it is advantageous to avoid constantly querying the Central Repository 4 for information. Uploading from and downloading to the Central Repository 4 is done via the Communications Manager 8 that accesses to the Local Repository 60.

The Local Repository 60 is a storage device located in the PC Environment 3. A Database Engine Module 54 comprises software to store information and access it. A Local Repository Engine 52 provides the user access to the Development Workbench Modules 34 and enables the Development Workbench Modules 34 to access the Local Repository 60 via the Database Engine Module 54.

A Hierarchy Diagrammer Module 38 is provided in the Development Workbench Modules 34, to enable a user to specify the data and process modules that provide the logical foundation for the application program. The Hierarchy Diagrammer Module 38 could for example include an Entity-Relationship Diagrammer, which
analyst and a programmer. The analyst can enter his thoughts, generate menus reflecting the input, and solicit input (modifications) from the programmer as to whether this is in fact the way the user envisions the way a problem is to be solved.

Once the application problem has been reduced to a series of Function Entities 90 and Process Entities 92, technical design begins. In technical design the program coding specifications are described through the Rule 94, Component 96 and Window 98 Entities.

The important aspect of Technical Design is the specification of the Rules and Components, Windows, and Views that are necessary to run the program. FIG. 7 is an example of Process flow diagram using entity-relationship modeling standards. The Square boxes in the figure, 134, 136, 138, 140, 142, 144, represent Process and Function Entities. The capsule-shaped boxes, 148-182, represent Rules. The oval-shaped boxes, 184, 186, 192, 194, 196, represent Components. The circles, 188, 190, represent Windows. The process flow diagram is used to specify the information contained in the Rule 94, Component 96, Window 98 and View 100 Entities (see FIG. 5) as well as the Relationships between them.

Referring now to FIG. 2 there is illustrated Development Workbench Modules 34, used to generate the entity relationship model and rules language code. FIG. 2A illustrates an exemplary implementation of the Modules 34 in a three-tiered system, wherein the Development Workbench Modules 34 reside in the PC Environment 3. The Development Workbench Modules 34 comprise a series of graphic-based tools that help a user design and implement an application by providing a pre-selected set of entities and relationships and a
list of windows files previously defined in the Local Repository 60. Clicking on one of these Window names will bring up a panel upon which you can "paint" the objects that will be presented to the end-user of the user's application.

In addition to the panel screen, there are primarily two types of objects to manipulate: entity objects and local objects.

Entity objects are Field 102 and View 100

Entities that have been defined and reside in the Local Repository 60. A Views menu can provide a list of View Entities 100 that are attached to the Window that a user is painting, followed by the selectable Field Entities 102 and multiply-occurring sub-views that are in turn attached to them. A user can select any of these available objects, place them on the panel, and customize them.

Fields could appear as empty bracketed boxes with a screen label to the left. The value of the Field (if any) appears between the brackets at runtime. The screen label was defined when the Entity was created and is associated with the Field in the Repository 4. A user can edit the screen label as a text object on the panel. If the screen label field of the Field entity is blank, then the Field short name is used instead.

These objects could be moved about the panel by clicking on the object and holding down the mouse button while dragging the object to the desired location.

Local objects are associated with the panel but are not defined to the Local Repository 60. The user could select Local Objects from an Objects menu. There are three types of Local Objects:

Control Objects, which can be selected by the
could be used for data modeling -- i.e. specifying the entity relationship model for the real-word data that will be used by the application program. With the Entity Relationship Diagrammer, a user can graphically identify entities and decompose the entities into sub-entities and defining attributes. For example, in FIG. 4, a Corporation 70 was decomposed into sub-entities Product 72, Staff 74 and Customer 76. The Entity Relationship Diagrammer provides modules to graphically specify such entities and relationships.

The Development Workbench Modules 34 could also include a Matrix Builder Module 42 that enables a user to store, in matrix form, mappings between different types of entities. The matrix mappings are typically used in the strategic planning phase of analysis to capture the relationships between data and process flow. The matrix created will also be saved in the Local 60 and Central Repositories 4.

Window Painter Module 16 enables a user to create panels, which are the interface through which the end-users of an application interact. The Window Painter Module 16 panels determine the "look and feel" of an application.

Using the Window Painter Module 16, the user can either create a new Window File for the related window entity or modify a previously created Window File that was stored in the Repository 4.

Using the example of a PC that is processing with the Microsoft Windows operating system, the Window Painter Module 16 provides the software necessary for a user to create graphic interface in that environment.

For example, a user could access the Window Painter Module 16 from the Development Workbench, where a blank window could appear. A user could then select a
Repository 60. This module uses the Local Repository Engine 52, the Database Engine 54 and the Communications Manager Module 8 in the PC Environment 3 to access data in the Local Repository 60, and send and receive data from the Central Repository 4. Using the DBA Module 44, objects and attributes can be selected from the Repository 4 for alteration or deletion. The DBA Module 44 includes a system security component, requiring users to log in to the mainframe environment 1 and only certain classes of users can have authorization to delete specific objects. The refresh feature enables users to download objects from the Repository 4.

The Development Workbench Modules 34 enables users to specify the data modelling necessary to specify the entities and relationships, as well as to input the rules, components, views, field and window panels necessary to create the final executable program in later development steps. Using the Development Workbench Modules 34 these logic structures can be stored in the Repository 4.

**F. Constructing the Program**

With the Entity-relationship model in place program construction can begin. Source code is generated from the Rules Language Modules, Components, Windows, Files, Fields, Views, Values and Sets that are stored in the Repository. Rules, Components, Windows and Files are Program Modules distinct from the Rule Entities 94, Component Entities 96, Window Entities 98 and File Entities 120 linked in the entity-relationship model (see FIGS. 5 and 6). Those Entities store information about the actual program modules from which the application program is created.

At this stage of construction much of the work
end user, with a mouse. Control Objects include pushbuttons, pushboxes, menu bar items, and pulldown items. Text Objects, which can be placed on the panel as labels or instructional messages.

By controlling placement of the screen objects, a user can build a window associated with a View Entity 100, and save that window specification for routine applications in the Local Repository 60 and in the Central Repository 4. The window files created in this example will be used to create the user interface of an application program. The converse function described more fully below provides the software modules to link the user specified window file to the windows provided graphic interface routines.

The Rules Painter Module 30 provides the interface to allow users to create Rules Language Modules that are associated with the Rule Entities 94. The Rules Language Modules and Rule Entities are linked. Each Rule Entity contains information concerning the functionality of the rule and the name of a corresponding Rules Language Module. The corresponding Rules Language Module contains statements to execute the functionality of the linked Rule Entity. Typical statements comprising rules language are described more fully below.

The Report Painter Module 40 is used to design formats for end user reports in a manner similar to that of specifying windows for graphical interface using the Window Painter Module 16.

The Database Administration Module (DBA) 44 is a communications facility that enables a user to refresh data in the Local Repository 60 and upload changes to the Central Repository 4. The DBA Module 44 is also used to generate reports about the contents of the Local
programmers to discover previously coded Rules and Components. A Find Where query will search all entity attributes throughout the entire database for particular words or character strings.

In addition the CASE facility allows programmers to define a keyword for all Rules, Components and Field created. A Search command can be performed to locate entities possessing a certain keyword. A programmer can perform sophisticated searches such as find all keywords starting with, for example, "CU" and ending with "Pp".

Once a programmer has located a module that may be re-usable, he or she can get further information by browsing the description or other attributes associated with the entity.

2. The Rules Language

The Rules Language is a high-level programming language which supports all standard flow of control constructs. What is unusual about the Rules Language is that it does not require a means of describing elaborate data structures, and it has data constructs which access information in the entity/relationship modules. The description of all the data structures used by a program within the CASE facility is stored in the View and Set Entities in the program's entity-relationship model. All Rules used by a program share data structures. The sharing of data structures provides strict coordination between the data passed from one Rules Language Module to another. This technique avoids one of the major sources of program errors -- a mismatch between the data passed between subroutines.

A Rule consists of zero or more declare statements followed by zero or more executable
in constructing the program modules is done. The data structures are defined by the View 100, Field 102, Set 116, and Value 118 Entities. The Code Generator Facility 24, FIG. 2, copies these entities into the program modules that are related to them by the Rule 94 and Component 96 Entities (see FIG. 5). Component Modules do not need to be built by the programmer, as they are previously programmed subroutines provided by the CASE facility to perform basic mathematical operations and operating system access. However, the CASE facility permits new components to be constructed and stored in the Repository 4, FIG. 2. The process of code generator is described more fully below.

15 1. Re-Usability Analysis

Even before the creation of the Rules Language Modules, using, as for example, the Rules Painter Module, the CASE facility speeds program development, because it provides a method to re-use previously generated code. With entity-relationship modeling, much of the same logic from one application can be re-used in other applications. It is easier to re-use code that has already been developed and tested than to re-create it. Keeping this in mind, a re-use analysis should be performed.

With the entity-relationship model stored in the Repository 4, FIG. 2, the Entities can be queried for usage by other Entities. For example, with the Repository 4 existing on a database supported by IBM DB2, a Where Used query on the Field Entity 122, FIG. 5, returns a list of all the View Entities 100A using that Field Entity 122. The usage of the View Entities can be queried further to establish what Rules, Components or Windows use those View Entities. This method allows
Four statements in the Rules Language handle the external flow of control between program modules. The USE statement enables one program module to invoke another Rule or Component. It is similar to a subroutine CALL statement in other programming languages. The syntax is:

```
USE MODULE Component
USE RULE Rule [ NEST ]
```

The next option indicates that all Windows invoking the Rule will come in "pop up" mode; i.e., it will be displayed over the screen that was previously displayed.

The RETURN Statement transfers control back to the Rule that executed the USE statement:

```
RETURN.
```

The CONVERSE statement provides communication between PC-based rules and the user interface. A typical converse statement is:

```
CONVERSE WINDOW window
```

The converse statement invokes at runtime several modules provided by the present invention to physically execute the converse relationship between window and rule. In the example of a PC resident rule accessing a PC based window, the converse modules would reside in the PC environment and interface the operating system of that environment to provide graphic user interface.

The function of the converse modules is to manage all the screen input and output for a rule. The modules send to the rule the user's input by populating a specified field. Prior to passing the end-users input to the rule conversing the window, the converse modules perform edit checking and validation of every input field specified by the attributes defined in the
statements.

A data type declared must be one of the following type: Smallint, Integer, Char, Varchar, Decimal, Signed Picture or Like (an already declared Item). The declare statement is in the form:

```
DCL
  declaration; [declaration; ...]
ENDDCL
```

where the declaration is:

```
identifier [ (s) ] [, identifier [ (s) ], ...]
declare type or EXTERN identifier [,
  identifier, ...]
SET
```

The data types are more fully explained in Appendix C attached hereto.

The Rules language supports three types of executable statements: 1) Assignment statements; 2) External flow of control statements; and 3) Internal flow of control statements:

<table>
<thead>
<tr>
<th>Assignment Statements</th>
<th>External Flow of Control Statements</th>
<th>Internal Flow of Control Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP</td>
<td>USE</td>
<td>IF</td>
</tr>
<tr>
<td>OVERLAY</td>
<td>RETURN</td>
<td>CASEOF</td>
</tr>
<tr>
<td>CLEAR</td>
<td>CONVERSE</td>
<td>DO</td>
</tr>
<tr>
<td></td>
<td>ASYNC</td>
<td></td>
</tr>
</tbody>
</table>

Assignment statements alter the data contained in and held by program variables. The MAP Statement places an expressed value in a variable location. The OVERLAY statement replaces the contents of a variable with specified data item. The CLEAR Statement replaces numeric fields with zero values and character fields with space values. The syntax of the assignment statements is:

```
MAP expression TO variable
OVERLAY data item TO variable
CLEAR variable
```
The CASEOF statement selects one of several alternative execution paths based on the value of a variable. The syntax is:

```
CASEOF variable
  CASE constant [ constant ... ] [ executable stmt
    ... ]
  [ CASE constant [ constant ... ] [ executable stmt ... ]
    [ CASE OTHER
      ENDCASE]
```

A DO statement controls the execution of repetitive loops. The syntax is:

```
DO [ FROM data item ] [ TO data item ] [ BY data item ] [ INDEX variable ] [ executable stmt ... ]
  [ WHILE condition [ executable stmt ... ]]
ENDDO
```

All data items and variables specified to execute a DO loop must be integer numbers. The defaults for the DO statement are: FROM = 1, TO = n, BY = 1, where n is an integer.

Conditions occur within the IF, CASEOF, and DO statements. A simple condition is:

```
expression logical operator expression
  or  expression INSET  Set
```

where logical operator is one of the following:

```
=  <=
<>  >
<  >=
```

A condition is built from simple conditions or other conditions:

```
simple condition
or ( condition )
or NOT condition
or condition AND condition
or condition OR condition
```

The INSET statement is used to determine
repository. If for example there was a specified set of values related to a rule for a given field (e.g. if a color field could only equal "red" or "blue" any answer "green" would be an error).

In creating the user screen, it is also the function of the converse module to interface with the operating system to output the user interface screens specified by the window files.

The Rules Language supports Asynchronous data flow with the ASYNC statement. For example, in a system using a Stratus mini computer performing in parallel, unsolicited data allows a Stratus-based Rule to send data to a PC-based Rule. This is supported using the following statements:

```
~ ASYNC ATTACH
~ ASYNC DETACH
~ ASYNC REFRESH
~ ASYNC ROUTE
```

The ASYNC ATTACH command will initiate the receiving of unsolicited input as for example by a PC-based Rule sent by a Stratus-based Rule. The ASYNC DETACH command performs the exact reverse of ATTACH. It may only be used after an ATTACH command, at which point it will discontinue the receiving of unsolicited input. The ASYNC ROUTE command switches data refreshing from one PC Rule to another. The ASYNC REFRESH statement will induce automatic updating of a specific field, so long as the Attach Statement has been used.

The Rules language has three different statements to order the flow of control within a Rule.

An IF statement controls execution based on a specified condition:

```
IF condition [ executable stmt ... ]
[ ELSE [ executable stmt ... ] ]
ENDIF
```
G. Code Generation

Once an application has been modeled, and the Rules, Components and Windows have been created, the CASE facility produces source code.

Preparation is the code generation phase. When an application is prepared, the View 100 and Set 116 Entities, FIG. 5, are used to create copybooks. A copybook is a file which is copied into the source code of a program module. The CASE facility creates a copybook for each data structure and includes a copy of that file in every executable Rule, Window or Component related to a particular View or Set.

Preparation also generates environment-specific source code for each Rule Language module. The Rule Entity 94, FIG. 5, contains an attribute specifying the environment destination of each Rule Module. The Code Generator, 24, FIG. 2, takes high-level Rules Language statements and translates them into source code in a language supported by the hardware environment of the Rule's destination. For example, if a Rule was to be executed on a Personal Computer that supported only the C language, the Code generator would translate the Rule Language Statements in C.

If the Rule Language statements specified in a module can be successfully generated into source code, the code is stored in files in the Repository 4. However, if there are logical errors in the Rule Language statements, no code is saved and error messages detailing the unsuccessful result are saved in a Failed Results File.

Once preparation has been performed, detailed reports can be made for each Entity in the entity-relationship model. Those reports are a program's technical documentation.
whether a given variable or constant appears as a value within a SET. For example suppose X is a data item whose data type is compatible to the data type of the set:

```
X INSET SET NAME
```

is a condition which evaluates to either TRUE or FALSE depending on whether or not at least one of the values, in SET NAME matches the value of X.

A programmer uses the Rules Language statements to write out the logic of the program. For further information on the Rules Language, reference should be made to Appendices A-F attached hereto.

3. User Interface Windows

The user interface for any application is constructed using the CASE facilities Window Painter 8, FIG. 2. As described above, he Window Painter Module 16 is the program designed to help build user interface in a given operating system. In the example of the PC environment above the rules painter would interface with the Microsoft Window Operating System. The Window Painter Module 16 would then feature the mouse-based use interface.

The Window Painter Module 16 is also used to create screen mappings of data designated in the Field 102 and View Entitles 100 (see FIG. 5). The Window Painter Module 16, FIG. 2, creates a file. That file contains data to create a screen mapping of the Window View. After creating and saving the panel, the CASE facility of the invention also generates other files, such as for example a file that contains the code for the "painted" panel. Another file could contain the code for the menu structures used by a panel.
the mainframe environment 2 from the PC environment 3, a main view module 36 provides access to the mainframe environment 1, via the communications manager module 8, creating an emulation of a non-intelligent terminal in the PC environment.

From the PC environment 3, access to the minicomputer environment 2 in this example is provided by a Talk View Module 46, which communicates with the System 88 Front-end Module 56 using a PC connect module 50, and file translation module 48. At this stage of development, each generated module’s source code statements can be examined with a Rule View Debugger associated with each respective environment. The Rule View Debugger is an aspect of the Testing Facility 10 of the present invention and is described more fully below. Successfully tested modules can be stored in the Central Repository 4.

I. Assembly

When all the source code modules of an application have been distributed to each environment, they must be assembled into a running computer program. The steps are to: 1) Compile the source code into object code; 2) Enable communication routines to allow interaction of program modules across environments; and 3) Bind or link the compiled code.

Assembly must be executed in each environment where program modules were distributed. For example, on a system incorporating PC processing, the PC will have a PC-based System Assembler 28, FIG. 2, that will enable a programmer to compile and bind the PC-based rules.

In the same example, separate assembly would have to be completed on a mini computer. For example on an IBM S/88 or Stratus mini computer, a command such as
The reader is referred again to FIG. 2A which depicts an example of an implementation of the Code Generation Module 24, FIG. 2 in the three-tiered environments of mainframe 1, minicomputer 2, and PC 3. In that example the source code for each of the Rules Language Modules, need not be generated in the hardware environment that will be each rule’s destination; however, the step of compilation of that source code would occur in the destination environment of the corresponding rule. In the PC environment 3, a Prepare Facility 59, FIG. 2A could prepare, for example C language source code, for each PC executable rule using the Rules Language Code, and all view fields and component windows associated with that rule module’s rule entity. The Prepare Facility 59 could also generate for example COBOL source code for rules designated to execute on the mainframe. In the mainframe environment 1, a mainframe front-end module 57 provides the ability to translate the Rules Language Module statements to the source code language statements supported by the hardware environment of that rule’s destination. The System 88 HPS front-end module 56 performs the same task in a minicomputer environment.

To perform code generation in the example, the code generation module in each environment uses the rules language modules plus information needed from the entity relationship model. To transport the Rules Language Modules and generate source code modules to the different environments, the user can, using the database administration module (DBA) 44, upload the module files to the Central Repository 4, and then, using separate modules 34, 46 to download the information to specific environments for compiling.

In the case of a rule designed to execute on
A Component assembler in a mainframe environment would perform these functions:

- provide the facilities for a programmer to compile his Component in a language supported by the system;

- allow the programmer to view the results of his compile (compile listing and link edit map);

- display a list of other Rules and Components affected by the setup of a particular Component;

- allow the user to edit the source code of a mainframe Component;

J. Execution

Upon successful assembly of the application modules in each hardware environment the program can now be executed and tested. The CASE facility provides the ability to execute and test the application from any environment in the hardware architecture. For example, using the hardware architecture comprised of an IBM Mainframe, an IBM Stratus mini computer and PC workstation, as in FIG. 1, a programmer seated at a PC would have the option to:

- Execute the PC based portion of an application; no links will be created with modules executing in Stratus or Mainframe other environment;

- Test the modules and modular executing in one other environment. In this case links are created with utilities other environments. This permits communication between environments;

- Execute or test the entire program. In this case links are created with each of the required execution environments.
"Build the Rule Router Application" would take the Frontier Rules and link them to every other Rule modules related to it in the mini-environment. The function also binds the code into an executable module.

Mainframe program modules are separately assembled. For example, in the exemplary IBM environment supported by the CICS operating system and DB2 relational database, a mainframe-based System Assembler 28, FIG. 2, provides assembly functions for the Rule and Component source code. For a Rule, an assembler would:

- verify that the Rule is a valid mainframe rule;

- verify that the Rule has completed the code generation process;

- prompt the user to indicate if the Rule is to be setup as a Frontier Rule;

- read the Bind file to load the on-line Views File and the on-line Relationship File for runtime PCI and Conversion use;

- load the source code to the online Source file for rule View use;

- automatically perform the DB2 Bind based upon the relationships defined to the Repository for Frontier Rules that use Components which issue DB2 calls;

- display a list of other Rules and Components affected by the setup of a particular Rule;

- assign a unique Identifier and a unique DB2 Plan name for Frontier Rules that use Components which issue DB2 calls;

- Rebind a DB2 Plan for a Frontier Rule when one of the Rule's related Components, that issue DB2 calls, has been modified;

- remove the rule from the mainframe environment when the Rule is no longer needed;
process and examine the contents a View Copybook at any
point. Rule View gives programmers the ability to:

1. Initiate the execution of a Rule;
2. Break the interface between a Rule and a
   Second Rule or Component;
3. Step into the logic of a Rule;
4. Step over Rule or Component Module;
5. Step back to the beginning of a Module;
6. Examine and modify any Field within a
   View owned by the active Rule;
7. Review the active Rule’s source code;
8. Save any View data for future reference
   and re-use;
9. Print the Rule source code and View data.

Rule View will assemble at each breakpoint, a
list of Views that can be examined and edited. The
number of Views displayed depends on where and how Rule
View is used. In most cases, the Views available for
display will contain the input, output of the Rule being
executed. In more advanced situations -- where
asynchronous Rules are being debugged or multiple
applications are being tested -- many Views may be
available for examination. The contents of a View can
be printed or saved in a file.

The Rule View editor permits the programmer toedit any data by using a Field Editor. With the Field
Editor, a programmer can change any data by typing over
the old information. The editor also permits the user
to restore the contents of any field to its original
value.

To review a Rule’s source code, a Text Editor
provides an option where the line of source code
currently being executed is highlighted at all times.
If multiple modules are running under Rule View, the
source that is displayed will be the source code that
K. Revising an Application

The process of changing the elements in an application using the Entity/Relationship Modeling system and the Rules Language is a straightforward process. The database is entered and the program element is changed. However, small changes in this system can have large consequences. In general any entity type that Owns, Uses, or Includes Entities that have been changed will have to be reprepared or "Modified". The CASE facility accomplishes the modification through the Software Distribution System 32, FIG. 2. (See the aforementioned International Application incorporated by reference, supra.)

L. Testing Facility

Finally, the CASE system provides debugging and testing facility that enables users to evaluate the performance of a application.

Generally the applications are first inputed on the computer at code level. Traditional code debugging tools are designed for testing at the code level only. Instead, the CASE facility of the present invention provides a Rule View Module for high-level debugging which is part of the Testing Facility 10 depicted in FIG. 1. A version of Rule View would exist in each of the operating environments in a hardware configuration. Applications spanning more than one environment require a separate testing for the modules in each environment.

Calls to the Rule View Module are automatically embedded by the CASE facility when code is generated. Rule View runs the application in a Rules-level debugger locating errors and problems that occur. It can be used interactively to step through a Rules
appropriate terminals can be used when implementing the invention on other mainframe hardware environments. A non-intelligent terminal is used sometimes, because it is less expensive for a massive user group to access a single mainframe processor, rather than giving each user his or her own personal processor. In these instances, however, it might be that the programming specialists would still develop applications with a PC, using the same Development Workbench Modules 34 as described in FIG. 2A. Those development tools permit the programmer, for example, to build user interface files (i.e. window files) that are used in conjunction with the CASE facility converse function described above. Given that the end-user in the case above has no PC to converse the created windows, the graphic interface specified in the windows files would be useless.

However, the present invention provides a feature to create a graphical interface using a non-intelligent terminal converse (NITC) Module 140, FIG. 2A. The non-intelligent terminal converse module makes it possible to build applications that display graphic user interface to an end-user using, for instance, a non-intelligent device connected to a mainframe. The non-intelligent terminal converse module can also convert existing PC workstation software modules so that they can execute on a mainframe environment. By providing this function in the present invention, a mainframe executing application can be designed, constructed, debugged and prototyped completely within a PC environment, using the Development Workbench Modules 34, without accessing the mainframe until public distribution.

In the entity relationship model, the window entity is still specified for a window file that will be
Owens the data in the current View.

M. Software Distribution for General Use

The previous discussion of the CASE tool facility of the present invention was limited to the modeling and development of a single copy of an application program, distributed, as for example, across the three hardware environments of a PC, a minicomputer and a mainframe. A single copy of the modules comprising the program was distributed to the appropriate hardware environments, and the application was debugged and its performance was rated. However, once the application is tested and ready for general use many copies of the modules comprising the program need to be distributed and maintained. The Software Distribution System Module 32 of the present invention will distribute multiple copies of the modules of an application throughout a parallel processing hardware environment, so that many users can use the same program. For more information on the Software Distribution System see the aforementioned International Application.

N. Non-Intelligent Terminal Converse (NITC)

In addition to the hardware configuration mentioned above, the CASE facility of the present invention can be also implemented using a hardware configuration in which the ultimate user of the application program does not have access to a processing terminal, such as a PC. Instead, the end-user would have access only to a non-intelligent terminal. An example would be an IBM brand 3270 terminal connected to a mainframe computer such as the IBM 3090, specified as an exemplary embodiment above. However, other
present in PC environment Windows, including e.g. colors, editable and text Fields (i.e., for display only), Field display attributes (e.g., size or type of Field, range, etc.), Pushbuttons and other function key equivalents.

Following the construction of the Application on the PC Workstation, the objects that make up the application must be uploaded to the Mainframe to be prepared for execution.

The run-time portion of the Non-Intelligent Terminal Converse module manages all the converse functions and provides the facilities for a developer to dynamically modify the converse functions.

The primary function of the converse modules is to manage all the non-intelligent terminal screen input and output for a Rule conversing Window. In addition, the non-intelligent terminal converse module communicates the end-user’s actions to the Rule by populating a selected field with the selected text string. Prior to passing the end-user’s input to the invoking Rule, the converse module performs the necessary edit and validation of every input Field as specified by the attributes defined in the Repository and in the Window definition.

The non-intelligent terminal converse module is invoked every time a Rule converses a Window. When a Rule converses a Window, the non-intelligent terminal converse module reads a pre-determined file to obtain the physical attributes of the Window. These physical attributes are used to construct the data stream commands used to display the Window on a non-intelligent terminal device.

The non-intelligent terminal converse module performs edit and validation of all input Fields prior
used for graphic user interface on the mainframe.

In the PC environment the Development
Workbench Modules 34 enable a user to paint the window
objects (called panels) with which the end user of the
application interacts. The Window Painter Module is
discussed above.

The panel can be stored in the Central
Repository 4 as a file associated with the Window
entity. However, these panels must be designed using
screen objects that can be supported on the non-
intelligent terminal converse terminal device.

A window to execute on both the PC and non-
intelligent terminal can be specified for example by
selecting an option in the Window Painter Module 16.
The choice of the option converts the current Window
into a format that mimics the non-intelligent terminal
converse screen. For example, Fields could be
translated to row/column coordinates, Pushbuttons could
be moved to the bottom of the screen and require
keyboard equivalents. Selecting this choice also sets
the Window Painter Module in a non-intelligent terminal
panel building mode that prevents the placement of new
objects that cannot be supported by a non-intelligent
terminal converse terminal device.

The major difference between a PC Workstation
and a non-intelligent terminal device is that the non-
intelligent terminal converse device manipulates text
characters, while PC Workstation manipulates graphic
pixels which gives the PC Workstation a greater degree
of control. To account for this difference, the Window
Painter Module could, for example, convert all text
objects to a standard font.

The Windows created in the mainframe
environment support many of the features that would be
present in PC environment Windows, including e.g. colors, editable and text Fields (i.e., for display only), Field display attributes (e.g., size or type of Field, range, etc.), Pushbuttons and other function key equivalents.

Following the construction of the Application on the PC Workstation, the objects that make up the application must be uploaded to the Mainframe to be prepared for execution.

The run-time portion of the Non-Intelligent Terminal Converse module manages all the converse functions and provides the facilities for a developer to dynamically modify the converse functions.

The primary function of the converse modules is to manage all the non-intelligent terminal screen input and output for a Rule conversing Window. In addition, the non-intelligent terminal converse module communicates the end-user's actions to the Rule by populating a selected field with the selected text string. Prior to passing the end-user's input to the invoking Rule, the converse module performs the necessary edit and validation of every input Field as specified by the attributes defined in the Repository and in the Window definition.

The non-intelligent terminal converse module is invoked every time a Rule converses a Window. When a Rule converses a Window, the non-intelligent terminal converse module reads a pre-determined file to obtain the physical attributes of the Window. These physical attributes are used to construct the data stream commands used to display the Window on a non-intelligent terminal device.

The non-intelligent terminal converse module performs edit and validation of all input Fields prior
to returning control to the invoking Rule. For all numerical Fields, the non-intelligent terminal converse module ensures that the data entered is numeric and adjusts the significance based upon an entered decimal point or the implied decimal point specified in a numeric picture string.

For example, if a decimal Field is defined as five digits in length with two of the digits to the right of the decimal point and edited using a numeric picture string of "9999.9", a string of 123 entered into the Field will have the following results. The decimal Field will contain the value 12.30 and the screen field will display 0012.3. In addition to using numeric picture strings to edit and validate numeric input, a range limit can be set using the Window Painter Module to ensure that the numeric value entered is not beyond the minimum and maximum values of the specified range.

Character Fields are only validated if they are the input value matches by a Set of permissible Values. This Set and its Values are defined as entities to the Central Repository. To set a Field to require a set of permissible values, the name of the Set entity must be specified in the Field’s Reference File Attribute when setting the Field’s Object Edit Specifications using the Window Painter Module. The non-intelligent terminal converse module will verify that the entered character string is contained in the set of permissible values.

For any fields in error, the non-intelligent terminal converse module will flag the fields in error and will display an error message. For non-intelligent devices that support color, the fields in error could be highlighted.

As stated earlier, the pushbutton objects on
Reserved Symbols

<table>
<thead>
<tr>
<th>Characters</th>
<th>Description</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>*&gt;</td>
<td>Left comment</td>
<td>-</td>
</tr>
<tr>
<td>&lt;=*</td>
<td>Right comment</td>
<td>-</td>
</tr>
<tr>
<td>(</td>
<td>Left parenthesis</td>
<td>LP</td>
</tr>
<tr>
<td>)</td>
<td>Right parenthesis</td>
<td>RP</td>
</tr>
<tr>
<td>=</td>
<td>Equal</td>
<td>EQ</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater or equal</td>
<td>GE</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than</td>
<td>GT</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal</td>
<td>LE</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than</td>
<td>LT</td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal</td>
<td>NE</td>
</tr>
<tr>
<td>;</td>
<td>Comma</td>
<td>COMMA</td>
</tr>
<tr>
<td></td>
<td>Semicolon</td>
<td>SEMI</td>
</tr>
</tbody>
</table>

Repository Entity Identifiers

- MODULE NAME
- RULE NAME
- WINDOW NAME
- VIEW NAME
- SYMBOL NAME
- SET_NAME

PRECEDENCE TABLE

The following precedence table lists the precedence or binding power of the Rules Language operators in increasing order. Operators which occur on the same line have amongst themselves the same binding power.

- OR
- AND
- NOT
- EQ
- NE
- LE
- LT
- GE
- GT
- INSET
- MINUS
- IN
- OF

The right column describes the associativity of the operations. We can see from the "AND line' of the precedence table that it is perfectly legal to write for conditions cond1, cond2, cond3

```
cond1 AND cond2 OR cond3
```

and that implied order or parsing is first

```
cond1 AND cond2
```

and afterwards
APPENDIX A: RULES LANGUAGE SYNTAX

Tokens of the Rules Language

Tokens are the atoms from which a programming language is built. All reserved words such as IF, AND, FROM, ... represent tokens of the Rules Language. Other examples are special symbols such as "(" (left parenthesis), ")" (right parenthesis), "<=" (less or equal relational operator), and the like. Finally you will also encounter tokens such as DICT_view (View Name) which denote references stemming from the Repository.

Reserved Words

<table>
<thead>
<tr>
<th>Reserved Word</th>
<th>Reserved Word</th>
<th>Reserved Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>EVERY</td>
<td>OVERLAY</td>
</tr>
<tr>
<td>ALL</td>
<td>EXISTS</td>
<td>PC</td>
</tr>
<tr>
<td>AND</td>
<td>EXP, EXP 10</td>
<td>PREV</td>
</tr>
<tr>
<td>ASCENDING</td>
<td>EXTERN</td>
<td>PUT</td>
</tr>
<tr>
<td>ASYNCH</td>
<td>EXTRACT</td>
<td>QUEUE</td>
</tr>
<tr>
<td>ATTACH</td>
<td>FALSE</td>
<td>REFRESH</td>
</tr>
<tr>
<td>AVG</td>
<td>FIELD</td>
<td>RETRIEVE</td>
</tr>
<tr>
<td>BEEP</td>
<td>FLASH</td>
<td>RETURN</td>
</tr>
<tr>
<td>BY</td>
<td>FORALL</td>
<td>RIGHTJ</td>
</tr>
<tr>
<td>CASE</td>
<td>FROM</td>
<td>ROUND</td>
</tr>
<tr>
<td>CHAR</td>
<td>IF</td>
<td>ROUTE</td>
</tr>
<tr>
<td>CICS</td>
<td>IN</td>
<td>RULE</td>
</tr>
<tr>
<td>CLEAR</td>
<td>INDEX</td>
<td>SET</td>
</tr>
<tr>
<td>COMPONENT</td>
<td>INSET</td>
<td>SETERROR</td>
</tr>
<tr>
<td>CONVERSE</td>
<td>INTEGER</td>
<td>SMALLINT</td>
</tr>
<tr>
<td>CURRENT</td>
<td>LEFTJ</td>
<td>SPACES</td>
</tr>
<tr>
<td>DCL</td>
<td>LENGTH</td>
<td>SQL</td>
</tr>
<tr>
<td>DELETE</td>
<td>LIKE</td>
<td>SQRT</td>
</tr>
<tr>
<td>DEPENDING</td>
<td>LOG, LOG10</td>
<td>STRATUS</td>
</tr>
<tr>
<td>DESCENDING</td>
<td>MAP</td>
<td>STRING</td>
</tr>
<tr>
<td>DETACH</td>
<td>MAX</td>
<td>SUBSTRING</td>
</tr>
<tr>
<td>DIV</td>
<td>MIN</td>
<td>SUM</td>
</tr>
<tr>
<td>DO</td>
<td>MOD</td>
<td>TO</td>
</tr>
<tr>
<td>DOMAIN</td>
<td>MODULE</td>
<td>TRIM</td>
</tr>
<tr>
<td>ELSE</td>
<td>MOVE</td>
<td>TRUE</td>
</tr>
<tr>
<td>EMPTY</td>
<td>NEST</td>
<td>TYPE</td>
</tr>
<tr>
<td>ENDCASE</td>
<td>NEXT</td>
<td>USE</td>
</tr>
<tr>
<td>ENDDCL</td>
<td>NOT</td>
<td>VIA</td>
</tr>
<tr>
<td>ENDDO</td>
<td>NUMERIC</td>
<td>VIEW</td>
</tr>
<tr>
<td>ENDEXTERN</td>
<td>OCCUR</td>
<td>WHILE</td>
</tr>
<tr>
<td>ENDFORALL</td>
<td>OF</td>
<td>WINDOW</td>
</tr>
<tr>
<td>ENDIF</td>
<td>ON</td>
<td>ZERO</td>
</tr>
<tr>
<td>ENDSSET</td>
<td>OR</td>
<td>ZEROES</td>
</tr>
</tbody>
</table>
Reserved Symbols

<table>
<thead>
<tr>
<th>Characters</th>
<th>Description</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>*&gt;</td>
<td>Left comment</td>
<td>-</td>
</tr>
<tr>
<td>&lt;</td>
<td>Right comment</td>
<td>-</td>
</tr>
<tr>
<td>(</td>
<td>Left parenthesis</td>
<td>LP</td>
</tr>
<tr>
<td>)</td>
<td>Right parenthesis</td>
<td>RP</td>
</tr>
<tr>
<td>=</td>
<td>Equal</td>
<td>EQ</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater or equal</td>
<td>GE</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than</td>
<td>GT</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal</td>
<td>LE</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than</td>
<td>LT</td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal</td>
<td>NE</td>
</tr>
<tr>
<td>,</td>
<td>Comma</td>
<td>COMMA</td>
</tr>
<tr>
<td>;</td>
<td>Semicolon</td>
<td>SEMI</td>
</tr>
</tbody>
</table>

Repository Entity Identifiers

MODULE_NAME
RULE_NAME
WINDOW_NAME
VIEW_NAME
SYMBOL_NAME
SET_NAME

PRECEDENCE TABLE

The following precedence table lists the precedence or binding power of the Rules Language operators in increasing order. Operators which occur on the same line have amongst themselves the same binding power.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Associativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR</td>
<td>left to right</td>
</tr>
<tr>
<td>AND</td>
<td>left to right</td>
</tr>
<tr>
<td>NOT</td>
<td>right to left</td>
</tr>
<tr>
<td>EQ, NE</td>
<td>non-associative</td>
</tr>
<tr>
<td>LT, LE</td>
<td>non-associative</td>
</tr>
<tr>
<td>GE, GT</td>
<td>non-associative</td>
</tr>
<tr>
<td>INSET</td>
<td>non-associative</td>
</tr>
<tr>
<td>MINUS</td>
<td>left to right</td>
</tr>
<tr>
<td>IN</td>
<td>non-associative</td>
</tr>
<tr>
<td>OF</td>
<td>right to left</td>
</tr>
</tbody>
</table>

The right column describes the associativity of the operations. We can see from the "AND line' of the precedence table that it is perfectly legal to write for conditions cond1, cond2, cond3

\[
\text{cond1 AND cond2 OR cond3}
\]

and that implied order or parsing is first

\[
\text{cond1 AND cond2}
\]

and afterwards
Another example: Given a partial qualification

\[ V_1 \text{ OF } V_2 \text{ OF } V_3 \]

involving three Views \( V_1, V_2, V_3 \) then the parser first recognizes

\[ V_2 \text{ OF } V_3 \]

and afterwards

\[ V_1 \text{ OF } V_2. \]
do_idx_stmt
assign_stmt: MAP expr TO variable
overlay_stmt: OVERLAY dat_item TO variable
clear_stmt: CLEAR variable
use_stmt: USE MODULE MODULE_NAME
use_stmt: USE RULE RULE_NAME nest_clause
nest_clause: (empty)
return_stmt: RETURN
converse_stmt: CONVERSE window_clause
window_clause: WINDOW WINDOW_NAME
async_stmt: ASYNC attach_detach RULE_NAME VIA RULE RULE_NAME
async_stmt: ASYNC ROUTE RULE RULE_NAME TO RULE RULE_NAME
async_stmt: ASYNC refresh_stmt
attach_detach: ATTACH
attach_detach: DETACH
refresh_stmt: REFRESH window_clause
refresh_stmt: field_clause
refresh_stmt: view_clause
refresh_stmt: occur_clause
refresh_stmt: beep_clause
refresh_stmt: flash_clause
view_clause: (empty)
view_clause: VIEW data_item
field_clause: (empty) clause
field_clause: FIELD data_item
occur_clause: (empty)
occur_clause: OCCUR data_item
beep-clause: (empty)
beep-clause: BEEP
flash_clause: (empty)
flash_clause: FLASH
cond_stmt: if_stmt
cond_stmt: case_of-stmt
if-stmt:
  | IF cond stmt-list ENDIF
  | IF cond stmt_list ELSE stmt_list ENDF

case_of_stmt:
  | CASE OF caseof_var case_list ENDCASE
  | CASE OF caseof_var case_list CASE OTHER
  | stmt_list ENDCASE

caseof_var:
  variable

case_list:
  single_case
  | case_list single_case

single_case:
  CASE case_lit_list stmt_list

case_lit_list:
  lit
  | set_const
  | MINUS int_lit
  | MINUS dec_lit
  | case_lit_list lit
  | case_lit_list set_const

do_stmt:
  DO stmt_list WHILE cond stmt_list ENDDO
  | DO stmt_list ENDDO

do_idx_stmt:
  DO do_clauses stmt_list while_clause ENDDO

do_clauses:
  from_clause to_clause by_clause
  | index_clause

from_clause:
  (empty)
  | FROM expr

to-clause:
  | TO expr

by_clause:
  | BY expr

index_clause:
  | INDEX variable

while_clause:
  | WHILE cond stmt_list

cond:
  | simple_cond
  | LP cond RP
  | not cond %prec NOT
  | cond AND cond %prec AND
  | cond OR cond %prec OR

simple_cond:
  | expr rel_op expr
  | expr INSET SET_NAME

rel_op:
  | EQ
  | NE
  | num_rel_op
num_rel_op: 
  LT
  LE
  GT
  GE

variable: 
  simple-var
  qual-id qual_var_list
  simple_var subscr_unit
  qual_id qual_var_list subscr_unit

subscr_unit: 
  LP item_list RP

item_list: 
  expr
  expr COMMA expr
  expr COMMA expr COMMA expr

qual_var_list: 
  OF VIEW_NAME
  qual_var_list OF VIEW_NAME

dat_item: 
  variable
  lit
  set_const

set_const: 
  SYMBOL_NAME
  SYMBOL_NAME IN SET_NAME

lit: 
  char_lit
  int_lit
  dec_lit
Comments

Comments are enclosed between "**" and "*" as delimiters. Comments cannot be nested. There is no limit to the length of a comment.

*> This is an example of a comment <*
*> This is <** *>another example <**> of a comment <*

*> It is
* perfection OK to
* spread a comment
* over more than
* one line
* and use * or < on their own
<*

Input past column 72 is treated as a comment (i.e., ignored).

Data Items

Data items are the variable and constants of the Rules Language. Figure 6-5 shows how these items are related to one another.

```
Data Item
   Variable
      Field
         View
   Constant
      Literal
         Character Literal
            Numeric Literal
            Set Symbol
```

Figure 3  Data Item Hierarchy Table

Variables

Variables are defined using the View and Field HPS entities. Fields and Views are defined and described outside of the Language itself using the facilities of the Repository. Note that, with certain restrictions, Fields and Views can be declared local to Rule Block by means of the DCL construct!
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>(</td>
<td>Left parenthesis</td>
<td>Grouping; subscripts</td>
</tr>
<tr>
<td>)</td>
<td>Right parenthesis</td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>Equal symbol</td>
<td>To form symbols for relational operators</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than symbol</td>
<td></td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than symbol</td>
<td></td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal symbol</td>
<td>Test for inequality</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal to symbol</td>
<td>Test for less than or equal to</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater than or equal to symbol</td>
<td>Test for greater than or equal to</td>
</tr>
<tr>
<td>-</td>
<td>Minus symbol</td>
<td>Negation</td>
</tr>
<tr>
<td>,</td>
<td>Comma</td>
<td>Separation of list element and subscripts</td>
</tr>
<tr>
<td>;</td>
<td>Semicolon</td>
<td>Termination of declaration of local fields</td>
</tr>
<tr>
<td>+</td>
<td>Addition</td>
<td>For future use</td>
</tr>
<tr>
<td>*</td>
<td>Multiplication</td>
<td></td>
</tr>
<tr>
<td>/</td>
<td>Division</td>
<td></td>
</tr>
<tr>
<td>++</td>
<td>Union</td>
<td></td>
</tr>
<tr>
<td>**</td>
<td>Intersection</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>Set difference</td>
<td></td>
</tr>
<tr>
<td>&lt;&lt;</td>
<td>Sub-Set</td>
<td></td>
</tr>
<tr>
<td>&gt;&gt;&gt;</td>
<td>SuperSet</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2  Binary and Unary Rules Language Operators
Comments

Comments are enclosed between "*" and "==>" as delimiters. Comments cannot be nested. There is no limit to the length of a comment.

* This is an example of a comment *
* This is <** *>another example <**> of a comment <*

* It is
* perfection OK to
* spread a comment
* over more than
* one line
* and use * or < on their own
<*

Input past column 72 is treated as a comment (i.e., ignored).

Data Items

Data items are the variable and constants of the Rules Language. Figure 6–5 shows how these items are related to one another.

![Data Item Hierarchy Table]

Variables

Variables are defined using the View and Field HPS entities. Fields and Views are defined and described outside of the Language itself using the facilities of the Repository. Note that, with certain restrictions, Fields and Views can be declared local to Rule Block by means of the DCL construct!
Fields

A Field is a variable which behaves like an atom; that is, it cannot be divided into smaller units. With the exception of a limited facility for declaring fields local to a Rule program, Fields are defined using the facilities of the HPS Repository. They are not defined within a Rule. Some examples of Fields and their types follow.

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLD_1</td>
<td>SMALLINT</td>
</tr>
<tr>
<td>WORD_COUNT</td>
<td>INTEGER</td>
</tr>
</tbody>
</table>

In the example given above, FLD_1 is a two byte (signed) integer variable and WORD_COUNT is a four byte (signed) integer variable.

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLD_2</td>
<td>CHAR</td>
</tr>
<tr>
<td>CUSIP_DESCR</td>
<td>CHAR (20)</td>
</tr>
</tbody>
</table>

FLD_2 and CUSIP_DESCR are character Fields of lengths 1 and 20, respectively.

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUST_BAL_AMT</td>
<td>DECIML (15, 2)</td>
</tr>
</tbody>
</table>

CUST_BAL_AMT is a "Dollars and Cents" variable with up to 15 digits precision, two of which are to the right side of an implied decimal point. DECIMAL (p,q) Fields are signed quantities.

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASH_TXN_BAL_AMT</td>
<td>PIC S9999V99</td>
</tr>
</tbody>
</table>

CASH_TXN_BAL_AMT and CASH_TXN_CR_AMT are both numeric variables with up to 4+2 = 6 digits precision, two of which are to the right side of an implied (V="virtual") decimal point. The S in the first example denotes an optional sign whereas in the declaration:

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASH_TXN_CR_AMT</td>
<td>PIC 9999V99</td>
</tr>
</tbody>
</table>

CASH_TXN_CR_AMT cannot be negative.

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP_BUFFER</td>
<td>VARCHAR (50)</td>
</tr>
</tbody>
</table>

The constructs of the Rules Language do not distinguish TEMP_BUFFER from a CHAR (50) variable. Both CHAR (50) and VARCHAR (50) allocate 50 bytes of storage and in both cases anything that is moved into either of them will be left justified and padded to the right with spaces. A VARCHAR (n) variable keeps track of its "actual" length through the use of a separate length Field which is completely transparent to the Rules Language programmer.

The following table summarizes the Field types which are supported within the HPS Rules Language and some of their properties:
Note that in accordance with Paragraph 1, SUB_VIEW defines the same tree structure regardless of whether it appears as a child of CG_VW_10 or of CG_VW_13.

\[
\text{SUB_VIEW} \quad (05), \\
\text{CG_VARCHAR} \quad \text{VARCHAR} \quad (10), \\
\text{CG_CHAR} \quad \text{CHAR} \quad (10),
\]

**Figure 6 Sub-View Data Structure**

The Field CG_CHAR that belongs to the View SUB_VIEW that belongs to the View CG_VW_10 can contain different data from the Field CG_CHAR that belong to SUB_VIEW that belongs to CG_VW-13. In fact, they occupy different storage locations. Furthermore, CG_CHAR appears elsewhere—it is also a Component of CG_VW_11. How do you tell these instances apart within a Rules program?

First, write the fully qualified name of the ambiguously determined items (which may be either Fields or Views). The fully qualified name begins with the name of the item at the lowest level (which may be either a Field or a View) and works up to the top of the tree naming each of the Views (not Fields), separating each of the names with the reserved word OF. (This naming convention is borrowed from COBOL and is different from the one used in C and PL/I. For example, in the case of CG_CHAR we have

\[
\text{CG_CHAR OF SUB_VIEW OF CG_VW_11 OF VW_1} \\
\text{CG_CHAR OF SUB_VIEW OF CG_VW-13 of VW_1, and} \\
\text{CG_CHAR OF CG_VW_10 OF VW_1}
\]

**Figure 7 Fully Qualified Names**

The general notation is as follows:

Let X be a Field or View which has a parent V1 which has apparent V2 ... and so on.

Let Vn denote the top node ...

Then, the fully qualified name of X is:

\[
X \text{ of V1 OF V2 ... OF Vn.}
\]

These fully qualified names are sufficient to discriminate between the instances of CG_CHAR. In fact, they contain redundant information for the Rules code generator to discriminate between instances. To arrive at the necessary and sufficient information, simply delete the names of the Views which are common to the fully qualified names. Of course, do not delete the name at the base of the upward path to the top level View. Applying this to the above example results in:
SUB_VIEW, CG_BIT. The child SUB_VIEW of CG_VW_13 has the Fields CGVARCHAR and CG_CHAR, but no subordinate Views.

VW_1,

CG_VW_11

CG_DATE CHAR (08),
CGVARCHAR VARCHAR (10),
CG_CHAR CHAR (10),
CG_BIT CHAR (01),

CG_VW_13,

CG_DATE CHAR (08),
SUB_VIEW (05), *occurs 5 times* 
CGVARCHAR VARCHAR (10),
CG_CHAR CHAR (10),
CG_BIT CHAR (01),
CUSIP_DESCR CHAR (20),
CUST_BAL_AMT DECIMAL (15,2),
CASH_TXN_BAL_AMT PIC S99999V99,

CG_VW_10

SUB_VIEW (05), *occurs 5 times* 
CGVARCHAR VARCHAR (10),
CG_CHAR CHAR (10),
INT_RATE DECIMAL (7,7),
CG_BIT CHAR (01),

*Figure 5 Data Structure From View*

The above View, VW_1, illustrates many of the concepts underlying HPS data structures.

Each of the sub-Views belonging to the above tree structure is itself a tree structure of which it becomes the 01-level View. For example, CG_VW_10 defines a tree with CG_VW_10 as the top node, SUB_VIEW, INT_RATE and CG_BIT as its 2nd level leaves and nodes, and CGVARCHAR AND CG_CHAR as its 3rd level leaves.

A view is uniquely determined within the Repository through the name of its 01-level node. In other words, VW_1 stands for the whole collection of all the Views and Fields in the figure.

Views and Fields can occur more than once within a true. But they are not allowed to form recursive constructs by referring to themselves, either directly or through a chain of intermediate child or parent Views.

For example, CG_CHAR is a Field and SUB_VIEW is a View each appearing more than once within VW_1.
Note that in accordance with Paragraph 1, SUB_VIEW defines the same tree structure regardless of whether it appears as a child of CG_VW 10 or of CG_VW_13.

```
SUB_VIEW (05),
  CG_VARCHAR   VARCHAR (10),
  CG_CHAR      CHAR (10),
```

**Figure 6  Sub-View Data Structure**

The Field CG_CHAR that belongs to the View SUB_VIEW that belongs to the View CG_VW_10 can contain different data from the Field CG_CHAR that belongs to SUB_VIEW that belongs to CG_VW-13. In fact, they occupy different storage locations. Furthermore, CG_CHAR appears elsewhere—it is also a Component of CG_VW_11.

How do you tell these instances apart within a Rules program?

First, write the fully qualified name of the ambiguously determined items (which may be either Fields or Views). The fully qualified name begins with the name of the item at the lowest level (which may be either a Field or a View) and works up to the top of the tree naming each of the Views (not Fields), separating each of the names with the reserved word OF. (This naming convention is borrowed from COBOL and is different from the one used in C and PL/I. For example, in the case of CG_CHAR we have

```
CG_CHAR OF SUB_VIEW OF CG_VW_11 OF VW_1
CG_CHAR OF SUB_VIEW OF CG_VW-13 of VW_1, and
CG_CHAR OF CG_VW_10 OF VW_1
```

**Figure 7  Fully Qualified Names**

The general notation is as follows:

Let X be a Field or View which has a parent V1 which has a parent V2 ... and so on.

Let Vn denote the top node ...

Then, the fully qualified name of X is:

```
X of V1 OF V2 ... OF VN.
```

These fully qualified names are sufficient to discriminate between the instances of CG_CHAR. In fact, they contain redundant information for the Rules code generator to discriminate between instances. To arrive at the necessary and sufficient information, simply delete the names of the Views which are common to the fully qualified names. Of course, do not delete the name at the base of the upward path to the top level View. Applying this to the above example results in:
Figure 8  Edited Qualified Names

This is the minimal information which the Rule code generator requires to discriminate between the instances of CG_CHAR. Furthermore, this is also the minimal information your eye would need to tell the instances apart with a glance at an outline of VW_1.

There is, however, one type of ambiguity which cannot be resolved with fully qualified names if partially qualified names are permitted. Consider the following View structure:

```
VIEW0
  VIEW1,
    FIELD1,  /*first occurrence of FIELD1 */
    FIELD2,  /*first occurrence of FIELD2 */
    VIEW2,
      FIELD2, /*first occurrence of FIELD2 */
```

FIGURE 9  AMBIGUOUS FIELD STRUCTURE

VIEW0 contains FIELD1 as an ambiguous reference because the only sensible choices for (partially qualified) names for the first occurrence are either:

FIELD1

or

FIELD1 OF VIEW 10,

but both of them also make reference to the second occurrence of FIELD1. Note in contrast that one can clearly make a distinction between the contents of:

FIELD2 OF VIEW1,

and

FIELD2 OF VIEW2.

Subscripts

The Rules Language supports views with subscripts (OCCURS Attribute of the View-View/HPS relationship). They are the counterpart of tables in COBOL and arrays in C or PL/1.

Assume that VW-2 is a View defined in the HPS Repository as follows:
Mike's computer is broken

Note that single quotes must be used. Double quotes are not valid.

Sets and Symbols

A set is a collection of constant value data items. All constants are of the same data type. For example, all of them will be CHAR(6) or all of them will be SMALLINT. Because of this property we can refer to the data type of a Set. The constants of a Set behave like Fields rather than views in the following sense:

- They cannot be broken down into lower levels and
- they cannot have an Occurs clause.
- In addition, the whole Set does not have an Occurs clause.

Example:

```
SET MONTHSET SMALLINT,
    JAN VALUE 1,
    FEB VALUE 2,
    MAR VALUE 3,
    APR VALUE 4,
    MAY VALUE 5,
    JUN VALUE 6,
    JUL VALUE 7,
    AUG VALUE 8,
    SEP VALUE 9,
    OCT VALUE 10,
    NOV VALUE 11,
    DEC VALUE 12;
```

The example defines a Set called MONTHSET which is composed of a collection of twelve constants which represent the twelve months of a year. Their symbols are JAN, FEB, ..., DEC and their associated values are integer literals 1, 2, ..., 12.

MONTHSET is of the type SMALLINT which means the format of the values is SMALLINT. There cannot be a VALUE 3.21 nor VALUE "NOT AN SMALLINT" nor VALUE 1234565. This last example is invalid because an SMALLINT cannot exceed the number 32767.

This example will be used for further illustration of the Set concepts.

Each of the constants of a set possesses an identifier called a SYMBOL, and a value. The SYMBOL is a vehicle for referencing
the highest level number supported is 39.

**Constants**

Constants appear in the Rules Language in two manifestations:

- literals, and
- Set symbols.

They can represent:

- characters, such as "New York City," or
- (signed) integer numbers, such as 123 or 1234567, or
- (signed) decimal numbers such as 123.45 or 1234.50.

**Numeric Literals**

There are two types of numeric literals: integer numbers and decimal numbers. An integer is a sequence of one or more digits. A decimal number is a sequence of one or more digits followed by a decimal point which may be followed by zero or more digits. A negative number is expressed by preceding the digits with a minus sign.

For example, 0 and 123 are integers. 123.0, -7734.33 and 123.456 are valid decimal constants as is 0.456.

These literals have restrictions upon the number of digits they contain depending upon their type (integer or decimal). Integers consist of up to 15 digits while decimals contain up to 16 digits (15 + 1 for the decimal point). Positive numbers may not be preceded by a plus sign but negative quantities must be preceded by a minus sign.

**Character Literals**

A character literal is a '(single quote) followed by zero to 50 character (other than ') followed by' a’. The following are valid character literals.

'This is a valid character constant'

'ZYZZY and PLUGH are magic words'

The last example is a null string. If it is necessary to include a single quote character in the literal itself, the usual dodge of using two consecutive single quotes may be employed. For example,
Mike's computer is broken

Note that single quotes must be used. Double quotes are not valid.

Sets and Symbols

A set is a collection of constant value data items. All constants are of the same data type. For example, all of them will be CHAR(6) or all of them will be SMALLINT. Because of this property we can refer to the data type of a Set. The constants of a Set behave like fields rather than views in the following sense:

- They cannot be broken down into lower levels and
- they cannot have an Occurs clause.
- In addition, the whole Set does not have an Occurs clause.

Example:

```
SET	MONTHSET	SMALLINT,
    JAN	VALUE 1,
    FEB	VALUE 2,
    MAR	VALUE 3,
    APR	VALUE 4,
    MAY	VALUE 5,
    JUN	VALUE 6,
    JUL	VALUE 7,
    AUG	VALUE 8,
    SEP	VALUE 9,
    OCT	VALUE 10,
    NOV	VALUE 11,
    DEC	VALUE 12;
```

The example defines a Set called MONTHSET which is composed of a collection of twelve constants which represent the twelve months of a year. Their symbols are JAN, FEB, ..., DEC and their associated values are integer literals 1, 2, ..., 12.

MONTHSET is of the type SMALLINT which means the format of the values is SMALLINT. There cannot be a VALUE 3.21 nor VALUE "NOT AN SMALLINT" nor VALUE 1234565. This last example is invalid because an SMALLINT cannot exceed the number 32767).

This example will be used for further illustration of the Set concepts.

Each of the constants of a set possesses an identifier called a SYMBOL, and a value. The SYMBOL is a vehicle for referencing
the underlying value. A Set symbol can be used in the same way as a Field. The principal difference is that the value of a Set symbol is constant and can never be altered through a Rules statement, whereas the value of a Field can be changed; for example, by clearing it or making it the target of a MAP or OVERLAY Statement.

Assume SYMXXX is a symbol belonging to a Set SETYYY. It can be referenced in either of the following ways:

SYMXXX

SYMXXX IN SETYYY

The IN keyword was chosen instead of the OF keyword to avoid overloading the meaning of the latter with too many different uses. SYMXX must be qualified with its Set if SYMXX is used, within the Rule, either as the symbol of another Set or as a Field name or as a View name.

Referring back to the MONTHSET example:

```
MAR
MAR IN MONTHSET
3
```

note that each have exactly the same meaning, namely the number three.

```
MAP FEB IN MONTHSET TO XXXVAR OF YYYVIEW
```

has the effect of moving the value 2 into the Field XXXVAR which is, hopefully, properly declared somewhere within the Rule or its bind file as a numeric sub-Field of the View YYYVIEW.

Within a Set, there cannot be two or more symbols with the same symbolName. Note though that a Set can possess several symbols with one and the same value!

Other Identifiers

Besides data items, the following entities are used within a Rule:

- Rule Name
- Component Name
- Window Name
- Set Name

They will be described in detail during the discussion of the executable statements where they occur.
APPENDIX D: Executable Statements of Rules Language

Assignment of Value

Three types of statements alter the value of data contained in Fields and Views: MAP, CLEAR, and OVERLAY. The syntax and semantics of each will be described in turn.

MAP STATEMENT

Syntax

The syntax of the MAP statement is:

MAP data_item TO variable,

where data_item is a constant, a Field name, or a View name and variable is either a Field name or a View name. Recall that the Field or View names must be unambiguously qualified and these names may include subscripts.

Some examples follows:

MAP 'Syntax' TO CG_CHAR OF CG_VW_11

MAP CG_CHAR OF CG_VW_11 TO CG_CHAR OF SUB_VIEW OF CG_VW_I3(3)

MAP 23400.00 TO CUST_BAL_AMT

Figure 1 Example Map Statements

Semantics

The results of mapping A to B, as an example, can vary greatly depending on the data types of A and B. One can see how those assignments work by studying the following matrix built according to the following principle:

The possible sources (A) for a MAP statement constitute the rows of the matrix and the possible destinations (B) constitute its columns. The syntactic correctness or result of the MAP operation is given at the intersection of the row and column. The numbers in parentheses refer to the numbered paragraphs immediately following the matrix. VW(5) and VW(8) are two Views—both with the multiple occurrences but one with fewer (5) and the other with more (8).
Figure 10  Example DCL...ENDDCL STATEMENT

Note that it is not possible to directly define a View within a DCL ... ENDDCL statement. It is possible to do so indirectly with the LIKE clause. In the above example, TEMP_VIEW is a temporary local View with nearly the same structure as RTAXCMLPI. The only difference is that the 01-level name is TEMP_VIEW rather than RTAXCMLPI and the TEMP_VIEW OCCURS 5 times.
APPENDIX D: Executable Statements of Rules Language

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Three types of statements alter the value of data contained in fields and views: MAP, CLEAR, and OVERLAY. The syntax and semantics of each will be described in turn.

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The syntax of the MAP statement is:

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Some examples follows:

MAP 'Syntax' TO CG_CHAR OF CG_VW_11

MAP CG_CHAR OF CG_VW_11 TO CG_CHAR OF SUB_VIEW OF CG_VW_13(3)

MAP 23400.00 TO CUST_BAL_AMT

Figure 1 Example Map Statements

Semantics

The results of mapping A to B, as an example, can vary greatly depending on the data types of A and B. One can see how those assignments work by studying the following matrix built according to the following principle:

The possible sources (A) for a MAP statement constitute the rows of the matrix and the possible destinations (B) constitute its columns. The syntactic correctness or result of the MAP operation is given at the intersection of the row and column. The numbers in parentheses refer to the numbered paragraphs immediately following the matrix. VW(5) and VW(8) are two views--both with the multiple occurrences but one with fewer (5) and the other with more (8).
<table>
<thead>
<tr>
<th>Source (A)</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(B)</td>
</tr>
<tr>
<td>View</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Field</td>
<td>ERROR</td>
</tr>
<tr>
<td>Num lit</td>
<td>ERROR</td>
</tr>
<tr>
<td>Char lit</td>
<td>ERROR</td>
</tr>
<tr>
<td>Set</td>
<td>ERROR</td>
</tr>
<tr>
<td>Symbol</td>
<td>ERROR</td>
</tr>
<tr>
<td>VW(5)</td>
<td>WARNING</td>
</tr>
<tr>
<td>VW(8)</td>
<td>WARNING</td>
</tr>
</tbody>
</table>

Figure 2 The Map Operation

(1) Mapping a View to a View means mapping all sub-Views and/or Fields with corresponding names which are subordinate to the source View and the destination View. For example, assume we have:

VIEW 1
ABC
DEF occurs (50)
OPQ
XXX
BBB
XXY
XYZ

VIEW 2
OPQ
ABC
DEF occurs (9)
BBB
ZZZ

where the specifics of the sub-Views and the Fields of VIEW1 and VIEW2 do not matter. Then, MAP VIEW1 TO VIEW2 will have the following effect:

ABC OF VIEW 1 is moved into ABC OF VIEW 2
OPQ of VIEW 1 is moved into OPQ OF VIEW 2
BBB OF VIEW 1 is moved into BBB OF VIEW 2
DEF OF VIEW 1 (1) is moved into DEF OF VIEW 2 (1)
DEF OF VIEW 1 (2) is moved into DEF OF VIEW 2 (2)
CHAR_VAR1 of type CHAR (10)
CHAR_VAR2 of type CHAR (20)
VARCH_VAR1 of type VARCHAR (15)
VARCH_VAR2 of type VARCHAR (20)

Assume also that we have a Rule which consists of the following MAP statements:

1. Map 'ABC' TO CHAR_VAR_1
2. MAP '** MY LENGTH IS 20 **' TO CHAR_VAR_2
3. MAP 'ABC' TO VARCH_VAR_1
4. MAP CHAR_VAR_1 TO VARCH_VAR_1
5. MAP CHAR_VAR_2 TO VARCH_VAR_1
6. MAP CHAR_VAR_2 TO VARCH_VAR_2
7. MAP VARCH_VAR_2 TO VARCH_VAR_2
8. MAP VARCH_VAR_1 TO VARCH_VAR_2

The following results will occur in the VARCHAR variables
#1 and 2 Nothing has yet been assigned to VARCH_VAR_1_LEN and VARCH_VAR_2_LEN
#3 VARCH_VAR_1_LEN = 5 = length of 'ABC'
#4 VARCH_VAR_1_LEN = 10 = length of CHAR_VAR_1,
#5 VARCH_VAR_1_LEN = 15 = length of CHAR_VAR_1, contents of VARCH_VAR_1 will be ' ** MY LENGTH IS'
#6 VARCH_VAR_1_LEN = 20 = length of VARCH_VAR_1, contents of VARCH_VAR_1 will be ' ** MY LENGTH IS' 20'
#7 VARCH_VAR_1_LEN = 15 = length of VARCH_VAR_1, contents of VARCH_VAR_1 will be ' ** MY LENGTH IS'
#8 VARCH_VAR_1_LEN = 15 = length of VARCH_VAR_1, contents of VARCH_VAR_1 will be ' ** MY LENGTH IS'

CLEAR Statement

The CLEAR statement sets numeric Fields to zero and character Fields to blank.

Syntax

The CLEAR statement has the form:

    CLEAR variable

where "variable" is fully or partially qualified name of either a View or a Field. If the variable being cleared has
MAP A(1) TO B

or

MAP A TO B(1)

(4) See the Field-to-Field MAP in Figure 2. A source literal of type INTEGER or DECIMAL behaves the same as a variable of that type.

(5) See the Field-to-Field MAP in Figure 2. A source literal of the form 'ABCDEFGHIJKLMNOPQRSTUVWXYZ' behave the same as a variable of type CHAR(8).

(6) See the Field-to-Field MAP in Figure 2. A source which is a symbol belonging to a Set of a given type behaves in the same way as a variable of the same type.

Mapping of VARCHAR Fields

The following describes how MAP statements operate with variables of type VARCHAR.

The major difference between variables of type VARCHAR (nn) and those of type CHAR (nn) is due to the fact that VARCHAR (nn) variables have an associated length field, named xxx_LEN for a VARCHAR variable xxx. xxx_LEN contains the "actual length" of xxx while nn is the "maximal length" of xxx.

Assume that B is a variable of type VARCHAR with length B_LEN and that A is a variable, a literal, a symbol of type VARCHAR, or of type "char." B_LEN is determined from the length of A in a MAP A TO B statement as follows.

If length of a <= maximum length of B, then:

\[ B_{\text{LEN}} = \text{lenth of } A \]
\[ \text{contents of } B = \text{contents of } A \text{ padded with spaces to the right} \]

If length of A > maximum length of B, then:

\[ B_{\text{LEN}} = \text{maximal length of } B \]
\[ \text{contents of } B = \text{first "max length of } B\text{" characters of } A \]

Examples of the Use of VARCHAR Variables

Assume the following:
CHAR_VAR1 of type CHAR (10)
CHAR_VAR2 of type CHAR (20)
VARCH_VAR1 of type VARCHAR (15)
VARCH_VAR1 of type VARCHAR (20)

Assume also that we have a Rule which consists of the following MAP statements:

1. Map 'ABC ' TO CHAR_VAR_1
2. MAP '** MY LENGTH IS 20 **' TO CHAR_VAR_2
3. MAP 'ABC ' TO VARCH_VAR_1
4. MAP CHAR_VAR_1 TO VARCH_VAR_1
5. MAP CHAR_VAR_2 TO VARCH_VAR_1
6. MAP CHAR_VAR_2 TO VARCH_VAR_1
7. MAP VARCH_VAR_2 TO VARCH_VAR_1
8. MAP VARCH_VAR_1 TO VARCH_VAR_1

The following results will occur in the VARCHAR variables

#1 and 2 Nothing has yet been assigned to VARCH_VAR_1_LEN and VARCH_VAR_2_LEN

#3 VARCH_VAR_1_LEN = 5 = length of 'ABC'

#4 VARCH_VAR_1_LEN = 10 = length of CHAR_VAR_1

#5 VARCH_VAR_1_LEN = 15 = length of CHAR_VAR_1, contents of VARCH_VAR_1 will be '** MY LENGTH IS'

#6 VARCH_VAR_1_LEN = 20 = length of VARCH_VAR_1, contents of VARCH_VAR_1 will be '** MY LENGTH IS' 20'

#7 VARCH_VAR_1_LEN = 15 = length of VARCH_VAR_1, contents of VARCH_VAR_1 will be '** MY LENGTH IS'

#8 VARCH_VAR_1_LEN = 15 = length of VARCH_VAR_1, contents of VARCH_VAR_1 will be ' ** MY LENGTH IS'

CLEAR Statement

The CLEAR statement sets numeric Fields to zero and character Fields to blank.

Syntax

The CLEAR statement has the form:

CLEAR variable

where "variable" is fully or partially qualified name of either a View or a Field. If the variable being cleared has
subscripts, that is, multiple occurrences of any of its Views or sub-Views, then subscripts may also appear. For example,

CLEAR VW_1

will zero all the numeric Fields of VW_1 and blank the character Fields. Recall that numeric Fields include INTEGER (n), DECIMAL (p, q) and Fields described with PIC elements S,9,and V. Character Fields include CHAR (n_, VARCHAR (n).

Semantics

A Field of underlying type "Character" (not including PICs) is set to blanks. A Field of underlying type "Numeric" (including decimals and PICs) is set to zero.

A View V, say, is treated as follows:

(1) Assume that V owns Fields only but no View. Then each one of those Fields is set to spaces or to zero, depending on whether its underlying type is "Character" or "Numeric." If V is a View that is subscripted (the corresponding OCCURS clauses could possibly be specified on a higher level than that of V), then clearing V means the same as clearing each v(S1) or v(S1, S2) or v(S1, S2 S3). Here S1, S2 and S3 denote the Subscripts of V and it depends on the number of OCCURS above and including the level of V, regardless of whether V is subscripted once, twice, or three times.

(2) If V has one or more views V1, V2, ..., as children, then treat V as follows: Clear the Fields which are children of V, just as was outlined above. Then check each V1, V2 to determine whether or not it also contains Fields as children and, if so, treat them according to (1) above. Otherwise examine each sub-View.

The net result of the above algorithm is as follows. Any View is ultimately partitioned into a Set of Fields. Each of those Fields is set to spaces or to zero, depending on whether its underlying type is "Character" or "Numeric."

OVERLAY Statement

This statement is used to replace ("overlay") one structure in storage with the content of another.

Syntax

The OVERLAY statement has the form

    OVERLAY data item TO variable

where data item is a constant, Field, or View and variable is either the name of a View or a Field.
APPENDIX E: Flow of Control With a Rule

The Rules Language employs the usual flow of control constructs: IF and IF ... ELSE for conditions execution, CASEOF for selection of one of several alternatives, and DO ... WHILE for control of repetitive loops.

Conditions

A condition is a mix of data items, relational operators, Boolean operators, and parentheses. A data item includes character, integer, and decimal constants, Fields, and Views. The relational and Boolean operators are:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>Equal to</td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal to</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal to</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than</td>
</tr>
<tr>
<td>=&gt;</td>
<td>Greater than or equal to</td>
</tr>
<tr>
<td>INSET</td>
<td>Is a member of</td>
</tr>
<tr>
<td>AND</td>
<td>Conjunction</td>
</tr>
<tr>
<td>OR</td>
<td>Inclusive disjunction</td>
</tr>
<tr>
<td>NOT</td>
<td>Negation</td>
</tr>
</tbody>
</table>

Figure 1 Relational and Boolean Operators

A condition is either a single relational condition (henceforth called a "simple condition") or two or more simple conditions connected with the Boolean operators. A simple condition has the form

data item relational operator data item

Some examples are:

<table>
<thead>
<tr>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUST_BAL_AMT &lt; 1000</td>
</tr>
<tr>
<td>GROSS_PAY OF RTAXCMIPI &gt;= FICA_CUTOFF</td>
</tr>
<tr>
<td>CUSTOMER_ID &lt;&gt; '1134-4'</td>
</tr>
<tr>
<td>SSN OF RTAXCMPO = '360-32-2528'</td>
</tr>
<tr>
<td>12 INSET MONTH_OF_YEARS</td>
</tr>
</tbody>
</table>

The Rules Language enforces data-type checking; comparisons can only be made between data items of like type—numeric with numeric and character with character. All of the comparisons of magnitude are available with numeric data but only tests for equality (=) and inequality (<>).
Either A or B or both must be a View. Nothing can ever be OVERLAYED to a Constant.

A Set is neither a constant, nor a variable, and absolutely nothing can be OVERLAYed from or to a Set.

Assume that A occurs nn times and B occurs mm times and that min denotes the smaller one of mm and nn. then

OVERLAY A to B

means exactly the same as the following Rule fragment:

DO FROM 1 TO min INDEX IX
   OVERLAY A(IX) to B(IX)
ENDO

If either A occurs multiple times and B does not or A occurs once and B multiple times, then OVERLAY A TO B is equivalent to either

OVERLAY A(1) TO B

or

OVERLAY A TO B(1)

It is permitted to OVERLAY a Field with a View or vice versa, as long as the Field is of type "Character." The reason is that Views themselves re considered to be of type "Character" (COBOL convention).

It is permitted to OVERLAY a constant (literal or symbol) to a View, as long as the constant is of type "Character."
APPENDIX E: Flow of Control With a Rule

The Rules Language employs the usual flow of control constructs: IF and IF ... ELSE for conditions execution, CASEOF for selection of one of several alternatives, and DO...WHILE for control of repetitive loops.

Conditions

A condition is a mix of data items, relational operators, Boolean operators, and parentheses. A data item includes character, integer, and decimal constants, Fields, and Views. the relational and Boolean operators are:

<table>
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<th>Operator</th>
<th>Meaning</th>
</tr>
</thead>
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<td>Equal to</td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal to</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal to</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater that or equal to</td>
</tr>
<tr>
<td>INSET</td>
<td>Is a member of</td>
</tr>
<tr>
<td>AND</td>
<td>Conjunction</td>
</tr>
<tr>
<td>OR</td>
<td>Inclusive disjunction</td>
</tr>
<tr>
<td>NOT</td>
<td>Negation</td>
</tr>
</tbody>
</table>

Figure 1 Relational and Boolean Operators

A condition is either a single relational condition (henceforth called a "simple condition") or two or more simple conditions connected with the Boolean operators. A simple condition has the form

data item relational operator data item

Some examples are:

```
CUST_BAL_AMT < 1000
GROSS_PAY OF RTAXCMI > FICA_CUTOFF
CUSTOMER_ID <> '1134-4'
SSN OF RTAXCMPO = '360-32-2528'
12 INSET MONTH_OF_YEARS
```

The Rules Language enforces data-type checking; comparisons can only be made between data items of like type—numeric with numeric and character with character. All of the comparisons of magnitude are available with numeric data but only tests for equality (=) and inequality (<>) are permitted with character data.
Each simple condition results in a value of either TRUE or FALSE. Two of these values can be combined with the Boolean operators AND and OR and the sense of one of them can be reversed with NOT.

For example,

\[
\text{CUSTOMER_ID} <> '1134-4' \text{ AND GROSS PAY} \geq \text{FICA LIMIT}
\]

is TRUE if both CUSTOMER_ID is not equal to 1123-4 and GROSS PAY is greater than or equal to FICA LIMIT; otherwise the condition is FALSE. It is assumed that CUSTOMER_ID is either CHAR, VARCHAR, or a View and GROSS PAY AND FICA LIMIT are INTEGER, DECIMAL, or described with numeric PIC elements. Further, for this condition to make sense, the relational operators < and >= must be applied before the two resulting values are ANDed. This implies all the operators have hierarchy of precedence. The usual hierarchy is used, and it is given in the following table.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Precedence</th>
</tr>
</thead>
<tbody>
<tr>
<td>INSET</td>
<td>Highest</td>
</tr>
<tr>
<td>=, &lt;&gt;, &lt;, &lt;=, &gt;, &gt;=</td>
<td></td>
</tr>
<tr>
<td>NOT</td>
<td></td>
</tr>
<tr>
<td>AND</td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>Lowest</td>
</tr>
</tbody>
</table>

**Figure 2 Precedence - Relational and Boolean Operators**

The concept of operator precedence is well known from the everyday usage of arithmetic calculations, where multiplication and division are executed before addition and subtraction. In the same way, a test for inequality is executed before two conditions are ANDed, which itself will be done before my conditions will be ORed.

Parentheses may be used to override the operator precedence. For example,

\[
\text{NOT X} = \text{Y or C} > \text{D is equivalent to (NOT} \text{ X+Y) or (C>D), which itself is equivalent to X} <\text{ <> Y or C} > \text{ D.}
\]

However,

\[
\text{NOT (X = Y OR C > D) is equivalent to X} <\text{ <> Y AND C} \leq \text{D (because it is true in general that NOT (X OR Y) is the same as (NOT X) AND (NOT Y)).}
\]
-82-

SMALL_INT > 1000000

Even more subtle errors are detected. Let POS-NUMBER be a
decimal number described by the picture "PIC 9999/V99" in the
HPS Repository. Then the next example condition is also not
permitted:

POS_NUMBER < 0

this is an error because POS-NUMBER does not have a leading sign
picture element $S$.

Not: On the comparison of character type items assume that $X$=
'ABC' and $Y$='ABC' and $Z$='ABC'. Then $X$ and $Y$ and $Z$
are all equivalent as far as testing them for equality is
concerned.

In other words, the complex condition $X = Y$ and $Y=Z$ and
$X=Z$ evaluates to TRUE. In addition, note that the ASCII
collating sequence and not the EBCDIC collating sequence
applies for relative comparison. Given the above
definition, the condition

$x <= '1BC'$

yields TRUE because the ASCII value of 1' is 49, whereas
the ASCII value of 'A' is 65.

IF STATEMENT

IF..., IF ... ELSE (Conditional Execution)

Syntax

The IF statement has the general form

IF condition
statement ...

[ELSE

statement ...]

ENDIF

where "condition" is a logical expression which may be either
TRUE or FALSE. "Statement" represents a Rules Language
statement, and "..." means that the immediately preceding item
may be repeated, and [ ] implies, and [ ] implies that what
is contained within [ and ] is optional. A then is not allowed
in the IF statement.
The following expressions are valid:

- JAN IN MONTHSET INSET NAMESET  => Results=FALSE<
- AL INSET NAMESET                 => Results=TRUE<
- AL <= JAN IN MONTHSET             => Results=FALSE<
- AL <= JAN IN NAMESET              => Results=TRUE<
- AL <= AL IN NAMESET               => Results=TRUE<
- AL <= AL NAMESET                  => Results=FALSE<
- SHRTINT INSET NAMESET
- LONGINT INSET MONTHSET

Of course, nothing can be said at code generation time about the results of the last two expressions because they involve variables. It might have come as a surprise to the reader that:

- JAN IN NAMESET INSET  MONTHSET evaluates to FALSE?

Comparison of like types is rigidly enforced. Comparisons between numeric data and non-numeric are always errors. The following table gives conditions arising between the comparison of two character types and or two numeric types. The significance of note (1), however, varies according to the types being compared.

<table>
<thead>
<tr>
<th>First</th>
<th>Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literal</td>
<td>Error</td>
</tr>
<tr>
<td>Set Symbol</td>
<td>Warning</td>
</tr>
<tr>
<td>Variable</td>
<td>(1)</td>
</tr>
</tbody>
</table>

Figure 3 Character and Numeric Comparison Error Conditions

(1) Comparing a character constant to a character variable is permitted so long as the length of the constant is less than or equal to the maximal length of the variable. Otherwise a syntax error is generated.

It is an error to compare a large (in absolute value) numeric literal with a variable which is "too small" to accommodate a value that large. For example, an SMLINT Field can accommodate values ranging from -32,768 to +32,767. Let SMALL_INT be an SMLINT Field. The following comparison is not permitted by the Rule code generators:

- SMALL_INT < 32768

- SMALL_INT > -32768
SMALL_INT > 1000000

Even more subtle errors are detected. Let POS-NUMBER be a
decimal number described by the picture "PIC 9999/V99" in the
HPS Repository. Then the next example condition is also not
permitted:

POS_NUMBER < 0
	his is an error because POS-NUMBER does not have a leading sign
picture element S.

Not: On the comparison of character type items assume that X=
'ABC' and Y = 'ABC' and Z = 'ABC '. Then X and Y and Z
are all equivalent as far as testing them for equality is
concerned.

In other words, the complex condition X = Y and Y=Z and
X=Z evaluates to TRUE. In addition, note that the ASCII
collating sequence and not the EBCDIC collating sequence
applies for relative comparison. Given the above
definition, the condition

x <= '1BC'

yields TRUE because the ASCII value of 1' is 49, whereas
the ASCII value of 'A' is 65.

IF STATEMENT

IF..., IF ... ELSE (Conditional Execution)

Syntax

The IF statement has the general form

IF condition
statement ...

[ELSE
statement ...]

ENDIF

where "condition" is a logical expression which may be either
TRUE or FALSE. "Statement" represents a Rules Language
statement, and "..." means that the immediately preceding item
may be repeated, and [ ] implies, and [ ] implies that what
is contained within [ and ] is optional. A then is not allowed
in the IF statement.
CASEOF Statement

CASE (Selection of One of Several Alternatives)

The CASEOF statement selects one of several alternative execution paths on the basis of the value of a character or numeric Field. It is equivalent in meaning to several nested IF ... ELSE STATEMENTS.

Syntax

The CASEOF statement has the following form:

    CASEOF VARIABLE
    CASE literal [ literal ] ...
        [ statement ... ]
    [ CASE literal [ literal ] ... ] ...
    [ CASE OTHER
        [ statement ... ] ]
    END CASE

The notation used here to express the syntax is more complex than that used for the IF statement. Square brackets ([ and ]) enclose items that may be omitted. Ellipses (...) indicate that the immediately preceding item may be repeated. Putting these two conventions together means that [ statement ... ] is equivalent to no statements, anything within [ and ] is optional or one statement, two statements (...following statement means that it can be repeated), three statements, and so on.

Semantics

The CASEOF statement is a shorter way of expressing the same flow of control using nested IF ... ELSE statements. The variable is compared to the list of literals following the first CASE reserved word. If it is equal to any of them then the statements following the first CASE are executed up to but not including the second CASE; flow of control then passes to the statements following the END CASE.

If the variable is not equal to any of the literals following the first CASE clause, then it is compared to the literals following the second CASE. If the variable is equal to any of them, then the statements following the second CASE clause up to, but not including the third CASE are performed; flow then passes to the statements following the END CASE.
statement. An "integer variable" is either a Field which is
defined as INTEGER in the Repository or is a DCL local to the
Rule. An "integer data item" is a literal, a Set constant, or
the name of a Field defined as INTEGER. if needed to resolve
any ambiguity, partial qualification and subscripting may be
required with Field names.

Some examples of DO-loops follows:

DO
  WHILE FICA OF RTAXCMPI <FICA_MAX_IN PARAMETERS
    statement1
    statement2

  ...
ENDDO

DO
  statement1
  statement2

  ...
  WHILE TOTAL_AMT > TOTAL_LIMIT
  ENDDO

DO TO LOOP_END BY STEP INDEX COUNTER OF RXYZZYI
  statement1
  statement2

  ...
ENDDO

DO FROM LEVEL OF RSTATUSI
  statement1
  statement2
  WHILE CODES (LEVEL) <> TERM_CODE IN VALID_CODES
    statement3

  ...
ENDDO

Semantics

For the first type of DO construct--without the explicit
counting mechanism--the statements between DO and ENDDO are
repeated in order of appearance while the condition in the WHILE
clause is TRUE. When the condition becomes FALSE, control
passes from the WHILE clause to the statement following the
ENDDO. Note that the while clause may appear at the top of the
loop, at the bottom of the loop, or anywhere in the middle.

In the second type of DO, default values are supplied for any of
the missing clauses (FROM, TO, BY). If FROM is omitted, the
loop count begins at 1; if TO is omitted, the count limits is
set to 32,767; if BY is omitted, the loop increment is set to 1.
Note that the INDEX clause need not appear. However, at least
one FROM, TO, BY, or INDEX must be given for the DO to be
recognized as in indexed DO. Also, IN, FROM, TO and BY values
need not be integer constant; integer Fields are also permitted.
statement 4
statement 5
ELSE
statement 6
ENDIF
ENDIF

ENDIF

Observe that the CASEOF statement implicitly uses tests for equality between a variable (Field or View) and a constant. The type checking enforced with the IF statement is also enforced here. Constants appearing in the CASE clauses must have the same type as the variable appearing on the CASEOF clause.

DO Statement

The DO ... ENDDO construct provides control of repetitive loops and there are two varieties--one with an explicit loop-counting mechanism and one without.

Syntax

The form of the DO ... ENDO loop control structure is as follows:

DO

[ statement ... ]

WHILE condition

[statement ... ]

UNDDO

The form with the explicit loop-counting mechanism is:

DO [FROM integer data item]
[ TO integer data item]
[ BY integer data item]
[ INDEX integer variable]

[ statement ... ]

[ WHILE condition ]

[ statement ... ]

ENDDO

The "condition" appearing in the WHILE clause is the same type of condition as described above in the section of the IF
statement. An "integer variable" is either a Field which is defined as INTEGER in the Repository or is a DCL local to the Rule. An "integer data item" is a literal, a Set constant, or the name of a Field defined as INTEGER. if needed to resolve any ambiguity, partial qualification and subscripting may be required with Field names.

Some examples of DO-loops follows:

```
DO
  WHILE FICA OF RTAXCMPI < FICA_MAX_IN PARAMETERS
    statement1
    statement2
...
ENDDO

DO
  statement1
  statement2
...
  WHILE TOTAL_AMT > TOTAL_LIMIT
ENDDO

DO TO LOOP_END BY STEP INDEX COUNTER OF RXYZZYI
  statement1
  statement2
...
ENDDO

DO FROM LEVEL OF RSTATUSI
  statement1
  statement2
  WHILE CODES (LEVEL) <> TERM_CODE IN VALID_CODES
    statement3
...
ENDDO
```

Semantics

For the first type of DO construct--without the explicit counting mechanism--the statements between DO and ENDDO are repeated in order of appearance while the condition in the WHILE clause is TRUE. When the condition becomes FALSE, control passes from the WHILE clause to the statement following the ENDDO. Note that the while clause may appear at the top of the loop, at the bottom of the loop, or anywhere in the middle.

In the second type of DO, default values are supplied for any of the missing clauses (FROM, TO, BY). If FROM is omitted, the loop count begins at 1; if TO is omitted, the count limits is set to 32,767; if BY is omitted, the loop increment is set to 1. Note that the INDEX clause need not appear. However, at least one FROM, TO, BY, or INDEX must be given for the DO to be recognized as in indexed DO. Also, IN, FROM, TO and BY values need not be integer constant; integer Fields are also permitted.
Finally, a WHILE condition may also be included with an indexed DO and it may appear anywhere within the loop.
Converse statement but never more than one Window Name. Note also that only PC-based Rules can have Converse statements.

**Asynchronous Support Structures**

This appendix summarizes the rule language constructs that invoke the unsolicited data output (UD) processes. Unsolicited data allows a one rule to send data to another Rule without the latter Rule asking for it. This is supported using the following statements:

- ASYNC ATTACH
- ASYNC DETACH
- ASYNC REFRESH
- ASYNC ROUTE

The following discussion relates to a hardware configuration with an architecture comprised of an IBM mainframe supported by the CICS operating system, a Stratus mini computer and a bank of PC work stations. All of these constructs are currently confined to PC based rules. There also exist Stratus subroutines to execute the following statements.

In defining the PC constructs, we will assume the existence of the following Rule entity instances:

- rpc1 A PC Rule conversing Window wpc1
- rpc2 A PC Rule conversing Window wpc2
- rpc3 A PC Rule refreshing wpc1
- rpc4 A PC Rule refreshing wpc2
- rst1 A Stratus Rule invoking a component which uses the send_message subroutine.

**ASYNC ATTACH STATEMENT**

**Syntax**

The ASYNC ATTACH statement has the following form:

```
ASYNC ATTACH RULE    rpc3 VIA RULE rst1
```

This command will initiate the receiving of unsolicited input by the PC Rule rpc3 sent by the Stratus Rule rst1.
. the Target Environment of the USEing Rule is PC, or
. The Target Environment of the used Rule is PC.
However, Rules on other machines cannot invoke a PC-based Rule
(except indirectly through the ASYNC facility).

RETURN Statement

An invoked Rule program executes the RETURN statement to
transfer control back to the invoking Rule. The RETURN
statement may be laced anywhere in a program. The Rules
Language code generator places an implicit RETURN at the end of
each Rule program.

Transfer of Data Between Rules

As was mentioned in the previous section, Rules may have at most
one Input View and one Output View defined in the Repository.
With this in mind, the following restrictions apply concerning
flow in the transfer of data:

. A Rule may not modify its Input View unless it also
  happens to be its Output (i.e., INOUT).

. A Rule may not modify the Output View of a module it
calls unless it is the same as the module's Input.

. A Rule may not share its Input View with that of its
child's Output. View sharing is permitted between
Rules of the same level and when the Views are the
same Usage (i.e., both Input).

. Output View of Rules and the Input Views of modules
it calls, are cleared upon invocation, as are locally
declared Views.

Converse Support Structures

The CONVERSE WINDOW supports communication between Rules
programs in the personal computer environment and the user of a
system.

The statement has the form:

CONVERSE WINDOW WINDOW_NAME

where WINDOW_NAME is the name given to the display when it was
entered into the HPS Repository.

Note that there is a difference between WINDOW_NAME and Window
View. Each WINDOW_NAME is associated with a View which is called
its Window View. Not every View in the Repository can be used
as a Window View. A Window View can only have a 01 level, 03
level, and 05 level. Note that a Rule can have more than one
Converse statement but never more than one Window Name. Note also that only PC-based Rules can have Converse statements.

Asynchronous Support Structures

This appendix summarizes the rule language constructs that invoke the unsolicited data output (UD) processes. Unsolicited data allows a one rule to send data to another Rule without the latter Rule asking for it. This is supported using the following statements:

- ASYNC ATTACH
- ASYNC DETACH
- ASYNC REFRESH
- ASYNC ROUTE

The following discussion relates to a hardware configuration with an architecture comprised of an IBM mainframe supported by the CICS operating system, a Stratus mini computer and a bank of PC work stations. All of these constructs are currently confined to PC based rules. There also exist Stratus subroutines to execute the following statements.

In defining the PC constructs, we will assume the existence of the following Rule entity instances:

- rpc1 A PC Rule conversing Window wpc1
- rpc2 A PC Rule conversing Window wpc2
- rpc3 A PC Rule refreshing wpc1
- rpc4 A PC Rule refreshing wpc2
- rst1 A Stratus Rule invoking a component which uses the send_message subroutine.

ASYNC ATTACH STATEMENT

Syntax

The ASYNC ATTACH statement has the following form:

ASYNC ATTACH RULE rpc3 VIA RULE rst1

This command, will initiate the receiving of unsolicited input by the PC Rule rpc3 sent by the Stratus Rule rst1.
Semantic Checking

ATTACH can only be used if:

Execution environment (Repository attribute of the
ATTACH'ed rule is PC and VIA RULE is STRAT

ASYNC DETACH Statement

Syntax

The ASYNC DETACH statement has the following form:

ASYNC DETACH RULE  rpc3 VIA RULE rst1

This command performs the exact reverse of ATTACH. It may only
be used after an ATTACH command, at which point it will
discontinue the receiving of unsolicited input by the PC Rule
rpc3 sent by the Stratus Rule rst1.

Semantic Checking

Same as for ATTACH.

ASYNC ROUTE Statement

Syntax

The ASYNCH ROUTE statement has the following form:

ASYNCH ROUTE RULE  rpc3 VIA RULE rpc4

This command will switch the action of refreshing a Window from
the PC Rule rpc3 to the PC Rule rpc4.

Semantic Checking

ROUTE can only be used if:

Execution environment (Repository attribute) of both
Rules is the PC.

ASYNC REFRESH Statement

Syntax

The ASYNC REFRESH statement has the following form:

ASYNC REFRESH WINDOW  wpcl
(FIELD  field_name
VIEW  view_name
OCCUR  field_occur
BEEP
FLASH )
What is claimed is:

1. A method of operating a data processor to generate a computer program, comprising the steps of:

   a. inputting information relating to functions of the computer program by specifying the information according to a preselected set of objects; said objects comprising a preselected set of entities and relationships;

   b. linking each entity to one or more other entities by the pre-selected set of relationships;

   c. storing the linked set of entities and relationships in a storage area;

   d. inputting logic constructs referencing objects stored in the storage area;

   e. relating the logic constructs to pre-selected ones of the stored entities; and
i is either an integer or a field of type INTEGER.

Semantic Checking

- WINDOW clause is mandatory.
- The VIEW clause, if given, must specify a sub-View of the View identified by the WINDOW clause.
- The FIELD clause, if given, must specify a Field name Included in the View identified by the VIEW clause.
- If OCCUR is used the View identified by the VIEW clause must be an occurring View.
- The OCCUR literal must be within bounds.

Guidelines Concerning Usage of ASYNCH

- A Rule cannot contain both CONVERSE statements and ASYNC statements.
- A Rule which CONVERSES cannot USE a Rule with ASYNC statement and vice versa.
- A Rule given the Repository defined attribute ASYNC, cannot have a USE....NEST statement (because NEST implies that somewhere in the hierarchy of the rules it calls or in itself, there will be a Rule with a CONVERSE).

Each WINDOW_NAME is associated with a View, called Window View. Not any View in the Repository can be used as a Window View. A Window View can only have an 01 level, 03 level, and 05 level. Note that a Rule can have more than one Converse statement but never more than one Window Name. Note also that only PC-based Rules can have Converse statements.
What is claimed is:

1. A method of operating a data processor to generate a computer program, comprising the steps of:

   a. inputting information relating to functions of the computer program by specifying the information according to a preselected set of objects; said objects comprising a preselected set of entities and relationships;

   b. linking each entity to one or more other entities by the pre-selected set of relationships;

   c. storing the linked set of entities and relationships in a storage area;

   d. inputting logic constructs referencing objects stored in the storage area;

   e. relating the logic constructs to pre-selected ones of the stored entities; and
f. storing the logic constructs and
information on the related preselected
ones of the entities in the storage area.

2. The method of Claim 1 including the further step of
utilizing the logic constructs and the referenced
objects to generate corresponding source code.

3. The method of Claim 2, comprising the further step of
storing the source code in the storage area.

4. The method of claim 2 comprising the further step of
utilizing the corresponding source code to generate
executable computer code.

5. The method of claim 4 including the further step of
storing the executable computer code in the storage
area.

6. The method of Claim 1 comprising the further step of
   
a. inputting additional information
   relating to the function of a second
   computer program;

   b. searching the storage area for
objects matching the additional
information; and
14. The method of Claim 13 comprising further steps of:
   a. transmitting the source code
      generated in respect of each of the
      logical constructs to the respective
      specified hardware environment; and
   b. utilizing the source code to generate
      executable computer code at the
      respective hardware environment.

15. The method of Claim 14 wherein the storage area
    comprises a Central Repository located at a preselected one
    of the hardware environments.

16. A method of operating a data processor to generate a
    computer program, comprising the steps of:
    a. inputting information descriptive of
       a real-world circumstance;
    b. using the information to build a
       model comprising a pre-selected set of
       entities and relationships reflective of
       the information;
    c. using the information to build a
       further model comprising a pre-selected
       set of entities and relationships that
       describe the function of the computer
       program in respect of the real-world
       circumstance;
c. storing the linked set of new entities and relationships in the storage area.

11. The method of Claim 10 including the further steps of:
   a. providing a plurality of hardware environments; coupled to one another to form an interconnected computer network; and
   b. specifying for each logical construct one of the plurality of hardware environments for execution.

12. The method of Claim 11 comprising the further steps of:
   a. storing in the storage area information regarding each one of the plurality of hardware environments; and
   b. utilizing each logical construct and information regarding the respective specified hardware environment for the logical construct to generate source code adopted to be executable in the specified execution environment.

13. The method of Claim 12 wherein steps a-f of Claim 1 are carried out in a pre-selected one of said hardware environments.
14. The method of Claim 13 comprising further steps of:
   a. transmitting the source code
generated in respect of each of the
logical constructs to the respective
specified hardware environment; and
b. utilizing the source code to generate
executable computer code at the
respective hardware environment.

15. The method of Claim 14 wherein the storage area
comprises a Central Repository located at a preselected one
of the hardware environments.

16. A method of operating a data processor to generate a
computer program, comprising the steps of:
   a. inputting information descriptive of
a real-world circumstance;
b. using the information to build a
model comprising a pre-selected set of
entities and relationships reflective of
the information;
c. using the information to build a
further model comprising a pre-selected
set of entities and relationships that
describe the function of the computer
program in respect of the real-world
circumstance;
d. providing certain ones of the entities as rule entities; each one of the rule entities describing an aspect of the function of the computer program and its relationship to other rule entities; and

e. providing a rules language comprising logic statements which provide executable functionality of the aspects described in the rules entities.
FIG. 2A

SUBSTITUTE SHEET
FIG. 3
FIG. 4
Fig. 5
Substitute Sheet
FIG. 6

SUBLSTITUTE SHEET
# INTERNATIONAL SEARCH REPORT

**International Application No.** PCT/US90/07013

## I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC

**IPC(5):** G06F 15/40, 15/21, 9/45

**US. Cl.:** 364/200; 364/900

## II. FIELDS SEARCHED

<table>
<thead>
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<th>Classification System</th>
<th>Classification Symbols</th>
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<tr>
<td>U.S. 364/200, 900</td>
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

## III. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of Document</th>
<th>Relevance to Claimed Invention</th>
</tr>
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<tr>
<td></td>
<td>US, A, 4,939,689 (Davis et al.) 3 July 1990</td>
<td>1-15 16</td>
</tr>
<tr>
<td></td>
<td>US, A, 4,930,071 (Tou et al.) 29 May 1990</td>
<td>1-15 16</td>
</tr>
</tbody>
</table>

* Special categories of cited documents:
  - A: Document defining the general state of the art which is not considered to be of particular relevance.
  - E: Earlier document but published on or after the international filing date.
  - L: Document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified).
  - O: Document referring to an oral disclosure, use, exhibition or other means.
  - P: Document published prior to the international filing date but later than the priority date claimed.
  - T: Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention.
  - X: Document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step.
  - Y: Document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

## IV. CERTIFICATION

**Date of the Actual Completion of the International Search:** 25 February 1991

**Date of Mailing of this International Search Report:** 29 March 1991

**International Searching Authority:**

**Signature of Authorized Officer:**

Christopher B. Shin