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HOW TO MODEL AUTOMATED GUIDED VEHICLE SYSTEMS USING PROMODEL FOR WINDOWS

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ABSTRACT

The ready availability of personal computers using the Windows Graphical User Interface combined with the ease of use of the ProModel for Windows simulation software and the need to demonstrate feasibility of proposed systems has resulted in a broad new group of modeling users who in the past had to wait for their ideas to be modeled by simulation experts. Previously the high cost of developing models on expensive hardware and difficult to learn software prevented many projects from being simulated. These projects did not benefit from the advantages of testing design ideas prior to implementation. This paper discusses the use of ProModel for Windows for modeling Automated Guided Vehicle Systems. The methodology and considerations needed to produce results with minimal effort are presented. The example presented here represents an actual system designed by Caterpillar Advanced Vehicle Systems.

1 INTRODUCTION

Automated Guided Vehicle Systems (AGVS) are designed to move loads within more complex systems and are usually modeled to determine the ability of the Automated Guided Vehicle System to meet throughput rates or to determine the maximum throughput that can be achieved with a minimum number of vehicles. In some cases the guide path design can be improved along with work search and parking algorithms. The sequence of steps presented below represent an attempt to improve accuracy, avoid common pitfalls and reduce the time needed to produce a meaningful simulation model by non-simulation professionals. Both an overall modeling methodology that has proven useful in the past and detailed modeling procedures for ProModel for Windows are presented.

2 PROBLEM FORMULATION

Determine the quantity of Automated Guided Vehicles (AGVs) needed to meet design throughput rates. Identify any special control procedures that need to be implemented as the actual system is being built.

3 MODEL DEFINITION

In this example two separate but overlapping AGVS are being studied. Each AGVS has dedicated Automated Guided Vehicles and in one area the paths cross over each other requiring intersection logic to avoid collisions. The workload for each AGVS represents a balanced system where the number of empty and full moves are equal to each other. The first AGVS is called Green Route and the second Red Route (see Figure 1).

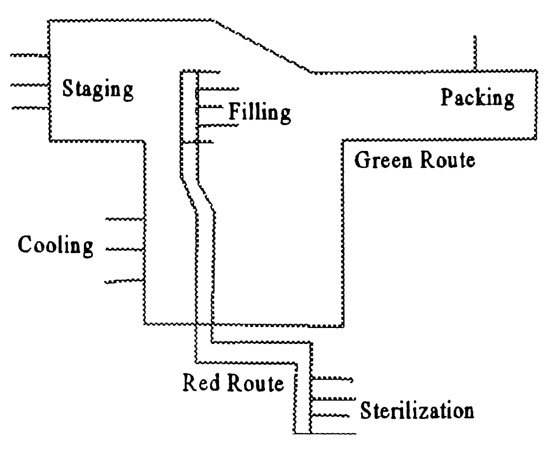

Figure 1 - AGV Path Layout

Green Route: Empty containers are being moved from Packing to Staging and full containers are being moved from Cooling back to Packing. The AGVS consists of a single loop with three off line spurs at Staging and three off line spurs at Cooling. The pickup and drop off points in Packing are located on the AGVS path. Empty AGVs queue on the path prior to Cooling and full AGVs queue on the path prior to unloading at Packing. Note that this path crosses over the red route.

Red Route: Full containers are being moved from Filling to Sterilization and empty containers are being returned from Sterilization to Filling. The AGVS consists of a single loop with four off line spurs at Fill and four off line spurs at Sterilization. Note that this and the green path cross over each other.

Green and Red Path Crossover: The AGVs wait as required at the Red and Green path crossover in order to avoid collision.

4 DATA COLLECTION

Data collection for most AGVS consists of understanding the performance characteristics of the AGVs and the required peak load movement requirements. Tables 1 and 2 shown on the next page list the AGV parameter and throughput requirements for the system. A scale drawing showing proposed path was provided by the customer.

Table 1: AGV Parameters

AGV Parameters	Value
Speed Empty	120 feet/minute[1]
Speed Full	120 feet/minute[1]
Acceleration	1.5 feet/second squared
Deceleration	1.5 feet/second squared
Pick up Time	40 Seconds
Deposit Time	40 Seconds

Note 1. Speed around corners is reduced to 80 Feet per minute

Table 2: System Throughput Requirements

From	To	Loads/ Hour
Packing	Staging	35
Cooling	Packing	35
Fill	Sterile	25
Sterile	Fill	25

5 MODEL BUILDING

5.1 MODEL PRE-PLANNING

We recommend that the very first step in building an AGVS model is to develop a layout showing the location of path and pick up and drop off stands. This should be done to scale using grid paper. An AutoCAD layout can be converted to a Windows Meta File (WMF) format and imported as a background. Nodes should then be placed and numbered on the layout. Place nodes every 10 feet (or the minimum distance that the real system will use to queue AGVs when they need to wait). This will allow queuing of AGVs prior to congested areas in the layout. If the overall length of the AGV is short, say five feet, then you should place nodes at the distance that would be used in the actual system which could be as short as the AGV. Working from a pre-numbered layout works best.

The ProModel Build Menu has been organized following the sequence used to build the majority of models. We will follow that same sequence for our first pass of the model and then come back and add special features needed for modeling AGVS.

5.2 BUILD GENERAL INFORMATION

For most systems select minutes for the time units and feet (or meters) for the distance units. The model notes should be used to list the simulation project team members and last date modified along with any information that will help someone who has the task of maintaining the model in the future.

5.3 BUILD LOCATIONS

Start with a layout of the overall system. For small systems we have found that using grid paper and sketching the path and pickup and deposit stands saves a lot of time. You should set the value of the grid units from the Options, Layout Defaults, Grid dialog box. We have found that a grid unit of 10 feet works for most systems. From the Options Menu select Show Grid and Snap to Grid. Note the location of the pick up and deposit stands (or other locations to which the AGVs will interface). Place and name these using the Locations Edit Table tools. Use an Entity Spot as the Location Icon for each pickup and drop off stand. Replace ProModel's default location name with one that better identifies the stand name. The rest of the default values need not be changed at this time.

5.4 BUILD PATH NETWORKS

Now build the path that the AGVs will follow. In the newer technology systems physical path is not used, but logical path should be placed so that proper control can be given to the system. The path can be made invisible later if needed.

Replace ProModel's default name if you wish. Set queuing to Yes so that fast AGVs will not pass slower AGVs on the path. The default of Speed and Distance rather than Time should be used. The following two items should be considered when laying out the path:

Path Direction. The ProModel default is bi-directional. This is correct for the majority of systems, but not for most AGVS. Therefore double click on the BI column for each segment that should be unidirectional and select unidirectional. Direction of travel will be from the "from" node to the "to" node. Leave off line spurs as bi-directional.

Node Limits. ProModel default is unlimited. Since only one AGV will occupy a node at a time open the Nodes Edit Table and set the limit to 1 for each node except the home node (starting position) for the AGVs which should be set to the maximum number of AGVs that will be used.

5.5 BUILD RESOURCES

Select an icon from the standard library or download the AGV icon library from the PROMODEL BBS. Enter the number of AGVs (starting with one is fine), leave down times as none and select stats by unit. In the Specs dialog box select Closest Resource for the resource search and Closest Entity for the entity search and then fill in the motion values appropriate for the AGV to be modeled. Now complete the following sections:

Search - Work and park search lists can be provided when needed to add additional control capability.

Work Search. When no work search is given ProModel will use the entity search rule selected in the Specs dialog box (closest entity). For most layouts this will allow an AGV to be called to a distant part of the system when within just a few moments an AGV will become available closer to the point of need. The method presented here uses a dummy location which will never need an AGV and forces a work search to that location. When no work is found control then shifts to the park search list which defines where an AGV can be sent to park.

For each node where an AGV will become empty provide a work search list. List each Node, set Type to exclusive and Location List to Dummy. The Park search list described below will move the AGV to the next place where a load can be picked up.

For each node where a load can be picked up list the location name in the Location List.

Park Search. The park search list is used to move the AGV to the next node where a dummy work search takes place. This process continues until the AVG has moved to the final park position which should be a load pickup location.

Logic. At this point an element of an array called zone is incremented upon arrival for those areas where only one AGV is allowed in the zone at any one time.

5.6 BUILD PROCESSING

The processing at each pickup location is a simple wait until statement that causes the loads to be picked up to wait until an empty AGV has arrived at the designated parking location.

5.7 BUILD ARRIVALS

A single entity is scheduled to arrive at each pickup location. This arriving entity causes another entity to arrive at the same location when the entity is picked up by the AGV. This causes the AGV system to always have work to do and is helpful in determining system throughput capability.

6 VERIFICATION

Several model runs were made and output produced compared with hand calculations. Animation was watched carefully to observe that intersection logic and proper movements were being made.

7 VALIDATION

Model results and animation were reviewed by both Caterpillar staff and the client for the proposed system. Model modifications were made as requested.

8 DESIGN OF EXPERIMENTS

Three sets of model runs will be made. The first set will run just the Red route by disabling arrivals to the Green route. Start with one AGV to estimate the number needed to meet throughput requirements then and then run with the estimated number and one and two on each side. The second set of runs will be made for the Green route by disabling arrivals to the Red route. The third set of runs will allow both routes to be active and will use the best number of AGVs from each system as a starting point and then increase if needed to account for congestion at the crossover area.

A warm up period of one hour will be used to allow AGVs to be dispersed throughout the system. Run length will be set to 100 hours. This allows for easy movement of the decimal point to convert total loads moved to total loads moved per hour. The model runs fast when animation is disabled therefore 100 hours is not an excessive run length.

9 MAKE PRODUCTION RUNS

Table 3 through Table 6 have been extracted from the production runs and are discussed in section 9.

10 ANALYSIS OF RESULTS

Table 3 shows results for the Green Route (Red Route disabled). The first run with a single AGV moved 3.91 loads per hour. Since the required thruput was 35 loads per hour it was estimated that nine active AGVs would be required. Additional AGVs may be necessary to allow for battery changing and maintenance activity which has not been included as a part of the model. The model was run for

Table 3: Throughput and AGV Results for Green Route
(Red Route Disabled)

Green Route AGVs	Throughput Per Hour		AGV Utilization				
	Full	Empty	Percent In Use	Percent Travel to Use	Percent Travel to Park	Percent Idle	Percent Blocked
1	3.91	3.92	73.12	13.45	13.39	0	0
7	27.1	27.06	71.81	13.86	13.21	0	1.12
8	31.14	31.12	72.11	14.05	13.29	0	0.56
9	34.47	34.45	71.2	13.6	13.1	0	2.1
10	38.91	38.9	72.1	14.03	13.29	0	0.58
11	43.06	43.05	72.56	14.06	13.36	0	0.02

Table 4: Throughput and AGV Results for Red Route
(Green Route Disabled)

Red Route AGVs	Throughput Per Hour		AGV Utilization				
	Full	Empty	Percent In Use	Percent Travel to Use	Percent Travel to Park	Percent Idle	Percent Blocked
1	3.6	3.61	84	16	0	0	0
5	17.97	17.95	83.81	15.94	0	0	0.25
6	20.52	20.53	80.11	15.3	0	0	4.58
7	24.93	24.92	83.18	15.8	0	0	1.02
8	27.36	27.36	81.22	15.27	0	0	3.5
9	31.4	31.96	82.66	15.49	0	0	1.84

Table 5: Throughput and AGV Results for Green Route
(Both Routes Enabled)

Green Route AGVs	Throughput Per Hour		AGV Utilization				
	Full	Empty	Percent In Use	Percent Travel to Use	Percent Travel to Park	Percent Idle	Percent Blocked
10	37.52	37.53	72.71	12.72	0	0	1.75

Table 6: Throughput and AGV Results for Red Route
(Both Routes Enabled)

Red Route AGVs	Throughput Per Hour		AGV Utilization				
	Full	Empty	Percent In Use	Percent Travel to Use	Percent Travel to Park	Percent Idle	Percent Blocked
8	26.97	26.98	81.9	15.04	0	0	3.07

7 through 11 AGVs. The percent in use stays at about 72 percent with no large increase in blocking.

Table 4 shows results for the Red Route (Green Route Disabled). The first run with a single AGV moved 3.60 loads per hour. Required throughput was 25 loads per hour so seven active AGVs would be required. The model was run for 5 through 9 AGVs. Percent in use varied from a low of 80.11 percent to a high of 84 percent. Blocking was higher than in the Green Route but not at a high level.

Table 5 and 6 show the output with both AGV Systems active. Ten Green Route AGVs and 8 Red Route AGVs were estimated to move the required throughput. A single run was made and all required throughput was moved. No further model runs were required. A slight decrease in throughput was caused by intersection congestion between the two routes.

11 IMPLEMENTATION

At the time this paper is being submitted the model is being expanded to include a third route (Blue Route). Results will continue to be discussed with both Caterpillar system design engineers and the customer. Control logic identified and implemented in the model needs to be integrated into the actual AGVS control system.

12 SUMMARY

ProModel for Windows provides an easy to use interface and animation graphics that make it possible for persons without highly technical simulation backgrounds to develop meaningful simulation models. Knowing that additional control logic is needed should allow for proper system pricing and reduced installation and testing time. Overall the end customer should receive a system that will meet their needs.

AUTHOR BIOGRAPHIES

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