Title: Knowledge Acquisition in GraPE (Grant Proposal Electronic Reviewing Assistant)

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Abstract

The review of grant proposals is an important task in every academic field, but there exist no exact methodologies to help referees in doing this. The objective of this project is to build an expert system to assist beginner referees in this process. The system will be based on ERA (Electronic Referee Assistant), a knowledge-based advisor for Informatics research papers, and named GraPE (Grant Proposal ERA). GraPE aims to provide guidance to beginner referees to help them make better reviews and become better reviewers. As a fact, an expert system's problem solving strategy relies on its knowledge. The knowledge has to be well defined, modelled, and represented in order to allow successful inference processes. This paper will describe the process of knowledge acquisition in GraPE, from the identification of knowledge sources to the knowledge modelling process.

Keywords: Expert System, Knowledge Acquisition, Electronic Reviewing

1.0 Introduction

Grant proposals submitted to any academic funding agency will undergo some method of assessment administered by the agency. The process will usually include assessment by referees. The funding agency will appoint several people to be referees to evaluate the proposal. The referee will provide their expert opinion on the proposal for the consideration of the agency.

The reviewing process is one for which academics receive very little training. There is no exact methodology for referees to follow for this task, and the standard of grant proposal refereeing varies greatly. Even though various funding agencies have provided notes on reviewing grant proposals, this is still insufficient. This project is aims to implement an expert system to assist referees in this process.

The system will be based on ERA (Electronic Referee Assistant), a knowledge-based advisor for referees of Informatics research papers (Caporale, 2003). While ERA has been successful in providing assistance in refereeing papers for workshops, conferences and journals, it cannot be applied to the process of refereeing Informatics grant proposals. This assistance is to be provided by the system developed during this project. The system is named GraPE (Grant Proposal ERA). GraPE will act as a referee advisor, assisting referees of Informatics grant proposals.

GraPE is based on a hierarchical structure of questions that a referee must answer when reviewing a grant proposal. There are several sections, each corresponding to a key aspect of a proposal, and having the goal of assessing the quality of that aspect of the proposal under review. If referee is initially unable to make this assessment, then it is decomposed into assessments of a number of more basic aspects and so on, a level is reached where the referee can respond. In this way, GraPE will ensure that the referee covers all the important issues in reviewing a grant proposal. Then GraPE will provide a recommended assessment based on the answers given by referee to all the questions. GraPE will provides detailed guidance and help referees to construct better reviews using inferences drawn from their answers, a facility that the available guidance notes from funding agencies do not provide.

The objective of this paper is to describe the process of knowledge acquisition in GraPE, from the identification of knowledge sources to the knowledge modelling process. This paper has been organised as follows. Section 2 presents an overview on expert system. Section 3 describes the knowledge acquisition stages. Section 3.1 presents the knowledge identification used in GraPE. Section 3.2 provides the overview on knowledge sources. Section 3.3 defines the knowledge elicitation. Section 3.4 presents the knowledge modelling and verification process. Finally, conclusions are presented in section 4.

2.0 Expert System

In order to implement GraPE, knowledge and expertise from experienced referees are needed, and these materials will be put in the system to achieve its objective. Expert system technology is the appropriate choice for this kind of system. According to Luger and Stubblefield (1998), an expert system, as these program are often called, uses domain specific knowledge to provide 'expert quality' performance in a problem domain.

Through expert system technology, the decision-making ability of a human expert can be emulated, and in this project, it is hoped that the system developed can emulate the methodology (and, to a certain extent, decision-making) of experts in the task of refereeing grant proposals.

The study and development of expert systems, which is an area in Artificial Intelligence, was first introduced in the late 60s (Russell and Norvig, 2003). An expert system is designed to be a 'specialist', focusing on solving problems in a specific domain. Expert systems have been implemented to solve a wide range of problems such as planning, diagnosis, monitoring, design and many more (Luger and Stubblefield, 1998). Among the domains that use expert system to solve problems are medicine, engineering, mathematics, business, computer science and education (Jackson, 1998).

A typical expert system consists of two main components, that is, an inference engine, and a knowledge base. Figure 1 shows the basic concept of an expert system based on the model in Giarratano and Riley (1998):

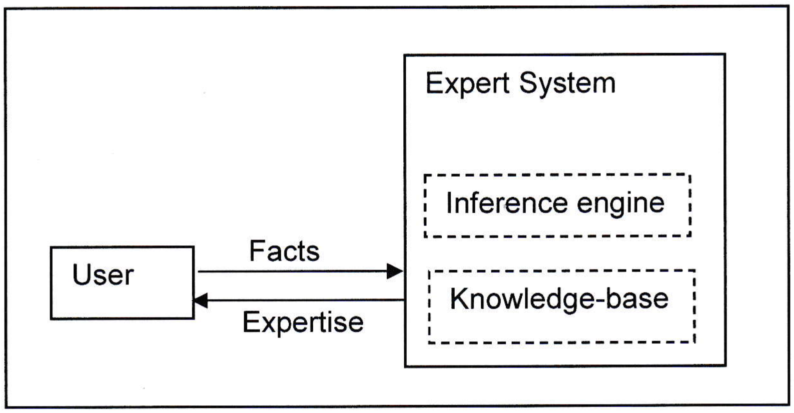

Figure 1: Basic Concept of an Expert System

From Figure 1, we can see that, users will supplies facts to the system and the facts will be used by the expert system, together with knowledge in the knowledge base to enable the system to provide expertise to the users. The expertise of the system refers to conclusion derived by the inference engine of the system, and this process is called inference. The knowledge base in the expert system is the expertise from human experts that has been encoded into the system. The process of transferring human's expertise to the system is where the developer has to extract the knowledge from experts and represent it in the system.

The mechanism provided by expert systems is suitable for developing GraPE. This is because, the component constitutes an expert system can be related to the reviewing process. Referee, as the user, will provide facts about the grant proposal they reviewed and GraPE will assist them by providing recommendation throughout the process, based on the conclusion drawn from the inference engine. The process of transferring expert knowledge to the system will be discussed in the next section.

3.0 Knowledge Acquisition Stages

An expert system's problem solving strategy relies on its knowledge (Luger and Stubblefield, 1998). The knowledge has to be well defined, modelled, and represented in order to allow successful inference processes. The process of knowledge acquisition can be divided into four stages, adapting the model of Giarranto and Riley (1998). These stages represent a sequential plan of knowledge acquisition, and at each stage certain tasks will be performed, these tasks being as follows:

1) Knowledge Identification: Identify what knowledge is relevant to the system, and its availability.

2) Knowledge Sources: Identify the sources of the relevant knowledge. All the sources will then be sorted according to their importance and availability.

3) Knowledge Elicitation: Specify and elicit how the knowledge will be acquired from its sources. The methods involved include structured interview, unstructured interview, and reading documents.

4) Knowledge Modelling & Verification: Classify and organize knowledge gathered from (iii) and model the knowledge accordingly to the system's function. Throughout the process, the correctness and completeness of the knowledge will be verified.

The detailed activities for each task for this project are described in following sections.

3.1 Knowledge Identification

At this stage, knowledge about what should be in the form has to be identified. In addition to this, the knowledge is such as to allow the system to rank all the sections in the form according to the level of importance of the section in the reviewing process. The form will adapt the ERA's electronic form framework. In each section, users will be asked a main question. Sub-questions will be given to the user if they want GraPE to help them in answering the main question. Based on the answers given for the sub-questions, the system will summarize and give a recommended answer for the main question to the user. This process can be viewed as a dynamic tree, with the main question being a parent node, and its sub-questions being its child nodes.

Hence, the knowledge identified here is a method or formula to enable the system to come up with a recommendation for users. Knowledge of a similar nature is needed for the later section in the system where a recommendation will be given to users on the final outcome of the review process. To summarize, the knowledge identified for the system is to be embedded in an electronic form, where a method or formula will be applied to user's answers to infer the quality of the paper against a number of criteria.

3.2 Knowledge Sources

In order to gather the required knowledge identified in Section 3.1, a list of knowledge sources has been compiled. The list includes existing systems, human experts and documents related to the topic of reviewing a grant proposal. The list ranked based on its importance to the system and its availability. Below are the knowledge sources for this project:

1) Expert from the domain: For this project, six academicians from the School of Informatics, University of Edinburgh, were selected as a domain expert. All of them are Engineering and Physical Sciences Research Council (EPSRC) peer review members. The academicians were interviewed to acquire the knowledge about the funding guidelines and proposal assessment in EPSRC

2) ERA: ERA is an expert system for referees of Informatics research papers. As stated in a previous section, the system developed in this project adapts ERA, and extends its functionality to the task of reviewing grant proposals instead of research papers. Some sections in ERA were adapted for GraPE, and so the knowledge embedded in ERA was to be extracted for GraPE's use.

3) Referee forms: There are various funding agencies in the United Kingdom that give out funding for scientific research proposals. Some of these funding institutions have referee forms available online. Two forms were found to be relevant as knowledge sources, namely, the referee form from 'The Engineering and Physical Sciences Research Council' (EPSRC) and the form from 'The Particle Physics and Astronomy Research Council' (PPARC). EPSRC is the primary funding body for Informatics grant proposal, and even though PPARC is not particularly for Informatics grant proposal, the form is referred for other aspects of the evaluation process.

4) Documents related to the domain: There are various books (Hamper and Baugh, 1995; Burke and Prater, 2000; Soraya and Scheinberg, 2000; Pfeiffer and William, 2000; Locke et al., 2000), papers (Connor and Mauranen, 1999; McCarthy, 2004; Jones and Bundy, 2004) and articles available for aiding the proposer in writing a good grant proposal, and obtaining research funding. Funding agencies such as EPSRC also publish guidelines to advise proposers in this matter. All these documents were collected and relevant knowledge extracted for GraPE.

3.3 Knowledge Elicitation

Based on previous section, there are two major types of knowledge sources that are available for this project, that are, human experts and related documents. Therefore, there will be two different acquisition strategies required in order to elicit the required knowledge from its sources. For the related documents, all the referee forms collected were analysed and compared, and sections that were common in most of the forms were identified. The questions featured in the forms were also analysed to understand the requirements for a grant proposal to be funded by the funding agencies.

Apart from the forms, knowledge that is related to the domain from articles and papers were also elicited. Most of the knowledge gathered from this source and the forms, were used in the interview sessions with domain experts. For human experts, an interview was conducted to obtain their knowledge about the reviewing process. The researchers used both structured and unstructured techniques, which are, card sorting and interviewing respectively. The following are the details for each method that was used:

1) Card Sorting: Each card will represent a criterion/section that should be featured in the form. Based on the knowledge gathered earlier, and ERA, several common features were listed. From ERA, features that are taken are 'Impact', and 'Presentation'. The rest of the sections are taken from the referee forms, and the knowledge gathered from related articles. The criteria and its description are illustrates in Table1 below:

Table 1: Criteria for Card Sorting

Card Index	Criterion	Description
A	Proposal's type	The type of proposal whether it is a blue sky research, or incremental research.
B	Novelty of the proposal	The originality of the problem proposed
C	Methodology or techniques used	The feasibility of the proposed methodology
D	Impact on community	How significance the result of a solution to the problem proposed will be.
E	Collaboration	The strength of partnership if any collaborators identified
F	Proposer's background	The proposer's potential in solving the problem
G	Project Management	The plan in order to achieve the solution of problem proposed
H	Resource Management	Resources requested for the proposal
I	Dissemination Strategies	Arrangements for dissemination
J	Presentation	The presentation of the proposal

All the experts had to sort the cards in ascending order from the most important criteria to the least important based on their judgment. The experts were also asked regarding any irrelevant criteria listed, or any additional criteria that should be added. Each criterion will represent a module/section in the system.

2) Unstructured interview: To capture details for each criterion mentioned above, further questions that relate to each criterion were asked. This is for constructing sub-questions in each section/module in the system. The complete set of questions for this acquisition process can be found in Appendix A.

3.4 Knowledge Modelling and Verification

The modelling process was to proceed step by step, in order to create the electronic referee form. The first step is to know what sections or aspects should be in the form, followed by the construction of relevant questions and sub questions, and the last step in the modelling process is to assign weighting values for each criterion, and come up with a formula to enable the system to make recommendations.

Step 1: Selecting the sections

From the knowledge elicitation activity, the knowledge gathered from the 'Card Sorting' activity with experts and the knowledge extracted from referee forms, along with the knowledge already embedded in ERA, were used in modelling the knowledge for this step. Table 2 shows the order of the sections (with '1' being the most importance) based on the experts' opinions from the card sorting activity.

Table 2: Order of importance of sections based on expert's opinion

	A	B	C	D	E	F	G	H	I	J
Expert 1	2	1	2	3	5	4	7	7	6	7
Expert 2	IRS*	1	3	1	4	2	5	6	7	1
Expert 3	1	2	4	3	6	5	8	9	7	10

* IRS – Irrelevant Section

Legend:

A: Proposal's type
B: Novelty of the proposal
C: Method/Technique Used
D: Impact on Community
E: Collaboration
F: Proposer's Background
G: Project Management
H: Resource Management
I: Dissemination Strategy
J: Presentation

From the table, it shows, some experts gave some of the sections the same level of importance, and one of the experts omitted the 'Proposal's Type' section, saying that the section is irrelevant. There are some obvious contradictions from one expert to another, but overall we can see that the level of importance for almost all the sections is judged to be similar. For example, 'Novelty of the Proposal' is ranked twice as the most important, and once as the second most important. One of the experts has suggested another section, that is, the idea of the proposal itself. This element has been included under the 'Proposal's Type' section. Based on these results, the researchers have ranked the criteria based on its importance as shown in Table 3:

Table 3: The order of importance of sections based on 'Card Sorting' activity

Order	Criteria
1	Novelty of the proposal
2	Proposal's type
3	Impact on Community
4	Method/technique Used
5	Proposer's background
6	Collaboration
7	Presentation
8	Project Management
9	Dissemination Strategy
10	Resource Management

For the referee form, each of the referee forms collected has a different approach to the reviewing process, but the objective underlying each section in the form is still the same. Table 4 below shows all the sections in the EPSRC form in order:

Table 4: Content of the EPSRC form

1. Research quality
2. Methodology
3. Adventure in Research
4. Impact
5. Collaboration
6. Dissemination
7. Resource and Management
8. Conclusion
9. Overall quality
10. Referee's area of expertise

From Table 4, we can see that in section (1) and (3), the referee has to comment about the quality and adventure in the research proposed. EPSRC notes in this section are asking referees to evaluate the originality and research risk of the proposal, and these aspects have already covered in the card index. The sections numbered 2, 4, 5, and 6 are also has listed in the cards for the 'Card Sorting' activity. Other sections (number 7 to 10) are actually to be found in ERA, and can be considered as administrative sections.

Based on the knowledge extracted above, sections that should be in the system can be finalized. The order of sections that has been ranked before (Table 3) has to be modified to suit the knowledge gathered from other sources. The 'Overview' section replaces the initial 'Proposal's Type's section. Table 5 below shows all the sections in the order of importance, and the source of the section are taken. The 'Proposer's Background' section was added based on the Card Index criterion.

Table 5: Content and order of electronic referee form, and its source

ORDER	SECTION	ERA	REFEREE FORM
1	Overview	✓	
2	Relevance	✓	
3	Novelty of the proposal	✓	
4	Method/Technique	✓	✓
5	Impact	✓	✓
6	Collaboration		✓
7	Proposer's background		
8	Project Management		✓
9	Resource Management		✓
10	Dissemination Strategy		✓
11	Presentation	✓	
12	Overall	✓	✓
13	Further Comments & Correction	✓	✓

The order of presentation of the electronic form will be as the same as the order of importance. This is based on expert's opinion and order of presentation of sections in ERA.

Step 2: Constructing the questionnaires

Questions in the electronic form of GraPE are in a hierarchical structure with the 'Overall' section as its root. The 'Overall' section have only one question, and the question represent the final outcome of the reviewing process, that is, whether the proposal should be funded or not. There are four possible choices for the final outcome for the user to choose. These choices are selected from both of the referee forms collected for the knowledge acquisition process. The next level in the structure comprises the main questions of each of the sections in the system. The main question asks the user to rate the quality of that particular section, based on his/her judgment. This question also will have four possible answers from which the user can choose. The construction of these questions is based on the referee form and the questions in ERA. The main question is quite similar for each section. For example, for the 'Novelty' section the question is 'Please grade the novelty of the idea proposed in the proposal', and the four possible answers are presented to the user, while for the 'Methodology/Technique Used' section a similar question is posed, 'Please rate the methodology/technique proposed'.

At the bottom level of this hierarchical structure will be the sub-questions for each of the main questions. All answers to these sub questions are to be used in the inference processes, for the system to come up with a recommendation for the user of an answer to the main question. To provide enough data to allow the inference process to make accurate recommendations, the sub-questions should be detailed and cover all the aspects of a particular section. The main knowledge used for this part is knowledge from the experts, and the related documents giving guidelines for writing a grant proposal. Some of the answers to sub-questions might lead to further sub-questions.

Step 3: Formulae used in the inference process

There are two types of inference process in the system. The first one is the inference for the 'Overall' section, where answers from all the main questions will be evaluated and an overall rating recommended. The other one is the inference for the main question of each section, where answers of sub-questions are used to recommend a score for that section. For the first type of inference, a formula will need to determine an accurate recommendation based on answers given earlier. To start with, all possible answers to a main question will be given a score, from 1 to 4, with 4 being the 'best'. Altogether there were 10 sections in the system, and each of the sections has a different level of importance in the reviewing process. Based on knowledge gathered from experts and the guidelines provided for proposers, the researchers have assigned a percentage to each section, where the percentage reflects the importance of that section to the whole process, with a higher percentage indicating a more important section. These values are assigned based on the ranking that has been determined in step 1 ('selecting the sections'). Higher ranking will indicate higher percentages. Some of the sections might have same percentage, and this is based on the ranking suggested by the experts. The values of these percentages are as shown in Table 6a below:

Table 6a: Percentage of important for each section

SECTION	%
Relevance	10
Novelty	15
Method	15
Impact	15
Collaboration	10
Proposer's background	10
Project Management	5
Resource Management	5
Dissemination Strategy	5
Presentation	10
TOTAL	100

Table 6b: Percentage of important for each section (without collaboration)

SECTION	%
Relevance	10
Novelty	15
Method	15
Impact	15
Proposer's background	10
Project Management	10
Resource Management	10
Dissemination Strategy	5
Presentation	10
TOTAL	100

There are some proposals that do not identify any collaborators because they do not require collaboration. In that case, the percentage has to be modified, and the 'Collaboration' section is omitted from consideration. Table 6b shows the percentage without the 'Collaboration' section.

The score for each section will then be multiplied by this percentage as a fraction of the whole, and totalled with the scores from all the other sections. This provides a total score with a value from 1 to 4, with 4 being the best. The researchers have come up with a rule to infer the final outcome of the score. The rule is operate like grading system, with the best score is 4, which represent 100% in percentage value. The rule is, if the sum is greater than 3.2, which is 80% of the total score (4) the proposal is recommend to be funded with high priority. If the sum is between 2.1 and 3.2;(50% to 79% from the total score) the proposal is recommended to be funded, but with minor correction, if it is between 1.2 and 2.0 (30% to 49%); the recommendation from the system is 'Fundable (with major correction)', and finally anything lower than that (less than 30%) is recommended to be unacceptable (reject).

The second type of inference is simpler than the one explained above. As said previously, answers to sub-questions are used to make this inference. Each answer is assigned a numerical value; lower value indicates higher score. Even though this is not consistent with the first inference (where higher value is considered the best), it will not confuse the users as all the values are in the program code only. The values provided in the interfaces are uniform and consistent. All these answer's values are assigned based on those used in ERA or on the experts' knowledge. For the sections adapted from ERA, the values will be the same, and for the added sections, knowledge gathered from experts is used to assign values. All the values in that section then will be totalled, and a simple rule will be applied to determine the most appropriate recommendation for users to answer the main question. Below is the rule used throughout the system for this type inference.

```
(if ( score < 3)
then (print GraPE would recommend a score of 1 (Outstanding)")
        else (if (score  < 10)
        then (printGraPE would recommend a score of 2 (Competent))
        else (if (< ?score 14)
        then (printGraPE would recommend a score of 3 (Adequate))
        else (printGraPE would recommend a score of 4 (Weak candidate) ")
                        )
                )
        )
```

4.0 Conclusion

The main objective of this project is to build an expert system that can provide help and guidance for inexperienced referees in reviewing grant proposals. Expert system technology was chosen for this project because it provides a well-understood approach for delivering expert knowledge. GraPE adapted some functions and features of ERA, and added some new functions to tailor the process of reviewing grant proposals. This paper described the knowledge acquisition (KA) process in GraPE. In the KA activities, knowledge was gathered from several sources, with the main source being experts in the domain, that is, referees of EPSRC grant proposals. Interviews were conducted in order to elicit knowledge from the experts. Other sources for KA are referee forms from various funding agencies, ERA, and related articles that provide advice for proposers about developing grant proposals. The knowledge gathered from this KA has been used to design and populate the GraPE knowledge base and its inference process. For a more accurate inference process, more knowledge is needed (e.g. collected by conducting more KA sessions with experienced referees) but due to time constraints and the unavailability of experts the system has been based on this knowledge only.

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APPENDIX A: Questionnaires for Interview Session

FUNDING AREA
1. What are usually the areas of Informatics' grant proposal? **to know the funding agencies area*
PROPOSAL TYPE
2. What types of proposals do you usually reviewed? **to classify the proposal*
FUNDING TYPE
3. In general, how many types of funding that are available for Informatics grant proposals? **to know type of funding*
RELEVANCE
4. How do you classify the funding type for a proposal? ** to know whether the proposal is suitable for that particular funding agency or not (relevance)*
NOVELTY/UNIQUENESS
5. Let say the proposal is proposing an extension for an existing technique. What is the best way for the proposal to present the uniqueness of the research? 6. What if it is a blue-sky proposal? 7. In general, what are you looking for novelty in a proposal? **to identify what referees looking for novelty of a proposal*
METHODOLOGY/TECHNIQUE
8. What sort of explanation should be in methodology/technique section, because it shouldn't be too technical yet the proposer has to deliver the idea clearly?
SIGNIFICANCE/IMPACT
9. How do you measure the impact of a proposal?
DISSEMINATION
10. How you evaluate the dissemination plan?
COLLABORATION
11. Is collaboration necessary? 12. Is it an advantage for a proposal if it identified any collaboration? 13. Is there a different expectation for proposals that have collaboration?
RESOURCE MANAGEMENT
14. How details the budget should be? 15. What aspect should be mention in justifying the resource?
PROJECT MANAGEMENT
16. What should be justified in Project Management section?
PROPOSER'S BACKGROUND
17. How you measure the suitability of the proposer?
PRESENTATION

18. Please rate the criteria you look in a proposal's presentation, with [1] is the 'Most important criteria', and [3] is 'Least important criteria ' *to weighting the criteria in Presentation section			
ORGANISATION			
The material is in the right order	1	2	3
The proposal is free from any unnecessary material	1	2	3
The proposal is self contained	1	2	3
The terminology is defined before it is used	1	2	3
ENGLISH			
The proposal is free from grammatical errors	1	2	3
The proposal is understandable	1	2	3
READABILITY			
The sentence and paragraph in the right length	1	2	3
BIBLIOGRAPHY			
The bibliography is relevant and exhaustive	1	2	3
OTHER CRITERIA			