Production Scheduling in Batch-Process Industry

ir. Pieter Leijten

Pieter Leijten was the first OOTI student to include a part of the post-graduate course Logistical Control Systems in his OOTI curriculum. Since then, his work has always been a combination of both computer science and logistics. Currently, he works at Fygir Logistics Information Systems. In the first part of this article, Leijten gives his views on working in a small company and evaluates the value of the OOTI course for his current job. In the second part, he describes the typical characteristics of production scheduling in the batch-process industry and Fygir's product GRIP.

Small versus large companies

Fygir Logistic Information Systems is an innovative Dutch company with offices in the Netherlands and the UK. Currently, 23 people are employed by Fygir. Fygir specializes in production planning software for batch-process industries. The standard scheduling software GRIP, currently market leader in the Dutch batch-process industry, is developed at Fygir's Rijswijk office. Customer-specific software is also developed there. These projects always incorporate at least one of the fields in which Fygir excels: planning, databases, and high user interface dependency (interactive systems).

Three years ago, at the start of my employment, only five people were working for Fygir. The stable growth of Fygir had consequences for me in the sense that every few months new people were joining the company and responsibilities and tasks were redivided. I could more or less choose the direction in which I wanted to develop myself. In a large company, this development tends to be slower, because you do not get the chance to prove yourself in too many areas and positions do not become available with the same frequency.

Especially in the beginning, the range of my activities was very broad. I got the chance to experience it all and make my choice for the future. Currently, I work in both sales and projects. The field of scheduling is relatively young, so the standard software is constantly being developed further. Suggesting and designing new functionality of the standard package is part of my job as well.

Other nice aspects of working in a small company are the short communication lines and informal contacts. At Fygir, we have a monthly dinner meeting to keep this informality in the company and to inform one another about current projects. Naturally, there are also minor disadvantages to working in a small company. During the setup period of a company, one cannot expect that all kinds of jobs have a responsible person (e.g., a secretary) for them. People that want a job that enables them to devote their time to their specific scientific interests only, might be better of in a large company. They should definitely not work for a small company in a startup situation. Personally, I find it very motivating to work in a small team and to be able to see the results of my efforts directly. At this moment, people still have various responsibilities at Fygir. I personally have always preferred some variety in my work.

Benefits of OOTI

In my sales job, I profit from the courses where presenting yourself and your story were handled. In my job, I often handle the first contact with a prospect. In some cases, e.g., presentations to higher management, appearance and presentation is almost as important as your scientific message. As a project leader, I profit most from the project management parts in the OOTI programme. As a designer, I profit from design and user interface affiliated parts in the programme, although the OOTI field of application (embedded systems and delay insensitive circuits) is not my current working field. Programming languages, development environments and databases that are frequently used by Fygir are C, NeXTSTEP, 4TH DIMENSION, and ORACLE. The FUSION design method is used for the development of object-oriented software.

Batch-process industries

Batch-process industries have certain characteristics that are essential for the scheduling approach. Examples of batch-process industries are: food & beverage industry, chemical industry, and pharmaceutics industry. In the following paragraphs, the batch-process industry is compared with the discrete industry and the major differences are explained in the field of storage of intermediate products.

In batch-process industries, the products are usually fluid. Therefore, they cannot be held in storage on pallets or on a pile on the shop floor. Those products have to be kept in tanks or silos. Usage of those tanks have to be planned in detail, because the tanks stay fully occupied until the last drop has been drawn from them. The number of tanks occupied at any point in time cannot be calculated from the quantities of each product in storage, without knowing which batches supply the product and which batches use it up and which tanks are chosen for the storage.

In discrete industries, the storage capacity might be limited as well. However, the number of different products in storage is not as important as in process industries. In a storage room, the space can usually be redivided easily among the products in store. In practice, when storage capacity is lacking for a short period in time, exceptions can often be made by using a part of the shop floor. In batch-process industries, the (perishable) product might even have to be thrown away, or at least production will be blocked for a while.

A generic optimization algorithm to solve scheduling problems for the batch-process industry does not exist. This can be explained as follows. Usually several stages can be distinguished in the production process. A batch in one stage delivers a product that is used in the next stage. A scheduling problem in which only one stage is involved, is called a single-level problem. For single-level problems algorithms or sorting rules are useful. Examples of rules are Earliest Due Date (EDD), that optimizes the average lateness of jobs and Shortest Processing Time (SPT), that optimizes the number of jobs completed. As a result of the flexibility in storage in discrete industry, the multi-level scheduling problem can be split up into several separate single-level problems. As explained above, in the batch-process industry this is not possible. Therefore, a purely algorithmic approach to batch scheduling is usually not possible because most multi-level scheduling problems can be mathematically classified as non-polynomial, resulting in calculation times that are unacceptably long even for small problems. Also it is very hard to model in advance all constraints that can arise in future situations.

GRIP$^{(R)}$

We will now describe the GRIP software that has been implemented in up to 40 production sites in the Netherlands, the UK, and Germany. Examples of companies that use GRIP are: Unilever, Akzo Nobel, Coberco Dairy, Nutricia, Gist-Brocades, Beiersdorf, etc.

Fygir's philosophy behind the design of GRIP, is that cooperation between planner and computer system will lead to maximum flexibility and optimal results. To achieve this, a lot of attention has been paid to the way in which man and computer exchange information. The GRIP graphical interactive planning board presents schedules in a clear way and allows for easy construction and manipulation of schedules. Schedules can be generated automatically, but it is also possible to guide the construction of a schedule step by step. GRIP can therefore best be characterized as a decision support system (DSS) that leaves room for intuitive considerations and exception handling by the planner. The advantages of the DSS approach over algorithmic approaches are: a more generic applicability, easy process modelling, and flexible control over the scheduling process.

System's architecture

The GRIP system comprises the following constituent parts.

- a relational database model
- scheduling heuristics for batch creation, sequencing and scheduling
- an interactive planning board
- a constraint calculation and checking mechanism
- dynamic charts for inventory and manpower
- graphical and textual reporting facilities
- on-line interfaces

Relational database model

GRIP has a relational database in which all data on the production process and planning are stored. This facilitates the access of information and the exchange of data with other computerized systems. The database contains four models.

1. The factory model.
The factory model includes the resource descriptions. Each physical part of the production process which must be available at a certain time in order for processing to take place can be included as a resource in the model. Examples are: packing machines, blenders, storage tanks, and specific tools. A number of parameters can be included in the resource description like maximum operating time, sequence dependent changeover matrices, or minimal and maximal contents.

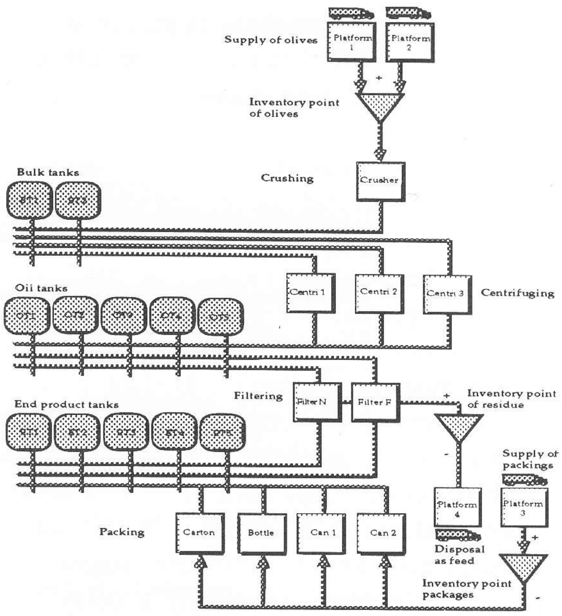


Figure 1: Example of a factory model in GRIP with resources for each production stage.

2. The stage model.
The stage model defines the over-all structure of the production process by defining the production stages that the different product families can go through. Stages can be linked into routes that represent a sequence of coupled production stages.

3. The product model.
The product model defines the product dependent data in each production stage. This is done by modelling process steps in all the stages a product goes through. Such a process step defines both the material requirements and the operation. The material flows are modelled as inputs and outputs of a process step. The material flows relate to inventory points or to other process steps in a previous or consecutive production stage. This network representation allows modelling of diverging and converging product structures, by-products, and alternative routings. Definition of the operation includes the specification of the resources that are required to perform the operation, batch size rules, changeover characteristics, availability of tanks for storage afterwards, etc.

The definition of products is guided by GRIP using the global structure of the production process from the stage model.

4. The planning model.
The planning model can be used to store schedules of various periods. The batch plays a central role in the planning model. A batch is the abstract representation of an activity that takes place between two points in time. It refers to a certain quantity of a specific product. Examples are: processing of a certain quantity of product with a machine or storage of a quantity of intermediate. GRIP keeps track of the dependencies among batches in a network. In this way the consequences for all subsequent stages in the production process, caused by a delay in the material supply or batch execution, can be determined immediately. Similarly, planners are supplied with visual information on the earliest and latest start time of each batch in order to meet delivery obligations.

Scheduling heuristics

Batches can be created starting from inventory points or from production orders that can be manually entered or read in through an interface to an external system. When determining the batch quantity, GRIP investigates the possibility of combining various orders for the same end product. When the maximum batch quantity or batch duration is exceeded, the system will divide orders into several batches. Sequencing of batches on resources or resource groups can be done according to a number of different sorting criteria, such as earliest or latest start time, predefined product sequences or minimization of change-over times. Allocation of resources to batches can be done using forward or backward loading principles.

Interactive planning board

The planning board has the layout of a Gantt chart showing batches on a horizontal time axis and a vertical resource axis. The selected view and the set-up of the planning horizon determine the part of the time axis and the resources axis that are shown on the schedule. The mouse can be used to select batches and move them around in the schedule.The screen can show several Gantt charts at the same time in different windows, giving the planner an overview of different parts of the factory. It is also possible to look simultaneously at windows on inventory simulation, manpower requirements, production order information, etc. The planner can make selections of batches with the mouse device or using the search editor. Selections of batches can be scheduled using the scheduling heuristics described above.

Constraint mechanism

Using an event-driven mechanism the planning model is continuously recalculated and checked on constraint violations, such as overlap of batches or batches that start later than the latest start time. Violations are shown with different graphical representations in the planning board such as color changes, arrows or icons. Constraint violations are temporarily allowed in building the schedule and can be lifted using the scheduling heuristics.

Dynamic charts

Together with the Gantt chart, a number of other windows can be shown simultaneously on the computer screen showing a selection of reports and charts. These are updated by multi-tasking processes using an event-driven mechanism. Important charts during scheduling are the inventory simulation and the manpower requirements. GRIP calculates and displays a simulation of selected inventory points starting from an initial inventory at a certain date. The inventory level of each product is further influenced by the material consumption and turnover by the scheduled batches. Using minimum and maximum inventory levels, GRIP can create and schedule batches to keep the inventory within bounds. Similarly, GRIP is able to deduce the required manpower from the schedule immediately.

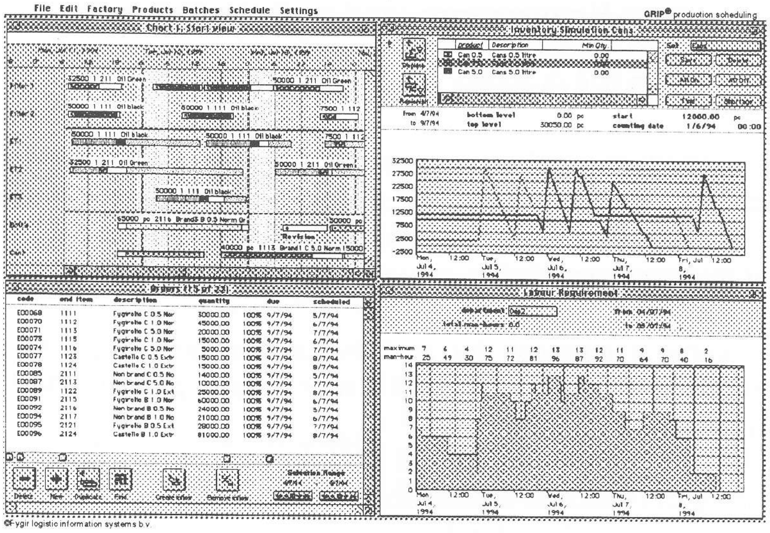


Figure 2: Screen display with simultaneous display of selected reports and charts.

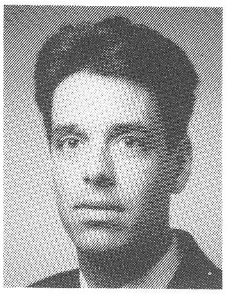
Reporting and interfacing

A planner's tasks include a number of administrative activities. An important part of these activities consists of reporting planning and production data in all kinds of reports and charts. These reports can serve to support people in their operational tasks (internal transport, quality control) or as management information (efficiency reports). It is also possible to export selections of data easily to a spreadsheet, word-processor, or a statistical package for further processing. This can be done during scheduling by running such packages in different windows and using copy - paste functions. Exchange of information with remote systems can be achieved by using file import and export or Standard Query Language (SQL) commands.

Results

The major improvements reported by companies that use GRIP include the following.

- Higher utilization of existing equipment, in some cases eliminating the need for investments in new equipment.
- Maintaining efficiency in a plant where the number of end products has grown to ten times the original number of end products.
- Shortened training times for new planners, allowing for the training of back-up planners.
- Less errors in schedules.
- Less unexpected events in production due to more regular updates of schedules.
- Improved communication between departments because of timely and comprehensible reports.
- Faster schedule generation allowing for evaluation of alternatives and better response to breakdowns. □



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