RESOURCE ALLOCATION AND ITS DISTRIBUTED IMPLEMENTATION

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ABSTRACT

During the execution of a project (investment, innovation etc.), three important parameters must be kept in mind: we have to execute the project as soon as possible, with minimal total cost and not to exceed resource (manpower, materials, engines etc.) availabilities.

Why does it important to execute the project as soon as possible with minimal total cost? If more than one company compete for the execution of an investment project, usually the chance of winning the tender will be higher if a company can execute the project with minimal total project time (TPT) and minimal total project cost. This problem could already be handled in the 60s and 70s with network planning (CPM, MPM, PERT etc.), scheduling (Gantt Diagrams, LOB etc.) and other related cost-minimizing (CPM/COST, MPM/COST etc.) techniques. The most difficult problem was to handle the resources. During the execution of a project we must keep in view the resources, because these resources are usually straitened. There are well-defined number of labours, engines and so on.

If we would like to execute the project with minimal TPT and minimal total project cost and optimal use of the resources (manpower, materials, engines etc.) the problem becomes easily so hard to solve (already at 5000-10000 activities) that computers available today cannot find the solution within a reasonable time. The real problem is more complicated, because before the execution of the project we can only estimate the duration time, (variable) cost and resource need of activities.

In real life it is common that the duration time of project activities cannot be estimated correctly. In this paper a novel algorithm is introduced by which an optimal resource allocation with minimal total cost for any arbitrary project could be determined. Moreover, this algorithm also handles the competences of the human resources.

A distributed problem solving environment is also introduced that implements the above mentioned optimal resource allocation algorithm with a parallel branch and bound method. The system is built on the Jini technology **[44]**. It is a dynamic, service-oriented infrastructure that utilizes spare cycles of networked workstations in an efficient way and solves computation intensive problems more easily due to the parallelization.

Keywords: Deterministic Resource Allocation, Stochastic Resource Allocation, Distributed Systems, Handling Competences in Resource Allocation.

I. INTRODUCTION

Our novel method schedules the activities in the alternative paths of an optimal resource allocation satisfying a given target function and taking into account that the duration times of the activities are probability variables, which have an expected value and standard deviation **[30]**. According to former studies 10-12% cost can be saved if the duration times of activities are handled as probability variables instead of deterministic values, hence the uncertainty of duration times can be managed and the total project time can approximately be determined if a significance level is given. **[27]** After all, the total project time is often influenced by unanticipated events. In the case when resources and the duration time of activities are changing at projects in progress, a new resource allocation for the running activities and for those still not started can be determined with this method. In this paper we introduce a new algorithm, which refines any feasible solution to determine an optimal resource allocation. This algorithm can be used when the duration times of activities are deterministic or stochastic variables. In the section 3 the deterministic version and section 4 the stochastic version of the resource allocation method will be introduced. In the section 5 a new method will be discussed, which can handle the competences of the human resources.

The main defectiveness of any Project Management software is that they cannot handle the human competences. In real life an activity is prepared by a group, or a subcontractor. What is the optimal size of the groups in terms of resource allocation? How can we collect the adequate people in order to prepare activities earlier? In this paper an algorithm is introduced, which can handle the competences of the human resources.

In the filed of combinatorial optimization or artificial intelligence the method called “branch and bound” is very popular. It is often used in

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such NP-hard optimization problems where the search of the solution with simple enumeration would need long time and large resource capacity that exceeds the capabilities of today's computers. **[6-8]** Typical examples are the knapsack or traveling agent problems, but our resource allocation optimizing problem is of this kind as well. **[4]** One of the advantages of branch and bound (B&B) is that it is only a framework method that defines only the iterative steps and the rules that must be applied at each step. **[10, 11, 41]** Every B&B algorithm can be characterized with four rules: the branching, bounding, problem selection and elimination rules. The rules are only directives and say nothing about the concrete implementation thus the B&B method can be adapted to a variety of problems. We also use this method to find the optimal solution for resource allocation. A more detailed description of the B&B algorithm can be found in **[13, 36, 41]**.

In our system we use a parallel B&B that can significantly decrease the computation time or can achieve a closer solution to the optimal one in the same time when all the solutions are feasible. Moreover, the distribution of the task to different computation sites will result in lower resource (e.g. CPU, memory) consumption at each site, thus can make a problem solvable that was unsolvable on a single machine because of the resource limitations. At a certain class of applications (e.g. at the ones needing many synchronization and inter-process communication) the parallelization does not decrease, rather increase the overall execution time, but the benefit of resource sharing can be more important. The parallelization issues of the B&B algorithm were discussed in many papers **[13, 29]**, the one that we use in our distributed problem solving environment will be discussed in more detail in section 6 from a theoretical approach and in section 7 from the implementation point of view.

II. BACKGROUND

When carrying out a project or a small-scale series production management, we would like to finish a project with minimal total project time and minimal total project cost using resources optimally. For determining the total project time we can use some of the common scheduling methods. Although the scheduling can be easily and quickly solved by a simple computer, the resource allocation problem is much harder and requires more time consuming computation.

For that very reason the heuristic methods are more popular then algorithmic ones. Heuristic methods find a feasible solution. These methods could be much faster, but some times the optimal solution would be important (equalized consuming resources, equalized production etc.). **[2, 3, 6, 8, 22, 32, 42]** Algorithmic methods find an optimal solution, but intermediate steps are usually infeasible solutions. If the computational demand is too high we cannot stop the algorithm in order to get the current feasible solution, because the intermediate step is not surely feasible. **[4, 21, 30]** The evolution methods are starting from a feasible solution and refine the solution, but the optimality is usually not guaranteed. **[27]** The introduced RALL-OPT method also starts from a feasible solution and refines the solution in every step. But this method guarantees the optimal solution in finite steps and the intermediate steps are all feasible. In the next section this new algorithm will be described in detail.

III. DETERMINISTIC RESOURCE ALLOCATION

As it was mentioned earlier our novel resource allocation algorithm solves the given problem with certain resource constraints starting from a feasible solution and continuing until the optimal resource allocation is found. This method primarily handles renewed resources (e.g. human resources). Moreover, considering that the total project time is often influenced by unanticipated events a new resource allocation for the running activities and for those still not started can also be determined with this method. The algorithm can also be used when the availability of resources are not a constant function, or to determine a resource allocation with minimal total project time (TPT) and minimal total project cost, or is capable of using different resources and can be applied in parallel projects

This deterministic resource allocation method schedules the activities in the alternative paths of an optimal resource allocation, satisfying a given target function. In this method the existence of a feasible solution is assumed. The algorithm finds the optimal solution in finite steps, according to the given target function.