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Ant Colony Optimization Algorithm for Software Project Scheduling Using Critical Chain Project Management

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Abstract: ***Software project managers are often faced with challenges when trying to effectively staff and schedule projects. Fail in scheduling correctly the execution of tasks leads to lower quality product to be delivered late and may over budget. An adequate model for software project planning has to deal with not only the problem of project task scheduling but also the problem of human resource allocation. The allocation of scarce resources then becomes a major objective of the problem. To develop a well-organized method for solving these issues, here an event based scheduler and an Ant Colony Optimization algorithm is used. The event based scheduler adjust the allocation of employees at events and keep the allocation unchanged at non-events. To solve the complicated planning problem, a well-organized Ant Colony Optimization algorithm is further designed. With the existing methods, resources and time are consumed by wasteful techniques such as student syndrome in which a person will only start to work on an assignment at the last possible moment of the deadline. It also delays the completion of task which is the impact of Parkinson's law. For solving the issues related with the existing methods, critical chain project management techniques are used. Critical chain project management recommends that task estimates are cut to half the length of a normal duration. It also uses safety buffers to manage the impact of constraint variation and uncertainty around the project. Incorporating critical chain to the existing method yields an optimal plan.***

Keywords: Software project scheduling, Planning, Project Management, Staffing, critical chain project management.

1. Introduction

Software project management is traditionally one of the major problems faced by software project managers. A project is well-defined task, which is a collection of several operations done in order to achieve a goal of the organization. In order to achieve the goal, all the tasks should be properly managed and control. Most of the project manager's time is spent on project planning, monitoring and control. Project schedule is the main plan included in any Project Management Plan. In addition, uncertainty is why we need project management. The ever-growing size and complexity of modern software systems has also added to the uncertainty. Studies show that most of the project fail today because of poor management. Most of the products are delivered late, may over budget or poor quality.

To manage a software project, the project manager needs to estimate the project workload, cost and decide the project schedule and resource allocation. Based on estimations of effort and duration, the schedules for manpower are developed. Also in staffing, staff organization and staffing plans are made. This area is considered extremely important because, on the one hand, inaccurate scheduling may cause significant delays in delivery and budget overruns and, on the other hand, improper staffing can lead to an undesired low level of quality in software products. Therefore, estimates give the opportunity to adjust project parameters to meet budgets and deadlines. For workload and cost estimation, some famous models like COCOMO have been developed and widely used.

Project management is usually conducted using traditional tools such as CPM (critical path method) and PERT (program evaluation and review technique). They are useful for task scheduling, but it does not consider the resource constraints. But this cause time waste when activities can be completed well before the estimated finish date. They perpetuate Parkinson's law. This law states that work expands to fill the time available for its completion.

The main resource in software project is human. People may be having different skills. It is common that employees joins multiple module development tasks simultaneously, and it is also possible that he/she stops their current work and joins the other more critical tasks. If task preemption is properly designed, human resources can be organized in a more efficient way. Employees have a maximum dedication, which must be respected to avoid overwork. Therefore assigning employees to the best-fitted tasks is challenging for software project managers.

Here we develop a practical and effective approach for the task scheduling and human resource allocation problem in software project planning with an ant colony optimization (ACO) algorithm and an event based scheduler. The representation scheme as event based scheduler takes both the issues of task scheduling and resource allocation into account. ACO promises to converge fast and perform well on the considered problem. But the problem with the existing system is that the projects lost time and resources are typically consumed by wasteful techniques such as bad multitasking, student syndrome etc. It also delays the completion of task which is the impact of Parkinson's law. A concept known as critical chain, holds for a resource feasible schedule. The scheduling mechanisms provided by Critical Chain Scheduling require the elimination of task due dates from project plans. Underlying the key differentiating aspects of Critical Chain-based project management are an appreciation for the impact of variation and of human behavior on the ability of a project to move with speed and reliability.

In this paper, the first section gives the previous algorithms and models used for project scheduling. It summarize the advantages and disadvantages of the scheduling mechanisms. Here the proposed model uses critical chain project management which reduces the duration of the project. It solves the constraints in the project by taking it in the critical chain. The model is described in the next section. Then the results are analyzed. Next section the paper is concluded and discussed the future enhancements.

2. Literature Review

Research attempt related to software project scheduling have employed a number of different techniques and methods for optimal task scheduling and employee allocation. Linet Ozdamar [2] proposes Genetic Algorithm (GA) which uses biological principle of evolution to artificial systems. GA is useful for solving complex problems and it is based on population instead of a single point. But it uses a large search space. Tad Gonsalves et al.[3] proposes Particle swarm optimization which is a meta-heuristic algorithm that solves the resource constrained project scheduling problem. PSO is relatively simple to implement and high quality solution are obtained. Also it can handle multiple projects. But the employee allocation issue is not taken in account. Giulio Antoniol et al.[4] proposes search based software engineering techniques to address problems associated with optimal allocation of work packages. There is a growing demand for search based techniques for solving the scheduling problem. It manage human resource well. But it handles task scheduling and employee allocation separately.

Tabu search based method proposed by Marek E. Skowro nski et al.[5] are relatively simple for multi skill scheduling problems. RCPSP could be extended by the skills domain to Multi Skill Resource Constrained Project Scheduling Problem. It takes skills in detail but there is no task preemption and allocate one employee to one task only. Time line model proposed by Carl K. Chang et al.[6] accompanied with Genetic algorithm produces optimal or near optimal schedules. It introduces the time-line axis. The time-line axis, considers more human resource factors in project management. But here it assign different groups to same task in different period and the search space increases. Constantinos Stylianou et al. [7] proposes an intelligent software project management tool (IntelliSPM). It is a tool to support software project management activities with optimization mechanisms from the area of computational intelligence. IntelliSPM makes use of single- and multi-objective GAs as well as a single objective PSO algorithm. In the constraint model proposed by Junchao Xiao et al. [8] the differences between human resource capabilities and capacities are taken into consideration. It enables the resources to be optimally scheduled and guarantees stability of the process. But it is complex and uncertainty is not taking in to account.

One of the contribution of this paper is using the Ant Colony Optimization (ACO) with an event based scheduler to effectively make a plan. It solves the complicated staffing problems and gives a best trail or schedule for optimizing time and cost. First, a representation scheme with an event-based scheduler (EBS) is developed. The EBS regards the beginning time of the project, the time when resources are released from any finished task, and the time when employees join or leave the project as events. To generate an actual timetable, the EBS adjusts the workload assignments of employees at events and resource conflict is solved according to the priority defined by the task list. The EBS only makes new assignments at event so it is able to keep the implementation of tasks in a more stable manner. Also it reduces the search space which is a major issue in the above methods. To solve the planning problem, Ant Colony Optimization (ACO) is designed. ACO contains many iterations which yields best result. The main tasks to be considered in an ACO algorithm are the solution construction, the management of the pheromone trails, and the additional techniques such as local search. In each iteration, ants set out to build plans for the problem. ACO promises faster convergence. It solves major combinatorial optimization problems.

3. Proposed Work

Here an enhanced scheduling method is proposed for reducing the duration of the project and to reduce the uncertainty. In [9], to develop a flexible and effective model for software project planning, it uses an approach with an event-based scheduler (EBS) and an ant colony optimization (ACO) algorithm. Ant colony optimization algorithm is used for the effective task scheduling and human resource allocation problem in software project planning. Mainly, ACO is used for optimization problems which aims to find a feasible solution which is minimized or maximized. ACO returns best trail of tasks which further undergoes critical chain management. The overall design of the work is summarized using the figure 1.

Here first the ACO operations are done. For that the parameters are initialized. Next it undergoes certain iterations for getting a best solution. The solution is made by the influence of pheromone and heuristic values.

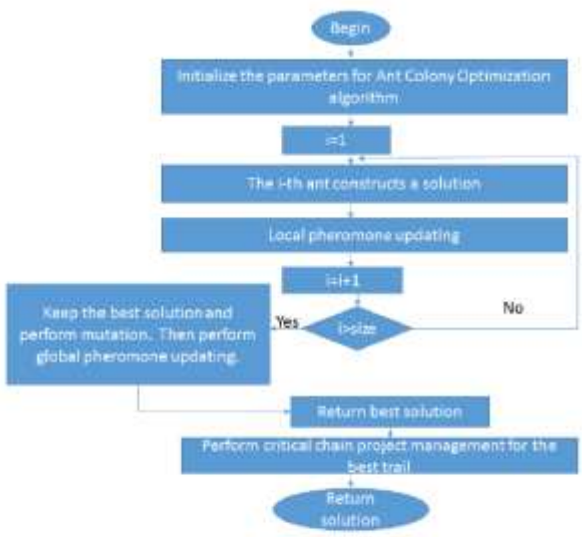

Figure 1: Design of the proposed work

3.1 Critical Chain project Management

Uncertainty is why we need project management. How we manage for uncertainty is by the improvement of project performance by getting projects done both faster and with better reliability of the promised deliverable dates. There are a lot of problems in project management. They all come from the core problem of managing uncertainty. Multitasking is a conflicting problem. It can be encouraged in certain circumstances. But it can be quoted as everybody loses and nobody wins. Another problem is student syndrome in which a person will only start to work on an assignment at the last possible moment of the deadline. It also delays the completion of task which is the impact of Parkinson's law. Also, delays accumulate in project, but early completions do not. We can solve these issues using critical chain project management.

Critical chain is the longest succession of dependent events that determines the length of the whole project. It is an outgrowth of the Theory of Constraints (TOC) developed by Eliyahu Goldratt[10] to scheduling, managing and manufacturing. TOC aims at achieving the goal of a system or organization by focusing on the weakest link in the chain which is the constraint. In project management, when we consume time which is our scarce resource, it leads to losing money. So in order to complete on time, add protection to various tasks. Here we not protect the individual activities but the whole project. For that add time at the end of the critical chain. Then define critical chain as longest sequence of activities which consider both the dependence of activities and the dependence of the resources. Buffer management provides us with a control mechanism which can protect the constraint and identify areas of the system which are not in control. It is the look ahead process that highlights when and where there is disruption. Critical task overruns can be absorbed by the buffer. The project schedule remains unchanged. Also if a critical task finishes early, the time saved added to the buffer status. The unit of measurement of the buffer is time. During the critical chain implementation, supply two estimates. One of these would be a most likely estimate and the other would include a safety margin or comfort zone.

4. Experimental Results

Here, the best trail of tasks is found out using the existing Ant Colony Optimization algorithm with an event based scheduler. It also provides the employee allocation in an effective manner. Next for reducing the duration of the project, we apply the critical chain concepts. The task estimates are reduced to a great extent and then the duration of the entire project is reduced using buffers. Here 10 task instances were taken and employees were registered with their working hours and skill sets. The event based scheduler gives the task list and the employee allocated to the particular task. It gives a more stable assignment. Then to solve the software project planning problem, here an ACO approach is used. The parameters for ACO were initialized first. It gives a best solution by going through the three steps: solution construction, pheromone update and mutation. By keeping the best so far solution, perform the mutation for better performance. This gives the best trail of tasks for the completion of project. The duration of the project using ACO is calculated. Next by using the critical chain concepts, the duration of the entire project is reduced considerably. The duration of each task is reduced first. Then for the protection of the tasks for completion, here the comfort zone is added with the task duration. So by using critical chain method, the entire project is protected in spite of protecting each task. The duration of tasks by using the ACO and the critical chain were plotted and compared using a graph. The output of the ACO is shown below in Table 1. It gives the best trail of tasks and the employees allocated with their working hours. Also the durations of tasks using critical chain and ACO are compared using the following graph in figure 2.

Table 1: ACO output

Task	Employee	Working Hours
3	Emp 18	20
9	Emp 20	25
7	Emp 6	45
2	Emp 2	40
6	Emp 7	78
5	Emp 4	36
10	Emp 8	34

The total duration for ACO = 278 hours. Next by using critical chain concepts we reduce the duration 50 percent. But it takes the buffer timings and final duration is calculated as 197. Each task duration is also reduced, it is pictured in the graph as shown below.

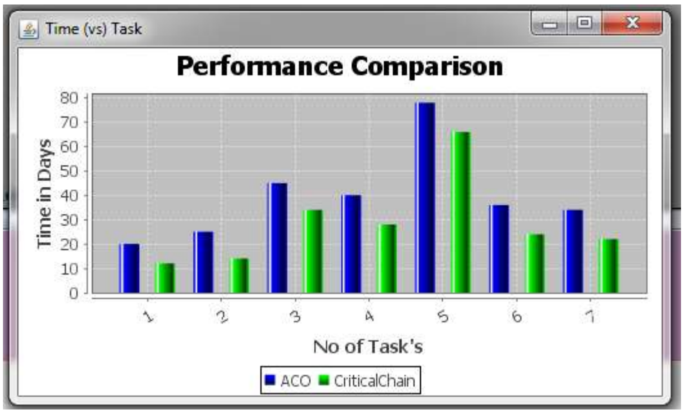

Figure 2: ACO versus critical chain comparison

5. Conclusion

Effective software project plan can reduce cost and time needed. In software project main resources are human resources. Here the difficulty in staff scheduling is taken into consideration and for that, the Ant Colony Optimization technique with an event based scheduler is used to solve the problem. It takes advantage of ACO to solve the complicated planning problem. With the event based scheduler the representation scheme is effective, and the proposed algorithm manages to yield better plans with lower costs and more stable workload assignments compared with other existing approaches. But to further reduce the duration and uncertainty, a scheduling model with critical chain project management is implemented. The main constraints which affect the success of project is taken in to account in the critical chain. Results shows that critical chain performs well for reducing duration and uncertainty. Implementing additional techniques in to the model helps for managing multi projects

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