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Georg Peters

Department of Computer Science and Mathematics, Munich University of Applied Sciences, georg.peters@cs.hm.edu

Simon Poon

School of Information Technologies, Faculty of Engineering and IT, University of Sydney, spoon@it.usyd.edu.au

M. Gordon Hunter

Faculty of Management, University of Lethbridge, ghunter@uleth.ca

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Georg Peters
Munich University of Applied Sciences
Department of Computer Science and Mathematics
Lothstrasse 34, 80637 Munich, Germany
Email: georg.peters@cs.hm.edu

Simon Poon
School of Information Technologies
Faculty of Engineering and IT
University of Sydney
NSW 2006, Australia
Email: spoon@it.usyd.edu.au

M. Gordon Hunter
University of Lethbridge
Faculty of Management
Lethbridge, Alberta T1K 3M4, Canada
Email: ghunter@uleth.ca

Abstract

Since its introduction half a century ago IT has become one of the most important infrastructure components of virtually any organisation. An important key area of qualitative research in information systems is interviewing decision makers. These interviews aim to disclose hidden structures within IT projects and usage to increase their efficiency and effectiveness. In this context, the definition and analysis of critical success factors for information technology projects are well established areas for qualitative research in information systems. The analysis of critical success factors is of special importance since the IT projects still suffer from high failures rates. Therefore it is an important research goal within information systems to better understand IT projects to improve their success rates. The interviews of critical success factors provide a good data basis to disclose hidden structures in this domain. Besides only quantitatively interpreting such interviews the analysis can be enriched by some qualitative methods to support quantitative analysis and may disclose formerly hidden structures within the data. Therefore the objective of the paper is to enrich the analysis of IT projects and evaluate rough sets based quantitative analysis techniques for symbolic data which are characteristic in the domain of critical success factors analysis.

Keywords

IT Project Management, Critical Success Factors, Qualitative Analysis, Rough Set Theory.

INTRODUCTION

Since its introduction half a century ago information technology has become one of the most important infrastructure components of virtually any organisation. Independent of the size of an organisation and its industry information technology is used. The usage of IT ranges from a credit card terminal in a small shop to a companywide enterprise resource planning systems as a backbone of large multinational firms.

Although it's long history and fundamental importance for organisations information technology is also regarded as very challenging. Especially information technology projects are considered to be risky with significant failure rates. Besides the eminent complexity covering technological aspects of hardware and software a further core challenge of information technology is its close intertwinement with organisational structures and people.

Analysing this intertwinement of information technology, organisations and people is one of the central tasks of the discipline information systems. The discipline of information systems is not paramount in its coverage of technical aspects of IT, like hardware and software, or purely organisational aspects of organisations but is centred on the interface of information technology on the one hand and organisations and people on the other hand.

For example, information systems are defined by UKAIS as (UKAIS 1997):

> "Definition. Information systems are the means by which organisations and people, utilising information technologies, gather, process, store, use and disseminate information.
>
> Domain of Study. The domain of information systems requires a multi-disciplinary approach to studying the range of socio-technical phenomena which determine their development, use and effects in organisations and society."

Although recent developments in information technology, like the logging of transactions in ERP systems or on websites, have provided huge amounts of data which can be analysed quantitatively the high importance for qualitative research in information systems has never changed.

A key area of qualitative research in information systems is interviewing decision and policy makers, like CIOs and IT project managers. The goal of these interviews is to increase the efficiency and effectiveness of the usage of IT by disclosing hidden structures within information technology projects and IT usage. The definition and analysis of critical success factors for information technology projects are well established areas for qualitative research in information systems.

However, besides only quantitatively interpreting such interviews the analysis can be enriched by some qualitative methods to support the quantitative analysis. These methods may disclose formerly hidden structures within the interview data.

The objective of the paper is to evaluate rough sets based quantitative analysis techniques for symbolic data which are characteristic of qualitative interviews. For our analysis we focus on aspects of IT project management and propose a method to disclose projects at risk. In this introductory paper we deliberately avoid any advanced mathematical representation of rough sets to bridge the gap between quantitative and qualitative oriented researchers.

The remainder of this paper is organized as follows. In the following Section we give a short introduction to the concept of rough sets and the motivation for their usage for the analysis of interviews. In the next Section we discuss selected challenges of information systems with a special focus on critical success factor for IT projects. Then we present a possible rough set approach to analyse interviews on the critical success factors. The paper concludes with a summary.

ROUGH SETS

Fundamentals of Rough Sets

Basically rough set theory is about the discernability and indiscernability of objects. It was introduced by Pawlak in the beginning of the eighties of the last century (Pawlak 1981, 1982, 1992) and has gained increasing importance especially in the fields of soft computing and granular computing.

The fundamental idea of rough set theory is to define a set by two approximations. The core of the sets is called lower approximation of the set and contains only objects that are unambiguous members of this set. They are discernible from the objects that do not belong to this core region of the set. However, if the membership of an object to a set is unclear – it is possibly a member of set 01 xor[1] set 02 xor any other set – it will be assigned to the upper approximations of all sets it may be member of. Normally reasons for these discernible objects are missing or incomplete information.

Note, in the mathematical definition of rough sets the lower approximation is defined as a subset of its corresponding upper approximation. So, the area of an upper approximation that is not covered by a lower approximation is often referred as boundary area.

Based on the discussion above, more formally, three properties of rough sets can be identified:

1. An object can be a member of one lower approximation at most.
2. An object that is a member of the lower approximation of a set is also member of the upper approximation of the same set.
3. An object that does not belong to any lower approximation is member of at least two upper approximations.

Property 1 ensures that an object in a lower approximation of a set has an unambiguous membership to this set since it cannot by a member of any other set. Property 2 defines the lower approximation as a subset of the

[1] xor = exlusive or.

corresponding upper approximation. Property 3 describes the unclear memberships of objects that are no members of any lower approximation.

A small graphical example of two rough sets, their lower and upper approximations and the boundary area is depicted in Figure 1. The object in the boundary area is located between the core regions of the two sets. Therefore, its membership in one of the two sets cannot be defined without further information.

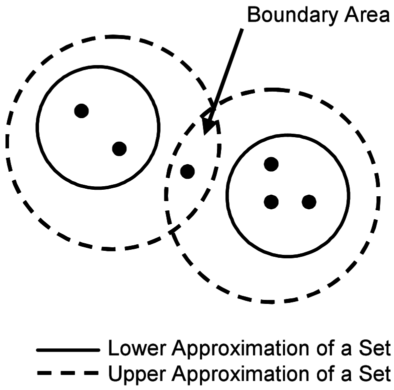

Figure 1

Lower and Upper Approximations

Note, in the context of our introductory paper we limit our presentation of the fundamentals of rough sets to the three properties as discussed above and also deliberately avoid any advanced mathematical presentation of rough sets. However, rough set theory is much richer and covers more advanced formal aspects such as certainty versus coverage, global and local coverage, reducts, indiscernability relations, minimal complex and besides others. Many of these methods and concepts have the potential to further enrich the analysis of qualitative interviews. Therefore, the reader is referred to Grzymala-Busse (2004) for the fundamentals of rough sets theory. More detailed introductions, especially on its mathematical foundations, can be found for example in Komorowski (1999) or Polkowski (2003).

Delimitations to Related Concepts

Many approaches to applying rough set theory have emerged. A brief description of some which are closely related to the use described here are as follows.

Set vs. Interval-Based Rough Set Theory. While original rough set theory is purely set-based, a new interval driven approach has emerged in the meantime (e.g. Yao et al. 1994). Applications of interval based rough set theory are in the field of cluster analysis (Lingras et al. 2004, Peters 2006) and others. However, in our paper we will only utilise the original set-based approach of rough set theory.

Rough Set vs. Fuzzy Set Theory. At first sight the relationship between rough and fuzzy sets may be not transparent since both theories deal with overlapping sets. However, there is a central difference in the concepts. In fuzzy set theory (Zadeh 1965; Zimmermann 2001) an object belongs to more than one set simultaneously indicated by membership degrees. In contrast to that, in rough set theory it is assumed that an object belongs to one and only one set. However, due to missing or contradictory information the actual memberships of the objects in the boundary areas remain unclear. Thus, both theories are complementary and not competing, so that hybrid approaches have been suggested in the literature already (see e.g. Dubois and Prade (1990) for a detailed discussion on the relationship of fuzzy and rough sets).

An Example for Rough Sets

Before we discuss the potential of rough sets for the quantitative analysis of qualitative interviews in information systems let us consider the popular example of medical diagnoses as given by Grzymala-Busse (2004).

Diagnoses of a GP. Eight patients showing different symptoms were check by a GP (General Practitioner). Four of the patients suffer from flu while the remaining four patients are well. The results are summarized in Table 1. In rough set terminology the two different diagnoses (the decisions of the GP) are defined as the following sets: {Flu=yes} and {Flu=no}.

When the records of the patients are analysed we determine that the records of the patients #1, #2, #3 and #7 are different from each other. The can be clearly distinguished from each other.

In contrast to that the records of the remaining patients #4, #5, #6 and #8 show contradictions. Patients #4 and #5 have the same symptoms {high, yes, yes}, however patient #4 suffers from flu while #5 is well. The same applies to patients #6 and #8 with the symptoms {normal, yes, no} but different diagnoses. A possible explanation is that important information is missing so that the GP needs to take a second look before a final diagnosis can be made.

A Rough Set View on the GP's Diagnoses. In rough set terminology the patients #1 and #2 belong to the lower approximation of the set {Flu=yes} since there are no conflicts with the diagnoses of the remaining patients. The same applies to patients #3 and #7. They belong to the lower approximation of the set {flu=no}. This means that new patients showing the same symptoms as patients #1 and #2 can be considered as ill and new patients with the same symptoms of patients #3 and #7 are without flu.

Table 1

GP's Diagnoses of Eight Patients

#	Symptoms			Decision
	Temperature	Headache	Nausea	Flu
1.	high	Yes	no	Yes
2.	very high	Yes	yes	Yes
3.	high	No	no	No
4.	high	Yes	yes	Yes
5.	high	Yes	yes	No
6.	normal	Yes	no	No
7.	normal	No	yes	No
8.	normal	Yes	no	Yes

However, the diagnoses of the patients #4, #5, #6 and #8 do not lead to a straight forward result. The analysis of the given data shows that a diagnosis is not possible for patients showing the same symptoms as patients #4, #5, #6 and #8. They may have the flu or they may be well. So, they simultaneously belong to the upper approximations of both sets: {Flu=yes} and {Flu=no} indicating their unclear set membership.

SELECTED CHALLENGES IN INFORMATION SYSTEMS

Challenges

Due to the nature of information systems dealing in open systems at the interface between information technology on the one hand and organisations and people on the other hand the challenges of IS are very complex and demanding.

Without any demand for completeness the challenges include such diverse aspects as:

- Business alignment of IT
- User acceptance of IT
- IT project management.

In our paper we focus on IT project management, an area of information systems where heavily overdrawn budget and schedules as well as complete failures have been widely experienced and also intensively discussed in the literature (e.g. Avital, Vandenbosch (2000), Chen et al. (2009)). Even after several decades of experience and research in IT project management these ventures are of high risk.

Critical Success Factors

One widely accepted approach to reduce risks in IT project management is the definition and evaluation of critical success factors (e.g. Akkermans et al. (2002), Al-Mashari et al. (2003), Hsu et al.(2008), Nah et al. (2001), Plant et al. (2007), Kappelman (2006)).

The critical success factors provide guidelines on how to set up and run a successful IT projects. However, due to the complexity of IT projects much of the research on critical success factors is of a qualitative nature rather than based on quantitative research methods.

Let us consider the well accepted critical success factors as suggested by Somers and Nelson (2001) and depicted in Table 2. They determined the importance of the critical success factors by interviewing IT project managers.

Table 2

Critical Success Factors (Somers and Nelson 2001)

Top management support	Dedicated resources
Project team competence	Use of steering committee
Interdepartmental cooperation	User training on software
Clear goals and objectives	Education on new business processes
Project management	Business Process Reengineering
Interdepartmental communication	Minimal customization
Management of expectations	Architecture choices
Project champion	Change management
Vendor support	Partnership with vendor
Careful package selection	Use of vendors' tools
Data analysis and conversion	Use of consultants

For example, possible values of the first critical success factor "top management support" could be "high", "average" and "low". More formally we can define its domain as: Top_Management_Support = {high, average, low}. Since these are ordinal data any classic quantitative analysis is rather limited without adding too much unsupported assumptions and information, like distances, to them.

However, in the following Section we present a new way of analysing qualitative interview data and use these critical success factors to disclose IT project management patterns.

ROUGH SET BASED ANALYSIS OF INTERVIEW DATA

Preliminaries

The objective of the application of rough set theory is to develop a traffic light-like warning system for IT project management.

The status of an IT project may be defined as follows:

- Red: The project is at risk.
- Yellow: The project needs further investigations before a decision on its status can be made.
- Green: The project runs well.

For the classification of an IT project we utilize rough concepts and define a red and a green set. If an IT project can be assigned to a lower approximation of one of these sets it membership is clearly defined:

- *Red set*. IT projects assigned to the lower approximation of the red set are definitely at risk so they need management action to be taken immediately.

- *Green set*. Projects assigned to the lower approximation of the green set are considered to run well and therefore 'just' need the normal attention of the management.

However, the status of the remaining projects is ambiguous since they do not belong to any lower approximation. In rough set terminology they are simultaneously members of the upper approximations of the red as well as the green set.

To obtain such a traffic light-like warning system we have to apply a two steps approach (see Figure 1) which consists of the classifier design and the classifications (Figure 1):

- *Classifier Design*. In the first phase we define the rough decision table based on interviews with experienced IT project managers and data of completed IT projects.
- *Classification*. Based on the rough decision table current IT projects can be classified and categorized into the proposed traffic light system. This aggregated and easily assessable information can be used by, e.g. a steering committee to define the required actions to successfully manage the IT project.

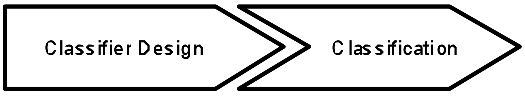

Figure 1

Two Step Approach of the Rough Analysis

The two steps, classifier design and classification, will be discussed in more detail in the following Sections.

Classifier Design -Creating the Rough Decision Table

As already discussed we propose to interview experienced project managers or evaluate completed IT projects according to predefined critical success factors to design the rough decision table. For each interview or evaluated project a record in the decision table will be created.

Due to the space limitations of the paper we only use the small sample rough decision table consisting of six (fictitious) interviews and a set of four critical success factors as depicted in Table 2.

Table 2

A Rough Sample Decision Table of Critical Success Factors

#	Critical Success Factors				Decision
	Top Mgt. Support	Project Team Competence	User Training on Software	Use of Consultants	Project Status
1	Average	high	extensive	No	Red
2	Low	weak	moderate	Yes	Red
3	High	high	moderate	Yes	Green
4	Average	weak	Low	No	Red
5	Average	high	extensive	No	Green
6	Average	high	extensive	Yes	Green

The records #2 and #4 are definite members of the red set while the records #3 and #6 undoubtedly belong to the green set. However, the records #1 and #5 have identical attribute values {average, high, extensive, no} but lead to contradicting decisions, red for #1 and green for the record #5. So, their membership in one of these sets is not clearly defined. In rough set terminology they are coevally assigned to the upper approximations of the red as well as the green set. Rough set theory also provides a concept to deal with missing attribute values (Grzymala-Busse 2008).

Classification -Deciding on the Project Status

Once developed the rough decision table can be used to classify on-going IT projects. In an on-going project the relevant attribute values have to be determined and compared to the attribute values of the rough decision table. In our example, the classification rules according to the traffic light system are shown in Fig. 2.

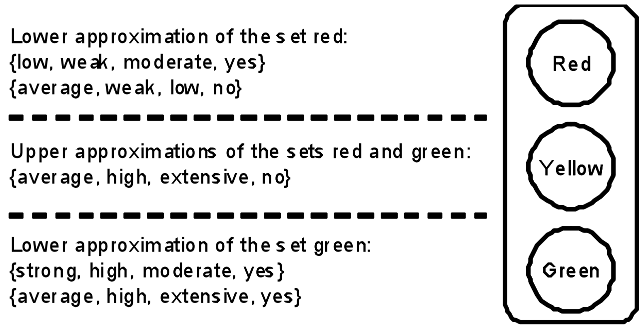

Figure 2

Traffic Light-Like Warning System for IT Projects

There are two limits respectively risks combined with the rough set analysis of the project status.

First, generally the rough decision table won't be complete. This means that it might not cover all possible combinations of attribute values. If the set of attribute values of a current IT project are new - not covered by the rough decision table, then the table has to be extended.

Second, the rough decision table has to be validated after each IT project. For example, according to the rough decision table an IT project runs well (classified as 'green') but eventually fails. Then a new record has to be inserted into the rough decision table with the project status 'red'. Consequently the rough decision table now consists of two new contradicting records. Therefore the table has to be updated and the traffic light-like system must indicate 'yellow' for this set of attribute values.

CONCLUSION

In this paper we have presented a novel approach to analysing qualitative interviews in information systems research with the objective to reduce complexity and design a simple well accepted traffic light-like warning system for IT project management.

We have applied rough set theory as an underlying formal method to bridge the gap between quantitative and qualitative oriented researchers. An advantage of using rough set theory is that it has a well developed mathematical foundation. Furthermore, the analysis technique proposed here can be supported by appropriate software tools. However, in our introductory paper we deliberately avoided any advanced mathematical representation of rough sets.

Presently we are conducting an extensive case study to evaluate and validate the proposed method in more detail. We are also investigating if and how further rough set concepts may be useful to the analysis of qualitative data in information systems research.

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