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# Concurrent product configuration and process planning: Some optimization experimental results

Paul Pitiot [a,b], Michel Aldanondo [b,*], Elise Vareilles [b]

[a] 3IL, CCI Rodez, Rodez, France
[b] Toulouse University, Mines Albi, France

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ABSTRACT

In nowadays industrial competition, optimizing concurrently the configured product and the planning of its production process becomes a key issue in order to achieve mass customization development. However, if many studies have addressed these two problems separately, very few have considered them concurrently. We therefore consider in this article a multi-criteria optimization problem that follows an interactive configuration and planning process. The configuration and planning problems are considered as constraint satisfaction problems (CSPs). After some recalls about this two-step approach, we propose to evaluate a recent evolutionary optimization algorithm called CFB-EA (for constraint filtering based evolutionary algorithm). CFB-EA, specially designed to handle constrained problems, is compared with an exact branch and bound approach on small problem instances and with another evolutionary approach carefully selected for larger instances. Various experiments, with solutions spaces up to $10^{17}$, permit us to conclude that CFB-EA sounds very promising for the concurrent optimization of a configured product and its production process.



## 1. Introduction

This paper concerns aiding mass customization, or, more accurately, how the two activities of product configuration and production planning can be achieved, optimized and computer supported in a concurrent way. An example relevant to the configuration and planning of a small aircraft illustrates our propositions all along the paper.

### 1.1. Concurrent configuration and planning

Product configuration can be defined as deriving the definition of a specific or customized product (through a set of properties, sub-assemblies or bill of materials, etc.) from a generic product or a product family [1] or [2]. Similarly, deriving a specific production plan (operations, resources to be used, etc.) from some kind of generic process plan, while respecting the product characteristics and the customer requirements, can define production planning with respect to product configuration [3] or [4]. As the decisions relevant to each of these two activities are closely dependent:

- decisions associated with the configuration of a product can have strong consequences on the planning of its production process (for example, a luxury finish requires additional manufacturing time),
- planning decisions can imply tough constraints to product configuration (for example, a given assembly duration prevents from using a particular kind of engine).

It is necessary to associate them in order to avoid inconsistencies and the traditional sequence "product configuration, then production planning". If many scientific works have been independently achieved on configuration or planning, as far as we know, scientific production is far less important when they are considered concurrently. Some initial ideas where proposed by Steward and Tate [5] and Schierholt [3]. More recent works can be found in [12] or [6].

### 1.2. Different requirements, two configuration/planning steps

Most of the times, configuration techniques support interactively the processing of customer requirements. This means that the consequences of each "elementary requirement" are computed and shown to the customer. By elementary requirement, we mean

* Corresponding author at: Centre Génie Industriel, Ecole des Mines d'Albi, 81013 Albi, France. Tel.: +33 563 49 32 34; fax: +33 563493183.
*E-mail addresses:* p.pitiot@aveyron.cci.fr (P. Pitiot), michel.aldanondo@mines-albi.fr (M. Aldanondo), elise.vareilles@mines-albi.fr (E. Vareilles).

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a restriction of the domain of a variable involved in configuration (for example "plane capacity belongs to [6, 12]"), or in planning (for example "final assembly operation should be located in Italy"). As the goal of a company that uses concurrent configuration and planning techniques is to put on the market a product diversity that covers a large demand segment, the elementary requirements can become very diverse and numerous. The process in turn can be tricky and longer.

Each customer can be interested in different kinds of requirements, for example customer "A" can be mainly interested in the product "performance" (speed, altitude, etc.) while the product "comfort" (finish level, seat-space, etc.) may mostly attract customer "B". The idea is to limit the collection of requirements to those that mainly interest each customer. These requirements are named "non-negotiable requirements", while the remaining ones are named "negotiable requirements". Therefore, a first step interactively processes the non-negotiable requirements and then asks the software to complete autonomously the processing of the negotiable requirements in a second step. This autonomous computation can be achieved either with default values or with some multi-criteria optimization (cost, due-date, performances, etc.). This paper focuses on this last optimization issue. For paper clarity, we will only consider the two conflicting criteria cost and cycle time.

We therefore consider the concurrent configuration and planning process presented in Fig. 1 in two successive steps. Step1: interactive configuration and planning which processes non-negotiable requirements and provides a first solution space reduction. Step 2: response optimization which processes negotiable requirements and provides a Pareto front shown to the customer for a solution selection. This paper is mainly concerned by this second step.

### 1.3. Goal and organization of the paper

In a previous paper [7] we have proposed an original adapted evolutionary algorithm for this problem "CFB-EA" (for constrained filtering based evolutionary algorithm). However, the presentation was mainly descriptive and only some initial experimental results could be presented. Our objective in this paper is to prove that CFB-EA is a good candidate for optimizing concurrent configuration/planning problems. Thus, we propose to:

- evaluate the CFB-EA algorithm in detail. For that purpose, a survey of the scientific literature will help us identify a competitive evolutionary algorithm "FRB-EA" (for feasibility rules based evolutionary algorithm), in order to set up experimental comparisons,
- for a given problem, identify a size limit where exact optimization, a branch and bound (B&B) in our case, cannot be used due to computation duration and must be replaced by evolutionary computations (CFB-EA or FRB-EA) in our case.

The paper is consequently organized as follows. In the next section, we describe how the previous two steps approach can be supported with constraint processing and discusses industrial and practical issues. In the third section, we formalize the optimization problem, review optimization techniques and finally detail the three optimization algorithms that will be used for experimentations. In the last section, we present experimental results that highlight the performance of CFB-EA and the limit where the exact approach should be replaced by evolutionary computations.

## 2. Optimizing configuration and planning considered as a CSP

### 2.1. Concurrent configuration and planning as a CSP

Many configuration or planning studies have shown that each of these two problems can be successfully processed when considered as a constraint satisfaction problem (CSP). As far as configuration is concerned, it has been explained by [8] or [9] while good surveys about planning can be found in [10] or [11]. Assuming a CSP for each problem, it is possible to bring them together in a single CSP and to process them concurrently in order to achieve support for concurrent configuration and planning.

This concurrent process and the supporting constraint framework present three main interests. Firstly, constraints linking configuration and planning can be processed in both directions (from product configuration to process planning, for example: a large flying range requires a specific tank assembly resource–from planning to configuration, for example: a given assembly duration forbids such cabin layout). Secondly, product and planning requirements can be processed in any order, avoiding the already mentioned sequence: "configure product then plan its production" [12]. Thirdly, the CSP framework is well suited for interactive

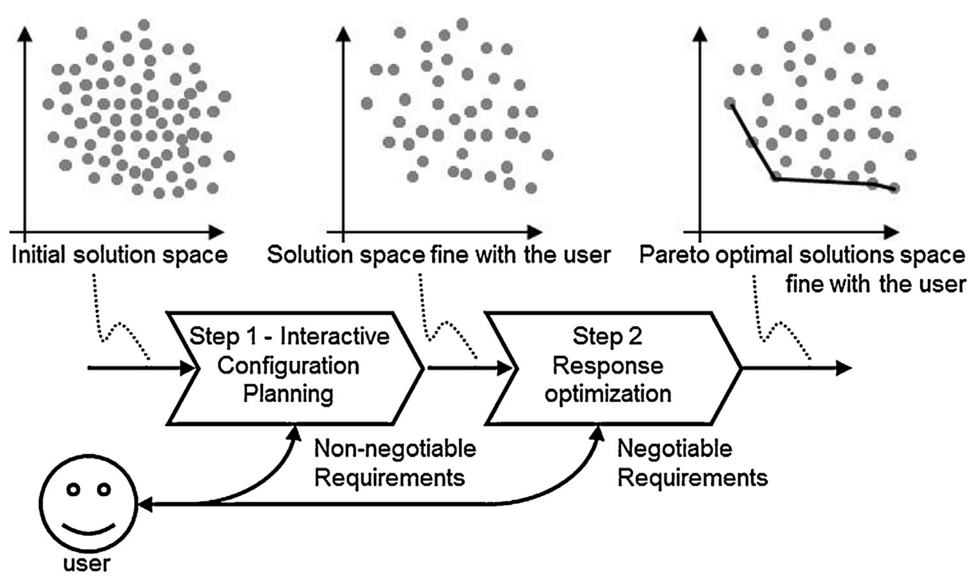


**Fig. 1.** A two-step approach for concurrent configuration and planning.