A Game-Theoretical Model for Task Assignment in Project Management

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***Abstract*- The assignment of tasks to employees is one of the most essential aspects of a project manager's job. A situation with employees working on tasks that they are not well-suited for can lead to a significant loss of time and resources in addition to a sub-par product or service. The simple difference between a good and bad task assignment for employees can easily result in major differences in a company's bottom line.**

We utilize techniques from game theory to produce an algorithm for matching employees and tasks based on manager and employee preference, employee time, and employee skills. As a result, we have created a deterministic algorithm for task assignment with built-in feedback mechanisms for measuring the health of the project group with respect to the work given.

I. Introduction

Skalebund [5] writes that 27% of managers' time and $105 billion annually is spent working with and correcting employees who are not sufficiently suited for their tasks. In order to reduce this number, we have examined the state of task assignment in project management and have devised an algorithm to produce a repeatable task assignment to workers. Currently implemented solutions often ignore employee preference of which tasks they work on which inhibits employee productivity [3]. Those that do take employee preference into consideration are non-deterministic, thus making it more difficult to evaluate the business process in an efficient manner.

We have taken into consideration the satisfaction and ownership of the problem by the employee and also the desires of the manager to have employees work on tasks for which they are most qualified for and to distribute the work load as evenly as logistically possible. In this sense, we seek to satisfy both the manager and the employee while doing so in a reproducible manner, so decision can be analyzed and used to improve the production process.

II. Background

Currently applied approaches to this problem involve a manager assigning tasks without considering the explicit preferences of employees or a more progressive, but time-consuming process of discussing tasks with each employee to understand their perspective. While the discussion is a step in the right direction, managers do not have a deterministic method for converting the information from the discussion into a task matching.

Currently planning software is available, but not open about its algorithmic background. Most of the task assignment in this planning software does not take into account employee preferences, but rather just the manager's assessment of employee qualification, such as SUMit Roster Software [6].

A related field to this problem is Job Shop Scheduling [1]. One of the leading actively-researched algorithms in this area is the TABU Search. Results from this algorithm have shown to be highly effective, but the algorithm itself does not explicitly account for many of the factors, including the two-sided nature of the task assignment, that we want to account for. Two-sided matching theory addresses the issue of matching two distinct sets of entities when both have potentially differing preferences, leading to potential stability problems. A stable matching is one in which no member m of the first set prefers another match w' to its current match, w, while the other potential match, w', is either not matched or prefers m to its current match, m'. Gale and Shapely proposed an algorithm for stable matching that they proved always provides a stable matching.

A stable matching is a matching which can be said to not be unstable. The definition of an unstable matching is one in which there exists a man M who prefers a woman W to his mate, W', and W prefers M to her mate, M'. It has been shown [2] that there always exists a stable matching for any two sets.

The Gale-Shapely Courtship Algorithm can be given as follows:

1. Some man proposes to his highest preferred woman and they attach
2. Some other man proposes to his highest preferred woman and they attach if she is unattached or if she prefers him to the man she is currently attached to

Step 2 is repeated until either all men are attached or have been rejected by all of their acceptable mates.

III. Our Approach

Due to the involvement of humans in such problems, it is difficult to employ parallel processing techniques.

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Further more, due to the fact that employees who have both ownership and enjoyment of their tasks are more productive, simply matching tasks to the most qualified employee will not always produce a better result. It is necessary to take into account the task preferences of individuals. In this paper, we propose an approach utilizing two-sided matching in order to provide an apt matching of tasks to employees.

Since an examination of the existing solutions reveals that these were not designed to handle the complexities in the above situation, we modified a game-theoretical algorithm that most closely fits our problem to meet the requirements for task assignment.

From examining current solutions, we determined that a successful mathematical approach must be able to handle:

1. Preferences of both managers and employees
2. Employees that have a limited amount of time and tasks that require time to complete
3. Cases in which employees (because of skills, time, etc.) are not capable of completing the tasks
4. Cases in which employees are overabundant in comparison to the number of tasks

Direct application of the Gale-Shapely algorithm may lead to a situation where some members do not have assigned tasks and some tasks have no assigned members.

To overcome this problem, we modify the Gale-Shapely algorithm to resemble a weighted knapsack algorithm. This adds a weight to each task, which is the estimated time required to complete the task. Each employee now has an allotment of time available to fill with tasks. Furthermore, we introduce callbacks to counter the effect of rejected tasks.

A task structure contains the following:

- Identifier
- Estimated Time Required
- Preference List
- Pointer to Next Non-Rejected Preference

An employee structure is defined by:

- Identifier
- Time Available
- Preference List
- Pointer to Next Non-Rejected Preference
- Callback List

Our algorithm can be described as follows:

1. A task from the set of unattached tasks selects its highest preference worker that has not rejected it.
2. If the worker prefers the task to their current task and has time to do the task, then he accepts the task.
3. If the task that is replaced can no longer be completed in the amount of time available, it becomes unattached and establishes a callback
4. The worker then recalls the highest (if any) preferred task that it has a callback for that it now has time freed for.
5. Repeat starting at step 1 until all tasks have been assigned or rejected by all preferred workers.

As with the Gale-Shapely algorithm [2] our algorithm will terminate when all tasks have been assigned, or they have been rejected by all workers the process terminates. Termination is guaranteed to occur since the preference rankings mean that there are no deadlock or loop conditions.

IV. Discussion

The theoretical results of our algorithm lie primarily in the feedback mechanisms provided by the potential cases that can result from the algorithm. These feedback mechanisms are a valuable perk of the algorithm that can be utilized in determining the necessary composition of a group along with providing stronger employee evaluation reviews. These three feedback mechanisms presented are the two polar cases and the median case of the result spectrum.

A. Unmatched Tasks

After the execution, unmatched tasks can imply several possibilities. Each of these has different approaches for resolution and need to be well studied before choosing a specific course of action.

First, the number of employees available to complete the set of tasks is insufficient. This is evidently the case when the unmatched tasks fill the time of the available employees. This scenario can alert a manager of worker efficiency or the necessity of hiring new employees.

Second, the set of employees is not sufficient for the tasks required. This is the case when there is still time left for the employees to complete tasks, but there are still unmatched tasks remaining. In this case, the collective skill set of the employees does not encompass the tasks as it should or is not distributed well enough to distribute the tasks with the time given. There are two ways to remedy this situation. Providing employees (particularly those with smaller skill sets and those who consistently do not receive many tasks) with additional training will increase their skill set and allow them to perform more of the tasks needed by the group. An alternative to this solution is to hire new employees/contractors in order to supplement the skills of the current group.

B. Unmatched/Excess Worker Time

Unmatched workers and excessive amounts of worker time remaining imply that there are more than enough workers to complete the tasks. In this case, it becomes efficient to take on new projects in addition to the current ones. If this becomes a consistent occurrence then the manager should evaluate the necessity to keep these workers on this particular project and take necessary actions based on that information (potentially relocating a worker to a project which suits him or her better).

C. Perfect Match

If the algorithm executes completely and all tasks and employees receive a matching, then the group is well suited for the set of tasks. The resulting match is a task-optimal stable matching (meaning that no task can be given to a worker which the manager prefers more in any other possible stable matching).

V. Future Work

Since task assignment is only one module of a working business group, this work and the applications developed during this process need to be integrated into a full business solution. Proper avenues for feedback and change need to be established with the individual group to utilize the mechanisms discussed in this paper.

These approaches have been shown to have theoretical merit; however, we have not had the opportunity to see observe them in practice. Examining a case study of a business group operating based on the algorithm presented in these papers is the next step in this line of research.

VI. Conclusion

The proposed algorithm uses a mathematically based approach to efficiently assigning tasks to members. The primary advantages of taking a mathematical and algorithmic approach to project management is that in analysis and review of a project cycle, the results of the assignment are reproducible and can be utilized to refine the inputs of the algorithm and the business process as a whole.

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