

# A cooperative production planning method in the field of continuous process plants

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## Abstract

In this paper an object-oriented representation of a continuous process plant is viewed as a directed multi-graph-based pictorial model. The associated modelling language has two components, the first describing the structure of production system in a pictorial manner and the second defining its behaviour. The structural–functional description realized through this language supports a significant reduction and so the initial multi-graph can be observed by a sequential graph. The context makes possible the natural development of the proposed cooperative production planning method. This method is mainly based on a horizontal decomposition, every department of the plant cooperates in order to obtain a good global plan. Coordination is made by the plant managers. The departments will solve multi-objective linear programming problems. In this process a large number of goals are set, including those expressed by experts. A specific rule-based computing technique is provided. This technique uses a rule constructor for expert knowledge acquisition and two facts categories defined by basic planning data and data generated by the mathematical solving method. Therefore, a production plan with high-quality technical and economic features can be constructed fast. © 2000 Elsevier Science B.V. All rights reserved.

*Keywords:* Advanced production management; Pictorial modelling; Multi-objective linear programming

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## 1. Introduction

A typical continuous process-based industrial complex transforms raw materials and ingredients (of various qualities and with different physical and chemical properties) into finished products through a series of processing phases carried out in several specialized continuous individual production cells (IPC) and in some batch IPCs. Raw materials and products are input and delivered, respectively, via

direct pipelines, buffer tanks and stores. At the plant level, interconnections between IPCs are normally pipelines with merging/distribution nodes sometimes provided with accumulation buffers. The material flows are usually oriented from plant input towards its output, although some recirculation flows are to be noticed. Various utilities (power, fuels, air, steam or cooling and composition water) are to be mentioned. Most of the IPCs are supposed to work in some steady-state regimes specified by the processing technologies, so that the continuous operation of the whole production process should be guaranteed. The main goal pursued by the managers of a plant is optimal control of the production process. When considering the history

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of the field, we can distinguish among four stages in approaching this problem: (1) “Ad manum” acquisition of data (regarding the areas of technology, supply–delivery, finance, etc.), the development of a linear programming (LP) mathematical model, translating it into a format suitable for an LP-solver, solving and analysing the obtained solution. This work, which today would seem discouraging from the very beginning, was nevertheless accomplished because of the huge financial and material resources involved; (2) Development of the mathematical model by using a descriptive, non-procedural language, similar to the one in which mathematicians have described an LP model [1–3]. Such a program receives data from the existing information system by means of locally designed interface, this software belonging to the class of matrix generators [4]; (3) Use of prototype products which are customized in order to identify with a particular production system [5]. This customized version of the prototype becomes part of the information system, being used for optimization. However, this integration is a loose one, because of the lack, at the design stage, of all the information system parts which have to be approached together with production optimization; (4) Embedding of production optimization into an advanced production management system (APMS).

An APMS has to achieve: (1) Interactive description of the production system in a manner which technologists in the field are familiar with. Starting from this description of the plant structure and functions, the APMS has to allow the description of next versions of the plant; (2) Automatic output, using a plotter, of a production system drawing on any of its versions, allowing the drawing to be inscribed with relevant production data for longer time periods (a quarter, a year, a five-year plan); (3) Development of production plans and schedules with high-quality economic and technical features by using optimization and/or simulation techniques (multi-objective linear programming (MOLP) and simulation in sequential graphs, respectively), see [6]; (4) Choice of the best version for future development of the plant using information in the APMS’s database which is processed by multi-attribute decision-making

methods, see [7]; (5) Monitoring of the production in a panel-like manner; (6) Recording of statistical data and their processing for prediction purpose. These decisional elements have to be shown in a graphical way; (7) Interfacing with process-control level and with the rest of the information system, by being used in a local-area network. This paper addresses the last aspect described above, the APMS paradigm.

## 2. The directed multi-graph based pictorial model

In this section a directed multi-graph-based pictorial model representing the plant is proposed. A simplified conventional representation of a typical part of a petrochemical plant is given in Fig. 1. An object-oriented [8] representation of the plant structure (“anatomy”) and functions (“physiology”) can be viewed as a directed multi-graph pictorial model (DMGPM). The multi-graph vertices, the objects, are described through a given set of pictograms (PG), the classes, in a form which end-users are familiar with. Multi-graph arcs are the links between objects. Each PG “embeds” the behaviour (B) of each IPC, the behaviour representing the I-O transfer in the context of several logical-mathematical constraints.

### 2.1. The pictorial language

An advanced modelling language (AML) is generally viewed as a tool capable to describe and quickly modify the structural and functional description of a real system. The AML presented in this paper takes into account the fact that the mathematical model, the interactive description of the plant, the behavioural relations and many other things will be the same for the entirety of continuous process plants. What is different for plants belonging to different industrial branches is the pictograms classes and the rules sets for linking the IPCs. Even for the same plant, the specific icons can be different for screen displaying and plotter printing. The paper will further present the modelling pictorial language and its facilities in the behaviour definition.

The basic pictograms set represents the main interface element between an APMS and an user. It

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