Computers in Industry 62 (2011) 460–466

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

A multiobjective-optimization approach for a piloted quality-management system: A comparison of two approaches for a case study

Hajer Ben Mahmoud [a,b,*], Raouf Ketata [a,b], Taeib Ben Romdhane [b], Samir Ben Ahmed [b]

[a] Department of Research Unit on Intelligent Control, Design and Optimization of Complex Systems, Tunisia
[b] National Institute of Applied Science and Technology, Northern Urban Centers, 1080 Tunis, Tunisia

ARTICLE INFO

Article history:
Available online 20 January 2011

Keywords:
Multiobjective problem
Quality-management system
Pareto concept
Analytical-hierarchy process
Multichoice goal programming

ABSTRACT

In recent years, steering a quality-management system (QMS) has become a key strategic consideration in businesses. Indeed, companies constantly need to optimize their industrial tools to increase their productivity and to permanently improve the effectiveness and efficiency of their systems. To solve such problems, two approaches were developed: the Pareto Analytical-Hierarchy Process (PAHP) and the Multichoice Goal Programming (MCGP) methods. The first integrates the Pareto concept and Analytical-Hierarchy Process (AHP) methods and the second combines the MCGP model with AHP methods. The goal was to determine the best solution while simultaneously verifying multiobjective-optimization functions and satisfying different constraints for a real-world case study. The latter was chosen because it presents a major problem for controlling the quality levels of production lines. A comparative study between the two approaches provides a path for designing a tool for decision support to ensure the effectiveness of a corporate QMS.

1. Introduction

In an increasingly competitive international context, companies constantly need to adapt and optimize their industrial tools to increase their productivity by implementing a quality-management system (QMS). Aiming to permanently improve the effectiveness and efficiency performance of organizations, a QMS can be measured against International Standards Organization ISO 9000, 9001 and 9004 [1–3]. Piloting such a system refers to the general aspects of quality management and its implementation [4].

In this context, several researchers have incorporated the optimization concept in various industrial fields such as the scheduling of complex system maintenance [5], container management [6], dynamic scheduling in the food-processing industry [7], the management of FIR (finite impulse response) filters [8], the assignment of antenna frequencies in the telecommunications field [9]. These practical applications have shown that optimization can yield benefits to companies in terms of its impacts on their resources and economics, as well as productivity gains [10].

Generally, application of this concept to real-world cases with often conflicting criteria is based on a multiobjective function [11]. Several solution methods have been proposed for this type of multiobjective-optimization problem. There are those that convert the multiobjective problem into a single-objective problem [12–15]; others have mainly been based on simple genetic algorithms, and the only differences are in how the algorithm selection is made [16–19]. A third class of methods is founded on the dominant Pareto concept, which aims to enable a best study that satisfies the objectives [20–23].

The difficulty of using these different techniques is ignorance of the relative importance of the criteria. Moreover, their complexity stems from the multitude of quantitative and qualitative criteria influencing the decision choice. An analytical approach often suggested to solve a complex problem is the Analytical-Hierarchy Process (AHP) method [24]. Several researchers have used AHP as a standalone methodology to make location decisions [25–27]. Many other studies have used AHP in combination with mathematical programming in disciplines other than location [28–31]. The AHP method provides an ideal classification for decision support, but it does not take into account constraints that exist in the decision environment. In this context, and to solve a multiobjective-optimization problem, two approaches were proposed based on the combination of AHP methods with the Pareto concept (called PAHP) and with Multichoice Goal Programming (MCGP).

The paper is organized as follows: Section 2 presents the problem definition. Both approaches are summarized and detailed in Section

* Corresponding author at: Department of Research Unit on Intelligent Control, Design and Optimization of Complex Systems, Tunisia. Tel.: +216 98 600 659; fax: +216 71 953 966.
E-mail addresses: hajerbenmahmoud@hotmail.com, hamden_bm@yahoo.fr (H.B. Mahmoud).

0166-3615/$ – see front matter.
doi:10.1016/j.compind.2010.12.010

3. In Section 4, we present a real-world case study to which we apply the two approaches, followed by a comparative study between them. Finally, we provide conclusions and relevant perspectives.

2. Problem definition

The nature of the variables and criteria to be optimized will influence the choice of optimization methods and their application domain. In our case, the chosen company presented us with the major problem of controlling the quality level of their production lines. To this end, they must fabricate a product of a quality that satisfies the requirements and expectations of customers within the imposed constraints of the available human and material resources. Indeed, the company must improve the overall performance of the production lines by implementing an information system to ensure the conformity and effectiveness of a QMS relative to international standards requirements. For this purpose, we must outline the modeling phase of the system. A multiagent approach was used considering the existing correspondence between physical entities (process) and agents; these permit a better management of QMS modeling variables [32]. This multiagent modeling was designed with a microstructure based on a dynamic diagram (sequence diagram) and a macrostructure through a static diagram (class diagram) for agent development [33]. Both models are reflected in this real-world case. The latter had identified many problems, namely the deployment and coherence of objectives and available resources.

Before embarking on solving this problem, we must automatically to go through the multiobjective-optimization phase; thus, we must ask: what kind of optimization method should we use? The choice of using a particular multiobjective-optimization method imposes objectives to be measured and affects both quantitative and qualitative criteria. In contrast, the application of techniques based on the Pareto concept had already resulted in acceptable solutions.

Moreover, this company stated a definite priority of one criterion over another and a set of constraints that must be taken into account to deploy each of the objectives. The complexity of this problem is summarized by the following question: How can we integrate, on one hand, the weighting concept of the criteria set by the company and, on the other hand, take all the constraints into account?

To answer these questions, the two proposed approaches are summarized in Fig. 1.

3. Proposed approaches

The modeling and optimization of a multiobjective problem (MOP) depends on the type of criteria to be optimized.

$$\text{MOP}\begin{cases}\text{Max or Min}\, F(x) = (f_1(x), f_2(x), \ldots, f_n(x)) \\ s.t\, g_i(x)\; i = 1, \ldots, m\end{cases} \quad (1)$$

where $n \geq 2$ is the number of decision variables, $x = (x_1, \ldots, x_k)$ is the vector representing the decision variables, $m$is the number of constraints, $g(x)$ is the constraint function and $F(x) = (f_1(x), f_2(x), \ldots, f_n(x))$ is the vector of criteria to be optimized.

In general, the Pareto concept is a reference optimization method, so it is usually used to solve this kind of MOP. Therefore, the difficulty in using this concept is the classification of the different solutions in order of priority of the criteria chosen by the decision maker. For this reason, we proposed PAHP, which integrates a weighting concept through the AHP method. Conversely, to solve the MOP, we proposed the direct method MCGP, which also integrates the AHP method. This method is able to deal with decision problems implying multiple objectives.

3.1. Pareto Analytical Hierarchy Process (PAHP)

The PAHP approach is based primarily on the combination of the Pareto concept, AHP and aggregation methods. Indeed, to respect the integrity of each criterion and to move the population towards an optimal solution set, the Pareto-optimality approach is one method that responds well to multiobjective modeling problems and the need to satisfy contradictory criteria. Its principle is to optimize the multiobjective function and determine a set of optimal solutions that satisfy Eq. (1).

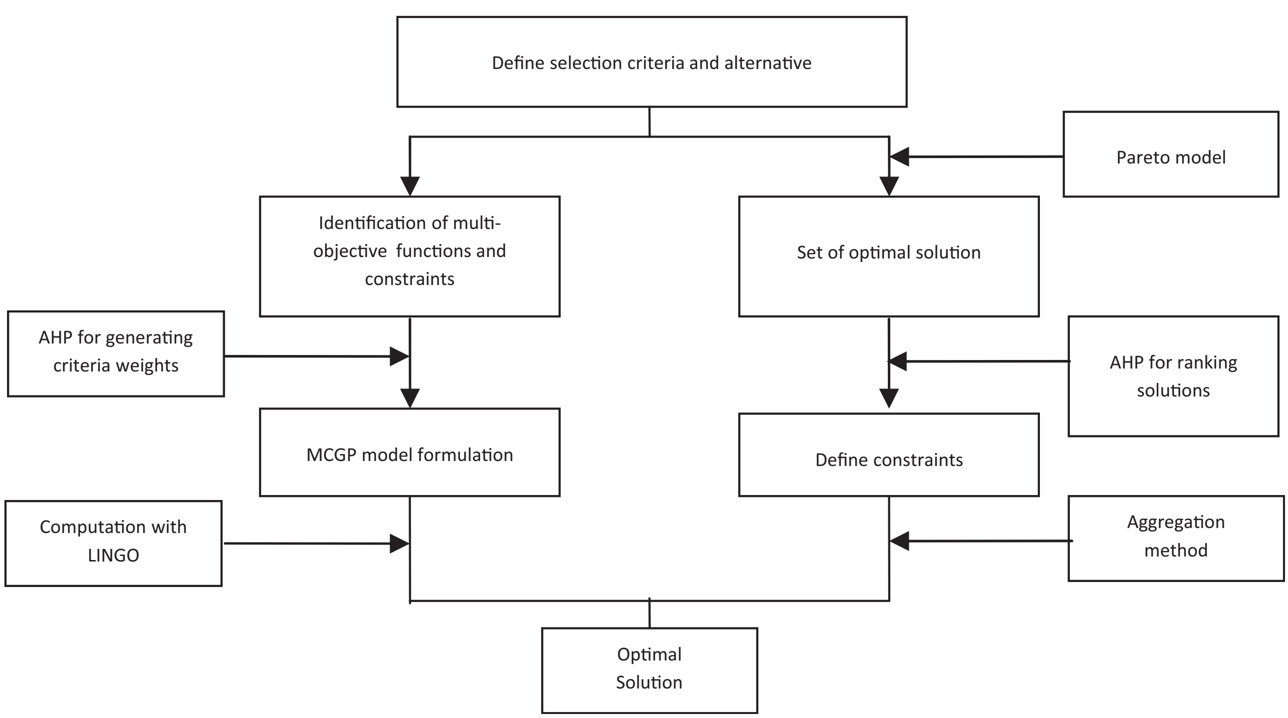

Fig. 1. New approaches.