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AutoMod II

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ABSTRACT

This paper is a tutorial on AutoMod II. It describes the model development environment, process system, movement systems, 3D picture construction, and run-time environment.

1. INTRODUCTION

AutoMod II (AM II) is an industrial simulation system that combines CAD-like drawing tools with a powerful, engineering oriented language to model control logic and material flow. The result is the modelling of a manufacturing system in accurate, 3 dimensional detail. AM II's CAD features are used to define the physical layout of manufacturing, material handling, and distribution systems Unlike most other simulation languages, AM II's powerful graphical interface accurately captures the physical constraints of distance, size, and space in 3-D.

AM II also provides the user with a set of "expert based" movement systems that have been developed from AutoSimulations Inc.'s (ASI) experience in industrial automation. As a result, the underlying model logic is generated for the user automatically from the geometry and the movement system input parameters. Furthermore, AutoMod II animations show exactly the logic of the model. The 3-D animation is an automatic part of model development.

AM II differs significantly from other simulation systems because of its ability to deal with the physical elements of a system in physical (graphical) terms and the logical elements of a system in logical terms. AM II also offers advanced features to allow users to simulate complex movement (kinematics and velocity) of equipment such as robots, machine tools, transfer lines, and special machinery. All graphics are represented in three-dimensional space with unlimited viewing control including: translation, rotation, scale, light-sourced solids, perspective, and continuous motion viewing.

AM II is really two programs. The build portion is for the physical and logical model definition. After the user has defined the physical and logical components of the model, it is then compiled into an executable model, where the simulation and animation run concurrently. The executable model is a fully interactive, it can be stopped at any instant in simulated time to examine statistics and model status and to conduct interactive modelling experiments.

2. MODEL DEVELOPMENT ENVIRONMENT

An AM II model consists of one or more systems. A system can either be a process system, in which control logic is defined, or a movement system. Each model must contain one process system and any number of movement systems. AMII loads are units of traffic that move between the individual processes in the process system. Processes can contain complex logic to control the flow of either manufacturing materials or control messages, contend for resources or wait for user specified times. Loads can move between processes with or without the use of movement systems. Normally, loads that use movement systems represent manufacturing materials that move directly from one process to another. Loads that do not use movement systems are typically control signals or logical messages.

Loads that flow through the process logic have the ability to claim and release resources, enter and leave queues, be added and removed from order lists, change the value of variables, counters, and load attributes, create a new load or kill an existing load, read from and write to external files, and determine the next process. All interarrival and event times can be represented by deterministic values or be derived ramdomly from one of several statistical distributions. AM II uses the latest in human interace technology. The interface is window oriented, utilizing pop-up and pull-down menus, dialog boxes, selection lists, and a mouse based editor for developing process logic.

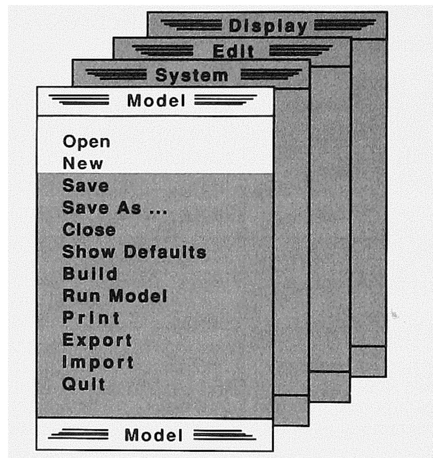


Figure 1. Model Development Menu Stack

3. PROCESS SYSTEM

The process system is the backbone of AM II and provides the general purpose simulation features required for simulation. While material movement is a necessity, it is not the most important element in manufacturing. Value is not added to a product by transporting it around the plant or mill. The value added operations in manufacturing are performed by the machines, processes, and labor that exist in the facility. AM II's process system is where the value added manufacturing operations and the control logic are simulated.

```
begin
  move into FixQ
    if FixedYet = 1 then send to die
      else
        begin
           choose a resource from among Picket (1),
           Picker (2)
           whose current loads is minimum
           save as RecIdle
           use RecIdle for uniform 10, 5 min
           set FixedYet to 1
           send to SizeWay
        end
end
```

Figure 2. Sample Procedure Logic

AM II's process system is both powerful and easy to use. AM II's programming procedures provide state-of-the-art compiler technology, with English-like syntax that is manufacturing oriented. There are virtually no bounds to the size and complexity of the logic that can be developed. There is rarely a need to drop down into a lower level language because AM II provides the user with the flexibility required to simulate any task required.

Process logic is defined in process procedures. Process procedures use an easy-to-use language that contains:

- if-then-else logic
- while loops
- access to global and load-specific variables
- actions to use, take down or bring up resources
- actions to multiply loads
- actions to choose processes, resources or queues based on their state

3.1 Loads

Loads are the active elements in AM II. They are created either from a creation specification using one of the standard statistical distributions, deterministically from reading data from a file, or based on user defined distributions. Loads are named and may have user defined attributes. These attributes are variables which are unique to the load. For example, a load that represents a car might have load attributes that indicate what color it is, what level of trim it has or whether it receives air conditioning. These attributes change as a result of the model logic in the process procedures. Like most everything else in AM II, loads also have 3D shapes and physical dimensions .

3.2 Resources

A resource is a general and flexible entity that can be used to represent a machine, an operator, a fixture, a container, etc. Often several resources are used in a process in a similar fashion. There are two levels in which the resource state is categorized. The first level is whether the resource is Busy or Idle (its state with respect to a load). The second level is the resource's availability, whether it is Up or Down.

Loads use resources for specified processing times, which can be based on a standard time with variations based on several random number distributions that are built-in to AMII, or on custom distributions. The processing times can be general for all loads or specific to each product type.

Resources can have downtimes. During the downtime period, the resource accumulates statistics in the down state. When the resource becomes available, it continues to work on the preempted load for the remaining processing time. Mean-Time-Between-Failure (MTBF) and Mean-Time-To-Repair (MTTR) are included and can be based on the same built-in statistical functions or on custom curves. The standard MTBF is based on model simulated time. AM II can easily accommodate MTBF based on machine run-time or machine cycles.

3.3 Queues and Order Lists

When loads are modeled they must always reside in a physical space. AM II uses two types of physical space: movement systems and queues. Queues have capacities which can range from 1 to infinity. If a queue is full (it has reached its capacity), the next load must wait until there is room. Loads within queues can be sorted and sequenced by using order lists. The queue contents can be shown dynamically during the animation.

Loads may be sorted and delayed at a process or queue until they are explicitly ordered to leave. A load can be directed to place itself on an order list. An order list is not a physical element but a way of sorting loads that are delayed for some reason. Once on an order list, the load still remains in the process and physical territory it was in prior to the order list inclusion.

The load can be ordered from that list by another load or from an order action in another part of the model. The load which has been ordered can be sent to another process by the ordering action or it may continue on its way.

Order lists are not attached to specific processes. Many processes may place loads on the same order list. Likewise, when a load is ordered to a process, that process has no control of where it is coming from.

3.4 Variables and Counters

AM II provides a number of ways of storing values during the simulation period. Variables are data structures that can change as a result of load executing the appropriate statement in a process procedure. Variables can be used in calculations or logically compared to other variables for any means useful to the modeler. In addition to integer and real numeric values, variables can also represent:

- Process Names
- Queue Names
- Resource Names
- Order List Names
- Counter Names
- Load Names

By loading the name of an AutoMod II entity into the variable, extensive if-then-else logic can be avoided, for example, by sending a load to a variable that has the process name loaded into it.

Counters are similar to variables but are positive integers only and use a maximum capacity. A load trying to increment a counter already at its maximum capacity will be stopped until it can successfully perform the increment. Statistics are kept on counters throughout the simulated period.

3.5 Blocks and Traffic Limits

AM II has powerful means of controlling the number of loads that can be either in processes or within physical space in the facility. Traffic limits prevent too many loads within a process, while blocks provide the same utility for physical space. Blocks are often used to control such things as AGV collisions.

Blocks are like counters in that they use a set limit—they cannot be incremented beyond the limit. Normally the limit is one so only one entity can occupy the physical space at a time. Blocks are commonly used as AGV intersections to prevent vehicles from colliding.

AGV's automatically increment/decrement blocks when entering/leaving blocks. Blocks can also be incremented and decremented from process procedures to prevent, for example, having a bridge crane and AGV collide.

3.6 Run Control

By using run control features, various experimental runs can be compared. Run control defines the length of the simulation (in simulated time units), when reports are printed to a file, and when statistics are reset. Resetting the statistics allow the model to run for an initialization or priming period prior to running the model in a "steady state" period from which statistics are again gathered.

4. MOVEMENT SYSTEMS

AM II's movement systems can be used to quickly and easily develop a detailed and accurate model of a conveyor, or Automated Guided Vehicle System (AGVS). AM II provides detailed movement systems so the user does not have to "reinvent" the simulation program to represent, for example, an accumulation conveyor. This is done automatically by drawing the conveyor and specifying the correct parameters.

A movement system in AM II is a special purpose system that moves loads between processes. The user defines the geometry of the movement system using AM II's CAD drawing tools. The user is prompted to "fill in the blanks" for the appropriate parameters for each movement system. AM II's expert-system logic for each system creates the correct model logic to accurately represent the system behavior based on the user's specifications. AM II provides the following movement systems:

- Conveyor
- AGVS
- ASRS
- Bridge Crane
- Power and Free Conveyor
- Robots (Kinematic Extension)

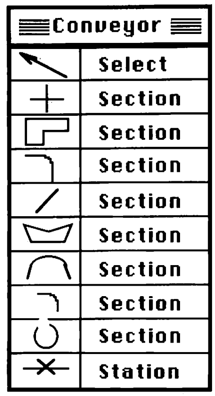


Figure 3. Conveyor Palette

4.1 Conveyor

A conveyor system consists of one or more conveyor sections on which loads move according to section-specific attributes. Loads move from section to section at transfer points. AM II correctly represents both accumulating and non-accumulating conveyor. The leading and trailing edges are tracked based on the load size as defined by each loads' geometry. AM II's CAD features offer numerous ways of defining conveyor sections and the placement of stations (points at which the conveyor physically interfaces with a process).

AM II represents load windows in the same fashion conveyor suppliers would program a conveyor controller. A window is the total amount of logical space that a loads needs on a conveyor. In the real world, rarely is the window size identical to the load size.

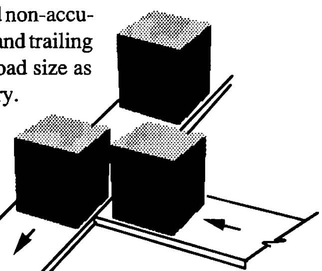


Figure 4 . Conveyor Window

Figure 4 shows an example of a load waiting to transfer onto a section. It will have to wait until a large enough space between the loads (window) is available before the load can make the transfer.

4.2 AGVS

An Automatic Guided Vehicle System (AGVS) is a movement system in which driverless computer controlled vehicles move along a guidepath carrying loads between pick-up and delivery stands as they are directed by a computer. When developing a simulation model of an AGV system, the modeler is concerned with movement control, collision avoidance, and task assignment. AM II provides powerful yet easy to use features for describing guidepath, control points, work search algorithms, and vehicle park rules. AM II models vehicle acceleration and deceleration automatically, calculates the shortest path for vehicle routing, and provides very sophisticated blocking and collision avoidance features. AGVs move by following the guidepath. The guidepath can be defined as unidirectional or bidirectional. In addition, the vehicles can "crab" to the side or rotate when moving into a spur. Crab and rotation speeds are fully programmable.

AM II matches closely the control features used by ASG suppliers. Due to the power and accuracy of AM II most of the major AGV vendors in the United States use ASI technology to simulate AGV systems.

4.3 ASRS

An Automated Storage and Retrieval System (ASRS) is one or more aisles of storage racks in which Storage/Retrieval Machines (SRMs) travel pick-up and retrieve loads. Storage racks are arranged along parallel aisles with each aisle being served by an SRM. The SRM can move vertically and horizontally at the same time. AM II's ASRS module includes the ability to move loads to and from different activity zones in the rack. Coupled with model processes, an AM II ASRS system can represent both the movement and the rack utilization of the ASRS system.

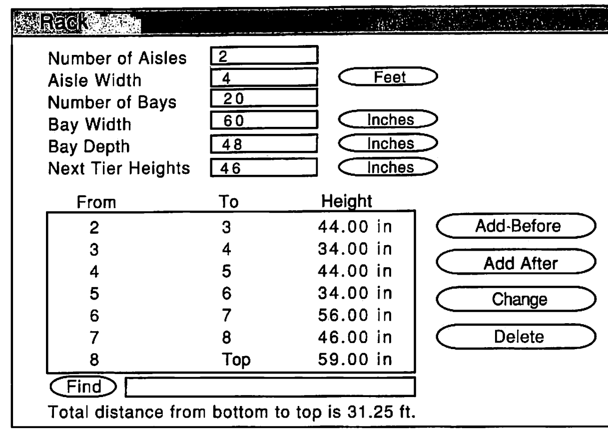


Figure 5. ASRS Parameter Window

Much like the parameters that have been explained for the previous movement systems, ASRS definition is divided into the CAD features for the physical description of the rack, as well as a fill-in-the-blank approach for the parameters such as acceleration, deceleration, velocity, creep speed, creep distance, fine position time, pick-up time, and set-down time.

4.4 Bridge Cranes

The AM II Bridge Crane movement system models the bridge and trolley movement over a series of user defined pick-up and delivery areas. When developing a model of a Bridge Crane system, the area bounded by the rails defines a grid where at each square of the grid the crane can pick-up and deliver loads. When using the Bridge Crane movement system, the modeler can graphically place the bridge. Likewise, pick-up and delivery stands can be placed, zones defined, and cranes specified with a detailed battery of parameters. Bridge Crane utilization can be optimized using sophisticated built-in expert rules.

4.5 Power and Free Conveyor

A Power and Free Conveyor is modeled as a chain with "dogs" attached to the chain. The power and free consists of one or more chains along which carriers move according to some chain-specific attributes. A power and free system generally consists of an overhead trolley with dogs hanging down at set intervals. AM II can also be used to model tow lines, where the chains run in the floor and the dogs pull carts around the system.

The carriers (or carts) transport loads around the system. Dogs move at the same speed on a chain, and therefore carriers are instantly traveling the chain speed when they are engaged. There is a certain amount of time required for a carrier to transfer to a new chain. This transfer time is modeled in AM II as the time required for a carrier to disengage from a dog and wait to pick up a new dog on the destination chain.

Carriers cannot pass one another. Whenever a carrier is stopped along a power and free section, the carriers behind stop as they accumulate, based on the carrier length. The chain does not stop when individual carriers stop. When carriers are ready to move forward, they must wait for a dog.

As with other movement systems, the definition of a power and free system is a combination of inputing graphics and specifying parameters such as section geometry, dog spacing, chain velocity, transfer times, transfer spaces, and carrier length.

4.6 The Kinematic Extension

The Kinematic Extension is an optional system within AM II. It can be used to simulate any device that has motion. A user can define three dimensional components and can inter-connect them with joints—either rotational or translational. These joints allow a user to create machines that have vertical traverses (movement up and down), radial traverses (movement in and out), rotational traverses (circular movement), as well as linear traverses (movement along a track). A joint (motion axis) is defined by its joint speed, motion limits (how far can the rotational joint pivot) and other dynamic parameters. Machines will move at the same speeds and with the same motions in the model as they do in the real world.

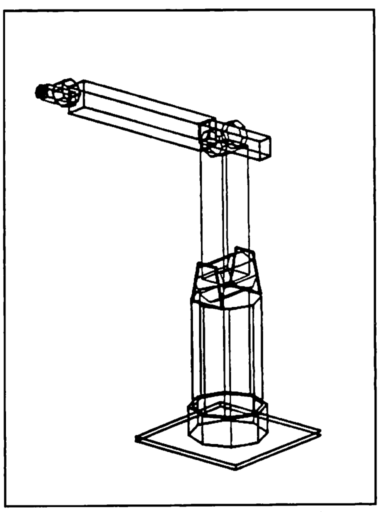


Figure 6. Robot Example

The Kinematic movement system enhances the power and flexibility of AM II by adding the ability to simulate cell-level, detailed machine tasks.

Kinematics can also enhance other movement systems. For example, an AGV can be built that has a multi-axis robot arm on the pay-load deck. The robot arm and the AGV can be synchronized so that the AGV correctly positions itself, the robot arm reaches out and picks up a load off of the dock, the robot arm retracts, and then the AGV takes off for its destination.

4.7 Movement System Summary

The five movement systems and kinematic extension are flexible, so simulating any movement system is very easy. For example: fork trucks are represented as AGVs with a flexible guidepath (set to the null color in the animation), multiple capacity control points, and virtually no blocking. Rotating Storage Carousels are represented as multi-level conveyors with some additional control logic to mimic the synchronization and bidirectional nature of the device.

5. 3D PICTURE CONSTRUCTION

Both dynamic and static objects can be displayed during model execution. Dynamic objects represent loads, resources, queues, and statistics.

The static layout is the background graphics of the plant. It may contain column lines, aisle markings, and walls. Labels can be used to identify specific areas in the facility.

There are several ways to create a layout of the system that is to be modeled. AM II comes with a utility named ACE (AutoSimulations Creation Editor). ACE is a three-dimensional graphics editor that allows the user to construct objects from standard graphics primitives. Cone, Box, Hemisphere, Trapezoid, Frustum, Cylinder, Arc, Vector (list), Set, Text, and Triad are primitives that can be selected, placed, and scaled to create any static entity in the facility.

AM II also has an optional utility called IGES/Sim. The acronym "IGES" stands for the Initial Graphics Exchange Standard. IGES is an industry standard exchange format for translating the graphic data from one CAD system to another. Any IGES file of a plant layout that was created from a CAD system can be easily imported into AM II through ASI's IGES/Sim utility. IGES/Sim can also export AMII graphics files to the IGES format.

6. RUN TIME ENVIRONMENT

In keeping with AM II's interactive features, the user has complete control of the model in the run time environment. The model can be viewed with the animation on, or run with the animation off. AM II uses concurrent animation—the simulation progresses as the animation picture is being updated. With animation off, the simulation doesn't draw the picture but still performs all simulation calculations. The user can suspend the simulation at any instant and review statistics through pop-up windows, take resources down, set break points or alarms, and control the view of the animation without constraint.

6.1 View Control

AM II provides a comprehensive, flexible, and easy to use method of interacting with a model during model execution. If the simulation project is in the experimentation phase where only parameter changes are made and the model needs to be re-run several times, AM II provides the ability to run in batch mode without animation. Whether the need is for a highly interactive mode or a batch mode, AM II lets you do it.

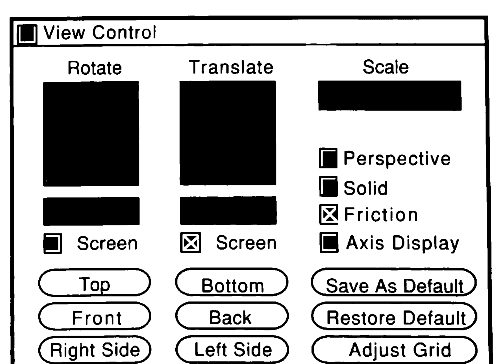
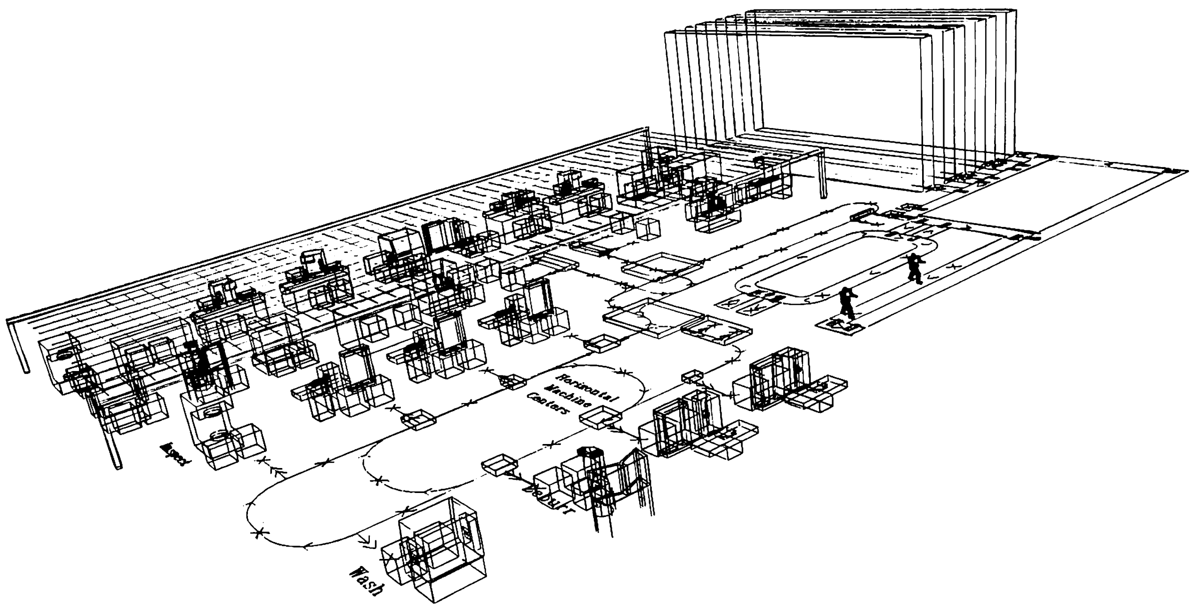


Figure 7. View Control Window

Figure 7 shows the view control window. This window provides the user with the ability to position the graphics of the model in any orientation desired. The View Control allows rotation, translation, and scale to be dynamically changed with respect to all three axes (X, Y, and Z). The workstations that AM II runs on have the graphics



performance to show the view changes dynamically. The animation picture can be shown in solid mode with all the correct Z sorting, so that hidden lines and surfaces are accurately represented. The animation picture can be shown in either perspective mode or orthographic mode. The friction toggle in View Control allows the user to spin or translate the model picture continuously. This is a helpful feature when the model's animation is being video taped or filmed.

6.2 User Interaction

AM II provides advanced debug and trace facilities. The model can be single stepped at any time during the animation. Also, the ability to set breakpoints and alarms allow the user to suspend the simulation when a certain event occurs or when a specific clock time is reached.

AM II also provides comprehensive reports. The reports can be displayed on request at any time during the animation. Printed versions of the reports can also be specified during model build.

AM II automatically keeps track of many statistics. These automatic reports are linked to each specific entity types such as:

- movement systems
- processes
- queues
- resources
- order lists, etc.

Reports can be sorted alphabetically or numerically for easier analysis. The user can also develop and generate custom reports from within process procedures.

7. SUMMARY

AM II is a industrial oriented simulation system that provides the ability to define the physical elements of a system using CAD-like graphics and to define the logical portion of the system using a powerful procedural language. The results are that a typical user can be between 3 to 10 times more productive using AM II in comparison to using any other simulation language. The accuracy and degree of detail with respect to movement systems is unapproached.

AM II allows the construction of very large, complex models. In fact, AM II's structured language has proven that the larger the project, the more benefits AM II has over alternative approaches.

AM II provides real three-dimensional graphic animation. There are no limits to the views or the size of the picture to be shown. The degree of animation realism is also unmatched as AM II provides light-sourced- solid graphics with Z depth sorting, so all entities are shown in the correct relation to one another on the screen.

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