An intelligent decision support approach for reviewer assignment in R&D project selection

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ABSTRACT

In the process of Research and Development (R&D) project selection, experts play an important role because their opinions are the foundation on which to judge the potential value of a project. How to assign the most appropriate experts to review project proposals might greatly affect the quality of project selection, which in turn could affect the return on investment of the funding organization. However, in many funding organizations, current approaches to assigning reviewers are still based on simply matching the discipline area of the reviewers with that of the proposal, which could result in poor quality of project selection and poor future financial return. Additionally, these approaches might make it difficult to balance resources and resolve conflicts of interests between reviewers and applicants. Therefore, to overcome these problems, there is an urgent need for a systematic approach to support and automate the reviewer assignment process. This research aims at proposing an intelligent decision support approach for reviewer assignment and developing an Assignment Decision Support System (ADSS). In this approach, heuristic knowledge of expert assignment and techniques of operations research are integrated. The approach uses decision models to determine the best solution of reviewer assignment that maximizes the total expertise level of the reviewers assigned to proposals. It also balances the distribution of proposals at different grades and solves conflicts of interests between reviewers and applicants. Its application in the National Natural Science Foundation of China (NSFC) and the computational results of its effectiveness and efficiency are also described.

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1. Introduction

As research and development (R&D) is a major force driving national competitive advantage, governments in many countries have increased the level of R&D investment by sponsoring R&D projects [1]. R&D project management is an important task, which generally begins with a call for proposals (CFP) distributed a funding agency to the relevant organizations, such as universities and research institutions. Proposals are submitted to the funding agency and then sent to experts for peer review. The review results are collected and ranked based on aggregation methods [2]. For example, there are six stages for R&D project management in the National Natural Science Foundation of China (NSFC): Proposal submission, Assignment of external reviewers, Peer review, Aggregation of review results, Panel evaluation, and Final decision [3,4]. Because the funding decision relies greatly on peer review results, an important research issue within these stages is the assignment of suitable referees to review R&D project proposals.

However, reviewer assignment in R&D project selection has received very little attention. According to our literature review, Cook et al. [5] and Sun et al. [4] have undertaken some work on this issue. In their studies, peer review is based on partial ordinal rankings of proposals, such that the objective function of reviewer assignment is to maximize overlapping among the subsets of proposals assigned to the various reviewers, and then the effective final overall ranking can be obtained. However, from a practical perspective, it is difficult for reviewers to select R&D projects by pairwise ranking if the number of proposals is large. In addition, Fan et al. [6] proposed an approach for proposal grouping, in which knowledge rules are designed to deal with proposal identification

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and proposal classification, and a genetic algorithm was developed to search for expected groupings. Proposal grouping can simplify the procedure of reviewer assignment. Based on this, Xu et al. [7] proposed a decision support approach for assigning reviewers to proposals; the basic idea of which is grouping proposals first and then assigning appropriate reviewers for each proposal group. Obviously, more effort is needed on this research issue.

Other parallels to our work could be found in the field of Operational Research and Decision Support Systems. In fact, the assignment problem is a very traditional problem in Operational Research [8]. It has been studied over the past 50 years or so and there have been many methods proposed to solve it. H.W. Kuhn [9] proposed a Hungarian method to obtain the optimal solution(s) for the standard assignment problem. Other researchers regarded more complicated assignment problems as special cases of 0–1 integer programming or transportation problems, and searched for optimal solutions using the Branch and Bound method [10–12], cutting plane technologies [13], and their variances [14]. Most of these methods require rigorous assumptions and can only solve well-structured problems [15]. However, reviewer assignment in R&D project selection usually deals not only with well-structured problems, but also with semi-structured or ill-structured problems [4]. For example, there could be conflicts of interests between reviewers and applicants. Avoiding conflicts of interests between reviewers and applicants is a key problem in the assignment process. However, improving the validity and efficiency of reviewer assignment is also important. These problems cannot be solved satisfactorily unless we combine the heuristic knowledge of the decision maker with the decision model through the establishment of an Assignment Decision Support System (ADSS).

Lots of decision models and methods (e.g., Mathematical Programming and Optimization, Decision Analysis, Economic Models, and Interactive Method) have been developed to help managers make better decisions in R&D project selection [16,17] in the past few decades. However, many of them are not being used, and have limited impact on de facto project selection [18,19]. With the advancement of computer technology, decision support systems (DSSs) have been proposed and developed to improve the usability of decision models and methods in real applications [18,20–22]. The use of DSSs has significantly improved institutions organizational agility, allowing them to achieve and maintain a considerable degree of administrative and operational efficiency [23]. However, although some of the proposed DSSs are useful, they use decision models and methods for specific tasks and fail to integrate operations research techniques into expert systems. Therefore, they cannot solve semi-structured or ill-structured problems well. As R&D project selection processes typically involve a large number of reviewers and applicants, there is the potential for many conflicts of interests, which should be taken into consideration.

In practice, many funding organizations still assign reviewers based on simply matching of the discipline area of the reviewers with that of the proposal, which could result in poor quality of project selection. Additionally, this approach might make it difficult to balance resources and resolve conflicts of interests between reviewers and applicants. The National Natural Science Foundation of China (NSFC), which we discuss in Section 2, is such an example. Therefore, to overcome these problems, there is an urgent need for a systematic approach to support and automate the reviewer assignment process.

The objective of this paper is to present a hybrid decision support approach to assist in the assignment of reviewers of R&D projects, which integrates heuristic knowledge of expert assignment and operations research models. The models are used for well-structured decision problems, whereas knowledge rules are for ill-structured decision situations. They complement each other and provide powerful support to the assignment process. The proposed approach is applied to the assignment process of a representative government funding agency, the National Natural Science Foundation of China (NSFC). However, it can be adapted easily to other situations and applied in other funding agencies and organizations.

Section 2 of this paper describes the research background. Section 3 proposes the process of reviewer assignment of R&D projects using an approach that integrates knowledge of expert assignment and operations research models to assign peer reviewers to proposals for project selection. In Section 4, an assignment decision support system (ADSS) is designed and developed to support the proposed approach. Section 5 discusses the application of the proposed approach in a real government funding agency. A summary of the contribution and limitations can be found in the final section.

2. Background

Founded in 1986, the NSFC (http://www.nsfc.gov.cn) is the largest government funding agency in China, whose primary aim is to promote theoretical and applied research [24]. There are seven scientific departments responsible for the selection and management of research projects. These departments are sub-divided into 38 divisions that focus on more specific research areas and these sub-divisions are divided further still into different disciplines. The NSFC maintains a dictionary of discipline areas that forms a tree structure; the closer a discipline node is to the root, the broader the discipline area that it represents. For example, keyword 'A01' represents 'Mathematics' and 'A0101' stands for 'Foundation Mathematics', 'A010103' represents 'Geometry' and 'A01010302' stands for 'Algebraic Geometry'. Every year, the NSFC receives a great number of project proposals. The project selection process is coordinated by the top management and accomplished by the seven scientific departments as well as their sub-divisions. The overall project selection task is decomposed and assigned to departments, and the departments further decompose their tasks and assign them to the sub-divisions. Division managers then assign external reviewers to evaluate the proposals. The NSFC maintains an external reviewer database containing more than 60,000 records.

In the NSFC, each external reviewer is required to declare no more than three discipline areas to which their research belongs and each proposal is required to declare two discipline areas to which it belongs. Thus, there are corresponding reviewer and proposal sets under each discipline area. There are four considerations in assigning peer reviewers to the proposals:

(1) Each proposal is required to be reviewed by a fixed number of referees. Different types of research proposal have different requirements. For example, *Free Program* requires that each proposal should be reviewed by five referees.
(2) In order to avoid conflicts of interests, a proposal should not be assigned to a reviewer who has a relationship with the applicant, such as a cooperator in publication or project, supervisor-student, ex-classmate or colleague.
(3) Each reviewer is provided a ratio of first-grade proposals in all the proposals they review. Thus, a balanced distribution of proposals at different levels could guarantee that each high-grade proposal has fair opportunity.
(4) Each reviewer is assigned to review several proposals that demand their time and energy to some extent. If a reviewer handles too many proposals, it is possible that they cannot provide a careful and thorough investigation of the proposals. Therefore, the work load for each reviewer should be as balanced as possible.