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Research paper

Innovative heuristics modeling for dynamic project cost control

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Abstract

Smart project management greatly improves the bottom line of the projects towards organization's competitive edge. The dynamic nature of cost escalations of the various tasks of the project is a serious issue during project execution stage. Efficient project management is a complex process with an effort to execute the project within the budget provisions. The complexity increases when more number of tasks and longer duration of the project are involved. In this paper, a Particle Swarm optimization methodology is proposed and implemented to generate essential predictive analytics in maintaining optimal project cost performance.

Keywords: *Project Management; Cost Optimization; Performance Modelling; Particle Swarm Optimization (PSO).*

1. Introduction

Organizations of all types (profit, nonprofit, government) are increasingly carrying out projects to accomplish their business objectives. Effective project management results in competitive advantage for an organization. Sarmiento, et al [1] explored this in greater detail. Competitiveness in today's marketplace depends heavily on the ability of a firm to handle the challenges of projects in terms of time and cost overruns as well as expected higher customer service levels. All these factors have driven business organizations to resort to techniques and insights towards dynamic project performance optimization on various projects undertaken as suggested by Mileff, et al [2].

The task of managing cost performance can be a major challenge for organizations which are faced with increasing pressure to lower overall project costs while improving customer service levels. Earned Value can help analyze a project and the technique integrates cost, time, and the work done (scope) to actually assess the project performance according to Paley [4] and Anbari.[5]. The Earned Value (EV) can then be compared to actual costs and planned costs to determine project performance and predict future performance trends according to Meredith et al. [7].

Particle Swarm Optimization (PSO) is considered as a stochastic global optimization algorithm and the robust performance of the proposed method over a variety of difficult optimization problems has been proved by Joines, et al [3]. In accordance with PSO, either the best local or the best global individual leads the behavior of each individual in the hyperspace. The ability pf the particles to remember the best position that they have seen is an advantage of PSO. An evaluation function that is to be optimized evaluates the fitness values of all the particles [6]

2. Method and methodology

A project consists of many activities and for illustrating the proposed model a project with 5 activities is considered. For various activities of the project, we collect the Earned Value (EV) and Actual Cost (AC) data for each period and compute Cost Performance Index $CPI_{ij} = EV_{ij} / AC_{ij}$ which gives the worth of work out of every \$1 spent where:

EV_{ij} = Earned value which estimated value of the work actually accomplished for task i for period j

AC_{ij} = Amount expended to date (actual cost) for task i for period j

A database consisting of these data values is created for each period during the course of execution of the project.

The main objective is to get an insight as to how the various tasks of the project perform with respect to cost in alignment with the earned value. The methodology based on PSO is developed accordingly and is illustrated in Fig. 1 in order to move towards dynamic cost performance optimization

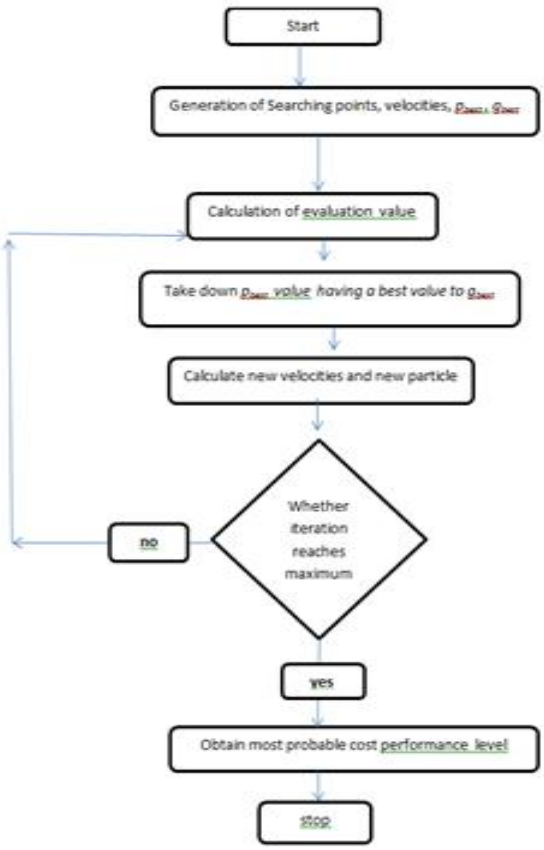

Fig. 1: PSO Methodology.

The PSO methodology is outlined below.
The individuals of the population, searching points, velocities, and are initialized randomly but within the lower and upper bounds of the CPI values which needs to be specified in the algorithm.
An evaluation function that is to be optimized evaluates the fitness values of all the particles. For every individual particle, a comparison is made between its evaluation value and its p_{best}. The g_{best} indicates the best evaluation value among the p_{best}.

The evaluation function is determined by the following function

$$f(i) = -\log\left(1 - \frac{n_{occ}(i)}{n_{tot}}\right) \quad i = 1,2,3,\cdots,n \;;$$

This formulated function is used to capture the most probable cost performance levels from the data base as well as the convergence criteria for stopping the algorithm.
$n_{occ}(i)$ is the number of occurrences of particle in the data set
n_{tot} is the total number of records in the data set.
n is the total number of iterations;
For every individual particle, a comparison is made between its evaluation value and its p_{best}. The g_{best} indicates the best evaluation value among the p_{best}. This serves as an index that points to the best individual particle generated so far.
The adjustment of the velocity of each particle is performed as follows:

$$v_{new}(a,b) = w * v_{cnt}(a) + c_1 * r_1 * [p_{best}(a,b) - I_{cnt}(a,b)]$$
$$+ c_2 * r_2 * [g_{best}(b) - I_{cnt}(a,b)]$$

Where,

$a = 1,2,\cdots\cdots,N_p$ (Number of particles)
$b = 1,2,\cdots\cdots,d$ (Dimension of the particle)

This is done to diversify the search space as well as to intensify the search towards better feasible solutions
In the above equation, $v_{cnt}(a)$ represents current velocity of the particle, $v_{new}(a,b)$ represents new velocity of a particular parameter of a particle, r_1 and r_2 are arbitrary numbers in the interval $[0,1]$, c_1 and c_2 are acceleration constants (often chosen as 2.0), w is the inertia weight that is determined using

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter$$

Where,
w_{max} and w_{min} are the maximum and minimum inertia weight factors respectively that are chosen randomly in the interval [0,1]. Also v_{min} and v_{max} are the minimum and maximum limit for velocities respectively
$iter_{max}$ is the maximum number of iterations
$iter$ is the current number of iteration

The following adjustments are necessary to ensure that the newly obtained particle does not exceed the established upper and lower limits of velocities.

If, $v_{new}(a,b) > v_{max}(b)$ then $v_{new}(a,b) = v_{max}(b)$

If $v_{new}(a,b) < v_{min}(b)$, then $v_{new}(a,b) = v_{min}(b)$

Then, based on the newly obtained velocity, the parameters of each particle is updated as follows

$$I_{new}(a,b) = I_{cnt}(a,b) + v_{new}(a,b)$$

Also the parameter of each particle is verified whether it is outside the lower bound and upper bound limits. In order to ensure that that the newly obtained particle does not exceed the established upper and lower limits of parameters, the following adjustments are carried out.

If $P_k < P_{L.B}$, then $P_k = P_{L.B.}$

Similarly, if $P_k > P_{U.B}$, then $P_k = P_{U.B.}$

Likewise, bounding is done for the other parameters as well.
This process continues until the evaluation function value is stabilized and the algorithm converges.

3. Implementation results

The analysis based on PSO for predicting optimal cost performance has been implemented in the platform of MATLAB . The detailed information about the CPI values for each task of the project for each period is captured in the form of a database as given in Table 1.

Table 1: A) A Sample Data of CPI

PI	T1	T2	T3	T4	T5
1	0.2	0.5	1	1.2	1.5
2	1	0.7	1.1	1	1.4
3	0.2	0.5	1	1.2	1.5
4	1	0.7	1.1	1	1.4
5	0.2	0.5	1	1.2	1.5
6	1	0.7	1.1	1	1.4

The random individuals are generated as given in Table 1b.

Table 1: B) Initial Random Individuals

T1	T2	T3	T4	T5
0.2	0.5	1	1.2	1.5
1	0.7	1.1	1	1.4

Table 1c represents random velocities as shown below:

Table 1: C) Initial Random Velocities

T1	T2	T3	T4	T5
0.1298	0.1298	0.1298	0.1298	0.1298
0.0376	0.0376	0.0376	0.0376	0.0376

Then simulation is performed on a large database of past records showing evaluation function improvement at different levels of iteration as given in Table 2 :

Table 2: Simulation Iteration

Number of iterations	Evaluation function value
50	0.5684;
60	0. 6554
70	0.8547
80	1. 1522

The emerging optimal individual obtained after satisfying the convergence criteria is given in Table3.

Table 3: Optimal Individual

T1	T2	T3	T4	T5
0.2	0.5	1	1.2	1.5

The final individual thus obtained represents the most emerging pattern for the most probable project cost performance levels for each task, The obtained performance levels mean that the earned value to the actual cost spent for task 1 is 20%, for task 2 is 50%, for task 3 is 100%, for task 4 is 120% and for task 5 is 150%
Based on the essential information provided by the final best individual, the following inference is noticeable.
CPI=1 indicates actual expenditure equals planned expenditure;
CPI>1 indicates better than expected cost performance;
CPI<1 indicates lower than expected cost performance;
CPI<1 calls for remedial measures to control the cost overrun so as to move towards cost performance optimization. In this case TaskT1 and Task T2 are not meeting the expected level of cost performance and requires investigation and intervention with remedial measures to control the cost overrun so as to move towards cost performance optimization.

4. Conclusion

Cost performance management is an important process of project management. For a typical project consisting of variety of tasks with respective budgeted cost and actual cost, the cost overrun in individual tasks will have huge impact on the total project cost. Cost performance index plays a vital role in identifying the cost overruns and thus gives an inference for control of cost of the individual tasks in particular and the project cost in general. To tackle the complexity in predicting the tasks with cost deviations, an innovative and efficient approach based on Particle Swarm optimization algorithm has been proposed and implemented. The heuristic modeling is aimed at predicting the most probable cost overruns of the project for the forthcoming period necessitating intervention with remedial measures to control the cost overruns so as to move towards cost performance optimization.

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