# INTSCHED – A DYNAMIC OPTIMISATION MODULE FOR MODELLING AND SIMULATION IN FLEXIBLE MANUFACTURING SYSTEMS

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**Abstract:** In this work an intelligent module ("INTSCHED") for control platform software is presented, which supports the optimisation of dynamic planning and supervision in FMS. This module, a simulation of the investigated manufacturing systems, consists of several input, output, communication and analysing modules. The central element of this module is the optimiser. In combination with several other modules the optimiser works out the best solution for the predefined manufacturing problem. The development of the optimiser is made by insertion of genetic algorithms and some other heuristic methods. This special tool supports the operator of the control platform in difficult situations and helps him to improve his decisions in critical but realistic problems. This module offers the possibility to use different working scenarios and to solve conflict situations in an intelligent way. The model is based on priority structures and queues of orders and activities. This module is implemented and verified on three flexible systems: flexible manufacturing system, flexible assembly system and flexible transport system; as a part of CIM factory solution.

*Keywords:* flexible manufacturing systems, scheduling, simulation, optimisation, genetic algorithm, working scenarios

## INTRODUCTION

Modern market requires a large variety of products with high quality and low prices at the same time. Such modern production is characterised by some trends: the variety of products is permanent increasing, the product lifespan is getting shorter, the number (total production volume) of identical products is decreasing, wishes from customers influence the product design significantly etc. Classical manufacturing systems are not capable of satisfying all the needs of the global market. The main goal of classical automated production systems was to manufacture large series of the same or very similar products at low cost. An answer to the changes of the market in production was the introduction of the concept of Computer Integrated Manufacturing (CIM) as global and Flexible Manufacturing Systems (FMS) as particular solution.
Modern manufacturing systems are mostly complex systems with an highly sophisticated level and with high efficiency. FMS is one of the most efficient manufacturing systems realised in modern industry. Modern FMS are the result of three main developments: integration of computer in manufacturing, using flexible structures and strategies and using the methods of artificial intelligence to increase the quality of decisions in real time with the main aim to increase the efficiency of the FMS.
The efficiency of FMS directly depends on the quality of ideas and intelligence which are implemented in the FMS. This is the unique medium which ties together all the operational functions and activities that are completed by different components of the system inside of FMS with limited resources and a lot of bottlenecks. It is necessary to design and implement intelligent tools for optimisation of FMS working scenarios and to solve conflict situations and control such a system in an intelligent way. The optimisation has to take three main parameters into consideration: the structure and functionality of FMS, the actual state of FMS and scheduling.
Scheduling problems for a complex FMS can pose extremely complex combinatorial optimisation problems, because several different constraints may be relevant in realistic problem situations, such as alternative processing plans for the manufacturing of a product, specialised production structures, and so forth.
For efficient scheduling of FMS, the system operator as a user of FMS has to make a lot of decisions in complex situations and good time. Quality of decision and time needed influence directly the efficiency of FMS.
The structure of an intelligent module ("INTSCHED ") for optimisation of complex FMS scheduling is presented in figure 1.

## "INTSCHED"

INTSCHED is realised as a software package and programmed in *Borland Delphi*. The module is designed as interactive support for FMS system's operator during:

- Diagnostics: machine tools diagnostics, equipment diagnostics, orders execution diagnostics, tool and system diagnostics, etc.
- Projection of alternative virtual scenarios;
- Optimisation during the scheduling of FMS;

- Finding solutions in complex conflict and chaotic situations, etc. The selected orders will be assigned to an installation (each order has a priority), where at once the proportional possibilities and their allowable combinations are determined (figure 2.g).

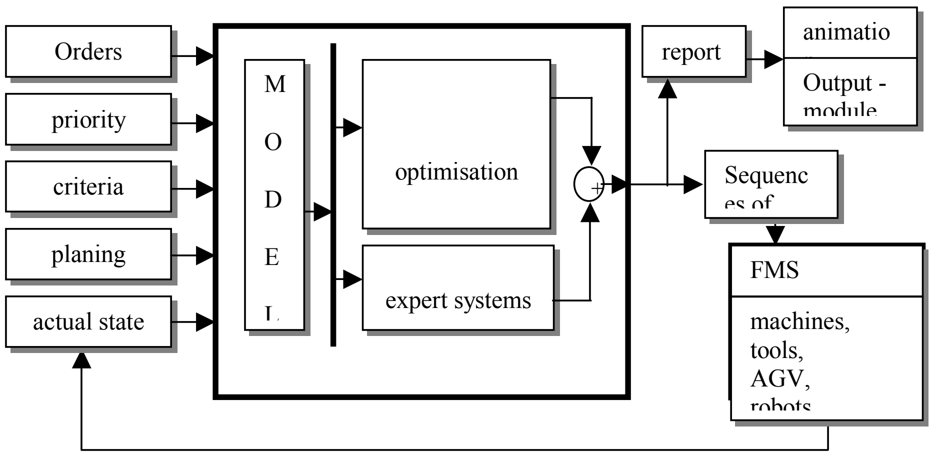


Figure 1. The structure of INTSCHED

The operator of the control platform initialises a population of orders and gives a time interval as stopping criteria (figure 2.c & 2.e). During this interval the module chooses an optimisation method (enumerative, branch and bound, genetic algorithm, ...) and in combination with multi - criteria (heuristic's) generates and optimises a plan of production.

The fitness function for the optimising of the scheduling is a complex function which considers diverse criteria. Two kinds of fitness functions are used. The first fitness function is a weighted total evaluation where a lot of simple criteria (priority, set-up time, process time, start date, due date, actual state of FS, minimising flow tools, minimising AGV routs, etc) are included. There are 47 different criteria implemented (figure 2.b). The criteria can be applied singly or in combination; depending on the state of the FMS, the expert - operator will design the best strategy for scheduling.

The second fitness function can be used as a objective function. There are a lot of objective functions which can be used as fitness functions: balancing machines, minimising flow times, minimising total number of reject, minimising make span (completion time for the last job), minimising total processing cost, etc (figure 2.c).

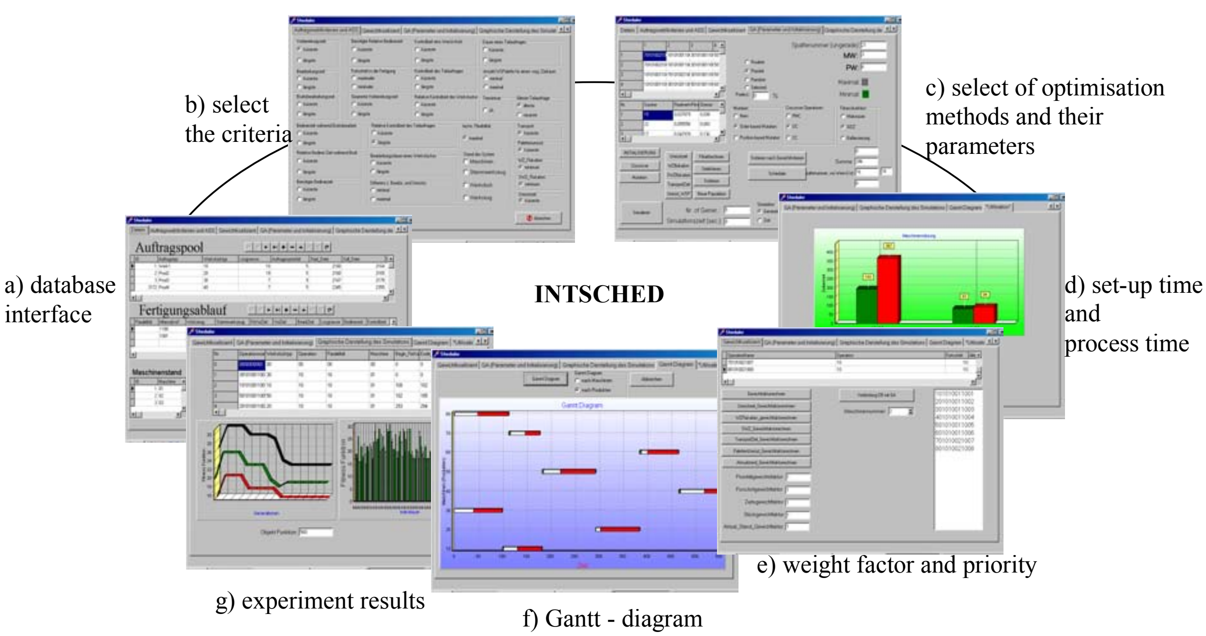


Figure 2. The user interface of INTSCHED

The result of optimisation is an (sub)optimal order. This order will be build in a virtual scenario in the case of simulation (off-line) or in a working scenario of FS in the case scheduling planning (on-line). The results obtained from scheduling give information how to build up the queues. The queues determine the operation sequences on machine tools, the flow of pieces, tool flow and sequence of set-up activities.
The necessary data containing the information on the state of the FS system can be transferred directly over the information-flow structure of the FS. Specific data can be given to the module via an interactive dialogue with the operator or over an intelligent sensor system (figure 2.a).

## CASE STUDY: COMPARISON OF TWO DIFFERENT WORKING SCENARIOS

INTSCHED offers the possibility to realise different virtual scenarios.
For high flexible FMS, we will compare two different virtual scenarios which can be realised by INTSCHED. These scenarios have different fitness functions and use different algorithms.

### First Scenario (WS_I)

The fitness function is a weighted total evaluation where a lot of simple criteria (priority, set-up time, process time, actual state of FMS, etc) are included.

$$\mathrm{SUM}((K_{ij} / G_i) * 100) \qquad (1)$$

with:

$K_{ij}$ – weighted total evaluation of criteria **i** for order **j,**
$G_i$ - weighted total evaluation of criteria **i** for all orders.

This function is used to solve conflict situations, because the technical methods can show up dynamic effects, which cannot be taken into consideration when creating the initial scheduling.

The algorithm is given as follows:

1. Provide orders,
2. Select the criteria (all together 47 criteria)
3. Initialisation of population (randomly)
4. Calculate the weighted function for each order
5. Sort the orders in a queue by weighted function
6. Calculate the object function (example make span)
7. Evaluation of population
8. Selection of chromosomes in new population
9. Repeat the steps 5 to 9 until time = stopping criteria
10. Visualisation of orders sequences with Gantt Diagram

### Second Scenario (WS_II)

The fitness is regarded as an objective function. There are a lot of objective functions which can be used as fitness functions: minimising flow times, minimising total number of rejections, minimising make span (completion time for the last job), minimising total processing cost, etc.

The algorithm is given as follows:

1. Provide orders
2. Select the criteria (all together are 47 criteria)
3. Initialisation of population (sequences of orders in each chromosome will be created by one just criteria)
4. Calculate the objective function (example make span)
5. Evaluation of population
6. Selection of chromosomes in new population
7. Repeat the steps 4 to 6 until time = stopping criteria
8. Visualisation of orders sequences with Gantt Diagram

### Example

To find out which of these two scenarios gives the best solution in short time, a comparison was set up. This comparison can help to choose a better strategy during practical applications.
The comparison considers a system of 42 orders and 4 machines. The allowable combinations of orders are determined. The information about the priority, products and time scheduling can be taken directly from a database.

### GA Operator Technique And Parameters

The important components of each GA are the syntax of the chromosomes, operator techniques and fitness function.

*Representation*. In the proposed approach an individual of a population is interpreted by orders which are coded to a string. This string gets the following information about orders: product, operation, sequence of operation, production alternative, material and tool (figure 3).

A String Gen

| product A, operation B, sequence C, alternative I (machine D), material E, tool F |
|---|

where A, B, C, D, E F and I are integers.

Fig. 3. The syntax of gen.

The length of a chromosome equals the number of orders. The position of a gene represents the position of the order in the sequences of the FMS scheduling.

*Operators*. The operators of GA construct a new possible solution [Davis, 1991]. For this example the following operator techniques are applied:

- roulette-wheel,
- order crossover
- order mutation

As fitness functions the minimising make span is applied here.

The parameters of GA are given in tab.1.

| Parameter | Description | Value |
|---|---|---|
| NI | Number of Individuals | 47 |
| PS | Selection Rate | 0.3 |
| PC | Crossover Rate | 0.6 |
| PM | Mutation Rate | 0.3 |

Table 1. The Parameters of GA

As stopping criteria the number of generations (200 generations) is used.

The results of the comparison are given in tab. 2.

| | shortest time | WS_I | WS_II |
|---|---|---|---|
| Make span | 2033 | 1721 | 1530 |

Table 2. Result of the comparison

The second strategy (WS_II) gives the best solution. It is more flexible for combinations, but it can only be used for off-line optimisation, because the information about the actual state of the FMS cannot be included in its fitness function.

The first strategy (WS_I) is very suitable for on-line optimisation. Here it is possible to include all important criteria (including also the actual state of the FMS) into the fitness function.

Both strategies are better than single criteria (in this case than shortest process time).

## CONCLUSION

The implementation of INTSCHED has the following advantages: (1) it can determine a high-quality scheduling, because several optimisations techniques are implemented, (2) it is very flexible to be connected with other software like SAP, (3) it can be directly connected with external databases, so production planning with scheduling can be integrated, and (4) it can directly get the real state of each FS subsystem over special interfaces in real time, so it can be used as real-time optimiser of complex FS dynamic scheduling.

This module is most suitable for application over a wide range of flexible manufacturing systems.

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