UNIK-PMA: A unifier of optimization model with rule-based systems by the post-model analysis

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Post-Model Analysis (PMA) is a framework that unifies an optimization model with a rule-based system and enables the multi-objective decision modeling that considers both numeric and symbolic objectives and decision variables. In this research, we have developed a system UNIK-PMA that implements the PMA procedure on the knowledge-assisted optimization modeler UNIK-OPT and a backward chaining rule-based system UNIK-BWD. This paper particularly elaborates the process of generating constraints of the linear programming model from the rule-based goals, which is a crucial step of PMA. UNIK-PMA is illustrated with an example of aggregate production planning.

1 Introduction

The integration of a Linear Programming (LP) model with a rule base is realized by adopting the Post-Model Analysis (PMA) approach [5, 9, 15, 16]. In this approach, a quantitative (cardinal) objective function is represented in an LP model, while multiple possibly qualitative (nominal or ordinal) objectives in a rule-based model. Two models are unified via the overlapped decision variables that exist in both models. Thus, this unified model can be used as a supporting medium of multiple objective decision makings with an objective in the LP model and multiple objectives in the rule base.

This paper describes a system UNIK-PMA that implements the PMA procedure. For this purpose, we first review the PMA procedure with an example of aggregate production planning in section 2. To unify an LP model with a rule base, it is a requisite to represent the LP model at the semantic level. So a knowledge-assisted modeler UNIK-OPT [8, 11] is adopted for this purpose in section 3. Then the procedure for extracting relevant rules with a selected LP model is explained in section 4. To support the trade-off between goals, the interpretation of the rule-based goals from the perspective of the LP model is crucial. So the process of generating constraints from
the rule-based goals is described in section 5. Finally, in section 6, the system UNIK-PMA developed on the UNIK environment [7] is demonstrated with typical illustrative screens.

2 Post-model analysis procedure

The PMA procedure depicted in figure 1 consists of the following six steps [16]:

Step 1 Formulate an LP model or choose one if it already exists. The LP model should be semantically represented in the way that it can be understood by, and is compatible with, the rules [3,4,11].

Step 2 Prepare a rule base or choose one if it already exists. Select concerned goals in the rule base.

Step 3 Identify overlapped decision variables between the LP model and the rule base, and extract rules relevant to the overlapped decision variables and concerned goals.

Step 4 Compute the optimal feasible solution of the LP model.

Step 5 Evaluate the optimal solution with regard to the goals in the relevant rules [2]. If the current rule-based goals are satisfied, a final solution is found. Stop.

Step 6 If the current rule-based goals are not satisfied, invoke nondominated trade-offs [1]. To compute the marginal rates of substitution among the goals, the rule-based goals should be interpretable to constraints of the semantic LP model [16,17].

Suppose the typical Linear Programming (LP) model for the aggregate production planning [10] in (1)–(8):

\[
\begin{align*}
\text{Minimize } & \quad Z = \sum_{i=1}^{N} \sum_{t=1}^{T} (v_{it} X_{it} + c_{it} I_{it}^+ + b_{it} I_{it}^-) + \sum_{t=1}^{T} (r_t W_t + o_t O_t + h_t H_t + f_t F_t) \\
\text{subject to } & \quad X_{it} + I_{i,t-1}^+ - I_{i,t-1}^- + I_{it}^+ - I_{it}^- = d_{it} \quad \forall i = 1, \ldots, N, \ t = 2, \ldots, T, \\
& \quad \sum_{t=1}^{T} X_{it} \geq \sum_{t=1}^{T} d_{it} \quad \forall i = 1, \ldots, N, \\
& \quad \sum_{i=1}^{N} k_i X_{it} - W_t - O_t \leq 0 \quad \forall t = 1, \ldots, T, \\
& \quad W_t - W_{t-1} - H_t + F_t = 0 \quad \forall t = 2, \ldots, T, \\
& \quad -p W_t + O_t \leq 0 \quad \forall t = 1, \ldots, T, \\
& \quad X_{it}, I_{it}^+, I_{it}^- \geq 0 \quad \forall i = 1, \ldots, N, \ t = 1, \ldots, T, \\
& \quad W_t, O_t, H_t, F_t \geq 0 \quad \forall t = 1, \ldots, T,
\end{align*}
\]