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Stochastic Time-Cost Tradeoff Using Genetic Algorithm

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Abstract: This paper presents a Stochastic Time-Cost Tradeoff analysis system (STCT) that identifies optimal construction methods for activities, hence reducing the project completion time and cost simultaneously. It makes use of schedule information obtained from critical path method (CPM), applies alternative construction methods data obtained from estimators to respective activities, computes an optimal set of genetic algorithm (GA) parameters, executes simulation based GA experiments, and identifies near optimal solution(s). A test case verifies the usability of STCT.

Keywords: Genetic Algorithm (GA), Time-cost Tradeoff Analysis, Optimization, Scheduling

I. INTRODUCTION

A. *Research Background and Objective*

A project network consists of numerous activities, and various construction methods are applicable to perform an activity. Project managers spend considerable time and cost for deciding an adequate construction method among available methods. One method may be the high-cost and high-speed, another may be the low-cost and low-speed to complete an activity. Once valid methods and managers' experience are applied to a project planning, the risk of project failure involved in time and cost overrun is significantly reduced. However, a big project has a number of activities and is difficult to find optimal set of construction methods in a simple way. Therefore, it is essential to select an optimal alternative set of multiple construction methods involved in a specific activity, considering the constraints of both time and budget. Consequently, the optimal time-cost tradeoff technique has been accepted as a critical method for efficient project schedule management.

B. *Research Scope and Procedure*

This paper proposes a Stochastic Time-Cost Trade-off analysis system (STCT) by hybridizing the genetic algorithm and simulation based scheduling (Lee, et. al 2015).

The research procedure to achieve its goal is described as follows: 1) Review previous researches associated with time-cost tradeoff, and investigate the limitations of conventional methods, 2) Develop the STCT system algorithm, 3) Verify the usability and practicality of the proposed system by a small project case. The computational model considers project direct and indirect costs which have effect on the project completion cost except for resource constrain, cash flow, etc.

II. LITERATURE REVIEW

The time-cost tradeoff analysis (TCTA) technique is well known as a method searching for an optimal solution by satisfying both the project completion time (PCT) and the project completion cost (PCC). TCTA is classified by three approaches, i.e., heuristic, mathematical, and optimization methods (Hegagy 2002). This study employs an optimization method which allows finding an optimal method combination of applicable construction methods by using genetic algorithm (GA).

Various researches have examined GA based TCTA methods. Feng et al. (1997) suggested a system based on a critical path method (CPM), which retrieves optimal tradeoff of time and cost using GA. Chua et al. (1997) presented a TCTA system considering resource constraints. Li et al. (1999) developed a quadratic time-cost curves discovery system (QTCD) on the basis of historical data. The QTCD system is integrated TCTA process utilizing GA as machine learning and GA based system (MLGAS). Hegazy (1999, 2002) developed an optimal time-cost analysis system taking into consideration practical variables, i.e., resource constraints, penalty or incentive according to whether to meet the demanding deadline or not. As mentioned previously, the existing GA-based TCTA methods have following limitations: 1) The process which integrates schedule information obtained from commercial scheduling software (e.g., primavera P6, MS-project, etc.) and construction method alternatives established by estimators is not presented. 2) Most of existing GA-based TCTA methods accepted output computed by one time GA experiment as a global solution without consideration of local convergence. 3) The optimal solution based on time-cost tradeoff analysis features having a variety of global solutions not a single solution. Thus repetitive GA experiments are required to reach reasonable and optimal solutions for each activity. 4) The existing GA based

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researches have ignored the verification of the initialization conditions (e.g., option setting and stoppage rule, etc.) which may influence the maturity of the GA experiments. The proposed STCT therefore can overcome the limitations by reconfiguring GA computations, hybridizing simulations with GA, and integrating the system with commercial project scheduling program (Primavera P6).

III. Stochastic Time-Cost Tradeoff Analysis

The procedure of STCT which generates optimal set of construction methods in a project network (Lee et. al 2015) is described as follows;

Step 1. The system imports schedule information from commercial project scheduling program (P6). The schedule data include following information, i.e., activity ID, predecessor and successor activity list, and activity duration. The schedule data obtained are reorganized in spreadsheet.
Step 2. Construction method data and schedule data are imported and loaded to the STCT system environment.
Step 3. STCT performs CPM calculations and decides the search space of GA by selecting either crash strategy (i.e., high-cost and high-speed) or normal strategy (i.e., low-cost and low-speed).
Step 4. The system calculates the CPM calculations by using a combination of construction methods which corresponds to value between crash and normal points. The output is provided with a range of PCT and PCC.
Step 5. The system user enters a demanding project deadline and project cost. The time and cost are used as constraints in GA experiments.
Step 6. Initial population is set for GA calculation.
Step 7. The user defines the initial range values relative to each GA options (e.g., mutation ratio, crossover ratio, the number of generation etc.). Then, it executes a sensitivity analysis to identify optimal GA options.
Step 8. The system runs the GA experiment. The output data calculated by using each combination is saved in a matrix to judge an optimal GA option.
Step 9. The optimal initialization values for GA options are adopted in the STCT system.
Step 10. The user inputs optimal GA values and sets the number of generations to the minimum number of generations calculated in Step 9 into the system. Then, stopping rule is selected from *StallGenLimit, StallTimeLimit,* and *TimeLimit*.
Step 11. The number of simulation iterations is set to 120 and the iteration counter (*i*) to 0.
Step 12. The GA experiment runs with GA values obtained in Step 9.
Step 13. The population generated by GA experiment is saved in a matrix. It is utilized as initial population in next generation.
Step 14. The system runs until the simulation experiment reaches predefined iteration number (i.e., 120).
Step 15. The system repeats from Steps 12 to 14.
Step 16. Minimum number of simulation iteration is calculated and checked for confirming to reach sufficient maturity.
Step 17. If the conducted simulation iteration is more than 120, then the system repeats Step 11-16. On the other hand, the sufficient maturity of the simulation reached, the final solution is accepted as a global solution and saved in a matrix.
Step 18. The system executes CPM calculation using a global solution which means optimal construction methods and suggests PCT and PCC to the system user.

IV. Case Study

The proposed STCT system is verified by applying a project network used in Feng et al. (1997), Hegazy (2002), and Shin et al. (2004). The optimal PCT and PCC values obtained from commercial GA tool (i.e., Evolver software) and STCT respectively are compared each other. According to the results of GA experiments, STCT comes up with a shorter PCT and cheaper PCC than Evolvers' answer in network of Feng et al. (1997). Even though the same values of PCT and PCC are drawn by STCT and Evolver implementation in network of Hegazy (2002) and Shin et al. (2004), each of optimal sets of construction methods are suggested differently. These results verify the calculation performance of STCT. Another experiment is performed for simulation performance verification of STCT using same networks. STCT calculates GA experiments of 10 times by only one system operating using simulation function while Evolver is activated 10 times respectively. According to result values, Evolver suggests same PCT and different PCC values each calculation, and it is verified probability that the software converges to local solutions. STCT draws an optimal PCT, PCC, and relevant optimal sets of construction methods by 10 times iterated calculating automatically. This demonstrates the strength of simulation-based STCT.

V. Conclusion

This study presents a stochastic time-cost trade-off analysis system (STCT) by hybridizing the genetic algorithm and simulation based scheduling. It was developed to overcome the limitations exposed by existing TCTA researches. The STCT improves the performance of existing TCTA as follows: 1) The STCT allows the reasonable choice of initializing the parent chromosome. On the other hand, existing methods initialize the parent chromosome randomly. 2) The STCT contributes to the decision making of construction managers by suggesting various construction methods. 3) The STCT spends a short time relatively when compared with existing TCTA system by applying the same project case. This indicates the performance improvement of STCT. The case study verified the usability and practicality of the proposed STCT method.

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