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Optimal Workflow Scheduling In Production Line of a Dairy Factory Using Petri Net and Genetic Algorithm

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ABSTRACT

Nowadays, one of the most important issues in production systems is production scheduling. Efficiency of a single production system should be in a way that it can produce the demanded product with higher quality and lower amounts of time and cost. Optimization in mathematics and computer science is defined as the process of choosing or finding the best member in a set of options. As an effective searching technique, genetic algorithm has resulted in adequate results in solving optimization problems regarding operational systems. Furthermore, colored petri dishes net is one of the most appropriate tools for modeling production discrete event systems. With regard to the existing crisis in dairy factories of Iran and concerning ever-increasing use of compute approaches in order to optimize production systems, the present work was formulated so as to optimally control workflow of production line in dairy factories by using genetic algorithm and colored petri dishes net. The proposed algorithm in the present study was efficient in improving the scheduling of workflow in a dairy factory.

KEYWORDS: optimization, workflow scheduling, genetic algorithm, colored petri dishes net.

1- INTRODUCTION

One of the most important issues in production systems in workflowscheduling, which aims to enhance efficiency of production system. Workflowschedulingis known as one of prominent issues in operations of factories, especially in multipurpose ones such as dairy products factories. Effective operation scheduling provides a great potential of economic efficiency [7]. The main goal of workflow scheduling is finding a sound sequence for performing workflow tasks [10]. In other words, the main purpose of workflow scheduling is allocation of suitable tasks to suitable resources [13]. However, it might encounter a few uncertainties regarding workflows (i.e. arrival time of workflow, execution path of instances, and execution time of task) and resources(i.e. long execution of workflow process and execution a single task by more than one resource) [12].

During the current decade, time has been the most important impetus in trade competitions. Therefore, it is a chief question how to reduce the cost caused by lost time. One of the simplest ways is to alter work content at any given point on the line. If production time are identical at all work points, there will be no lost time and the line will be completely stable. Therefore, it is important to take any step to reduce time difference between work points as much as possible [5].

Optimization in mathematical and computer sciences is the process of choosing or finding the best member in a set of available choices. In fact, optimization tries to minimize time, cost, and risk and to maximize profit, quality, and effectiveness of the whole process [4].An important issue in optimization is finding values for variables that result in minimization or maximization of objective function with regard to the restrictions [6].

Colored petri net is one of the most efficient tools for modeling production discrete events system. It is a graphics to attain equations of system state. One is enabled to consider variations of system state in modelingby using petri nets. They can be used to depict system behavior as flowcharts and block diagrams [9]. Colored petri nets are adequate in taking decisions to find the best ways, to predict the effects of addition or elimination of resources, or to obtain optimized time schedules in industrial scale [4].

Colored petri systems have been widely used in different investigations in various applications. Yu-guang et al. (2011) modeled and analyzed an assembly center by using colored petri net and they were able to obtain the minimum operation time for a scheduling case [14]. Chun-jian et al. (2012) proposed a method called multi-grade colored Petri net in order to analyze complex systems. They used this method to analyze a training simulator system. This model can show complicated environments of the system and solves problems of adopting classical research approach so as to develop precise mathematical model [2]. Lee et al. (2006) used simulation models of timed colored petri system for air cargo terminal operations. They found that these models can efficiently be used for these operations and they will help greatly to design and control these operations in future [8]. Dotoli and Fanti (2006)

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designed a model of urban traffic network by using timed colored petri net and they found out that the model is efficient in real-time status [5]. Ghaeli et al. (2005) formulated scheduling of batch plants with complex system using petri net and then presented a heuristic search algorithm for scheduling these plants [7].

Genetic algorithm is one of the most widespread optimization procedures, which has long be used to solve complicated optimization problems [6]. In fact, genetic algorithm consists of a group of random searching methods. It uses the "survival of the fittest" principle and therefore, new members are created through selection process of their parents [3].

Suksonghong et al. (2014) used multi-objective genetic algorithms to solve optimization problems in power generation companies. They concluded that using these algorithms may optimize investment in these companies [11]. Oliveira et al. (2014) adopted genetic algorithm for optimization of the projects related to public illumination and they found out that the proposed method had good results in optimization of such projects [3]. Bi et al. (2014) optimized water distribution system by using genetic algorithm [1]. Dezani et al. (2014) stated that using genetic algorithm and petri net analysis is a good method to optimize urban traffic [4]. Moreover, Zhang and Zeng (2010) proposed an improved genetic algorithm to solve grid work flow scheduling.

Dairy is one of the most important food products; however, one of the most important problems of dairy factories is that workflow of their production lines is not optimized. Therefore, the present study was formulated in order to optimally control workflow of production line in dairy factories by using genetic algorithm and colored petri dishes net.

2- Simulation and algorithm

Optimization is defined as obtaining the best possible result with regard to the conditions. We used genetic algorithm and petri net for optimization of workflow scheduling in a dairy factory in which tasks are prioritized according to priority limitation matrix and number of children. Fig. 1 shows the dairy factory workflow using the petri net.

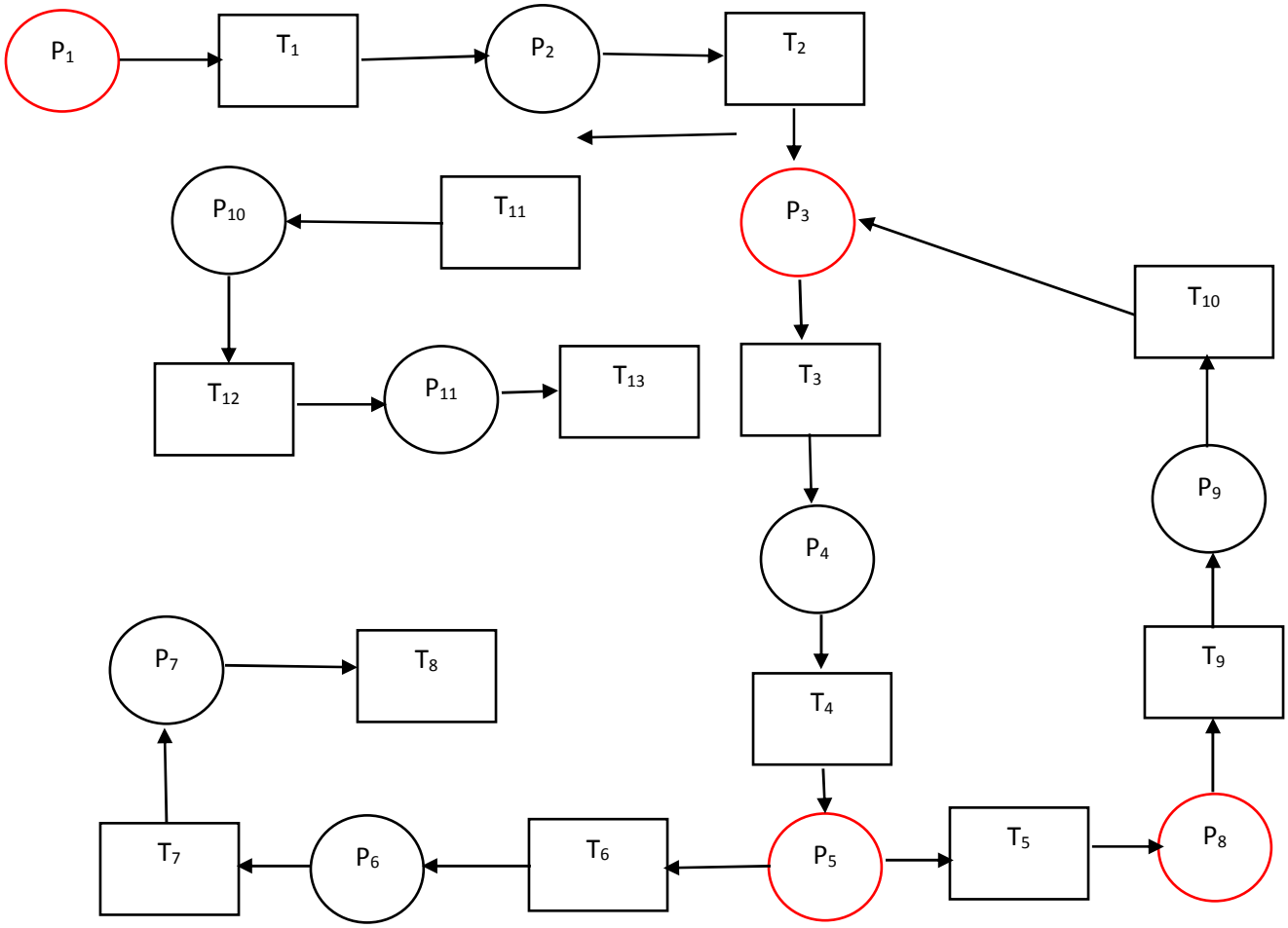

Figure 1: Workflow of the dairy factory represented by petri net

We used binary coding method in which chromosomes are shown in binary strings. In this method, each decision making variable is shown as binary strings and chromosome is formed when these strings come together. In other words, each chromosome shows a possible state of scheduling. In this algorithm, each chromosome is shown by a binary (R,T) where T is the set of tasks and R is the set of resources. $R_i \in RT_i$ represent the resource allocated to the task $T_i \in T$; that is, a resource is selected for each task. In fact, each chromosome shows how resources are allocated to tasks and also depicts the execution order of tasks.

Scheduling is performed based upon the allocated priority so that priority of tasks does not change during the execution of genetic algorithm by the order of allocation of resources to tasks varies. Scheduling algorithm continues until the number of generations exceeds the predefined value.

The algorithm works as follows: first, the primary population is formed; then, fitness function in estimated for each chromosome in the current population; next, crossover and mutation are performed on chromosomes of the current population; selection of chromosomes in the current population and children continues until the children are created and the chromosomes with the lowest fitness function are transferred to the next generation; this continues until the number of generations reaches the defined value. Fig. 2 depicts workflow of the algorithm.

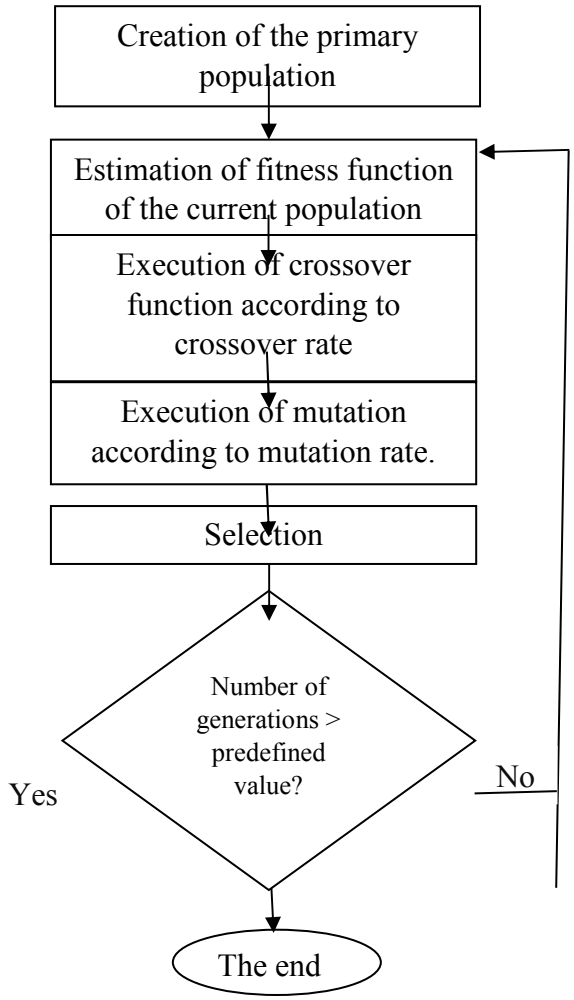

Figure 2: The flowchart of the proposed algorithm

3- Optimization process

The fitness function is achieved by a suitable transfer on objective function, i.e. the function which is supposed to be optimized. Fitness function determines each string with a numerical value indicating its quality. The higher the quality of the resulting string, the fitter the response and therefore, creation of next generations become more

probable. If the problem is maximization or minimization, fitness will look like maximum or minimum objective function.

There are several methods to turn objective function into fitness function. The simplest way is to consider fitness function to equal objective function. This procedure is appropriate when objective functions should be maximum. However, since genetic algorithm normally looks for the maximum function, this procedure is not efficient in minimization problems. Therefore, minimization problem should be turned into maximization problem. If φ_i of objective function equals the ith, the simplest way is to deduct φ_i from the constant C so that $\varphi_i \leq C$ for each generation.

$$f_i = C - \varphi_i \qquad (1)$$

If it is not possible to guess the biggest value of objective function, φ_{max} and φ_{min} can be found in each generation and fitness can be estimated as follows:

$$f_i = (\varphi_{max} + \varphi_{min}) - \varphi_i \qquad (2)$$

Optimization problems usually have conditions to ne met when the problem is being solved; if there are few or simple conditions and they are probably met per se, the members not meeting the conditions in each generation can be randomly replaced for new ones; however, in complex situations, the conditions are considered as penalty function in the objective function.

$$\varphi_{i_{new}} = \varphi_i + p_i \qquad (3)$$

p_i should be in a way that the members of each generation not meeting the conditions appropriately have lower fitness.

After fitness of all the members in a generation is determined, the children from fitter couples are normally fitter. As it is in nature, genetic algorithm give higher chance of reproduction to fitter members.

The easiest selection method is roulette wheel in which a circle with unequal portions is considered and each chromosome has a portion with the central angle $\frac{2\pi f_i}{\sum f_i}$. Then, a number is resulted and the string whose portion includes the random number is selected. This type of selection can be compared with the movement of roulette wheel in which bigger portions are more probable to be selected.

The most important genetic operators are crossover and mutation. Crossover is considered the most important operator in genetic algorithm and it is a success key inthis algorithm. It haphazardly interchanges the information between the strings with the simplest type being single-point crossover. In single-point crossover, a random number is first selected from the interval between one and chromosome's length and then, bits of the two selected strings are combined to exchange their place and consequently, two children are created. Crossover operator can also be two-point where two points are randomly selected and crossover occurs between these two points.

The second important operator in genetic algorithm is mutation. The main function of mutation is to reach unknown spaces in the interval of variables and to prevent from convergence to local optimums. Each bit in a single chromosome might unlikely be selected randomly and its value turns to zero from one or vice versa.

Table 1 shows a sample solution for the problem stated in this research. In the table, thirteen tasks are allocated to five different resources. Here, we tried to perform allocation in a way that time, cost, and objective function (as a blend of time and cost) are minimized.

Table 1: allocation of tasks to different resources

T	1	2	3	4	5	6	7	8	9	10	11	12	13
R	4	1	3	3	2	2	1	1	4	3	3	2	**1**

In this table, thirteen variables ranging between 1 and 4 are considered as optimization parameters. The values are allocated to thirteen tasks. Then, total cost and time are determined and optimization is performed. If the time of a given task on a given resource is considered infinite, a large number is used instead of infinite so that the plans allocating the given task to the given resource are eliminated during the process of optimization.

First, an objective function is considered which has already included cost. For optimization, genetic algorithm parameters are considered as follows:

- Number of generations: 50
- Population: 200
- Crossover rate: 0.7
- Elitism: 10

Fig. 3 shows the variations in optimization process and alterations of the objective function in which execution time is considered to be the objective function. It is obvious that time has decreased from 400 in the first generation to 49.55.

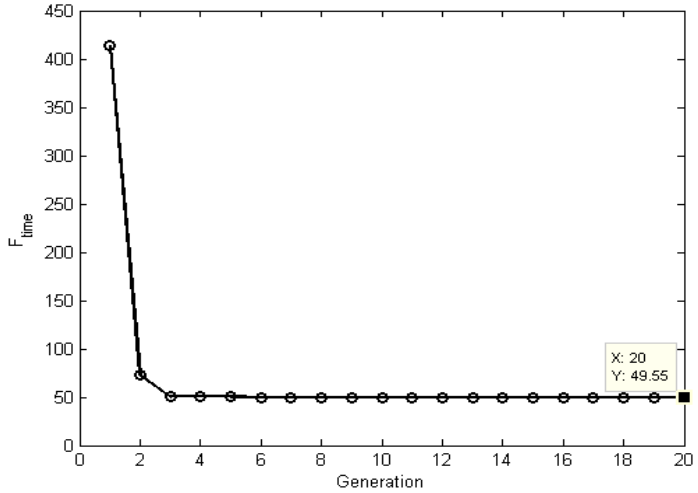

Figure 3: Variations of optimization process and the objective function

Table 2 shows how tasks are allocated to resources for the minimum time.

Table 2: allocation of tasks to resources for the minimum time

T	1	2	3	4	5	6	7	8	9	10	11	12	13
R	1	1	2	2	3	3	3	3	4	4	2	2	**2**

Now, we consider that cost is the function to be optimized. Fig. 4 shows how cost function varies.

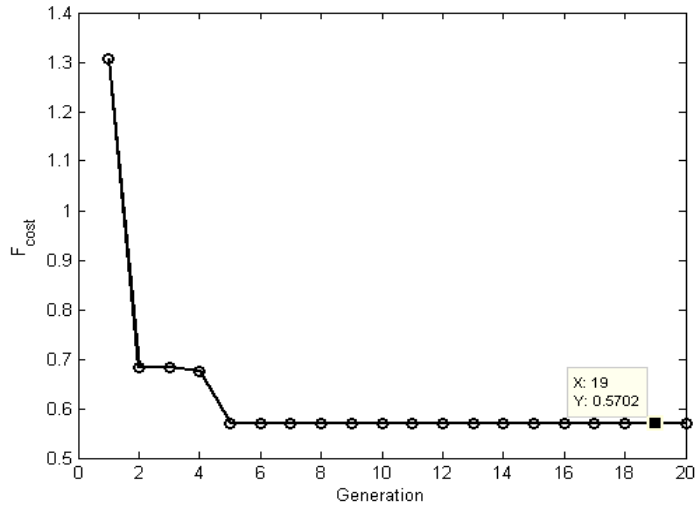

Figure 4: variations of cost function

As evidenced in Fig. 4, cost function has become convergent after around five generations and it reduced from 3.1 to 0.57. Table 3 demonstrates how tasks are allocated to resources.

Table 3: Another Task allocation to the resources

T	1	2	3	4	5	6	7	8	9	10	11	12	13
R	3	2	3	3	4	4	4	4	4	4	1	3	**1**

It is clear that task allocation is quite different from the last one. Now, combination of these two functions is considered to be the objective function.

$$Out = \alpha f_1 + \beta f_2 \quad (4)$$

Fig. 5 shows the variations of this objective function.

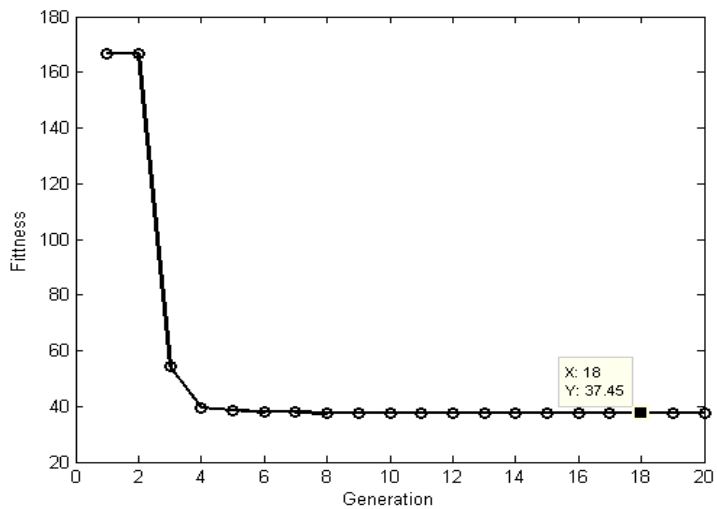

Figure 5: Variation of the combined objective function

Table 4 shows how tasks are allocated to the resources.

Table 4: Another example of allocation of tasks to resources

T	1	2	3	4	5	6	7	8	9	10	11	12	13
R	1	1	2	2	3	3	3	3	4	4	2	2	**2**

We were able to optimize the workflow in the production line of the dairy factory. The value of cost function has become convergent after five generations and decreased from 1.3 to 0.57. Time has also decreased from around 400 in the first generation to 49.55. It revealed that using genetic algorithm through petri net had a profound influence on optimization of time and cost in the production process during the optimization of workflow in the factory.

4- Conclusion

Workflow scheduling is one of the most important issues in production lines. A sound scheduling can improve performance of a system. Static procedures for scheduling workflow can reach an optimal global solution for a given case under static conditions. However, they cannot deal with uncertainties and dynamic nature of workflow. Dynamic methods can optimize workflow scheduling with regard to all uncertainties and dynamic trends. But, the results are usually optimized only for a given task and they are not preferred for the entire system. We proposed a fuzzy method for optimization of workflow scheduling by using petri net and genetic algorithm. Our method is compatible with dynamic trends and can deal with uncertainties and alterations efficiently.

Several methods such as counter algorithm, linear programming, etc. are used to optimize workflow scheduling, but they are capable of solving only a small part of the whole problem. In practice, there are numerous operating cases in a given system and consequently, the scope of the problem can be very vast, especially when the workflow has complex structures. Solving these problems is not practical by using conventional methods. Therefore, heuristic methods are recommended for these problems. Genetic algorithm is one of most important heuristic procedures. In our method, prioritization of tasks is on the basis of limitation matrix and number of children.

Although the proposed algorithm had good performance according to the simulations, it might be unable to present suitable and optimal response in some conditions just like other heuristic methods. However, using this algorithm in appropriate situation with given number of tasks and resources, suitable performance is assured and it can be regarded as a proper scheduling procedure in many fields.

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