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Multi-agent Formula for automated guided vehicles Systems

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ABSTRACT

Automated guided vehicle system (AGVS) is traditionally used in manufacturing and warehousing. Especially, AGVS has many applications in flexible manufacturing system (FMS) (see, e.g., Ganesharajah, Hall, & Sriskandarajah, 1998; Seo & Egbelu, 1999;
Vosniakos & Mamalis, (1990). Agents are event-driven objects that can integrant in automated manufacturing environments to control certain tasks. In this paper a set of agents (a multi-agent system) is introduced to control an automated manufacturing environment. The studied problem can be modeled as a job shop where the jobs have to transported between machines by AGVs. This article introduces based on a disjunctive graph to modulate the joint scheduling problem and for machines and AGVs scheduling. The objective is to minimize the make span. Some case studies were used to show the effectiveness of simulation in solving these problems

1. Introduction

Flexible manufacturing system is a automated manufacturing systems. That consists on machining centres with automated loading and unloading of parts an automated guided vehicle system for moving parts between machines , and other automated to allow unattended production of parts .In a flexible manufacturing a comprehensive computer control system is used to run the entire system.

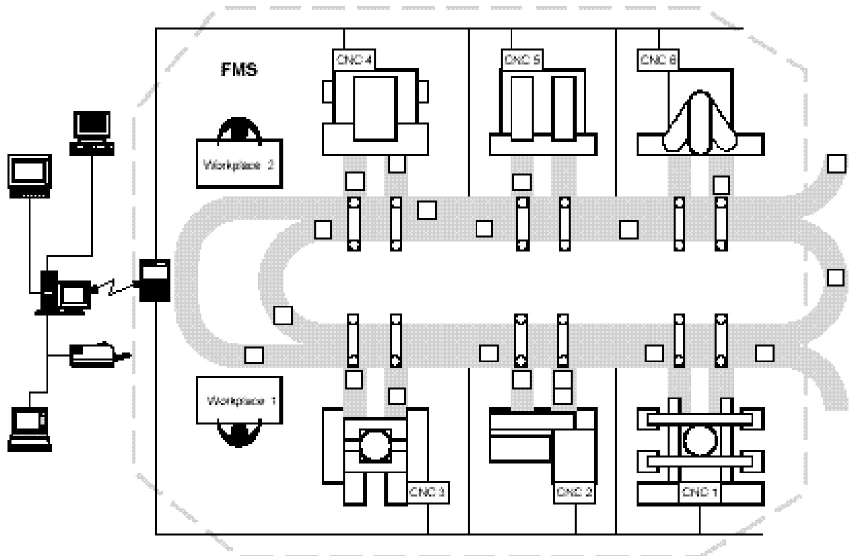

Figure 1. Basic FMS layout

Although these FMS produces benefits like

- Increased return of Equity
- Better competitive edge
- Ability to introduce new products quickly
- Reduced set-up time
- Improved manufacturing control
- Lower WIP inventory

And some other benefits, these FMS are so complex that they can outrun our ability to manage them. The causes which make these machines flexible also add to the complexities of the system. Real time control of FMS is not a trivial task .Flexible routings, processing and part mix as well as the nature of a shop floor, place tremendous demands on the control system. Schedules and strategies lose legality in a rapidly changing system and thus cannot be directly applied overlong planning horizons .To make matters even more difficult no two FMS are identical Because of nature of FMS and differences between systems researchers argue that generic, model solution may be too difficult to resolve in real time. Thus arise a need for an effective tool that can used to manage all the complexities in an effective manner. Various researchers have changed many ways to solve these problems .The popularly used methods are Share model, queuing network, simulation, perturbation analysis and signs. The following Table gives the methods and when they can are used.

Table 1. Usage of models

Model	When Used
Division	Feasibility
Queuing Network	Design/Operation
Simulation	Design/Operation/Detailed Decision
Perturbation Analysis	Decision/Operation/Efficiency
Petri nets	Design/Operation

To select one of these methods depends on the stage of decision making. Choobineh and Suri (1986) gives a set of questions from which a decision can be arrived. A Flexible Manufacturing (FMS) simulation model is setup as shown in Figure 5 following the studies of (Li et al., 2003) and (Li et al., 1997). If a company decides to go for FMS (decided by use of sharing model) all the problems faced from there onwards can be satisfactorily solved by simulation.

A Multi-agent System (MAS) is a loosely coupled network of problem-solver entities that work together to find the answer to problems that are beyond the individual abilities or knowledge of each entity (Flores-Mendez, 1999). In other words a multi-agent system is a set of agents that either cooperate or compete to solve a problem. A MAS is usually used in cases where the problem is complex, data is decentralized, and estimate is asynchronous. In such cases, it is preferred to share tasks over some agents and let them autonomously work and interact with each other.

The surplus of this paper is structured as follows. In section 2 we describe the agent architecture adopted in this research. In section 3 we describe agent communication. In section 4 we discuss a typical example of agents coordinating their activities in to complete a task. This is followed by some closing remarks in section 5.

2. Problems

After it is decided to go for simulation there lies ahead several complex problems. Previous researches have shown that separating the FMS roles introduces flexibility (Flores-Mendez, 1999). After further investigations and a deeper understanding of the different algorithms we interpreted the Network Flow algorithms to be very similar to the Greedy Look-Ahead algorithm. The research done regarding Network Flow (Rashidi and Tsang, 2005) had over 3000 jobs and 10’000’000 arcs which is very time consuming and therefore they limited to the best solution within 2 minutes. In general FMS planning, scheduling, and controlling problems are directly attributable to causes such as layout, number of resources, complexities of the transporter network variety of product mix, managerial, objectives, etc. However, the problems themselves usually vary from system to system. A problem set is a set of real time decisions faced during operation (Grabowski et al., 1986). At first, the study indicated that the due time based methods seemed to allow for more precise scheduling however, when they took bad time estimates into account which is quite common in practice, the Inventory based approach out preformed the due time methods (Briskorn et al., 2006). So finding a common solution is not possible. In this paper some of the problems from a system and its repairs were discussed.

So to solve the problem we separate it into:

1. Design problem
2. Planning Problem
3. Scheduling Problem

4. Control Problem

2.1. Design Problems

While developing a design some decision must precede others. These design problems have to be presented in a sequential manner. However many of the problems are interrelated. There will be most back and forth iteration among the solutions. Design of FMS consists of discovering the process planning, number of pallets in the system, number and design of fixtures, strategies for running the FMS, no of AGV's needed for example. One of the main problems is to identify the type of material handling system and its capacity (Tempelmeir and Heinrich, 1986). Kim and Jang developed a model to find the best number of AGVs of FMS having 8 workstations,8 part types and 5 AGVs. Figure 2.1.1 shows the basic layout of the system

2.2. Planning Problems

FMS planning problems are defined as those decisions that have to make before the FMS can begin to produce parts. So if there is some problem in planning then it's really going to affect scheduling and control. The planning can be for production and maintenance.

2.3. Scheduling Problems

FMS scheduling problems are concerned with running the FMS during real time once it has been set up during the planning stages. There are many possible ways that can be taken to schedule to make parts through the system. Different approaches might be applicable in different situations. Some of problems in are finding out the part types that have to be produced, developing best scheduling methods and algorithms, and setting priorities the parts to be machined, improving Scheduling of the existing system.

2.4. Control Problems

FMS control problems are defined as those associated with the continues checking of the system, by keeping track of the production to be certain that production needs are met as scheduled (Choobineh and Suri, 1986). The main problems in control are discovering a policy to handle machine tool and other breakdowns, scheduled, periodic, preventive maintenance and find out in process and finished goods inspection.

2.5. Case Study

The case studies mentioned here concentrates on the different problems and how they were overcome. The case studies were given for

1. Planning Problem-No of AGVs needed
2. Scheduling problems-Optimum scheduling of jobs in existing system
3. Control problems-Preventive maintenance using stochastic model simulation

2.5.1. AGV Needs

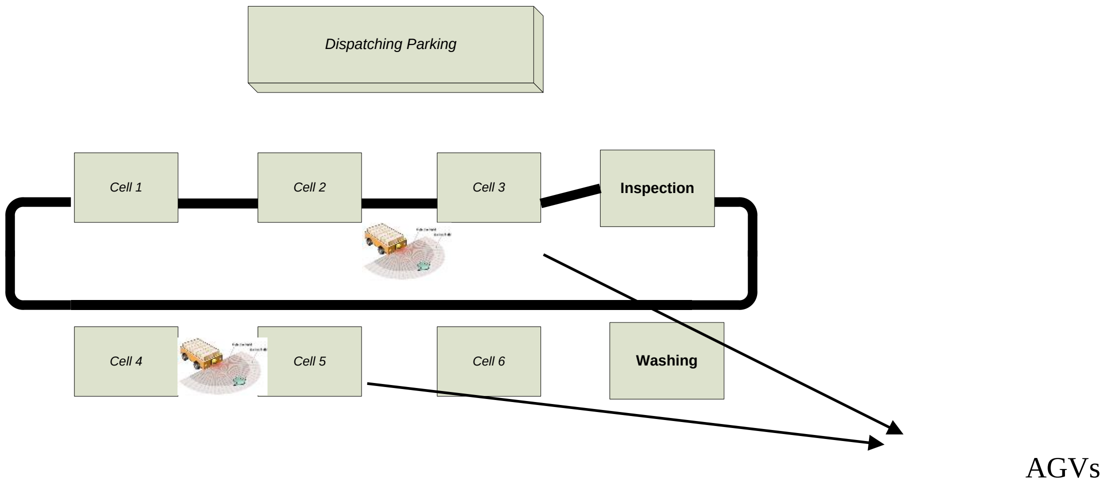

Figure 2. Layout of FMS under study

The objective of the model is to decide the machine dispatching rule and the AGV sharing rule to minimize the mean flow time with the AGV request time. The model involves 10 machine dispatching rules, 4AGV sharing rules and 5 AGV request times. His model assumes the arrival time of the parts be exponentially shared and the total simulation time is 9600 minutes, being one month.

For example, Part A starts with Cell 3 and then goes through Cells 5, 1, 4, 2, and 6. After to complete this process, it goes to the washing machine for washing and continues to go to the inspection station to be inspected. Here, PT stands for Processing Time, TP for Total Processing time, and DD for Due Data.

Two assumptions are made:

1. Any job cannot be processed more than once by the same machines.
2. Every job must visit the washing station and 50% of all jobs must visit the inspection station.

2.5.1.1. Factors in Simulation

Three factors to affect the simulation are considered: machine dispatching rule, AGV sharing rule, and AGV request time.

(1) Machine Dispatching Rules (Briskorn et al., 2006).

The Machine dispatching rule followed here is one of the most commonly used methods. Here NINQ is used.

Table 2. Dispatching rules

Dispatching Rule	Explanation
SPT	Shortest Processing time
LWKR	Least Number of Work remaining
MWKR	Most Number Of Work remaining
FOPNR	Fewest Number Of operations remaining
MOPNR	Most Number of operations Remaining
FIFO	First In First out
SLK	Slack/Number of operations
CR	Critical Rate
NINQ	Shortest Queue of the next process machine

(2) AGV Allocation Rules
The AGV allocation rule is invoked whenever the processing reaches a certain degree.
AGV allocation rules used are:

- Cyclical Order: when tries to cycle through the transport
- Random Order: when there is no need
- Preferred Order: when tries always to select the AGV with the highest priority
- SDT (Small Distance Transport) Order: when tries to select the nearest AGV

The rules above are defined in ARENA. Note the preferred order depends on the priority based on the AGV velocity.

(3) AGV Request Time

The AGV request time refers to the time an AGV is called whenever the machine processing reaches 60% - 100% of the needed processing time in the base model. Since this factor is expected to significantly improve the AGV use, it is the most critical one in this paper.

2.5.1.2. Simulation Analysis

The formula used for finding the number of repeats is

$$n \cong n0 \times (h02/h2) \quad (1)$$

where,

H0: initial half width

n0: the number of initial replications

h: the expected half width

where the standard deviation between the number of replications is large within 95% confidence interval.

Consequently, to reduce this standard deviation, 0.5 as the value of h was chosen and thus 80 was obtained as the number of replications. Therefore the results were yielded by repeating simulations 80 times for all alternatives.

The performance measures employed in this paper were

1) mean flow time and
2) Throughput.

To determine the number of AGV simulation was performed based on shortest processing time. Four AGV shares were simulated using all the dispatching rule and AGV request time. For throughput, there was little difference when the number of AGVs is 3 with less than 70%" of AGV request time. Without AGV request time, we know the throughput greatly improves when the number of AGVs is equal to or greater than 4. On the other hand, for the case of mean flow time, there was little difference when the number of AGVs is 4 and 5 with "less than 80%" of AGV request time while there was difference with "greater than 80%" of AGV request time. Obviously, as the number of AGVs comes larger, mean flow time becomes less .With the consideration of AGV request time, 4 AGVs would be most pertinent since there was no significant difference with "less than 70%".

With the SPT machine dispatching rule the 4 AGVs would be the best number because there was little difference between 4 AGVs and 5 AGVs.

2.5.2. Optimal scheduling of jobs in a existing system

FMS being an expensive, highly automated and flexible system, it is essential that its capacities should be used in a cost-effective way. In continuation the existing system A6 module upgraded will be presented – by scheduling methods, use of simulation and decision rules– in order to ensure optimal use of FMS capacities Scheduling is used in order to achieve optimal or at least sub-optimal load of production system elements. The scheduling provides us with all the data required to carry out the planned production in specified interval.

General n/m scheduling issue, where n jobs should be scheduled to m machines (taking into account proper

Sequence of operations defined by technology routings) is a very complex task and has many possible solutions in real-life situations and for real-life number of jobs. There are additional scheduling limitations which reduce the number of possible solutions, however, they make scheduling more difficult. These limitations are: logical –they originate from technology routings (operations can be scheduled only after their predecessors have been completed), and physical (only one operation at a time can be carried out on a machine). Scheduling in complex manufacturing systems must take into account features of these systems, as well.

2.5.2.1. Scheduling methods

FMS efficiency depends considerably on the selected scheduling method. It can be seen from Figure 3 that there are two groups of scheduling methods:

- optimization methods, which allow for definition of optimal scheduling, however, they cannot be used in practice as they require too many data, and
- non-optimization methods, which allow for a definition of sub-optimal scheduling (it may be optimal) and they can be used in practice (Yalcin and Boucher, 2000).

The Modules of a commercial PPC system is give as follows

- planning
- Material requirements
- planning
- Material flow planning
- Capacity planning
- Release of jobs in to FMS
- Fine planning and termination in FMS

2.5.2.2. Scheduling simulation

Fine planning and termination of jobs in FMS is with the last module of a PPC system. This task is carried

in four consecutive sub-modules :

1) Flow termination of jobs,
2) Rough termination of capacities,
3) Fine termination – scheduling (basic), and
4) Scheduling simulations.

2.5.2.3. Decision rules

The result of scheduling simulation is a set of possible schedules and the planner should select the optimal one. Optimal schedule selection process is presented the following figure

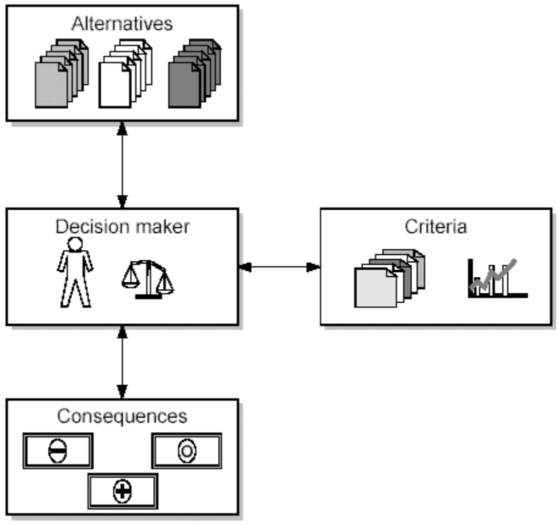

Figure 3. Method for selecting optimal schedule from the simulated alternatives

2.5.2.4. Simulation

The simulation was carried out for the set-up shown in Figure1.1Taking into account the selected planning interval and survey of jobs that should be processed in FMS, by means of the PPC system the basic or starting schedule of jobs was obtained, as presented in Figure2.4

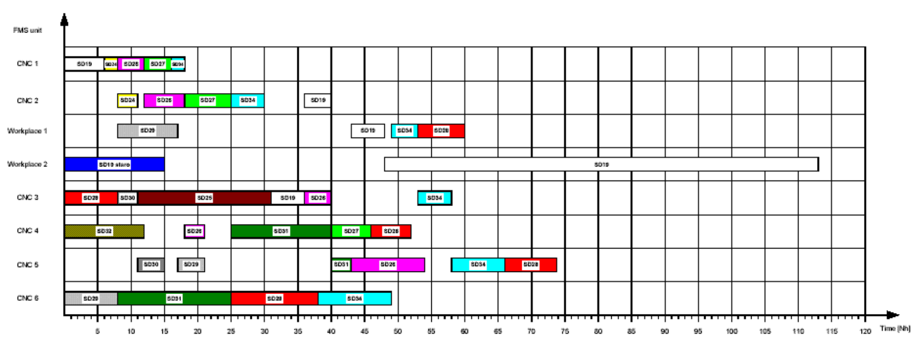

Figure 4. Basic schedules Of FMS

Then simulation was carried out in FMS using the following eight scheduling methods:

M1 Shifting Bottleneck (minimizing Cmax),
M2 Shifting Bottleneck (minimizing Tmax),
M3 LRPT – Longest Remaining Processing Time,
M4 MS – Minimal Slack,
M5 Shifting Bottleneck (minimizing = C1),
M6 Shifting Bottleneck (minimizing = T1),
M7 SRPT – Short Remaining Processing Time,

M8 EDD- Earliest Due Date.

Then the simulations were evaluated Simulations were evaluated by four criteria:

- Maximal completion time Cmax,
- Total tardiness = T 1 ,
- Number of late jobs NT, and
- FMS efficiency ηFMS.

Evaluation of the basic one and eight new scheduling simulations was viewed in four criteria and results of the evaluation are presented in Table 3. For final evaluation of the basic scheduling and eight alternatives we used the relative weight marking method the results of which are presented in Table 4.

Table 3. Final Value of Scheduling Criteria

Criterion	Weight	Alternative								Basic Schedule
		M1	M2	M3	M4	M5	M6	M7	M8	
Max Completion Time	2	88	88	90	90	98	99	110	113	113
Total tardiness	3	324	324	342	342	175	167	168	221	217
Number Of late jobs	1	9	9	10	10	6	7	5	7	7
FMS efficiency	4	0.57	0.7	0.57	0.57	0.7	0.58	0.62	0.58	0.59

Table 4. Schedule Marking Results

Criterion	Weight	Alternative								Basic Schedule
		M1	M2	M3	M4	M5	M6	M7	M8	
Max Completion Time	0.2	20	20	19.5	19.5	18	17.5	15	14.3	14.3
Total tardiness	0.3	1.8	1.8	-1.4	-1.4	29	30	29.8	20.3	21
Number Of late jobs	0.1	2	2	0	0	8	6	10	6	6
FMS efficiency	0.4	33.2	33	33.5	33.5	38	40	36	34.2	34.5
Sum Of Points	1	57	52	51.6	51.6	93	93.5	90.8	74.8	75.8
Position		7	6	8	8	2	1	3	5	4

Looking closely at the schedule marking results we can see the best scheduling is earned by using the M6 method (Shifting Bottleneck – minimizing = T 1), which has the following advantages over the basic scheduling:

- maximum completion time Cmax is reduced by 14 %,
- total tardiness is reduced by 30 %,
- FMS efficiency increases approximately by 9 %,
- there are seven late jobs in both cases, and
- average deviation between the basic and the ideal alternative schedule is approximately 20 %.

The following Figure gives the optimum schedule.

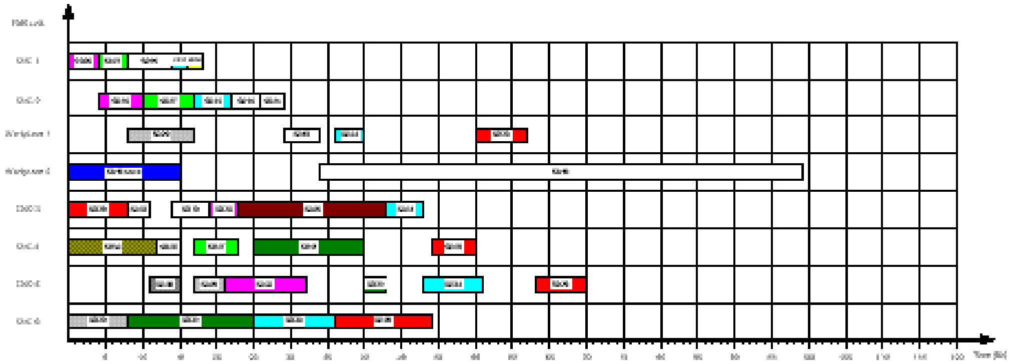

Figure 5. Optimum Schedule

2.5.3. Preventive Maintenance

As preventive maintenance is one of the important part of control (Choobineh and Suri, 1986) it is necessary to give importance for preventive maintenance .Many previous studies earlier conducted fall in the category of piecewise deterministic process, based on the assumption the automated production systems can be considered as deterministic systems as long as no machine breaks down or stoppage occurs. But in a stochastic model each machine is subjected to random failure according to a homogeneous Markov process. But in practice many factors affect the failure like age, production rate etc. So to overcome this problem stochastic approach simulation VC++ model was developed for preventive maintenance.

Two work station models were considered for planning production and preventive maintenance model in FMS. The system had both continuous variable and discrete variable.

The preventive maintenance under consideration can be defined as follows: performing preventive maintenance on workstation FMS within workstation life expectation. The FMS is as good as new in the beginning of the and at the end of it's life expectation it is renewed so they return new. At every time interval of T PM is performed .The objective of the model is to determine optimal interval T* such the total cost of expected repair, preventive maintenance and renewal is minimized.

2.5.3.1. Assumptions

1) The FMS starts to operate at time zero.
2) The failure rate is occurring to the exponential distribution exp ((λ), a(t)
3) Two machines are identical
4) Failure arrival rate is proportional
5) Renewal and minimum repair do not alter rate distribution
6) The repair and time are negligible
7) The demand is constant

2.5.3.2. Cost Analysis

It is assumed cost depend on

- The repair activity offer failure
- The PM activity
- The renewal activity

The decisions available are preventive maintenance, minimal repair and renewal. Cp, Cf, Cr represent average cost for PM, Every minimal repair and every renewal respectively. Interest rates and inflation rates are also taken into account.

Based on the above assumption the total cost in the life expectation of FMS is

$$Tc=Cr+Cp(1-qN+1)/(1-q)+\sum M(i)Cfqi \quad (2)$$

Based on the binary search algorithm the model was formulated

In this model the life expectation of machine is 10years, price to install a new system Cr=$1000, 000, Cost of Preventive maintenance is Cp=$1000, Cost for minimal repairmen Cf=$500, inflation rate is 3%per year, and interest rate is 8% per year,

The min time for maintenance .2year

i.e X=2 and K=50.

The optimal cost and the optimal results were found and tabulated as given below (Table 5).

Table 5. Results after iterations

Iteration	Ni	TC (Ni)	Nu	TC (Nu)
1	13	2642877	38	1524274
2	22	2061527	41	1460914
3	29	1775338	44	1405372
4	34	1623142	45	1388408
5	38	1524274	47	1356588
6	41	1460914	48	1341669
7	43	1423087	48	1341669
8	44	1405372	49	1327369
9	45	1388408	49	1327369
10	46	1372157	49	1327369
11	47	1356588	50	1313662

After running the simulation the optimal point is found to be 50 i.e. preventive maintenance is performed as often as possible. This result is determined by the cost of the minimal need and preventive maintenance.

3. Conclusion

Difficult planning, scheduling and control problems have created an interest in simulation as an online tool. Conventional simulation models were “throw away models” (Grabowski et al., 1986) in the sense they are never used after the associated plans or designs have been finished. An online simulation model is however is intended for daily or periodical use as it was mentioned earlier that FMS are dynamic in nature, the online simulation models require a higher flexibility and adaptiveness.

The case studies shown in this paper discussed the problems and the methods to solve them. Although previous researches like this have shown the effectiveness of simulation as a tool for these problems still real time simulation is a challenging task. The AGV case study gives the best number of AGVs to be used for the system .The number came out to be four and it was also found that adding more AGV doesn't make any difference. The stochastic model simulation for the preventive maintenance case study deals with a different approach. Normally the models are based on discrete values whereas this deals with continues variables.

Future researches may be concentrated on this area because stochastic modelling proves to be more effective than the normal .The focus of the present researches are more towards online simulation which needs increased programming and simulation software. But as said earlier the advancement brings more sophistication and so problems.

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