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A Fuzzy-Logic based Resource Levelling Optimisation Tool

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Abstract: This paper focuses on the development of a Resource Levelling tool that uses Fuzzy Logic to optimise the standard or "Exact" method for resource levelling on a project. Unlike extant resource levelling tools that use fuzzy logic in conjunction with other artificial intelligence techniques such as genetic algorithms, our proposed approach is an independent resource levelling algorithm that is based on fuzzy logic. The paper describes a MATLAB implementation of the algorithm along with results from an example project. Based on these results, the proposed algorithm appears to provide superior resource levelling performance when compared to traditional resource levelling approaches.

Keywords: project management, project levelling, fuzzy logic.

1. INTRODUCTION

Resource levelling is a commonly used planning technique to reduce the sharp variations among the peaks and valleys in the resource demand histogram while maintaining the original project duration (Moselhi and Lorterapong 1993). It can be accomplished by consuming the floats of non-critical activities so that the fluctuations in the resource utilisation profile are minimised and project duration remains unchanged. Efficient planning of resource utilisation profile can avoid resource over allocation, reduce idle workforce, and reduce the magnitude of worker hire and release cycles, which ultimately leads to actual savings in project time and cost.

There are several exact, heuristic and meta-heuristics methods in literature that have been proposed for solving the resource levelling problem. Exact method such as linear-integer programming and branch and bound can guarantee optimum solutions, but exact method require more computational effort and storage since they have to explore whole search space on the contrary to meta-heuristics which only visit promising regions. Hence, numerous researchers have focused on heuristic methods. The minimum moment algorithm has been used as a heuristic approach to calculate a measure of the fluctuations in daily resource demand. This method of levelling activity resources is structured on the assumption that there is a histogram moment of the used resource that is a minimum (Weber, 2005). However, heuristic method can only produce good feasible solutions and by no means guarantee an optimum solution. The developments in meta-heuristic algorithms in recent years enabled powerful alternatives for resource levelling problem.

Genetic algorithm, fuzzy genetic algorithm and neural networks are among the meta-heuristics implemented for resource levelling problem. Fuzzy logic has been used previously in resource levelling optimisation, however it has only been used in conjunction with genetic algorithms: at the time of writing, a pure fuzzy logic approach has seemingly not been attempted in resource levelling optimisation.

Fuzzy logic usually involves classification of states of a process into individual sets or rules. In the context of resource levelling, fuzzy logic can be used to classify the various activities into "priority" states. These priorities determine the order in which the activities are shifted to level the project schedule, which should ensure an optimal resource levelling solution.

The purpose of this paper is to develop an independent resource levelling tool that uses a Fuzzy Logic Algorithm to optimise the standard for resource levelling on any given project. In the next section, we provide an overview of the recent work in this area, focusing on exact, heuristic, and meta-heuristics methods in literature that have been proposed for solving the resource levelling problem. Next, we describe our proposed Resource Levelling Optimisation Tool for Project Management in Section 3, then present preliminary resource levelling results using this tool in Section 4. The paper concludes with a discussion of the proposed tool and our plans for future work in this area.

2. RELATED WORK

There are several exact, heuristic, and meta-heuristics methods in literature that have been proposed for solving the resource levelling (RL) problem. One of the earliest attempts to reduce resource level fluctuations in construction projects using exact methods has been done by Easa (1989). The integer-linear optimisation model guaranteed optimal levelling by minimising absolute deviations from a uniform resource level (Easa 1989). Son and Mattila (2004) introduced a linear program binary variable model to level resources that allows selected activities to be split, stopped, and restarted. They solved two example projects and claimed that the better and more realistic levelling can be achieved by a developed model (Son and Mattila 2004). Branch and

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bound is another exact method commonly used to solve resource levelling (RL) problem. Demeulemeester and Herroelen (1992) presented a branch and bound procedure which adopted a depth-first methodology to solve RL problem. In the introduced model, nodes have been constructed in a manner that partial schedules, which were feasible both in terms of precedence relations and resource limitations, were coded in them (Demeulemeester and Herroelen 1992).

Harris (1990) introduced a heuristics rule, named as packing method, to solve levelling problems. This method, which was based on minimising the moment of the resource histogram, has been modified by Hiyassat (2000). In this modified method, activities to be shifted are selected by considering both resource requirements and their free floats. After this paper, Hiyassat (2001) stated that the modification of the minimum moment approach also performed well for projects with multiple resources (Hiyassat 2000).

Genetic algorithm (GA), fuzzy-genetic algorithm, and neural networks are among the meta-heuristics implemented for RL problem. Genetic algorithm, being inspired by natural evolution mechanisms, has been a powerful technique to search optimal or near optimal solutions to multi-projects and multi-objectives RLP (Iranagh and Sonmez 2012). Hegazy (1999) introduced a GA based method which can simultaneously optimise resource allocation and resource levelling through GA procedure that searches for an optimum set of activities' priorities leading to shorter project duration and better-levelled resource profiles (Hegazy 1999). Another GA-based fuzzy resource levelling optimisation has been presented by Masmoudi and Hait (2011). This new GA was developed to cope with fuzzy multi-resources and multi-projects RLP under time uncertainties.

Neural networks have been used increasingly for solving combinatorial optimisation problems. They are based on the input-output data alone in which the model can be trained, making them a powerful tool for solving RL problem (Jain and Pathak 2014). Shimazaki, Sano and Tuchiua have formulated the RL problem as an Augmented Lagrangian Multiplier (ALM) optimisation and have studied the possibility of mapping ALM optimisation onto a Hopfield Neural Network (Shimazaki et al. 1991). Savin, Alkass and Fazio have developed a new artificial neural network model and added a control block for the computation of the new set of weight of the neural network block which was not addressed by Shimazaki (Savin et al. 1996).

3. THE RESOURCE LEVELLING OPTIMISATION TOOL

As noted, the purpose of this research is to develop a Resource Levelling tool that uses Fuzzy Logic to optimise the standard or "Exact" method for resource levelling on a project. The main difference between the scope of this research, and others described in Section 2, is the development of an actual tool that is applicable to a variety of projects. The above papers and journal articles outline various techniques to optimise resource levelling, but none of them have been implemented in a tool yet. The second difference is the algorithm used; fuzzy logic has been used previously in resource levelling optimisation, however it has only been used in conjunction with genetic algorithms or neural networks. A pure fuzzy logic approach has evidently not been attempted in resource levelling optimisation yet. As such, the contributions to the field from this research are not only limited to the development of an independent resource levelling tool, but also the qualitative observations of using fuzzy logic for resource levelling.

In this section, we begin with a brief overview of fuzzy logic, then describe the method used to develop the Resource Levelling Optimisation Tool for Project Management.

3.1 Fuzzy Logic

Fuzzy Logic, although used since the early 1920s, was popularised as a viable computational algorithm by L.A. Zadeh in 1965 (Zadeh, 1965). The conventional measure of logic, a hard true value (1) or a hard false value (0), is binary in nature and limits the user to a binary set of options. Zadeh (1965) suggested the idea of "fuzzy sets" that are logic functions which are not binary in nature.

Fuzzy Sets dictate that any condition can be modelled over an infinite set of points ranging from false (0) to true (1), thus making the logic "fuzzy" in nature. These logic functions can be represented on a graph as trapezoidal or triangular functions. Each logic function corresponds to a fuzzy-rule. The idea being that the rule is intentionally vague in nature to deal with a variety of data-points within the area of the trapezoid or triangle. The implementation of multiple such rules can allow the user to completely and accurately define a problem using these fuzzy sets, and thus compute a solution over the entire range of all the fuzzy sets.

Fuzzy logic provides a very probabilistic approach to problem-solving techniques than enables any fuzzy-based algorithm to be inherently adaptive and tailor itself automatically to cope with virtually any problem at hand. A common application of fuzzy logic in present day is in the area of control systems. Here fuzzy logic is used to classify the various states of any process that needs to be controlled. The states are characterised into the fuzzy-rules. The controller, using these rules, determines the state of the process at any given time, and adjusts itself and the process to the desired conditions automatically.

As mentioned above, fuzzy logic usually involves classification of states of a process into individual sets or rules. In the context of resource levelling, fuzzy logic can be used to classify the various activities into "priority" states. These priorities determine the order in which the activities are shifted to level the project schedule, which should ensure an optimal resource levelling solution.

3.2 Methodology

In this paper, we limit our scope to the standard technique for Resource Levelling for a single resource. The tool is designed to take a text file consisting of tabulated set of project activities with their respective durations, predecessors, and