# Resource Constraints in Reliability Conditions through Particle Algorithm

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**Abstract**
Scheduling as one of the most fundamental issues of competitive production in the market with today's rapid changes plays an important role in maintaining the competitive position and survival of manufacturing organizations; therefore, the development of structure and scheduling techniques in order to optimize these techniques is very important. Therefore, this study will examine the optimization of multi-skill project scheduling with human resource constraints in terms of reliability through particle algorithms. A new algorithm proposed based on the Particle Mass Optimization (PSO) rules for the scheduling problem. Also, in the original PSO algorithm, particles are looking for solutions in a continuous space of solution. The results show that the proposed hybrid algorithm leads to an effective solution with an optimal scheduling satisfaction.
***Keywords:***
*Project Scheduling, Human Resources Constraints, Particle Mass Weight Optimization Algorithm.*

## 1. Introduction

In the modern business world, the desire to increase productivity and employment has led manufacturing industries to seek an opportunity to cut costs and increase profits. Scheduling has a significant contribution to progress and success of the projects. This issue has always been one of the issues of interest to researchers in management science and operational research. The very difficult nature of this issue is another reason for many researchers to pay attention to. Therefore, there are certain techniques and methods to solve these issues. The issue of scheduling projects with limited resources includes a set of activities that, while meeting the requirements and resources constraints, as well as optimizing the target function, are scheduled (Koulinas et al, 2014).

The issue of scheduling a project with limited resources is, in fact, the most common issue of scheduling. Workshop scheduling issues, workshop process, scheduling, and other scheduling initiatives are all subsets of this issue. Project scheduling is one of the main tasks and main activities in project management. The existence of resource constraints and the pre-requisite relationships between activities makes it difficult to schedule a project (Brucker et al, 1999).

Scheduling as one of the most fundamental issues of competitive production in the market with today's rapid changes plays a very important role in maintaining the competitive position and survival of manufacturing organizations. Therefore, the development of structure and scheduling techniques in order to optimize these techniques has particular importance.

With the development of the industrialized world and the shortage of resources, the time has become one of the most fundamental constraints, so that the scheduling of the production resources has a direct effect on increasing productivity, decreasing production time and consequently increasing the efficiency and profitability of an organization. Project scheduling is one of the main tasks and activities of project management. The existence of resource constraints as well as the prerequisite relationships between activities makes it difficult to schedule a project. The issue of scheduling a project in terms of resource constraints is, in fact, the most common issue of scheduling. And the issue of work shop scheduling for its processes' and other scheduling issues are all subsets of this issue (Sabzeparvar, 2014).

The issue of scheduling a project in the context of resource constraints is the timing of project activities with regard to prerequisite relationships and resource constraints. It includes a project with J activities which is demonstrates like J= 1,2,….,j. The time for any J activity is shows by $D_j$. Each activity can only start once and can be terminated or not. Due to technical requirements, there is a set of prerequisite relationships between activities that are represented as a set of relationships in the form of $P_j$, and shows that activity J is not possible to start unless all of its prerequisites and necessities have been completed. The prerequisite relationships can be represented using AON networks, which assumed to be non-circular.

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Over the past six decades, the impact of timing mechanisms of the production system has been proven to boost the production and performance of machines. Recently, due to rising consumer demand, reduced product life cycles, a change in competition in global markets, the rapid development of new technologies and processes, the issue of scheduling has become important as a powerful, logical tool in manufacturing systems. In spite of the economic pressures and competition in global markets, a timely, accurate and effective timing can be an effective tool to maintain customer satisfaction from product delivery and delivery (Roshanaei, 2012).

Nowadays, with increasing issues and the importance of speeding up answers, classical methods are not answerable to many issues, and innovative search algorithms are used more than the full-scale search for problem solving space. Also, real-world scheduling issues include simultaneous optimization to reconcile a set of multiple goals (Chaharsooghi et al., 2008).

The concept of PSO is the crowding of particles with a random or crowded position, which searches for the best position in the best fit. The congestion involves individual factors called particles, represented by a vector, in which each particle is a potential solution to the problem of optimization. A particle is like a point in a multidimensional space and the position of a particle indicates its position and velocity. The position of each particle represents a probable solution to the problem. In each repetition, each particle is a new position in the search space, which is driven by the variable velocity of a conductor vector. The corresponding fitness is calculated from the new position of each particle and the best position is stored. So, the speed is an important parameter in the search for a good solution. Two different situations are used to update the speed:

1) The best position obtained from all particles is the best global solution obtained by all factors.
2) The best position is to encounter a particle, which saves individual experiences of a particle.

In the paper (Xia et al., 2005), The combination of refrigeration algorithm and mass optimization of particles is used to solve the problem of manufacturing a flexible workshop. In the proposed method, the mass optimization algorithm for particles in the allocation of operations to machines and simulated refrigeration algorithms are used to determine the sequence of operations. The suggested algorithm have applied only on three different data collections and compared to the other ones. The results are showing that the suggested algorithm has a good applicability for solving the issue of producing flexible work of workshop, although it needs more time to be solved.

In the paper written by Xiong et al. (2012) a multi-purpose compelling approach with structure of a permutable chromosome have developed and designed several genetic operator suitable for this issue. The most important issue in multi-purpose optimizing is to find partout or non-occupied set of answers.

Tay et al. (2008) have investigated multi-objective scheduling, in which the proposed method combines fuzzy logic and genetic algorithm. The proposed algorithm is based on combining the new biological concept of genetically modified organisms to achieve the ultimate high-quality solution as well as the usage of powerful FL's capabilities in controlling evolutionary algorithms. In this algorithm, the genetic algorithm is initially utilized to generate primary populations, evaluate solutions and generate new generations. During the next step, a fuzzy multi-objective evaluation method has been applied to both investigate and decide which solutions are more suitable for transferring to the next generation.

Saidi-Mehrabad et al. (2015) provided an ACO-based approach to solve the scheduling issue. An ant algorithm uses pheromone traces as well as intelligent information simultaneously for selecting and scheduling activities. Innovative information is normalized and dynamically calculated. The factors of the algorithm are dynamically adjusted, while the other features included within different parts of this algorithm have resulted in better overall results rather other solving approaches to the issue.

Li et al. (2011) developed the detachable diagram model of the workshop problem, and the fact that the work scheduling problem of a flexible workshop should be taken into accounts by any machine. With the development of the disjoint diagram, a new neighborhood construct is extracted while the prohibited search method is used in order to solve the issue.

## 2. The Competency Function

In order to solve any optimizing issue, initially a competency function must be designed. The suitability function ought to enjoy certain characteristics. This function returns the answer for each solution (set of input values) provided by the particles. In other words, this merit function is the same as the target function and progressed simultaneously to be designed in such a way that whatever the answer is presented is closer to the optimal response, it returns the larger number of capability, which indicates the greater competency of the same particle.

$$tpv= \alpha \left[\sum_{t\in T}\sum_{l\in lt} pv_{lt}\right] + \left[\sum_{k\in t}\sum_{h\in hk} pv_{hk}\right] \quad (1)$$

Tpv= [i] Competency

## 3. Particle Swarm Optimization Algorithm (PSO)

Social engineering psychologist, James Kennedy, and electrical engineer, Russell C. Eberhart, are the primary owners of the idea beyond the PSO algorithm. They initially intended to utilize a combination of social models and existing social relationships to create a type of computational intelligence that does not require specific abilities. The first simulation which has done in 1995 led them to simulate the behavior of birds to find seeds (Bullnheimer et al., 1999). This work was influenced by Hepner and Grenner's work, which was carried out in 1994 in order to simulate the behavior of birds as a nonlinear system. Kennedy and Eberhart's work led to the creation of a robust algorithm for optimization, called the algorithm of swarm optimization or PSO (Olariu et al., 2006).

Considering the PSO algorithm, there are numerous organisms that referred to as particles while distributed within the search function space which desired to be minimized (or optimize) its value. Each particle calculates the value of the objective function in a position of space in which it is currently located. Hereafter, using the combination of its current location's information and the best place it used to be in the past, as well as the information of one or more particles of the best particles in the aggregate, it chooses a direction for movement. All particles are directed to the motion, and after completing the move, one step of the algorithm ends. These steps are repeated several times until the desired answer is obtained. In fact, the mass of particles that searches for the minimum value of a function act like a bunch of birds looking for food (Hoorfar, 2007).

This algorithm has a set of particles which contains a potential solution. Comparing to evolutionary computational algorithms including genetic algorithms, a bunch is a mass optimization algorithm for particles equivalent to a population and a particle equivalent to a chromosome. The particles fly through the multi-dimensional search space. In this space, according to both its own and neighbors' experiences, the position of each particle is adjusted. The mass optimization algorithm particle combines the local search method by the particle's personal experiences as well as the general search method by neighbors' experiences and attempts to balance the exploration of the search space and the extraction of the answers.

***PSO Stages***

- Initial Setting: applied to an amount of particle with random velocities and locations in D dimensions.
- Estimation: Estimating each particle in the population.
- Update: Calculating the velocity of each particle using equation 2 and stepping up to the next situation by considering the equation 3:

$$V_j^i[t+1] = WV_j^i[t] + c_1 r_1\left(X_j^{i,best}[t] - X_j^i[t]\right) + c_2 r_2\left(X_j^{gbest}[t] - X_j^i[t]\right) \quad (2)$$

$$X_j^i[t+1] = X_j^i[t] + V_j^i[t+1] \quad (3)$$

- Closure: Suppressing the algorithm when it reaches a cessation criterion, otherwise referring to the second stage.

In which $V_j^i[t]$ represents the j dimension of t repetition. W stands for inertia weight. $C_1$ and $C_2$ for weight factor, $r_1$ and $r_2$ are random numerals between 0 and 1, $X_j^i[t]$ is the location of j dimension, while $X_j^{i,best}$ is the j dimension of each particle.

The bases of PSO algorithm is based upon the fact that in each moment every single particle set its own place according to the best location. The results of the modeling are search processes in which particles are tend to succeeded regions. They learn accommodation from each other and moves to their own best neighbors according to the acquired knowledge.

## 4. Local Search for Hybrid Algorithm

When a particle moves in a continuous solution space, it moves to a better position due to the inertia of the particle speed. A local search mechanism is proposed to pso, and the particle position is defined by rewriting equation 3 as follows:
Equation (4):

$$X_{id}^{new} = X_{ic} + V_{id}^{new} + Rand(-l_{max}, +l_{max}) \quad (4)$$

That Rand represents a random integer.

## 5. Affiliated Issues

Solving many real-world issues needs to be done in the presence of a set of constraints and limitations. Such issues are called conditional optimization issues. In this set of issues, the optimization of a function is performed in the presence of a set of constraints or restrictions. In recent years, several methods have been proposed to solve the4 conditional problems using innovative algorithms which the most important of them are:

***1) The method of inaccessible members elimination***

In the method of elimination, all particles that lead to ineffective solutions will be eliminated. This method is a special type of penalty method, which does not allow individuals who point to inaccessible points to participate in evolution. Although the elimination method is apparently logical but is faced with many problems in practice. Consider the conditions that, in solving an issue, most particles point to the answers to the set of inaccessible solutions. In this case, the elimination method will reduce the number of particles participating in the reproduction stage, or, in other words, the increase in pressure will be selected. This leads to a decrease in the genetic enrichment of the population, and hence the probability that the algorithm will be captured in local optimizations will be increased.

***2) The method of repairing unworkable members***

In this method, the inaccessible solution produced by particles is transformed into practical solutions by enforcement of a determinate and predetermined process. One of the problems of this method can be pointed out as problem-oriented, in such a way that the process of repairing non-practical answers and converting them to practical solutions varies from one issue to another. In other words, the repair process should be designed and proposed for each issue. Many of the compound problems will be solved by using the repair method.

***3) The method of hereditary operator modification***

In this method, by defining the certain hereditary operators, particles are always produced in the range of practical solutions. One of the disadvantages of this method depends on the type of problem. But by defining proper operators, an efficient hereditary algorithm can be designed and presented to solve specific problems. Offering specific encryption methods is one of the tools that can be used in this method. In some studies, it has been shown that the use of this method in certain matters is often more useful than penalty method.

***4) Penalty method***

In all the ways that have been said so far, it is impossible to produce inaccessible answers. The disadvantage of these methods is that in matters of strict constraints, a large proportion of the search space belongs to the inaccessible areas. In this case, if the actual areas are distributed throughout the region, it is difficult to find these areas in the search space due to the lack of production of practical solutions. Therefore, in these conditions, the optimal response by these methods will be time-consuming. If in such a situation the algorithm is allowed to search both practical and non-practical areas, the search time is reduced, while it is possible to find a better response than other methods. The penalty method is based on such an idea. The basis of this method is to convert a conditional optimization problem into an unconditional optimization problem by imposing a penalty function into non-practical areas. The working way is to add a penalty function to the target function for inaccessible responses. For functions that include multiple limitations, a penalty is considered for failure to meet each restriction, and for each particle, the total penalty will be achieved from the weighted sum of the restrictions penalties which are not satisfied. In this way, the designer finds the capability to lead the search well by assigning appropriate weights to constraints based on their degree of importance. This method has many disadvantages, despite its great merits. The most important objection to this approach is to return a value for any practical or non-practical answer. Therefore, all useful information related to the degree of satisfaction of constraints is eliminated.

Among the above-mentioned methods, methods for eliminating and fining are methods that are not very dependent on a type of problem and can be enforced to conditional problems in any context. However, the elimination method has not been much appreciated due to its weaknesses. On the other hand, repairing methods of inaccessible members and modifying hereditary operators are related to the issue and for each issue, a particular process and algorithm must be designed and proposed.

***5) Using the restoration process***

The algorithm randomly starts the production process for the pso elementary population. Each particle gives timetables. The next step is to use the proposed algorithm to adjust the particle positions. The algorithm uses the new velocity according to equation 2 to update the current position of the particle into a new position according to equation (3).

## 6. Conclusion

In this research, the optimization of multi-skill project scheduling with human resource constraints in reliability conditions has been investigated through particle swarm optimization (PSO). The results show that the proposed hybrid algorithm leads to an effective solution with an optimal scheduling satisfaction. The parameters of the PSO research method are less than other meta-heuristic algorithms. A large number of particles do not need to obtain higher values of merit, but few particles have unstable solutions.

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