Requirements Uncertainty Prioritization Approach:A Novel Approach for Requirements Prioritization

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Abstract- **Requirements Prioritization is to ensure the product developed resonates with the expectations of the stakeholders. Requirements prioritization techniques assist in ensuring this where assessments about the priorities of the requirements will be carried out by stakeholders whose judgment is all about their perception of the system which cannot be precise always. Guesses to be made about yet to be built system where only partial knowledge is available. Imprecision shrouded in the forms of uncertainty, incompleteness and vagueness do exist. In order to incorporate these imprecision elements a novel approach for requirements prioritization called Requirements Uncertainty Prioritization Approach (RUPA) is introduced where the basic prioritization technique Numerical Assignment is shaped as Extensive Numerical Assignment by means of probability distribution and grade intervals. The backbone of the approach is Interval Evidential Reasoning Algorithm, used to aggregate the imprecise assessments of stakeholders. A case study is examined to illustrate the usefulness of this approach.**

Keywords- **Imprecision, Numerical Assignment, Requirements Prioritization, Uncertainty.**

1 INTRODUCTION

Requirements Prioritization (RP) is a significant activity of Requirements Engineering phase with the aim of planning which subset of requirements from a large set to be implemented in the current and subsequent releases and still guarantee the stakeholder satisfaction [1]. This activity is necessary to be carried out as it is not possible to implement all requirements because of constraints regarding human resources, technical difficulties, cost, schedule and any other risks etc. The added advantages of RP can be found in [2, 3]. RP is a decision making activity by the stakeholders about the priorities of requirements. The Literature has in its store many RP techniques based on precise judgments. But the fact is that during the early stages of project life cycle, the understanding of stakeholders about the priorities of requirements may be uncertain, vague or imprecise. Hence, uses of RP techniques that do not take uncertainty into account are of minimal use in cases which involve minimal knowledge. Uncertainty brought on by lack of knowledge has to be modeled in some form during RP. Another concern is about aggregating the judgments of stakeholders. It is quiet easy task to determine the priorities of requirements if a single stakeholder is involved. But the scenario is diverse group of stakeholders to be involved and it is more challenging to aggregate their judgments. Conflicting choices and imprecision in the assessments need to be handled properly to produce reliable results.

In order to address the issues of uncertainty and aggregation discussed above, a novel approach called Requirements Uncertainty Prioritization Approach (RUPA) introduced. The core idea of the approach is to extend the simple and easy to use RP technique Numerical Assignment (NA) to a more sophisticated one by accommodating imprecision in inputs.

The modified NA is called Extensive NA, structured to receive imprecise inputs in the form of probability distribution and grade intervals. These inputs coalesced with the conflicting choices of stakeholders are aggregated to generate reliable requirement priorities using Interval Evidential Reasoning (IER) Algorithm that in turn has its roots in the evidence combination rule of the Dempster Shafer theory of evidence. The words uncertainty, imprecision, ignorance, vagueness and subjectivity are used in this paper interchangeably. RUPA was applied for an Examination System case study and found this as the most promising.

The paper is structured as follows: Section 2 discusses about the imprecise nature of human judgment. Section 3 about the uncertainty aspect conferred in the RP techniques present in the literature. Section 4 describes the novel approach RUPA introduced in this paper. Section 5 about the usefulness of RUPA by applying it to an Examination System case study and section 6 concludes with a note on future work.

2 IMPRECISE NATURE OF HUMAN JUDGMENT

One of the motivations for this paper is the imprecise nature of human judgment. Judgment appears almost in every aspect of life and in most of the cases it is imprecise. In many decision situations using a single number to represent a judgment proves to be difficult and sometimes unacceptable. It is based on intuition, experience, intelligence, assumptions, opinions, beliefs of the person and the situation in which he is making judgment. Judgment using only precise numbers always has the probability of being incorrect [4]. Information would have been lost or distorted in the process of pre aggregating different types of information such as subjective judgment, probability distribution, or an incomplete piece of information into a single number [6]. Two cases are discussed below reflecting the imprecise nature of human judgment.

1.1 Assessment of Student Performance in Exam

Universities and educational institutions are setting away old, stagnant and faulty evaluation system of giving marks and moving towards embracing grades. In the marking system, students are evaluated precisely on a scale from Zero to 100. But the research results indicate that the evaluation is indeed imprecise as the standard of examination differs from subject to subject, evaluation of answer script differs from examiner to examiner. The same examiner when asked to evaluate the same answer script twice will give two different marks. The difference between a 72 and a 73 is likely to be statistically insignificant, especially if what is being graded is subjective material, such as essays. It is likely that the student with the 73 would feel superior to the one with a 72.But the student who acquired grade A can be treated as superior to grade B student. By using the broader grades, we are being more realistic in our marking [9]. University Grants Commission[7], being the authorized agency to maintain the standard of higher education and co-ordination among the universities in India, advocates for a 7 point scale of grades as given in Table 1.

TABLE 1
SEVEN POINT GRADING

Grades	Grade Point	Percentage equivalent
O-Outstanding	5.50-6.00	75-100
A-Very good	4.50-5.49	65-74
B-Good	3.50-4.49	55-64
C-Average	2.50-3.49	45-54
D-Below Average	1.50-2.49	35-44
E-Poor	0.50-1.49	25-34
F-Fail	0-0.49	0-24

1.2 Performance Appraisal of an Employee

Performance appraisal is the measurement and assessment of an employee’s job performance for the purpose of aligning the employee’s work behaviors and results with the organizational goals. Traditional rating scales were all precise. One such example is graphical rating scale. These scales were simple to use and develop but suffered from rating errors as evaluations varied too widely from rater to rater. Another major criticism is that they produce distorted and unreliable data. The problem stems from the fact that some managers are hard graders, while others are not. One manager might assign a ranking of ‘1’ to perfection, whereas another manager might rate ‘1’ as a much lenient standard. So, a better method of rating employees performance is devised by Smith & Kendall (1963) called Behaviorally Anchored Rating Scale (BARS) [32]. This minimizes evaluators impreciseness, improves reliability of personnel assessment. An example BARS is shown in Table 2. Instead of precise values, intervals are employed to deal with imprecision.

TABLE 2
BEHAVIORALLY ANCHORED RATING SCALE

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Numerical scale	Relative amount of activity
9	More than usual amount of typical activity
8	
7	
6	Usual amount of typical activity
5	
4	
3	Less than usual amount of typical activity
2	
1	

As it is evident from the above two instances that human judgment is imprecise and uncertain by nature, the same notion of imprecision has to be appropriately modeled during requirements prioritization too.

3. REQUIREMENTS PRIORITIZATION TECHNIQUES ADDRESSING IMPRECISION

This section speaks how various research articles about requirements prioritization have highlighted the necessitation of incorporating uncertainty feature about requirements priorities into the prioritization technique.

- Ruhe in [33] mentions the current challenges of requirements prioritization as conflicting requirements, incompleteness and uncertainty of information, not enough stakeholder involvement, geographically distributed stakeholders, resource bottlenecks etc. One of the observations in Grant Ruhe's essay about estimation perspectives says that as upfront estimates cannot be precise, several software schedule and cost estimation models are towards providing optimistic, most likely and pessimistic estimation ranges rather than point estimates.

- Grant Ruhe in [34] says estimating is about predicting in the face of uncertainty and incomplete knowledge. He also adds that most go for precise answers with a high probability of being incorrect. But this built in human characteristic to prefer precision over accuracy pretends to be certain and it is this perspective that is a major contribution factor to the well reported high percentage of failed software projects.

- In [35], authors discuss recent approaches to RP exploits different MCDA techniques and the limits of these techniques are attributed to the strong assumptions they adopt such as the completeness and certainty of the set of requirements to be evaluated and the plausibility of a rating scale based on discrete categories.

- Ruhe in [36] launches a release planning framework for RP which integrates the strength of computational intelligence with the knowledge and experience of human experts. RP activity is portrayed both as an art and a science. As art, it relies on human intuition. As science, it relies on computational algorithms to generate best solutions. Hybrid approaches that integrate human judgment with formal techniques have proven most promising.

- In [37] the argument on the need for more sophisticated decision support mechanism is augmented by the claim that some stakeholders may like to provide only partial information or no information at all, as they have no knowledge about the imp of requirement.

- Moisiads in [38] introduces a RP tool which draws out stakeholders opinions using graphical fuzzy rating scale. The argument is that people tend toward ranges rather than single point when expressing attitudes.

- In [39] a new automated and distributed prioritization method for RP was introduced and the paper concluded with future challenge as considering the uncertainty factor in requirements prioritization.

- In [10] it is reported that benefit values are approximations and one loves to live with this approximations as they save time and easier to use when applying the RP method. The paper concluded with a challenge to empirically compare two RP methods once with an approximation and once without.

- B Regnell et al in [40] argue that the imprecise nature of human judgment is there always irrespective of absolute or relative judgment. Some requirements can be estimated precisely, some other with reasonable precision and some others cannot be estimated at all.

The work in this paper is captured by the arguments of the various authors as discussed above stating the need for incorporating uncertainty, imprecision and incompleteness and tries to fill the gap by offering Extensive Numerical Assignment (ENA) implanted in RUPA.

4. REQUIREMENTS UNCERTAINTY PRIORITIZATION APPROACH (RUPA)

The prioritization approach introduced in this section demonstrates how incomplete, uncertain, imprecise and conflicting goals of stakeholders are transformed into an ordered list of requirements. The approach is shown as an activity diagram in Figure 1. The outcome of each activity is shown as a note icon immediately below the activity node. The sequence of activities described below in 5 steps.

1. Identify relevant stakeholders for the project under consideration and assign weights.
2. Obtain inputs from stakeholders with Extensive Numerical Assignment.
3. Aggregate inputs collected applying Interval Evidential Reasoning Algorithm.
4. Use Utility theory to compute ranks.
5. Distribute outputs to the stakeholders, obtain degree of satisfaction and reach consensus.

1.1 Identify stakeholders and assign weights

This section first discusses the issue of involving a single stakeholder or a group of stakeholders in RP and later discusses the issue of assigning weights to stakeholders.

Single Stakeholder or Group of Stakeholders

As increasing number of software products are delivered to market instead of single customer [23], this supports the need for involvement of a group of customers during requirements prioritization. Nevertheless, every stakeholder will have his own interest in different requirements and is not willing to compromise for someone else. If only a single stakeholder is involved in requirements prioritization rather than a group, it may not be possible to satisfy the diverse group of stakeholders associated with the project. Another concern is that the result may be a failed project. Chaos Report 2009 augments this by disclosing ten main factors for project failures as one amongst them is lack of user involvement.

The importance of a group of stakeholders being involved in requirements prioritization is well accepted as the quality of the final software product is determined verily by the accurate identification of stakeholders and their needs [15]. Various groups of stakeholders and their categorization discussed [17-21] facilitates deeper understanding about various stakeholders and their stake in the product. Seaver (1976) concluded that group judgment is more accurate than individual judgment primarily due to decrease in error variance around the true value [41].

In [42], it is proposed to opt for team estimates as they are less prone to extreme outliers when compared with individual estimates. In [43] it is recommended that assorted group of stakeholders comprising developers who provide cost and risk ratings, customers who provide benefit and penalty ratings and Project Manager who arbitrate conflicts and makes trade-off decisions. In [44] RP is termed as a group solving process and a major challenge for Requirements Engineer is to understand this group process and find efficient ways of carrying out this. Almost all approaches for Requirements Prioritization propose the involvement of a group of stakeholders rather than individuals in decision making. Thus, it is evident that a balanced set of stakeholders is appreciated to get the most relevant information.

Assign Weights

Once the stakeholders are identified, the subsequent task is to differentiate them as all of them are not equally important [16]. Key users, secondary users, and unimportant users to be identified and set apart [33]. This discrimination can be done by assigning weights, which act as the drivers for the prioritization process [24]. If needed it is of course suitable to involve more that have a stake in the product [23].

Weights can be assigned by Project Manager or Requirements Engineer. An example how weights can be assigned to stakeholders using AHP is discussed in [25]. When assigning weights, people who actually use the product should have greater impact [45].

1.2 Inputs with Extensive Numerical Assignment

The next task is to get inputs from stakeholders for prioritization of requirements. For this a prioritization technique to be employed which is simple and fast at the same time provides accurate and trustworthy results [46]. Numerical Assignment (NA) is the most common, simple and fast prioritization technique but may not provide accurate and trustworthy results. It is based on ordinal scale where requirements are grouped into some priority groups. Number of priority groups is only three in general and the descriptors of the groups as high, medium, low. The descriptors can also be essential, conditional and optional [43]. Category descriptors are grades to which a requirement is assessed.

This simple NA has many drawbacks. Several requirements will be placed into a group and hence lead to ranking ties. Category descriptors with NA are subjective [43] and the stakeholders may not have a uniform understanding what they actually mean. NA is not flexible enough to accommodate any form of uncertainty. Another setback is if customers prioritize themselves, they may place 85 percent of the requirements as critical, 10 percent as standard and 5 percent as optional [47]. The solution is to restrict the number of requirements to be placed in a group. However, no empirical evidence of good or bad results exists with such restrictions. Another drawback with NA is that it does not provide rich set of outputs for analysis. For example, if multiple stakeholders assess the requirement priorities, the conflicts between stakeholders stay hidden.

The idea is to transform Numerical Assignment into Extensive Numerical Assignment (ENA) with rich set of inputs, flexible enough to accommodate imprecision. The next two sub sections discuss which aspects to take into consideration during prioritization and how inputs to be modeled for ENA.

Prioritization Aspects for consideration

Initially customers are provided with the list of requirements for assessment. Requirements can be assessed along the dimensions of several criteria as discussed in [25]. General trend is customers who are also end users prioritize requirements from the perspective of importance or benefit it provides to them. It is the value gained by implementing the requirement and is opined by the customers as something that makes them feel good. They are not bothered about other aspects of prioritization like cost, schedule, risks etc. Developers then prioritize from the perspective of cost. Hermann and Daneva found 240 papers based on benefit and cost estimation [48] . Project manager now has to make trade-off decisions to identify which set of important requirements can be implemented at lower cost in order to maximize customer satisfaction [43]. Industry analysts have proposed several techniques that involve estimating the relative value and relative cost of each requirement, such that the highest priority requirements provide the largest fraction of the total product value at the smallest fraction of the total cost. In essence, you're trying to identify those requirements that will maximize the product value within the existing cost constraints.

Modeling of Input

As discussed, customers initially assess requirements from the aspect of importance. They are provided the flexibility of assessing in both qualitative and quantitative terms. Assessment is all about prediction. Assessment in qualitative terms is subjective and uncertainty inherent in subjective judgments is usually expressed by means of probability (Hampton Moore and Thomas 1973). Such probability is a measure of the degree of belief in the assessment done. This degree of belief if assigned to a single category descriptor like low, medium, high may lead to loss of information and hence it is recommended to provide degrees of belief as membership in each category [38]. This is probability distribution across grades expressed as {(Low, x %)(Medium, y %)(High, z %)} where x, y, z are degrees of belief in low, medium and high grades respectively and the sum of x, y and z must be equal to 100.

More flexibility provided to the decision maker by creating the provision to specify degrees of membership to interval grades as well as precise grades. Interval grades are necessary to describe degrees of belief [5]. The uncertainty in the measured value is certain not to lie outside this interval. Now the complete list of grades to which a requirement can be assessed with degrees of belief as follows {Low, Medium, High, Low-Medium, Medium-High, Low-High}. The last interval grade Low-High creates the provision to express ignorance i.e; the importance of the requirement is unknown. The assessment done in this manner with probability distribution and grade intervals is called Belief Decision Matrix (BDM).

1.3 Aggregation of Inputs with Interval Evidential Reasoning Algorithm

The requirements importance assessments done by the customers are aggregated applying Interval Evidential Reasoning (IER) algorithm. IER is an extension of the Evidential Reasoning(ER) approach to accommodate intervals in assessment. ER algorithm[50] is developed for aggregating multiple attributes which is based on a Belief Decision Matrix for problem modeling and the evidence combination rule of the Dempster-Shafer theory of evidence[50] for aggregation. Both ER and IER proved to be providing more rigorous yet useful results and have their prominence in a number of applications [26-30]. IER deals with interval uncertainty in assessing alternatives on an attribute. In the context of requirements Prioritization the alternatives are the requirements to be prioritized and the attributes are stakeholder groups. The data from each stakeholder in the form of Belief Decision Matrix is aggregated by applying IER. This section discusses how requirements can be assessed and aggregated with interval uncertainties under IER framework. A complete description of the algorithm can be found in [6].

Let the alternatives to be assessed are the requirements of the system designated as R= $\{R_1, R_2 \ldots\ldots R_M\}$.Let the stakeholders designated as S = $\{S_1, S_2, \ldots\ldots S_N\}$ and let the weights of the stakeholders are $\{w_1, w_2, \ldots\ldots w_N\}$ where w_i is the weight of the stakeholder group S_i with $0 \le w_i \le 1$ and

$$\sum_{i=1}^{N} w_i = 1 \tag{1}$$

let P number of evaluation grades are defined for which an attribute is assessed, as represented by

$$G = \{G_1\ G_2 \times\times\times G_i \times\times\times G_P\}$$

In the ER assessment framework because each grade G_i is a grade interval from G_i to G_i the P grades can be rewritten as follow

$$G = \{\ G_{11}\ G_{22}\ \times\times\times G_{ii} \times\times\times G_{PP}\ \}$$

where G_{ii} is the ith evaluation grade.

In the IER assessment framework the complete set of evaluation grades which are individual grades and grade intervals be as follows

$$G = \left\{ \begin{array}{ccccc} G_{11} & G_{12} & \cdots & G_{1(P-1)} & G_{1P} \\ & G_{22} & \cdots & G_{2(P-1)} & G_{2P} \\ & \cdot & & & \\ & & \cdot & & \\ & & \cdot & G_{(P-1)(P-1)} & G_{(P-1)P} \\ & & & & G_{PP} \end{array} \right\}$$

The assessment of a requirement by the stakeholder groups S_m and S_n:

$A(S_m) = \{ (G_{ij}, B_{ij,m}); i = 1 \times \times \times P ;\ j = i \times \times \times P ;\ i \le j \}$

$A(S_n) = \{ (G_{ij}, B_{ij,n}); i = 1 \times \times \times P ;\ j = i \times \times \times P ;\ i \le j \}$

Where $B_{ij,m}, B_{ij,n} \ge 0$ is the belief degree associated with the grade interval G_{ij} and the total belief degrees by definition should be 1.

$$\sum_{i=1}^{P}\sum_{j=i}^{P} B_{ij,m} = 1 \text{ and } = 1 \sum_{i=1}^{P}\sum_{j=i}^{P} B_{ij,n} \tag{2}$$

Suppose w_m and w_n are the normalized weights for S_m and S_n. Then the basic probability masses assigned to the grade interval G_{ij} by $A(S_m)$ are given by:

$$m_{ij} = w_m B_{ij,m} \ (i = 1 \ldots P; j = i \ldots P), \tag{3}$$

$$m_G = 1 - \sum_{i=1}^{P}\sum_{j=1}^{P} w_m B_{j,m} = 1 - w_m = 1 - w \sum_{i=1}^{P}\sum_{j=1}^{P} B_{ij,m} \tag{4}$$

m_G is the remaining probability mass that is to be assigned to individual grades and grade intervals in the set .

Similarly, the basic probability masses assigned to the grade interval G_{ij} by $A(S_n)$ are given by:

$$n_{ij} = w_n B_{ij,n} \ (i = 1 \ldots P; j = i \ldots P), \tag{5}$$

$$n_G = 1 - \sum_{i=1}^{P}\sum_{j=i}^{P} w_n B_{j,n} = 1 - w_n = 1 - w \sum_{i=1}^{P}\sum_{j=i}^{P} B_{ij,n} \tag{6}$$

n_G is the remaining probability mass that is to be assigned to individual grades and grade intervals in the set G.

By aggregating the two assessments the combined probability mass for each grade interval G_{ij} denoted by C_{ij} is generated by adding all the probability mass elements.

$$C_{ij} = \frac{1}{1-K}\left(-m_{ij} + n_j + \sum_{k=1}^{i}\sum_{l=j}^{P}(m_{kl} n_j + m_j n_{kl}) + \sum_{k=1}^{i-1}\sum_{l=j+1}^{P}(m_{kj} n_{il} + m_{il} n_{kj}) + m_G n_j + m_j n_G \right) \tag{7}$$

Where K is the combined probability mass assigned to the empty set ϕ.

$$K = \sum_{i=1}^{P}\sum_{j=i}^{P}\sum_{k=1}^{i-1}\sum_{l=k}^{i-1}(m_{kl} n_j + m_j + n_k) \tag{8}$$

The probability mass at large in G is denoted by C_G given by:

$$C_G = \frac{m_G n_G}{1-K} \tag{9}$$

The scaling factor $\frac{1}{1-K}$ is used to ensure that

$$\sum_{i=1}^{P}\sum_{j=i}^{P} C_{ij} + C_G = 1.$$

The assessments by all the stakeholder groups for a requirement are aggregated in a recursive manner. The overall assessment of a requirement by all the stakeholder groups represented as given below.

$$A(S) = \{(G_{ij}, B_{ij})\ (i = 1....P, j = i....P)\}$$

Where B_{ij} is the Combined Belief Degree by all the customers about the importance of a requirement to the grade G_{ij} given by $B_{ij} = \frac{C_j}{1 - C_G}$ (i = 1... P; j = i ... P)

(10)

1.4 Utility Theory to Compute Ranks

The Combined Belief Degrees data obtained using (10) is not does not adequate to rank alternatives Hence Utility theory [6] is employed to compute the minimum, maximum and average expected utilities. The average utilities when arranged in sorted order give the ranks of the requirements. Suppose u (G_{ii}) is the value of the grade G_{ii} with $u(G_{i+1,i+1}) > u(G_{ii})$ as is supposed that $G_{i+1,i+1}$ is preferred to G_{ii}. If the uncertainty turned out to be favorable to the assessed alternative, then B_{ij} could be assigned to the best grade in the interval H_{ij} which is H_{jj}, then the maximum value would be calculated as:

$$u_{\max}(S) = B_{ij}\sum_{i=1}^{n}\sum_{j=1}^{n} u(G_j) \tag{11}$$

If the uncertainty turned out to be against the assessed alternative, the belief degree B_{ij} assigned to worst grade in the interval H_{ij} then the minimum value would be given by:

$$u_{\min}(S) = B_{ij}\sum_{i=1}^{n}\sum_{j=1}^{n} u(G_i) \tag{12}$$

The average of the two is given by:

$$u_{avg}(S) = \frac{u_{\max}(S) + u_{\min}(S)}{2} \tag{13}$$

4.5 Obtain Degree of Satisfaction and Reach Consensus

The prioritized list obtained by aggregating the assessments by the end users is now studied by the Project Manager and/or developer to assess from the aspect of cost and optimal set of requirements that provide high customer value within the cost constraints are identified. Two lists are prepared as selected and discarded list of requirements for the current release, distributed to the customers along with supporting information like priorities and combined belief degrees generated for importance aspect, cost aspect, final priorities combining both importance and cost aspects, percentage of preference of one requirement over other, histograms showing the combined belief degree customer group wise and requirement wise etc. This pack of information about the requirement priorities will be towards convincing the end user to stay satisfied with the selected and discarded list of requirements.

The end users are in turn requested to provide degree of satisfaction with the prioritized list. As this is subjective and varies from person to person, the degree of satisfaction is input in the form of probability distribution across individual grades and grade intervals. The same set of grades used for requirements prioritization is used. All these inputs are aggregated with IER and if Combined Belief Degree is nearer to one, it means that majority of the end users are satisfied with the priorities. If not, it is the responsibility of the Project Manager to perform sensitivity analysis of all outputs and employ some structured approach for obtaining consensus with the dissatisfied. If the list cannot be materialized even after negotiation, redoing the assessment of requirements to be considered.

4 CASE STUDY

A case study was conducted to prioritize the requirements of Examination System to be implemented for Adikavi Nannaya University, India. The motto of this system is “doing something is better than nothing” as the system is being operated manually since its inception. This system is an internal application development and hence the two groups of relevant stakeholders identified are students, who are interested to get the automated system and the System Manager(SM), employee of the University, played the role of both Project Manager and developer, responsible for implementing the requirements. Students were categorized into 2 groups Technical and Non Technical Students designated as TS and NTS respectively. They were assigned the weights 0.6 and 0.4 respectively as it is evident that technically sound students can assess the system in a better manner than their counterpart and

(1) is also satisfied. Four students are selected under each group as representatives for the entire student community of the University. All students under a group carry the same weight. As students are end users, they were asked to assess the requirements from the aspect of importance. SM's concern is the cost as discussed in 4.2. But as this is an internal application development other aspects like technical difficulties, resource constraints and any other policy matters of the Institute were the concern. A total of 11 requirements were identified, placed in a spreadsheet and distributed to students. The dependencies among the requirements were not taken into consideration. A sample assessment is as shown in Figure 2. The grades across which requirements to be assessed are Low, Medium, High, Low to Medium, Medium to High and Low to High designated as L, M, H, L-M, M-H and L-H respectively. The total number of grades in the set proved to be sufficient enough for assessment. Complete ignorance about the importance of a requirement will be assessed under Low to High. The sum of all assessments for a requirement must be 100 as mentioned in (2). The entire process of carrying out the assessment completed within 10 minutes as the spread sheet data found to be very user friendly with attached comments. Apart from this, the grade interval Low to High which allowed specifying ignorance was found to be interesting as it created a sense of confidence in the decision maker about the trust worthiness of the method.

REQUIREMENTS IMPORTANCE OF UNIVERSITY EXAMINATION SYSTEM							
	LEVELS OF IMPORTANCE						
REQUIREMENTS IDENTIFIED	L	M	H	L-M	M-H	L-H	TOTAL
R1:Login		20	80				OK
R2:Mid Marks Display	20	30	50				OK
R3:Online ApplicationSubmission		20		80			OK
R4:Online Payment of Exam Fees			80				Sum must be equal to
R5:Download Hall Ticket						100	OK
R6:SMS Alerts to Mobile	60	40					OK
R7:View Semester end Result-individual					100		OK
R8:View CGPA/SGPA of all students			100				OK
R9:CGPA/SGPA to Marks Converter				20			Sum must be equal to
R10: Online Conduct of Exams				75			Sum must be equal to
R11:Examination System Info			100				OK

FIGURE 2 : REQUIREMENTS IMPORTANCE: UNIVERSITY EXAMINATION SYSTEM

The assessments from all 8 students were consolidated to produce Belief Decision Matrix as shown in Table 3. This data is aggregated applying Interval Evidential Reasoning Algorithm. The step by step calculation can be found in [25]. Basic probability masses were calculated using (3), (5) and remaining probability masses using (4), (6). The next step is to compute combined probability masses using (7) and the probability mass at large in G using (9). Finally Combined Belief Degree about the importance of a requirement by both TS and NTS is generated using (10). This process is repeated for all requirements. As this data is not sufficient to produce ranks minimum, maximum and average utilities are generated applying (11), (12), (13) and as shown in Table 4. The average utilities when arranged in sorted order produced priorities of the requirements. The entire calculation is done with very much less effort as the calculations were done by applying formulas in excel spreadsheet. By reading the prioritized list, System Manager is able to get an understanding of the students' expectations of the examination system. The SM has studied the prioritized list from other relevant aspects and identified which set of requirements can be implemented in the current release within the identified limitations and at the same time maximize student satisfaction. Requirements which will be implemented in the current release and which will be postponed for later release are marked as shown in Table 5.

TABLE 3
COMBINED BELIEF DEGREES

Req Id	Student Group	L	M	H	L-M	M-H	LH
R1	TS	0	25	75	0	0	0
	NTS	0	10	90	0	0	0
R2	TS	0	20	67.5	0	12.5	0
	NTS	50	22.5	27.5	0	0	0
R3	TS	0	35	65	0	0	0
	NTS	0	5	42.5	20	32.5	0
R4	TS	5	30	40	0	5	20
	NTS	37.5	17.5	37.5	7.5	0	0
R5	TS	0	30	62.5	17.5	0	0
	NTS	0	22.5	77.5	0	0	0
R6	TS	0	12.5	75	0	12.5	0
	NTS	7.5	60	32.5	0	0	0
R7	TS	0	22.5	77.5	0	0	0
	NTS	0	20	80	0		0
R8	TS	0	10	65	0	0	25
	NTS	0	20	80	0	0	0
R9	TS	12.5	32.5	55	0	0	0
	NTS	0	35	42.5	0	12.5	10
R10	TS	25	18.75	31.25	0	0	25
	NTS	52.5	17.5	0	0	5	25
R11	TS	0	12.5	87.5	0	0	0
	NTS	5	35	60	0	0	0

The prioritized list is distributed to the students specifying R1, R2, R6, R7, R8, R9, R11 can be implemented immediately. In the initial discussions, it was the case that Requirements R3, R4, R5, R10 could not be implemented. R4 is online payment of exam fees with priority 11, and this is not approved for implementation as the University follows the practice of collecting exam fees along with admission fees. So, the implementation of this requirement does not come under the jurisdiction of Examination system. So, some means of tracking the fees details only should be established. R3 and R5 are online application submission and online download of hall ticket. The System Manager initially said no for this keeping in mind the resource constraints and the complexity of coordination among different cases of students like regular, backlog, detained, readmitted etc. But as these requirements were ranked 4 and 6 respectively, System Manager has decided to allow online application submission and online download of hall ticket for regular students and all other cases to undergo manual procedure.

TABLE 4
MINIMUM, MAXIMUM AND AVERAGE UTILITIES

Req.Id	Utilities		
	MIN	MAX	AVG
R1	0.9512	0.9512	0.9512
R2	0.7092	0.7207	0.7150
R3	0.8109	0.9036	0.8573
R4	0.6788	0.7327	0.7058
R5	0.9106	0.9167	0.9137
R6	0.8120	0.8229	0.8175
R7	0.9406	0.9406	0.9406
R8	0.9200	0.9497	0.9309
R9	0.8003	0.8606	0.8305
R10	0.4743	0.6299	0.5521
R11	0.9005	0.9005	0.9005

In [3], it is argued that how a high value requirement for the customer can be neglected for the reason of cost, schedule and any other constraints. In view of this, partial functionality was promised. R10, online conduct of exams, postponed as it seemed to be unrealistic and crazy. It does not mean that discarded Requirements will not be implemented at all but will be held in the waiting mode and can be made available in the next release. This information regarding the approval or denial of requirements is distributed to the students complemented by supplementary information like combined belief degrees for each requirement in the form of histogram, how much one requirement has priority over another. The degree of satisfaction with the prioritized list is obtained by the students and it is aggregated to give combined belief degree as 0.98. As this is nearer to 1, it is evident that majority of the students are satisfied with the requirements. As this was an in house application, negotiating with the students was found to be not a difficult task.

TABLE 5
SELECTED AND DISCARDED LIST OF REQUIREMENTS

Req.Id	Rank	Yes/No/Partial
R1	1	Yes
R2	10	Yes
R3	6	Partial
R4	11	No
R5	4	Partial
R6	8	Yes
R7	2	Yes
R8	3	Yes
R9	7	Yes
R10	12	No
R11	5	Yes

6 CONCLUSIONS AND FUTURE WORK

This paper proposed a novel approach for RP by incorporating the imprecise nature of human judgment during prioritization. This was applied for a small in house project and the results found to be encouraging. This approach is found to be simple, inexpensive, scalable and at the same time providing reliable and useful results.

On a small project the stakeholders can probably agree on requirement priorities informally. Large projects require rigorous prioritization techniques. Literature does not address much about requirements prioritization in the case of large projects. Our next task is to apply RUPA for a large project and see whether the approach was trustworthy i.e; whether we can arrive at the same conclusions as with the small project . The convincing benefits of the approach to be understood by comparing the results with the most traditional requirements prioritization technique, Analytic Hierarchy Process [46]. In the case study, only two groups of stakeholders are involved. A real time project has to be verified with a more number of stakeholder groups participating. The other concern is, if the combined belief degree specifying the overall degree of satisfaction is not nearer to one, how to find the most and least dissatisfied stakeholders.

Finally, an approximate method of uncertain assessments termed as Pignistic Transformation [49] to be applied to IER to interpret its validity. If it is proved to be correct, complex IER calculations can be made simpler as the input data for aggregation with Interval Evidential Reasoning is reduced to input data for aggregation with Evidential Reasoning.

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