Efficient Resources Allocation in Technological Processes Using an Approximate Algorithm Based on Random Walk

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***Abstract*— one of the main challenges of the management of complex manufacturing processes is the development of hierarchical control systems. Effective control of technological processes can be achieved by using a distributed control system with multi-level hierarchical structure. The hierarchical structure is characterized by decomposition into interrelated local subsystems. These subsystems are controlled by local decision makers that require coordination. In this paper, the concept of coordination is understood as the act of making the right allocation of tasks and resources and management actions to meet the objectives of production. An optimization program, based on random walk methods, was applied to a dairy factory data for the optimization of the obtained profits.**

Keyword- Distributed objects, Coordination, Resources allocation, Optimization, Random walk

I. INTRODUCTION

The ever increasing complexity of modern technological complexes has become the centre of researchers' attention. This complexity lies in complex modelling, complex spatial structure, and complex hierarchical structure [1][2][3]. With respect to modelling issues, complexity is given by the large number of variables and constraints needed to model the systems, whereas in spatial structure, complexity appears due to the spatial distribution of interconnected subsystems. This leads to a hierarchical complexity, as the result of the autonomous management of each subsystem.

The design and analysis of large complex systems with a hierarchical structure requires the decomposition of the global system into smaller units called subsystems. These subsystems might work independently from each other to achieve a common goal. Simultaneous management of the technological process operations by intelligent units creates the following problems [1][2]: synchronization, resource allocation, work capacity, scheduling, etc. Therefore, the task of decision-making coordination is a key factor for reliable operation of the system.

Coordination provides ways to study processes. From this perspective, system design depends on the methods of coordination, chosen to manage the interaction between subsystems; and the resources involved in the process. Thus, the main methods of coordination and their respective tasks are categorized according to resource availability and the nature of the process operations. The solution for the problem of coordination is to determine the interaction of the subsystems in which management of each of the subsystems will be optimal according to the general criterion for the system as a whole [4].

The problem of coordination in multi-level system can be studied with sufficient generality in the two-level system. Two-level hierarchical system THS has been studied extensively in the literature [5] [6]. Two-level hierarchical system and the interaction between subsystems can be mathematically expressed as bi-level optimization problem:

$$\begin{aligned} & \min_{u} F(u, v(u)) \\ & s.t.: G(u, v(u)) \quad 0 \\ & \qquad \min_{v} f(u, v) \\ & \qquad s.t.: g(u, v) \quad 0 \end{aligned} \qquad (1)$$

Where,

F Objective function higher level (Coordinator)

u Vector of decisions (Coordinator)

G Set of constrains (Coordinator)

f Objective function of lower level

v Vector of decisions lower level

g Set of constraints lower level

Many of the exact solution methods for optimization of the THS are based on "branch and bound" method and Gomory’s algorithm, both of which can deal with problems of moderate size. In this paper, we propose the use of an approximate algorithm, based on a modification of the random walk method, for the management optimization of dairy factory with hierarchal structure

II. MATERIALS AND METHODS

The analysis presented here refers to the feasibility study of a dairy plant. A model of this hierarchical structure of dairy plant is presented in figure 1. The manufactured products and their economic parameters are listed in Table 1 [7]. Table 2 [7] summarizes the restrictions imposed by technical parameters of machines.

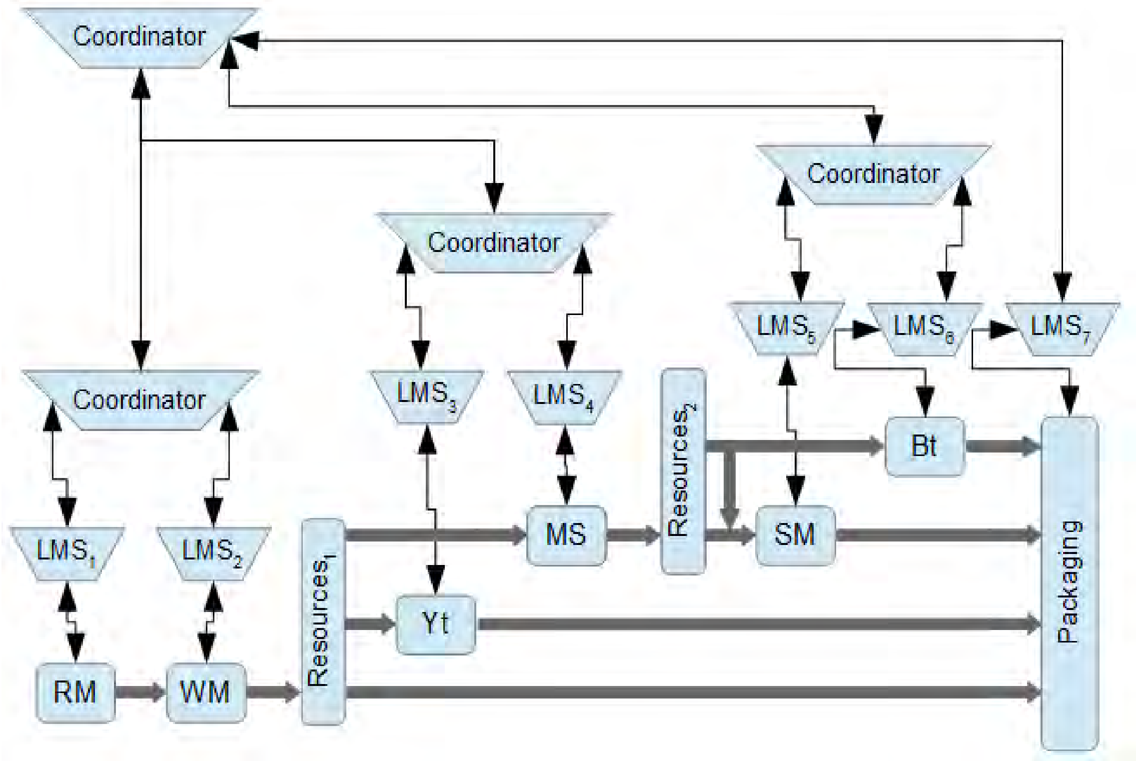

Fig. 1. Hierarchical management system. RM – raw milk, WM – whole milk, Yt – yogurt, MS – milk separation, SM – Skimmed milk, Bt – Butter, LMS – local management system, thick arrows – mass flow, thin arrows information flow.

TABLE I
Economic parameters

Variables	Products	Contribution Margin $/[kg or Lt]	Yield Kg or Lt of product per liter of raw milk
X_1[kg]	Cheese type 1	1.20	10.00
X_2[Kg]	Cheese type 2	0.70	6.00
X_3[Kg]	Cheese type 3	0.90	8.00
X_4[Lt]	Yogurt	0.25	0.90
X_5[Lt]	Milk 3%	0.10	1.00
X_6[Lt]	Skimmed milk	0.15	1.00
X_7[Kg]	Butter	1.00	2.00
X_8[Lt]	Cream	0.30	1.00

TABLE III
Constraints

Restrictions	Capacity	Times used per day
Volume of raw milk RM	10000 Lt.	-
Amount of fat from RM	400	-
Yogurt fermentation tank	1000 Lt.	1
Cheese press	200 kg.	2
Cheese tank	4000 Lt	2
Cheese brine tank	1500kg	-
Butter churn	200	2
Skimmed milk demand	1000	-

The mathematical model is comprised of equations and inequalities (2):

$$max \;\; Z = 1.2\,x_1 + 0.7\,x_2 + 0.9\,x_3 + 0.25x_4 + 0.1x_5 + 0.15\,x_6 + 1x_7 + 0.30\,x_8 \tag{2.1}$$

$$s.t.: \;\; 10x_1 + 6x_2 + 8x_3 + 0.9\,x_4 + 1x_5 + 1x_6 + 2x_7 + 1x_8 \quad 10{,}000\,; \tag{2.2}$$

$$0.24x_1 + 0.17x_2 + 0.23x_3 + 0.025x_4 + 0.03x_5 + 0x_6 + 0.8x_7 + 0.25x_8 \quad 400\,; \tag{2.3}$$

$$x_1 + x_3 \quad 400\,; \tag{2.4}$$

$$10x_1 + 6x_2 + 8x_3 \quad 8000\,; \tag{2.5}$$

$$x_1 + x_2 + x_3 \quad 1500\,; \tag{2.6}$$

$$x_4 \quad 1000\,;\, x_6 \quad 1000\,;\, x_8 \quad 80\,;\, x_7 \quad 200 \tag{2.7}$$

$$x_1 = 0\,;\, x_2 = 0\,;\, x_3 = 0\,;\, x_4 = 0\,;\, x_5 = 0\,;\, x_6 = 0\,;\, x_7 = 0\,;\, x_8 = 0\,; \tag{2.8}$$

Equation (2.1), maximizes the profit, Equation (2.2) ensures that the amount of raw milk RM used equals the quantity supplied by local farmers. The inequalities (2.3-2.7) correspond to resources availability and machine capacities.

A simplified algorithm of iterative random search method

The method consists of an iterative search of adjacent points, which improve the value of the objective function:

1. In the first step, we seek the maximum value, which the decision variables **x** can take in the feasible region **Ω**. Based on the minimum value of **x**, and a parameter ***err*** a step is calculated.

2. A search direction $\mathbf{e_1}$ that corresponds to a variable x_{e_1} in X is randomly chosen.
3. The variables corresponding to the other directions are assigned the value of the step, and to the variable x_{e_1} the maximum value allowed by the feasible region **Ω**.
4. Thus, the search passes from point $P_0|_{X=0}$ to a point $\mathbf{P_1}$.
5. From point $\mathbf{P_1}$ to $\mathbf{P_2}$ by selecting a different search direction $\mathbf{e_2}$.
6. The value of the variable corresponding to this direction x_{e_2} is increased in one step.
7. The other variables keep their value, and the value of x_{e_1} is corrected to meet the feasible region.
8. If the point $\mathbf{P_2}$ enhances the value of the objective function, that direction is preserved and its value increased in one step.
9. If the point $\mathbf{P_2}$ does not increase the objective function, we return to the point $\mathbf{P_1}$ and a new direction is chosen.
10. The whole process is repeated while the value of the objective function does not converge.

Figure 2 shows an illustration of the search process.

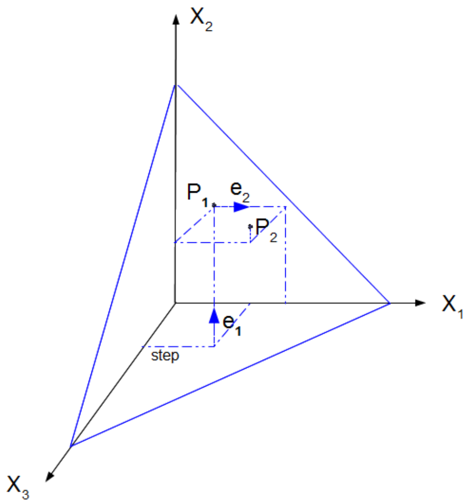

Fig. 2. Scheme of the search process

III. RESULTS

According to the formulation of the search process, the objective function is a function of the parameter err and the feasible region **Ω**, $fo = F(err, \Omega)$. Given Ω, the impact of variations of parameter err on the result of the objective function must evaluated.

Figure 3 shows the relationship between variations of parameter err and the objective function value, expressed as a fraction of the value calculated by exact methods. The value of the objective function obtained by the proposed algorithm approaches the exact value for small values of the parameter err. This result is predictable because a decrease of the search step leads to a more comprehensive search. It is important to note that for high values of err, the difference between the value obtained from the objective function and the exact value is less than 8%.

Figure 4 shows the results of the objective function for a fixed value of the parameter *err (err = 0.1)*. The search process is random, so one might expect different results for each execution of the algorithm, however for a series of tests it was found that the results are concentrated in a few values. In the example, 81% of the times the difference was less than 2% from the exact value, and in the remaining fraction, the difference did not exceed 3%.

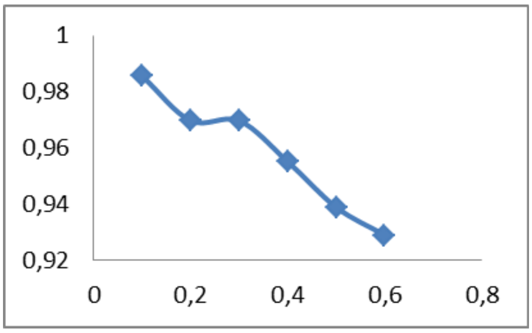

Fig. 3. Relationship between variations of parameter err and the objective function value.

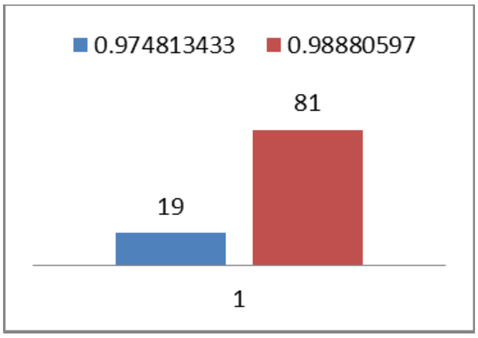

Fig. 4. Results of the objective function.

IV. CONCLUSION

We have written an algorithm based on a random walk method for the coordination in a dairy factory with hierarchical management structure. The coordination aspect studied here is the allocation of resources. In this work, we found that for smaller steps, the value of the objective function is improved. However, even for larger steps, the difference between the obtained value and the exact values does not exceed 8%.

ACKNOWLEDGMENT

This work was supported by "Secretaría Nacional de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT)", Ecuador.

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