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Research Article
A Dynamic Stakeholder Classification and Prioritization Based on Hybrid Rough-fuzzy Method

Asmaa Elsaid, Rashed Salem and Hatem Abdul-Kader

Department of Information Systems, Faculty of Computers and Information, Menoufia University, Menoufia, Egypt

Abstract

Background: Stakeholder prioritization is one of the most significant areas of software engineering. Although several stakeholder classification models have been proposed in the literature, they have many limitations that have to be considered. Most of existing stakeholder's classification models assigns the same importance weight for stakeholders classified to the same class; this is not the case in real world. Moreover, the models used to prioritize stakeholders automatically are without any methodology to previously classify stakeholders. Also, most of existing stakeholder's classification models relies on manual classification. In order to overcome these limitations a novel automatic power-interest stakeholder classification and prioritization model based on rough-fuzzy hybridization method is presented. **Materials and Methods:** The novel automatic model proposed in this study is based on the classes presented by Mendelow's model with the computer intelligent rough set theory and fuzzy logic. The rough set theory is utilized to classify stakeholders into one of 4 classes "High power/high interest, high power/low interest, low power/high interest and low power/low interest". Then, fuzzy logic is used to get the degree of importance for each stakeholder in its predetermined class. **Results:** The rough-fuzzy hybridization method with Mendelow's model proved to be a convenient method to support the stakeholder classification and prioritization process. The output of the proposed automatic model is an accurate stakeholder prioritized list. Verification and validation processes are conducted to an updating faculty website case to ensure the correctness of the resulted stakeholder prioritized list. Also, the Weighted Score Method (WSM) is conducted to show how well the proposed model performs when comparing it with two existing models. **Conclusion:** A novel automatic model is proposed in this study based on Mendelow's model with the computer intelligent rough set theory and fuzzy logic to overcome the existing models limitations and open up a new, accurate and highly efficient way for the stakeholders classification and prioritization process.

Key words: Stakeholder prioritization, rough sets theory, fuzzy logic, Mendelow's power-interest model, responsibility assignment matrix

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Corresponding Author: Asmaa Elsaid, Faculty of Computers and Information, Menoufia University, Shebin Elkom, Egypt

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Stakeholder prioritization is an effective and crucial task for the successful completion of any project. Experience has shown that without proper stakeholder prioritization, the end product will fail. In software projects, stakeholders have a valuable role and precise knowledge in defining the system needs, so they have to participate in electing and analyzing of software requirements. So, their identification and prioritization must be carried out before requirements election. The stakeholder is an individual, a group or an organization who may affect, be affected by or perceive itself to be affected by a decision, activity or outcome of a project[1]. Any project manager realizes that different stakeholders have different power/interest for projects. Therefore, more concentration is required for stakeholder classification and prioritization[2].

In projects, so many stakeholders are identified and needed to be differentiated in order to determine the varying influence they exert on the project, by classification and prioritization process. The classification and prioritization process helps to achieve trade-off among the competing personal preferences. The constraint on projects prevents project management from involving all possible stakeholders equally. Therefore, the classification and prioritization process has to be established. In addition, the prepared documentation of classified and prioritized stakeholder must be monitored and reviewed during the project because the interest and the power for stakeholders may change over time. So, stakeholder classification and prioritization step is usually repeated many times during the project which consumes a great time and effort.

Stakeholder prioritization using intelligent approaches have been undertaken in the requirement engineering process previously[3]. Lafuente identified stakeholder using fuzzy logic algorithm which is used to take into account uncertainty and vagueness of stakeholder identification[4]. Also, Poplawska *et al.*[5] proposed a framework that provides an accurate stakeholder profiling and salience measurement approach based on the hybrid use of fuzzy logic and the well-known three interesting circle taxonomy of power, urgency and legitimacy. The Poplawska framework limitation is that it didn't provide any methodology to previously classify stakeholders before the prioritization process (stakeholder classification to dormant, discretionary, demanding, dominant, dangerous, dependent, definitive and non-stakeholder classes is done manually)[5].

The main point of this study is presenting a novel automatic model for stakeholder classification and prioritization process using rough-fuzzy hybridization method. The proposed model relies on the well-known two dimensional grid Mendelow power/interest model. The hybridization of rough set theory and fuzzy logic approach help in opening up a new, accurate and highly efficient way for classifying and prioritizing stakeholders. The rough set theory as the first stage, classifies stakeholders into one of four classes: (1) High power/high interest, (2) High power/low interest, (3) Low power/high interest and (4) Low power/low interest. The fuzzy logic approach as the second stage is applied to overcome the rough set discrete data limitation and get the accurate stakeholder prioritized list. The accurate stakeholder prioritization list is determined not only by depending on classifying stakeholders to one of the four mentioned classes but also by receiving an importance degree of member ship to these classes. An accurate and efficient stakeholders classified and prioritized list is produced to assist developing the power-interest stakeholder classification and prioritization model.

MATERIALS AND METHODS

Stakeholder classification models: In previous study, there are many models for stakeholder classifications. In this study, some of the most commonly used models are discussed. Savage *et al.*[6] proposed a stakeholders classification method that depends on the potentiality of both, threats and cooperation for the classification. By assessing each stakeholders potential to threaten or to corporate with the organization, managers can identify supportive, mixed blessing, non-supportive and marginal stakeholders[6].

Clarkson[7] presented a stakeholder classification method in which each stakeholder is classified as primary or secondary. The primary stakeholders are essential for the survival of the organization through their engagement. The secondary are those influenced or affected by an organization. However, secondary stakeholders, who do not engage in transactions with the organization are not essential for organizations survival[7].

Mitchell *et al.*[8] relied on the power and legitimacy of each stakeholder's relationship with the organization to classify stakeholders. In that model the urgency of the stakeholder's claims on the organization is also used in the classification process. This model is called the salience model, which defines the salience as the degree to which managers give priority to the competing stakeholder claims. The outcomes of this classification process might help in answering the fundamental question of which groups of stakeholders deserve or require manager's attention and which groups are not[8].

Turner *et al.*[9] have developed a process to manage stakeholders. This process consists of the identifying stakeholders and assessing their awareness, their support and their influence. This process leads to strategies for the communication and strategies for assessing stakeholder satisfaction. The stakeholder knowledge base developed from this process provides a knowledge of who is aware or ignorant and whether the attitude of stakeholder is supportive or opposing[9].

Philips classified stakeholders as normative or derivative. Normative stakeholders are those who directly engage in organizations transactions and derivative stakeholders are those who affect the organization or are affected by its actions. The organization should be concerned with both groups although its obligations are due only to the normative group[10]. Fletcher *et al.*[11] proposed a mapping process for stakeholder expectations. This process is based on value hierarchies and Key Performance Areas (KPA)[11]. Winch categorized stakeholders as internal or external. Internal stakeholders are those directly involved in decision-making processes and external stakeholders are those that can affect or can be affected by the organizations activities[12].

The most widely or perhaps the most famous and simple used model throughout the software engineering is the two-dimensional grid, Mendelow power/interest model[13]. This model classifies stakeholders into four groups: (1) High power/high interest, (2) High power/low interest, (3) Low power/high interest and (4) Low power/low interest. Due to its easiness and generalization (can be applied to classify stakeholders in any organization), this model is used in the proposed model presented in this study and is discussed briefly in the next study. Many manual, online templates, interactive screen applications and online software are created to support Mendelow's power-interest model.

All previously mentioned models depend on only manual classification of stakeholders which consumes great time and effort. In addition, the previously mentioned models didn't provide any methodology to prioritize stakeholders; giving all stakeholders classified to the same class the same weights. Moreover, the model used to prioritize stakeholders automatically by Poplawska *et al.*[5] who didn't provide any methodology to previously classify stakeholders before the prioritization process. In this study, an automatic classification of stakeholders is presented based on rough set theory and Mendelow's power-interest model. Besides that, the proposed model utilizes the fuzzy logic approach to prioritize stakeholders automatically and efficiently.

Proposed automatic power-interest stakeholder classification and prioritization model: The technologies that are involved in the proposed automatic power-interest stakeholder classification and prioritization model are presented in this study. The involved technologies include mechanisms for automating stakeholder classification and prioritization. The involved technologies are the rough set theory, Mendelow's power-interest model and fuzzy logic. Figure 1 shows that the input of the proposed automatic model is the stakeholder data set. The processing step relies on classifying and prioritizing stakeholders based on two stages:

Stage 1: Stakeholder classification stage based on rough set theory, classes presented by Mendelow's power-interest model

Stage 2: Stakeholder prioritization stage based on the classified stakeholder set resulted from the previous stage and fuzzy logic

Finally, the output of the proposed automatic model is a stakeholders list. The list of stakeholders contains the stakeholder's classification and the actions that resulted from the rough set theory and Mendelow's power-interest model. Also, the list contains the ordered stakeholders prioritized based on the fuzzy logic system.

Stakeholder classification stage: Mendelow's power-interest model with the computer intelligent rough set theory is applied to classify stakeholders automatically (stage 1) in the proposed model presented in this study.

Mendelow's power-interest model: Mendelow's model is a popular model for performing manual stakeholder analysis and classification. To analyze and classify stakeholders by Mendelows model, the following questions should be answered[13,14]:

- What is the power of each stakeholder?
- What is the level of interest for each stakeholder?

Mendelow[13] proposed a matrix to help to analyze stakeholders. In this classification, stakeholders are grouped according to their power and their interest towards the project and its outcomes. Someone's position on the grid shows the actions that have to be taken with them as follows:

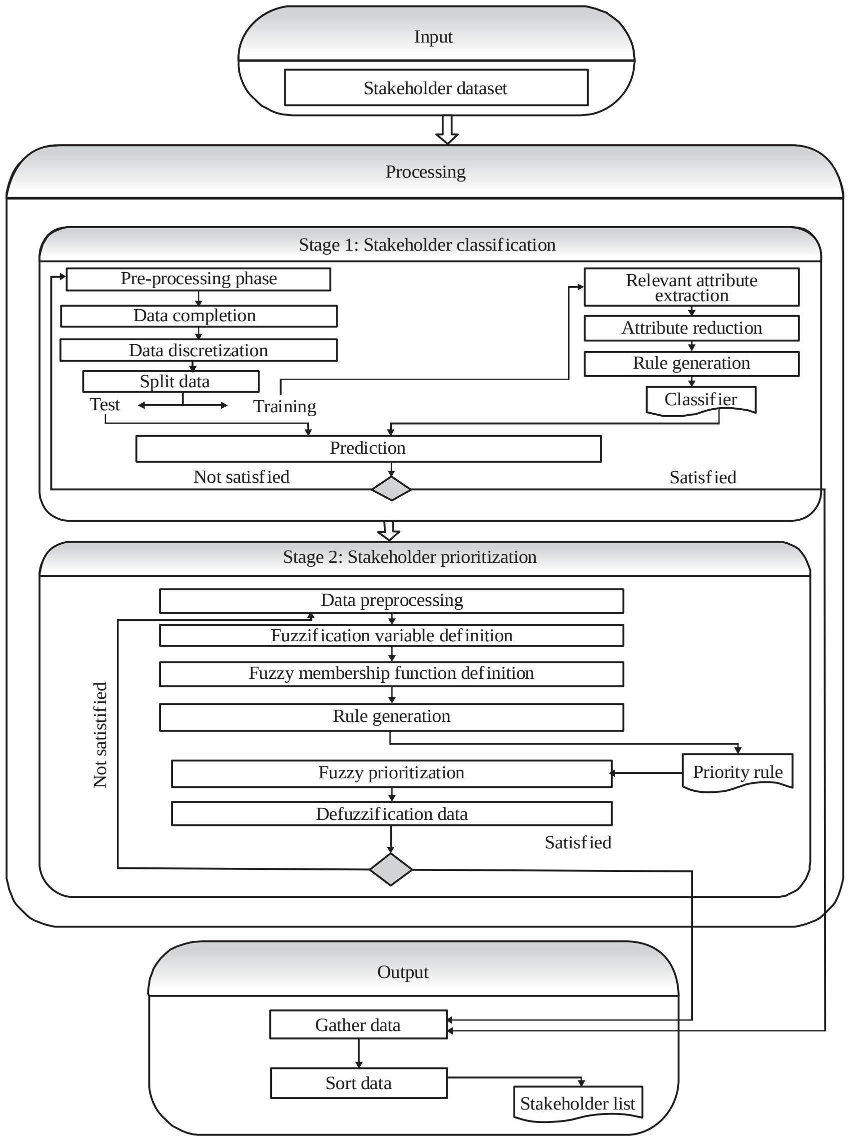

Fig. 1: Proposed automatic power-interest stakeholder classification and prioritization model

- **High power, interested people:** These are the people that must fully engage and make the greatest efforts to be satisfied
- **High power, less interested people:** Put enough work with these people to keep them satisfied but not so much to the degree that makes them bored with the study
- **Low power, interested people:** Keep these individuals adequately informed and talked to them to ensure that no major issues are arising. These individuals can often be very helpful with the detail of the project
- **Low power, less interested people:** Again, monitor these people but do not bore them with excessive communication

Each stakeholder will be classified as one of the following; high power/high interest, high power/low interest, low power/high interest or low power/low interest. These classifications are obtained by automating the Mendelow's power-interest model using rough set theory. These classifications are considered the first output decision of the rough set theory. The second output decision of the rough set theory is the actions that have to be taken with each classified stakeholder.

Rough set theory: Rough set theory is an intelligent mathematical tool proposed by Pawlak[15] to deal with uncertainty. Rough set theory is based on the concept of approximation spaces and models of sets and concepts. There is a brief explanation of rough set theory principles[15]. Rough set theory is used in the proposed automatic model to classify stakeholders according to the following phases[16,17].

Pre-processing phase: In this phase, the decision table required for rough set analysis is constructed. For the creation of this decision table, a number of data preparation tasks such as create and select conditional and decision attributes, data conversion, data completion checks and discretization of attributes are performed. Also, data splitting is performed by creating two randomly generated subsets, one subset for analysis containing some of the objects in the data set (Training set) and the other subset for validation containing the remainder of the objects in the data set (Test set).

Attribute reduction and rule generating phase: This phase is to generate the preliminary knowledge, such as the analysis of decision tables to extract and eliminate redundant attributes and identify the most important attributes from the dataset, derivation of rules from reducts, rule evaluation and prediction processes.

Classification and prediction phase: This phase utilizes the rules generated from the previous phase to predict a class for a new stakeholder. To transform a reduct into a rule, the condition feature values of the object class from which the reduct originated has to be bind to the corresponding features of the reduct. After that, to finish the rule, a decision part containing the resulting part of the rule is added. Objects which has never been seen before is classified by the generated rules from the used training set. These rules are the actual classifier. This classifier predicts the classes for new objects. When there is more than one matching rule, a voting mechanism to choose the decision value is used.

Stakeholder prioritization stage: Mendelow's power-interest model with the computer intelligent rough set theory is applied to classify stakeholders automatically (stage 1) in the proposed model presented in this study. Rough set theory is concerned with discrete data only, this means that each stakeholder is assigned to only one class. All stakeholders belonging to the same class are considered to have the same importance and are treated the same way (the same weight). This means that all stakeholder in the same class are considered identical. This standard definition doesn't necessarily represent the reality. In order to incorporate the uncertainty and difficulty of the classification of rough set theory, stakeholder prioritization process has to deal with another intelligent mathematical approach. This approach can complement the discrete data of the rough set theory. This approach is the fuzzy logic which is used in for prioritizing stakeholders. By using, fuzzy logic approach, stakeholders aren't only assigned to a unique class but also receive a profile of membership to four classes.

Fuzzy logic: Fuzzy logic, introduced by Zadeh, is another intelligent mathematical approach for managing uncertainty[18]. Fuzzy logic is based on "Degrees of truth" rather than the usual "True or false" (1 or 0) which is the base of the modern computer. A methodology for implementing fuzzy logic is the Fuzzy Inference System (FIS)[19]. The Fuzzy Inference System (FIS) specifies the linguistic priority of stakeholders that have been classified using Mendelow's power-interest model. Subsequently, priority values will be defuzzified to specify the degree of importance for each stakeholder. Fuzzy logic is used in the proposed automatic model to prioritize stakeholders according to the following steps.

Data pre-processing: In this step, data preprocessing is performed to estimate and normalize the rough set discrete information system table resulted from the previous stage. Estimating and specifying quantitative values (numeric values) for data in the rough set information system table allow preparing the fuzzy logic numeric table. In order to avoid inconsistencies during the fuzzification process, the numeric values of prioritization variables will be normalized to a determined range[20].

Defining variables to fuzzification: In this step, the prioritization input and output variables are determined. Domains (variable sets) for all input and outputs of the fuzzy system are defined. The values in these sets are fuzzified using appropriate membership function[20,21].

Define fuzzy membership function: There are several membership functions such as centroid trapezoid, triangular, bell shaped, etc. The most two popular membership functions are triangular and trapezoid due to their ease of use and calculation[20]. Representation of all fuzzy variables within fuzzy sets is defined properly.

Determine fuzzy-inference system and generate rule set: In this study, the Takagi Sugeno (TS) fuzzy model is employed[22]. In the TS fuzzy model, the rule consequents are usually taken to be either crisp numbers or linear functions of inputs. In this study, the rule consequents are linear functions. Compared with the other fuzzy systems, TS fuzzy inference system rule-based model suitable for the approximation of many systems and functions. A major distinction between the linguistic model developed by TS model and the other fuzzy systems is that the consequents TS model are (crisp) functions of the input variables while in the other fuzzy systems linguistic model has fuzzy sets in both antecedents (input variables) and consequents (output variables) of the rules. The knowledge base of any fuzzy system is based on certain if-then rules. To generate the rule set of this model, the TS fuzzy model is used according to the following form[23]:

$$\text{If } x \text{ is A and y is B then } z = f(x, y) \tag{1}$$

where, A and B are fuzzy sets but $z = f(x, y)$ is a crisp function in x and y. The antecedent could obviously be more complex with ANDs. The function in the consequent can be any function in the first order model that takes the following form:

$$f(x, y) = px+qy+r \tag{2}$$

where, p, q and r are constants. These types of rules have a fuzzy antecedent and crisp consequent. There are a variety of ways to combine the rules in FIS. Three particularly important operations are intersection, union and complement which correspond to AND, OR and NOT, respectively. Fuzzy union is to take the maximum, fuzzy intersection is to take the minimum and fuzzy complement is to take the complement of the fuzzy set[23].

Defuzzification: Once all fuzzified values for all fired rules have been determined, the defuzzification step has to be performed. The purpose of defuzzification is to obtain a single crisp value from the fuzzified operations. Two particular methods for the defuzzification of the TS model are available. These methods are the weighted average (wtaver) and the weighted sum (wtsum). In this study, the weighted average method is employed to defuzzify the determined fuzzified values. Once the defuzzification values have been obtained which represent the weight of each stakeholder in the predetermined class from the classification stage, all the defuzzification values (stakeholder weights) can be merged in a single document to be ordered and to prepare a prioritized stakeholder list.

RESULTS AND DISCUSSION

Empirical evaluation: Academic faculty staff stakeholders case study

Motivation: It is generally quite difficult to find real datasets with the information needed to conduct our study. For that reason a real world project, the faculty website system was conducted for the validation of the proposed model presented in this study. After a deep study and analysis of a lot of faculty staff and students complaints about the bad services presented from the faculty website system, it is found that the faculty website system needs to be updated as soon as possible to enhance services offered to students and faculty staff. The sample comprised of undergraduate students, graduate students and also different positioned faculty staff members. Trained interviewers administered questionnaires[24] as a tool for collecting information from students and faculty staff.

Data characteristics and description: The data for this study was collected by the large numbers of complaints that arrived to information technology unit in the faculty. Online questionnaire and documents analysis as examples of requirements election techniques were utilized[24]. Participants (students and staff) of the faculty assisted to complete a prepared online questionnaire. The questionnaire consists of two parts; the first part is to determine each stakeholder power and interest and the second part is concerned with requirement prioritization suggestions. In this study, the concentration is on classifying and prioritizing faculty staff stakeholders. The following sub sections summarize the steps used to identify and decide the sample of stakeholders to be involved in the proposed power-interest stakeholder classification and prioritization model:

- **Specify stakeholder types:** This step specifies stakeholder types for the faculty website system. Various types of the faculty stakeholders are determined by analyzing and reviewing faculty staff organization charts. From the faculty staff organization charts, the power attribute for the faculty stakeholders can be determined from the faculty stakeholder's job position, their last certificate and their job duration (how long has the stakeholder working in that job position). First, each faculty stakeholder is categorized as an external stakeholder or an internal stakeholder. The external faculty stakeholder is the person that has an interest in the project but he/she has no job position in the faculty. For the external faculty stakeholder the power attribute is stated to (0) or no power. Second, for the internal faculty stakeholders; job positions are classified from higher power to lower power as follows: Dean, vice-dean, professor, associate professor, lecturer, assistant-lecturer, demonstrator, graduate and undergraduate. The internal faculty stakeholder's last certificate classified from higher power to lower power as follows: After PHD research, PHD, Master, B.SC and certificate of secondary. The internal faculty stakeholder's job duration is ignored for the faculty case because all collected stakeholders that have the same job position and certificate have the same job duration. According to the pervious stakeholder classification, the power attribute for both the stakeholder classification stage (stage 1) and the stakeholder prioritization stage (stage 2) is determined

- **Specify stakeholder roles:** In this step, roles to be included in the proposed power-interest stakeholder classification and prioritization model presented in this paper are specified. The roles and responsibility assigned to each participants (students and staff) is decided by using the responsibility assignment matrix (RASCI Matrix)[25]. The RASCI matrix is used to know exactly the role and responsibility for each stakeholder in completing each task in the system. Each stakeholder in the faculty case is assigned to one of the following roles (sorted by the highest interest to lowest interest):
  - **Accountable:** The person who is accountable for the tasks and signs off the work
  - **Responsible:** Person or group involved in getting the work achieved
  - **Consulted:** Expert (person or group) who needs to be consulted in this matter or subject
  - **Support:** Person or group who may provide input
  - **Informed:** Person or group who is informed about the action or decision

By RASCI matrix, the interest attribute for both the stakeholder classification stage (stage 1) and the stakeholder prioritization stage (stage 2) is determined:

- **Select and associate stakeholder with roles:** In this step, a sample of academic faculty staff (ensuring that different power of faculty stakeholders) is selected to prepare the stakeholder dataset used in the proposed power-interest stakeholder classification and prioritization model. The roles and the responsibility (interest attribute) associated for each stakeholder is decided by RASCI matrix described in step 2. The first three columns in Table 1 (roles, faculty job position and last certificate) show the selected stakeholder dataset and their roles

Table 1: A sample of academic faculty staff dataset

Roles	Faculty job position	Last certificate	D1: Power/interest	D2: Action
Support	Undergraduate	Secondary certificate	Low/low	Minimum effort
Support	Graduate	B.SC	Low/low	Minimum effort
Consulted	Demonstrator	B.SC	Low/low	Minimum effort
Responsible	Assistant lecturer	Master	High/high	Manage closely
Accountable	Vice-dean	After PhD	High/high	Manage closely
Responsible	Lecturer	PhD	High/high	Manage closely
Consulted	Lecturer	PhD	High/low	Keep satisfied
Support	Demonstrator	B.SC	Low/low	Minimum effort
Consulted	Graduate	B.Sc	Low/low	Minimum effort
Support	Associate lecturer	Master	Low/low	Minimum effort
Consulted	Vice-dean	After PhD	High/low	Keep satisfied
Support	Associate professor	After PhD	High/low	Keep satisfied
Responsible	Lecturer	PhD	High/high	Manage closely
Support	Graduate	B.SC	Low/low	Minimum effort
Support	Assistant lecturer	Master	High/low	Keep satisfied
Support	Graduate	B.SC	Low/low	Minimum effort
Support	Assistant lecturer	Master	High/low	Keep satisfied
Support	Demonstrator	B.SC	Low/low	Minimum effort
Support	Demonstrator	B.SC	Low/low	Minimum effort
Consulted	Lecturer	PhD	High/low	Keep satisfied
Support	Undergraduate	Secondary certificate	Low/low	Minimum effort
Consulted	Lecturer	PhD	High/low	Keep satisfied
Support	Lecturer	PhD	High/low	Keep satisfied
Support	No power	No power	Low/low	Minimum effort
Support	Lecturer	PhD	Low/low	Minimum effort
Responsible	Lecturer	PhD	Low/low	Minimum effort
Responsible	Lecturer	PhD	High/low	Keep satisfied
Support	No power	No power	Low/low	Minimum effort

- **Conducting the proposed model:** In this step, the stakeholder classification and prioritization for the faculty website case study will be conducted by following the proposed power-interest stakeholder classification and prioritization model presented in this study as follows:

Stage 1: Stakeholder classification stage

This stage is based on the intelligent rough set theory mathematical tool and Mendelow's power-interest model. Based on this stage, the output of this stage is that each stakeholder is going to be classified to one of the following groups; high power/high interest, high power/low interest, low power/high interest and low power/low interest. The phases of the rough set theory are applied to the faculty stakeholders in order to classify each of them as follows:

- **Pre-processing phase:** This phase consists of the following sub phases
- **Preparing the information system table (input dataset):** Table 1 shows a sample of the information system of the faculty stakeholders studied in this case. This table consists of three conditional attributes (roles, faculty job position and last certificate) and 2 decision attributes (power/interest, action)
- **Data completion, discretization, conversion and splitting:** The data stored in the database, either by human or physically, can contain interference factors such as noise data, vacancy data and inconsistent data. While, large number of raw data in the database isn't in a level suitable for knowledge discovery, the preprocessing of stakeholder data is necessary. All objects that have one or more missing values are removed and data conversion was performed on the initial information system. Data conversion was performed to generate a form in which specific Rosetta tool can be applied[26]. Rosetta tool is rough set software utilized in this model to classify stakeholder automatically (classification stage). In the proposed model, data conversion is performed by assigning each faculty stakeholder attribute a number. For example, the first faculty stakeholder shown in Table 1 that has the following attributes: Roles as support, certificate as secondary, job position as undergraduate, decision 1 as low/low and decision 2 as minimum effort takes "1,0,0,0,0" respectively, depending on the discritization table of the faculty stakeholders shown in Table 2. This step is called discretization. The outcome of this step is to generate two randomly discritized subsets; the first subset represents the training set which is used for the analysis and contains 85% of the objects from the dataset and the other subset is the testing set which contains the remainder of objects
- **Attribute reduction and rule generating phase:** The discretized training set is the input for Rosetta tool. Rosetta tool eliminates the redundancy of attributes to generate the most important attributes from the faculty stakeholder dataset. After that, Rosetta tool generates a set of rules that's used to classify each stakeholder to one of the four groups high power/high interest, high power/low interest, low power/high interest and low power/low interest. The problem is that the numbers of classification generated rules from the rosetta tool was slightly large. To reduce the number of classification generated rules, the Johnson algorithm is used in conjunction with Rosetta generated rules. Johnson's algorithm is a heuristic algorithm using a greedy technique. The idea of Johnson's algorithm is that it always selects the most frequently occurring attribute in the clause. In Johnson's algorithm, the attribute that appears more frequently is considered to be the most significant. Johnson's algorithm generally finds out a solution close to the optimal[27]. Figure 2 shows the attribute reduction set and rule generation set
- **Classification and prediction phase:** To validate the performance of the rules used to assess how well the performance of rules in classifying new cases, we apply the generated rules from the previous step to the test set. The output of the classification step is two decisions; the first decision attribute is to classify each stakeholder to one of the four groups (high power/high interest, high power/low interest, low power/high interest) and the second decision attribute is the action assigned to each stakeholder class. Figure 3 concludes that the actual decisions found in the test set are not correct due to the

Table 2: Discretization results of faculty stakeholders

Meaning	0	1	2	3	4	5	6	7	8	9
Roles	Informed	Supported	Consulted	Responsible	Accountable					
Certificate	No power	Secondary	B.SC	Master	PhD	After PhD				
Jon position	No power	Undergraduate	Graduate	Demonstrator	Assistant lecturer	Lecturer	Associate professor	Professor	Vice-dean	Dean
Decision 1	Low/low	Low/high	High/low	High/high						
Decision 2	Minimum effort	Keep informed	Keep satisfied	Manage closely						

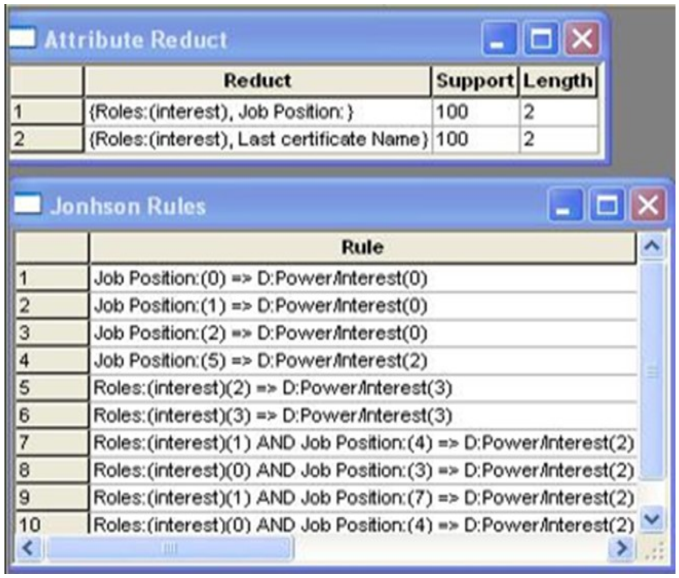

Fig. 2: Attribute reduction set and Johnson rule generation set

Object 0: ERROR	Actual	=	0 (0)
	Predicted	=	2 (2)
	Ranking	=	(1.0) 2 (2) 1 rule (s)
Object 1: ERROR	Actual	=	0 (0)
	Predicted	=	3 (3)
	Ranking	=	(1.0) 3 (3) 1 rule (s)
Object 2: ERROR	Actual	=	2 (2)
	Predicted	=	3 (3)
	Ranking	=	(1.0) 3 (3) 1 rule (s)
Object 3: ok	Actual	=	0 (0)
	Predicted	=	0 (0)
	Ranking	=	(1.0) 0 (0) 1 rule (s)

Fig. 3: Example of predicted classes for stakeholders

mistake in the input test dataset and need to be corrected in the information system table according to the right decision given in the predicted line. For example, object 0 (first stakeholder in test set) is classified in actual decision 1 (0; low power/low interest) but the model gives the right predicted answer which is (2) High power/low interest). The right predicted answer is used to update the information system table. Finally, depending on the classification of each object (decision 1), the action that has to be taken with each stakeholder is decided (decision 2). Back to the previous example, after the updating the information system table with the right predicted result for object 0, the action (decision 2) changed from "Minimum effort given to this stakeholder to the correct action which is keep this stakeholder always satisfied".

Stage 2: Stakeholder prioritization stage

This stage is based on the intelligent mathematical fuzzy logic tool. This stage starts with the preprocessing of the prioritization variables (the power and the interest of each stakeholder). Subsequently, the preprocessed values of the prioritization variables will be fuzzified to serve as the input to the FIS. In this study, a proposed Fuzzy Logic Prioritization Model (FLPM) is presented. The FLPM employed TS fuzzy inference system to specify the linguistic priorities of stakeholders. For each stakeholder, prioritization is determined according to the power and the interest of that stakeholder. Figure 4 shows the FLPM, the input of FLPM are power, interest variables and the output is stakeholder_weight which is assigned to each stakeholder to be prioritized and ordered. Prioritization stage steps are as follows:

- **Data preprocessing:** The goal of this step is to prepare a table that contains the estimated or specified numeric values for the two input variables; interest and power. The power and the interest numeric values of each stakeholder taken from the table are considered the input to the fuzzy logic tool. Table 3 shows two numeric values stated for each stakeholder; one to show the power of the stakeholder (faculty job position and last certificate) and the other to show his/her interest (roles). The numeric values assigned to the power and the interest attributes

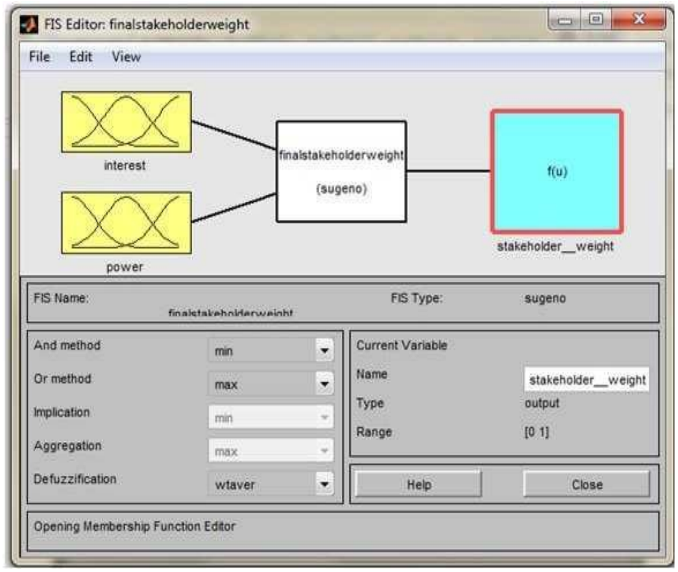

Fig. 4: A screen for the input variables of FLPM

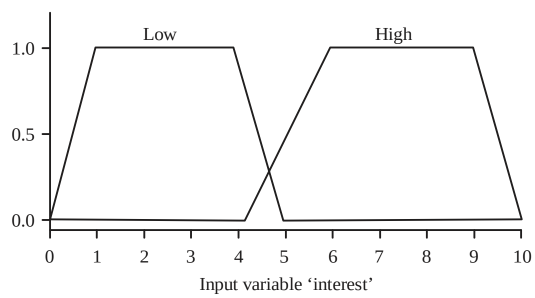

Fig. 5: Membership functions for interest input variable of FLPM

Table 3: Power and Interest input numeric values

Power attributes		
Certificate	Job position	Power numeric values
External	External	0.0
Secondary	Undergraduate	1.0
B.SC	Graduate	2.0
	Demonstrator	4.0
Master	Assistant lecturer	6.0
PhD	Lecturer	7.0
After PhD	Associate professor	8.0
	Professor	9.0
	Vice-dean	9.5
	Dean	10.0
Interest attributes		
Roles		Interest numeric values
Informed		2.0
Support		4.0
Consulted		5.2
Responsible		8.0
Accountable		10.0

which used in the prioritization process were normalized to the range from 0-10. For example, B.SC certificate stakeholder that has a demonstrator job position and his/her role is consulted is assigned 4 as a power numeric value and 5.2 for the interest numeric value

- **Define fuzzy membership function:** During the prioritization process, each of the priority factors will be fuzzified under one of two fuzzy categories: Low (L) and High (H). Consequently, two membership functions are defined for each input (power and interest) and its corresponding categories. The trapezoids shape is employed for the input membership functions. This is demonstrated in Fig. 5. The consequent stakeholder weight is obtained from four consequent membership functions. These four functions are to define each quadrant of Mendelow's power-interest matrix for stakeholder. The problem is that two different stakeholders that have different numeric power and interest values may give the same stakeholder weight. For example, if one stakeholder has numeric power value (7) and numeric interest value (4) and another one has numeric power value (4) and numeric interest value (7). Although both of stakeholders have 7 and 4 for input variables but these two stakeholder should be in different quadrant (high/low and low/high, respectively) in the Mendelow's power-interest matrix. The solution of the previous problem is that each quadrant of Mendelow's power-interest matrix will be given a weight to ensure that the stakeholder weight values from each quadrant

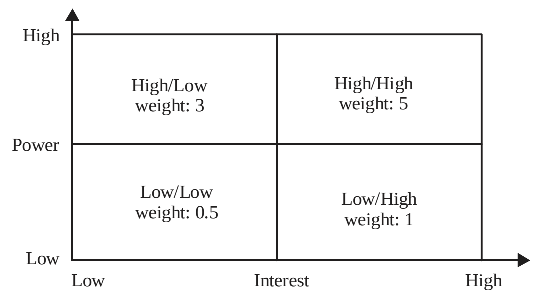

Fig. 6: Proposed weights for Mendelow matrix

aren't repeated (unique). Estimated quadrant weights used in this case are shown in Fig. 6. The membership consequent functions created using the specified weights stated for each Mendelow power interest quadratic are as follows:

$$\text{LowLow} = 0.5x+0.5y \quad (3)$$

$$\text{LowHigh} = x+y \quad (4)$$

$$\text{HighLow} = 3x+3y \quad (5)$$

$$\text{HighHigh} = 5x+5y \quad (6)$$

Generate rule set: Once all fuzzy variables within each fuzzy set are defined properly, the fuzzy rule base of FIS has to be generated. The generated rule base for academic faculty staff stakeholders system are the following:

- If (interest is low) and (power is low) then (stakeholder weight is low/low)
- If (interest is high) and (power is high) then (stakeholder weight is high/high)
- If (interest is low) and (power is high) then (stakeholder weight is high/low)
- If (interest is high) and (power is low) then (stakeholder weight is low/high)

Fuzzy-inference system: To generate a prioritized list of stakeholders, each stakeholder is presented to the system which takes its power value and its interest value as input and determines which rule to be fired. For each rule, the inputs are combined to get the rule strength. These rule strengths are combined with the output membership function to find consequent fuzzified value for that rule using max min method.

Defuzzification: Once all fuzzified values for all fired rules have been determined, a single numeric value of fuzzy priorities is generated by the defuzzification step. The defuzzify equation for weighted average ((wtaver)) method is defined as follows:

$$f = \frac{w_1 z_1 + w_2 z_2}{w_1 + w_2} \quad (7)$$

where, w_1 and w_2 values are the minimum of the membership grades in each rule and z_1 and z_2 are the output level of each weighted rule. Once the defuzzification values for all stakeholders have been obtained, all of these stakeholder weights are used to form a single document in descending order to determine the final position of each stakeholder within the importance prioritized list as demonstrated in Table 4.

In Table 4, stakeholder 5 who has high power/high interest from classification stage and the highest stakeholder weight (97.5) from prioritization stage is considered the most important stakeholder in the stakeholder dataset. The greatest effort should be done to ensure that this stakeholder is satisfied with the work achieved. Also, the Table 4 shows that the lowest stakeholder that are low power/low interest and have the lowest stakeholder weight (2) is stakeholder 25. The action that has to be taken with this stakeholders is to monitor this stakeholder and do not bore him/her with excessive communication.

Verification of faculty staff stakeholder classification and prioritization: A verification process is conducted to ensure the correctness of the proposed automatic power-interest stakeholder classification and prioritization model presented in this study. The verification step aims to demonstrate the consistency, completeness and correctness of the model. One step to verify the correctness of the proposed model is by comparing or reviewing the final academic faculty staff stakeholders list (Table 4) with the manual Mendelow's power-interest matrix which was prepared by the project manager at the beginning of faculty website project. The manual Mendelow's power-interest matrix is filled by the suggested academic faculty staff required for faculty website project and their power/interest classification. Figure 7 shows the project manager which has vice-dean job position, is considered the highest and the most important stakeholder in the manual Mendelow matrix. The same result can be extracted from the final academic faculty staff stakeholders list as shown in Table 4. In addition to the power/interest classification, a stakeholder_weight is used to differentiate stakeholders that lie in the same class (quarter). For example, project manager, project responsible and developer are classified to the high power/high interest quarter but their

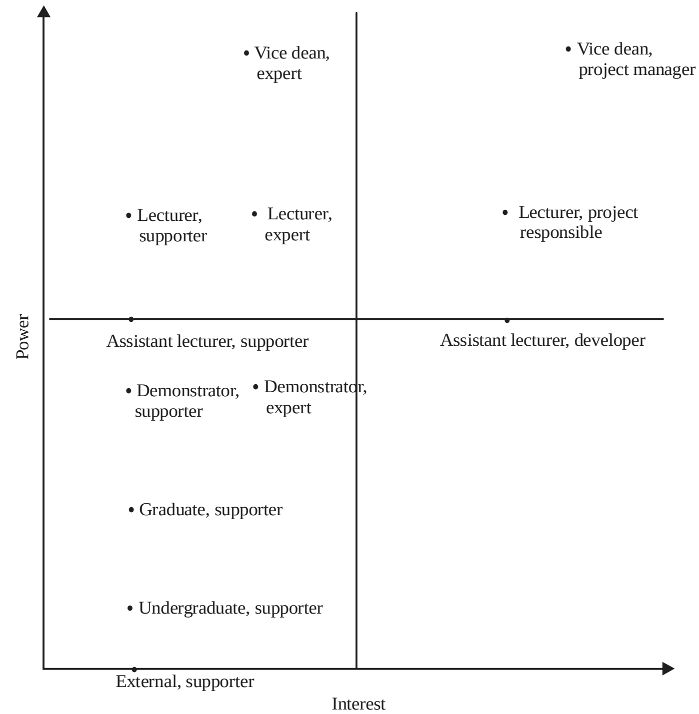

Fig. 7: Manual Mendelow power/interest matrix

Table 4: Ordered list for academic faculty staff stakeholders

Stakeholder	D1: Power/interest	D2: Action	Stakeholder-interest	Stakeholder-power	Ordered-stakeholder-weight
S5	High/high	Manage closely	10.0	9.5	97.50
S6	High/high	Manage closely	8.0	7.0	75.00
S13	High/high	Manage closely	8.0	7.0	75.00
S4	High/high	Manage closely	8.0	6.0	70.00
S11	High/low	Keep satisfied	5.2	9.5	47.90
S7	High/low	Keep satisfied	5.2	7.0	39.80
S20	High/low	Keep satisfied	5.2	7.0	39.80
S22	High/low	Keep satisfied	5.2	7.0	39.80
S12	High/low	Keep satisfied	4.0	8.0	36.00
S23	High/low	Keep satisfied	4.0	7.0	33.0 0
S10	High/low	Minimum effort	4.0	6.0	30.00
S15	High/low	Keep satisfied	4.0	6.0	30.00
S17	High/low	Keep satisfied	4.0	6.0	30.00
S3	Low/low	Minimum effort	5.2	4.0	5.20
S9	Low/low	Minimum effort	5.2	2.0	4.07
S8	Low/low	Minimum effort	4.0	4.0	4.00
S18	Low/low	Minimum effort	4.0	4.0	4.00
S19	Low/low	Minimum effort	4.0	4.0	4.00
S24	Low/low	Minimum effort	5.2	0.0	3.90
S2	Low/low	Minimum effort	4.0	2.0	3.00
S14	Low/low	Minimum effort	4.0	2.0	3.00
S16	Low/low	Minimum effort	4.0	2.0	3.00
S1	Low/low	Minimum effort	4.0	1.0	2.50
S21	Low/low	Minimum effort	4.0	1.0	2.50
S25	Low/low	Minimum effort	4.0	0.0	2.00

weights are as follows: Project manager takes weight of (97.5) while project responsible takes weight of (75) and developer takes weight of (71.5). Also, the Fig. 7 shows that the lowest stakeholders that are low power/low interest are the external stakeholders who are considered as a supporter that tried to provide the proposed model with filling online questionnaire. The proposed model also aims to classify that external stakeholder as low power/low interest and assign him/her a stakeholder_weight of (2).

The verification step ensured the correctness of the output from the proposed automatic power-interest stakeholder classification and prioritization model presented in this study by reviewing it with the manual Mendelow's power-interest matrix prepared by the project manager. In addition to the correctness of the proposed automatic power-interest stakeholder classification and prioritization model presented in this study, it saves time and effort especially in the case of working with large numbers of stakeholders. Besides that, the classification and the prioritization weight given to each stakeholder ensures the accuracy and precision of the stakeholder prioritization process which is considered the most significant area of software engineering.

Comparative study: In this study, a comparison among the proposed automatic power-interest stakeholder classification and prioritization model is presented, the manual model proposed by Voola and Babu[28] and the automatic salience prioritization model proposed by Poplawska *et al*.[5] is presented. These three models will be compared and evaluated according to the consultation of experts and some subjective measurements. Weighted Score Method (WSM)[29,30] is applied to put a semblance of objectivity into the subjective comparative process. The WSM assists in showing the three models findings with absolute confidence and provides facts to back up expert choice. The comparative study gathers important, interesting and valuation characteristics about the three compared models. In addition, the comparative study helps to discover the attitude or decisions of the experts towards the proposed automatic power-interest stakeholder classification and prioritization model. The WSM is also explained in this study.

Weighted score method: The WSM is a technique that attempts to covert the subjective comparative process performed by the consultation of experts into the objectivity form. The characteristics that are collected by applying the WSM are important in picking the best model among the three models mentioned previously. The WSM oriented comparative is typically applied in the following fashion.

Criteria identification: In this step, some pre-defined system quality attributes[31-33] are going to be specified to represent the comparison criteria for WSM. These quality attributes are identified and defined according to taxonomies and ilities of quality attributes collected from different references as indicated in Table 5. These quality attributes can enhance the overall value of the models with their presence. The identified quality attributes are summarized in Table 5. Table 5 presents a name and a description of each quality attribute or criterion. Each quality attribute or criterion is assigned a symbol (e.g., C1-C9). The fourth column defines possible values that can be assigned to the three compared models. These values represent to what extent the three compared models address the corresponding quality attribute. For example, attribute C4 represents modifiability attribute. It refers to the ability of the model in applying new changes to the stakeholder dataset. Finally, the last column is the scoring column. These scores are assigned for each quality attribute or criterion to reflect how well each one of the models addresses the quality attribute or criterion. Table 5 shows the scores are values between 0 and 1; 1 indicates full coverage of the quality attribute by the model, 0 indicates no coverage and values between 0 and 1 represent different levels of addressing the quality attribute.

Weighting quality attributes: The set of quality attributes that were defined in the previous step are assigned with a weight reflecting how much each quality attribute is important to the consulted expert. Expert assigns this weight to show the quality attribute whose degree of presence or absence in the model can have a direct influence on its value. A 9-point scale is used to represent the weight. A weight of 9 is assigned to the quality attribute when it is very important to be addressed to ensure the effective model. A weight of 0 is assigned to a quality attribute when it is not important at all to be addressed. The weights may be normalized so that their total is one.

WSM conduction: The overall score of each model, reflects how well the model performs with respect to all quality attributes, is calculated using Eq. 8:

$$S_i = \sum_{j=1}^{j=n} \left(W_j \times S_{ij}\right) \qquad \text{for } i = 1, 2, \ldots m \tag{8}$$

where, W_j is the weight of the jth quality attribute, S_{ij} is the relative score of the ith model in terms of the jth quality attribute and S_i is the overall score of the ith model in terms of all quality attributes.

Table 6 summarizes the comparison using WSM method. Figure 8 depicts the overall score of the proposed automatic power-interest stakeholder classification and prioritization model, the manual model and the automatic salience prioritization model. The model with the highest overall score (Si) represents the model with the best quality characteristics. Figure 8 shows the proposed automatic power-interest stakeholder classification and prioritization model presented

Table 5: Comparison criteria identification

Criteria symbol	Criteria name	Criteria description	Measure criteria in each model	Criteria scoring system (0-1)
C1	Automation level	Level of human involvement starting from gathering stakeholder dataset, the classification stage and the prioritization stage. As the level of human involvement increase in the model, the correctness, precision and accuracy of output is decreased	Automated Partially automated Manual	1 0.5 0
C2	Questionnaire friendliness	This subjective measure refers to the capability of the questionnaire interface to be appealing. The intension is to determine the questionnaire to which decision-makers are attracted and has capabilities (help menus, colorful images and videos etc.) of explaining themselves clearly. To ensure that the collected stakeholder dataset is correct and complete. Online questionnaire can contain colourful pages, images and supportive videos to help in explaining misleading past about the designed questionnaire. Other questionnaire contains plain pages with black text and for explanation the attendance of questionnaire owner is required	Attractive Not attractive	1 0
C3	Understandability/clarity	It refers to the degree that a reasonable knowledge of a models should be able to comprehend it. If we can't earn a model, we won't understand it. If we can't understand a model, we can't use it. The understandability can be shown in each model by clearly understanding the following, the prepared questionnaire sections or fields and the stages of steps of stakeholder classification and priorization. On using online questionnaire for collecting stakeholder dataset, images and videos can be added to make the questionnaire understable. For manual questionnaires, the owner of the questionnaire must attend the session to clear the misunderstanding. Finally for mailed questionnaires, this depends only on written explanation or notes but these are not enough and misunderstanding and errors increases. Automatic stages is explained by prepared images with full explanation for different input, output, screens and videos, videos contain a brief explanation of what the model can do and how to use the model properly	Online questionnaire+automatic stages: Fully clear Manual/mailed questionnaire+automatic stages: Partially clear Manual/mailed questionnaire+manual stages: Not clear enough	1 0.5 0
C4	Modifiability	It refers to the ease or capability of changing stakeholder input dataset to accommodate new changes. The prepared classified and prioritized stakeholder's documentation must be monitored and review during the project because the interest and the power for stakeholders may change over time. So stakeholder classification and prioritization step is usually repeated many times during a project. So, the modifiability attribute has to be applied mandatory in software projects. Therefore, more concentration is required in specifying the way each model tries to apply this attributes	Applied Not applied	1 0
C5	Data validation	Data validation is used to restrict some possible values (numbers, dates and text) for the different fields while collecting the stakeholders dataset. Prevent participants from entering invalid data values while filling the questionnaire. To ensure the correctness of the collected data. This quality attribute can be done automatically or checked by human or not done at all. Missing or ignorance of this attribute can lead to filling some fields with wrong data	Automatically Human Not found	1 0.5 0
C6	Respondent acceptability	Models consist of different types of stakeholders, each one has different schedule and different locations. So preparing a session for all identified stakeholders to gather stakeholders dataset is very complex task. So selecting a stakeholder gathering technique that can support these characteristics is efficient	Not specified Specified	1 0
C7	Data completion	It refers often to the case when real world data contains missing values. Removing all object that have one or more missing values is the aim of data completion. This attribute can be done automatically or checked by human or not done at all. Missing or ignorance of this attribute can lead to improper classification and prioritization for the stakeholder dataset	Automatically Human Not found	1 0.5 0
C8	Respondent stakeholders categories	This attribute shows which group of stakeholder is chosen to participate in each model. Some models are limited to specific kind of stakeholders and other are general and use all kinds of stakeholders. Models that cover specific kinds of stakeholders do not hold real world cases	All kinds Specify some stakeholders	1 0.5
C9	Analysis feature	Gathered dataset can also be analyzed continuously by automatic analysis feature if exist, to increase the speed and accuracy of analyzed data. Charts and graphs and other important infrenced information can be produced from analyzing the collect dataset	Available Not available	1 0

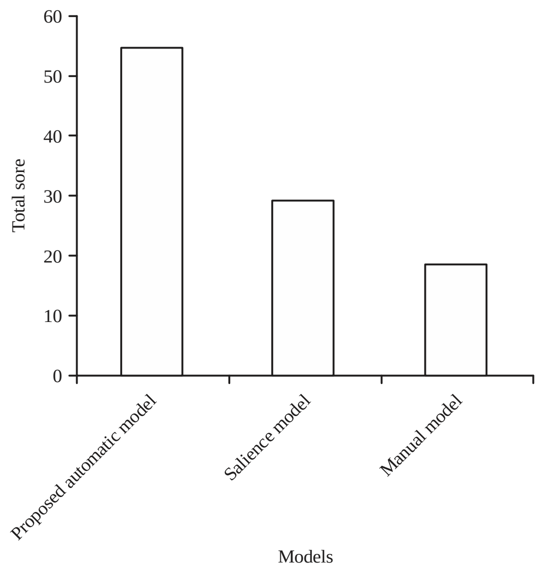

Fig. 8: Overall score of three compared models

Table 6: The WSM table

Challenges/methods	Expert weighting	Proposed automatic model	Salience model	Manual model
C1	6	0.5	0.5	0
C2	5	1	0	0
C3	8	1	0.5	0
C4	9	1	1	1
C5	8	1	0.5	0.5
C6	4	1	1	0
C7	6	1	0.5	0.5
C8	5	1	0.5	0.5
C9	7	1	0	0
Total score		55	29.5	18.5

Table 7: Other comparison characteristics

Models/inherent characteristics	Classification method	Respondent sample size	Average time (min)
Proposed automatic model	Presented	25	12
Manual model	N/A	8	7
Salience model	N/A	14	15

in this study has the highest overall scores from the perspective of the quality attributes obtained.

Other comparison characteristics: Some important facts concerning the three comparative models are noted down by the experimenter. Classification method, respondent sample size and average time are the characteristics that were planned to be noted down in this part. The comparison among the three models using these characteristics are shown in Table 7 .The description of these characteristics s as follows.

Classification method: The proposed automatic model presented in this study is only the model among the three comparative models which used a classification model.

Respondent sample size: Larger sample sizes generally lead to an increment in the precision and the quality of results. This criteria shows the sample size of the stakeholders who participate in each model. For the proposed model, a total of 25 respondents are collected by the online questionnaire from all kinds of the academic faculty staff. On the other side, the salience automatic model collected a total of 14 respondents from the organizations key stakeholders. The manual model involved a sample of 8 students from the second and first year Master students only. This emphasis that the proposed model tried to cover a large sample size with different variation of the faculty staff.

Average time: This characteristic is used to estimate the average time spent in filling each questionnaire. Internet access delay time for online questionnaire is considered in that estimation.

From the data, it can be inferred that the proposed automatic stakeholder classification and prioritization model presented in this study based on Mendelow's power-interest model is simple, general and understandable and takes reasonable average time.

CONCLUSION AND FUTURE RECOMMENDATIONS

The study presents a generic automatic power-interest stakeholder classification and prioritization model based on rough-fuzzy hybridization method. The proposed model consists of two stages. The first stakeholder is to classify stakeholders based on rough set theory and the second stage is the stakeholder prioritization stage based on fuzzy logic. By the classification stage; the model was able to extract knowledge in the form of rules to classify academic faculty staff working on "Updating faculty website project" into four groups "High power/high interest, high power/low interest, low power/high interest, low power/low interest". This classification is based on Mendelow's power-interest model. In order to incorporate the uncertainty and discrete data limitation of the classification of rough set theory, fuzzy logic is used in the stakeholder prioritization stage. Using fuzzy logic approach, stakeholders aren't only assigned to a discrete class but also receive a degree of a membership of that stakeholder to the predetermined rough set class. Finally, a verification process and a comparison study are applied to the proposed automatic power-interest stakeholder classification and prioritization model presented in this study. Both of them showed that the output from the proposed automatic model is correct, understandable and simple in the stakeholder's classification and prioritization process.

In future, more empirical evaluations on other real world projects will be conducted to ensure the effectiveness of the proposed model. This model could be applied for classifying and prioritizing stakeholders as the first step for requirement prioritization process in software product management. The remaining requirement prioritization steps can be completed to develop the first software urgent release for the faculty website project. Using intelligent systems like fuzzy approaches for analyzing and prioritizing gathered requirements will be considered as our future study.

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