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THE APPROACH USING CUMULATIVE VOTING AND SPANNING TREE TECHNIQUE IN IMPLEMENTING FUNCTIONAL REQUIREMENT PRIORITIZATION: A CASE STUDY OF STUDENT'S FINANCIAL SYSTEM DEVELOPMENT

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ABSTRACT

Requirement Prioritization (RP) occurs while gathering the user requirement of system development. This is to ensure the process for eliciting requirements meets the business flow as well as project management such as timeline and cost. The techniques used in RP are a combination of ratio and ordinal scales that are cumulative voting and minimal spanning tree techniques. The significance of RP is to improve project development time which may require many months or several years, therefore it is essential to determine the requirements that should be implemented at the beginning. From the result, the RP combination technique can be applied in identifying the priority of functional requirements for the case of developing a student's financial system.

Keywords: *Requirement Prioritization, Functional Requirement, Cumulative Voting, Spanning Tree, Student Financial System.*

1. INTRODUCTION

Building new software or system is a complex task. The development of a detailed study of requirements prioritization (RP) is necessary to give value to the customers' business and make the product competitive in the market [1]. Many participants were involved during software/ system development. It requires participation among users, stakeholders, developers, business analysts, systems analysts, programmers, quality assurances and other stakeholders. Various techniques and approaches are being used to fulfill the requirements and satisfaction of users and their stakeholders. To produce high-quality software, the primary concern of the development team is to select and rank the most favorable requirements from the pool of requirements with the aim to maximize stakeholder stratification within budget and resource constraints [2]. This decision-making turns out to be complicated and tedious when the number of requirements is more. Many factors need to be considered when deciding in choosing the requirement priority.

RP is an important activity during requirement management and is defined as giving order or importance to requirements [4]. To add value to the customers' businesses and make the product competitive in the market, a thorough analysis of requirements prioritization (RP) must be developed [1].

RP performs a key role in the development of software by improving its budget, scheduling, and quality [3]. RP is vital to software quality and success of software development, especially Agile

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Software Development as most software projects have many candidate requirements, each with constraints on the timing and cost, to be considered [5]. RP helps the developer to understand and set the priorities for certain modules to be developed. It also assists the project manager to set the timeline and project cost of system development.

Typically, there are more client requirements than features that can be developed in the time allotted and with the resources at hand. Because of this, some of the desired features won't be finished or will be added in later releases [27]. Most projects include many software requirements which need to be prioritized according to the limited resources in terms of time, budget, and customer satisfaction which is the major purpose of software development [6]. Through RP one can easily manage the resources such as budget and schedule by determining the highest priority requirements before the low priority ones [3].

The first step in developing the proposed software is to identify what stakeholders really need. RP is considered one of the critical activities that help to implement suitable requirements according to stakeholders' needs [13],[30]. In practice, a software system's success depends on the correctness, completeness, and consistency of the user's functional requirements [32], [34].

The focus of RP implementation is user involvement in the development process. However, all the stakeholders give their perceptions and agree on the requirements that a specific software release should contain [3].

The main contributions of this paper can be summarized as follows:

- Applying the combination techniques of requirement priorities in developing the student financial system.
- The outcome of the combination technique being used for determining the expected time and duration of system development.

RP is not an easy task; many authors have worked on prioritization and suggested several techniques [4]. The RP technique is either one or can be a combination of many techniques available. The discussion of RP techniques in the Literature Review is being presented more in Section 2. The research design process is discussed in Section 3. The findings and discussion of the results are presented in Section 4. Finally, Section 5 concludes this paper.

2. LITERATURE REVIEW

The requirements engineering process consists of five activities: requirements elicitation, requirements analysis, requirements specification, requirements validation, and requirements management [30], [34]. Among this sub-process, requirements elicitation is the key process to identify the need of the different types of stakeholders [31]. All this process is important and will affect the development of the system if it is not being managed effectively. There is various type of requirements that need to manage. One of the requirements like software requirements namely Business Requirements (BR) that deal with the benefits of implementing requirements, Process Requirements (PR) that deal with time and cost issues during development, Functional Requirements (FR) that deal with the actual functionalities of the software, and finally Non-Functional Requirements (NFR) that deal with requirements such as usability, security, and performance [12]. For this research study, FR has been considered as the development perspective to validate the proposed adaptive RP technique.

To identify the FR prioritization, various discussions and confirmation from respective users are vital. Various techniques are used in the industry for RP, but none of them can fulfill the industry requirements and expectations of the experts [13]. Some are suitable for a small number of requirements, and others can be used in very complex projects involving many variables [5]. Various stakeholders are participating in the system development to prioritize the requirements in a precise way according to their importance, therefore, those requirements can be ordered in execution [6]. The iterative process takes place to obtain the confirmation of RP identification.

A few of the popular RP techniques are categorized as [5], [15]: Nominal scale, Ordinal scale and Ratio scale as depicted in Figure 1 [6]. The nominal scale comprises the undermost appraisal level and incentive according to a numerical perspective [16]. MoSCoW (Must have, Should have, Could have and Would have) requirement is based on human opinion, based on their experience, desire and influencing factors at that time such as market demand, cost, risk, time and resource [11]. In Numerical Assignment techniques, each requirement could be assigned with a number scale from 1 to 3 to identify its importance, with the meaning of (1) Does not matter, (2) Rather important and (3) Very important [6].

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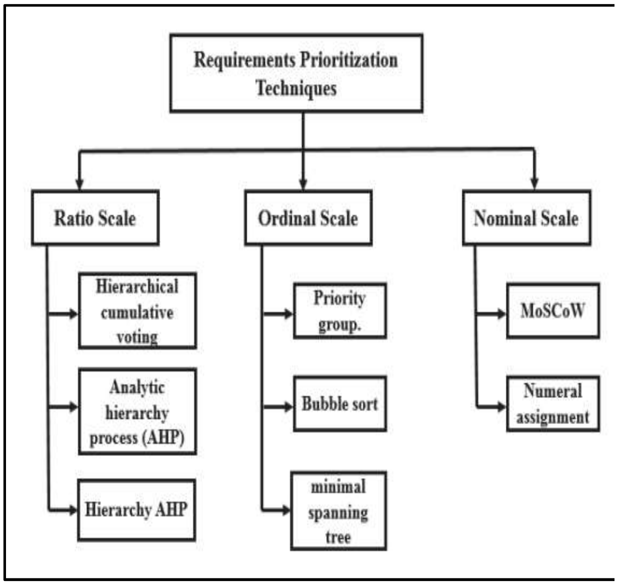

Figure 1: RP Technique Classification

The ordinal scale generates ranked lists of requirements [6], [15]. The priority groups technique is identical to the numerical assignment technique, which assigns every requirement to one of three groups: low group, medium group, and high group [6]. In bubble sort prioritization, two requirements are taken and then compared manually; if the person conducting the comparison feels that 1st requirement should have higher priority than the other requirement then he/she swaps the priority and continues this process until all the requirements have been compared. The result will be a prioritized set of requirements [11].

Another prioritization technique suggested by [28] is the Minimal Spanning Tree (MST). According to the MST technique, redundancy won't occur if the decisions are made in a way that ensures consistency, in which case there will be only n-1 comparisons (n is the number of requirements). In a minimum-spanning tree, distinct pairs of needs are built. It is a directed, sparsely connected graph [27]. The Spanning Tree represents the hierarchical order and dependencies of all interrelated requirements. From Spanning Trees, one can easily pairwise compare requirements with Analytic Hierarchy Process (AHP). FRs are collected from any sources using appropriate elicitation techniques and must be specified in the form of Software Requirement Specification (SRS) [12]. The techniques involve generating a ranked list of requirements. Then, it will show one requirement is more important than another requirement. It is also identifying the successor for the requirement. It is also identifying the successor for the requirement. Then, a diagram of a Spanning Tree will be developed and will be discussed further in Sections 3 and 4.

The Ratio scale is considered more powerful (the scale often ranges from 0 - 100 percent) as it is feasible to quantify how much more significant one criterion is compared to other scales. The absolute scale, which can be utilized in instances when an absolute number can be supplied, is an even more powerful scale (e.g., the number of hours). More advanced evaluations and calculations are feasible with increasing levels of measurement [17]. The relative difference between needs can be determined using ratio scale methods [18].

Cumulative Voting (CV) is a ratio-scale requirements prioritization technique where the customers/stakeholders are given a fixed number of units used for prioritization of requirements by giving the vote to the requirements that the customers/stakeholders think are important or deliver the highest functionality [11]. According to [25] and [26], CV is a simple and effective method for medium-large sized requirements. Numerous approaches for prioritizing tasks have been developed and presented, but none of them have been implemented considering the interdependencies between FRs. This CV method had been demonstrated by [6] as an easy strategy to employ and is thought to be one of the most precise techniques when choosing these requirements. It is also one of the fastest strategies, but it is not appropriate for processing a large volume of needs.

However, according to [6], when there are too many needs, this CV method will not work properly, the prioritizing calculation will be incorrect, and the points will not add up to 100. Keeping track of how much has been assigned and how much still needs to be disposed of might be challenging.

Analytic Hierarchy Process (AHP) is the most frequently discussed prioritization technique within decision-making in requirements engineering [9], [10], [12], [14], [19], [20]. AHP is designed for decision-making of a complex type [15]. AHP is led by comparing all possible pairs of hierarchically categorized entities such as requirements as well as stakeholders for obtaining comparative priorities for all objects [9]. AHP specifies the parameters and substitutes for each requirement and uses them to construct a hierarchy to activate pair-wise comparisons; then the users can determine their favorites for each pair of attributes by assigning a decision scale [14].

In developing this system, the project team selected the CV technique compared to the AHP technique in analyzing the prioritization requirements before constructing the Spanning Tree. CV is being recognized as one of the easiest to use, fastest, and most accurate approaches. When used in its most basic form, it has some robustness issues related to tactical voting and demands some mental work when used for lists of many items, therefore it represents an ideal way for conducting prioritization sessions [19], [20], [25].

2.1 Problem Statement

There are numerous different techniques presented in the literature on how to prioritize requirements [18]. In addition, the RP techniques are categorized into nominal, ordinal, and ratio scales [3], [18]. The main philosophy is to identify and manage which techniques are suitable based on scalability of project development. The aspects of requirement prioritization can be categorized into two different categories: commercial aspects and technical aspects [39]. Technical aspects like time, cost, penalty, and risk should be considered important aspects of requirements prioritization [39][18]. Meanwhile, the commercial aspects that can be included in this category are the importance, sale, strategy, customer satisfaction, customer importance, marketing, financial benefits, product's users, product's business, and product's technology [39]. However, certain factors that cause chosen techniques in RP, such as large number of choices making the procedure of prioritization complicated [29].

3. Research Design Process

The research method design step-by-step approach is shown in Figure 2. The researcher performs exhaustive research activities by analyzing and determining various existing requirement prioritization techniques. Prioritization is performed by stakeholders (users, developers, consultants, marketing. Representatives, or customers), under different perspectives or positions, who respond to questionnaires appropriately designed [29]. Prioritizing requirements is a crucial activity in developing a system. Therefore, prioritization facilitates the development of software for users with specialized demands. In this research, the engagement of the main user and developer is essential during the development of the requirement listing. A series of meetings and discussions were held during this activity. This is to ensure all the requirements have been collected and noted in the listing.

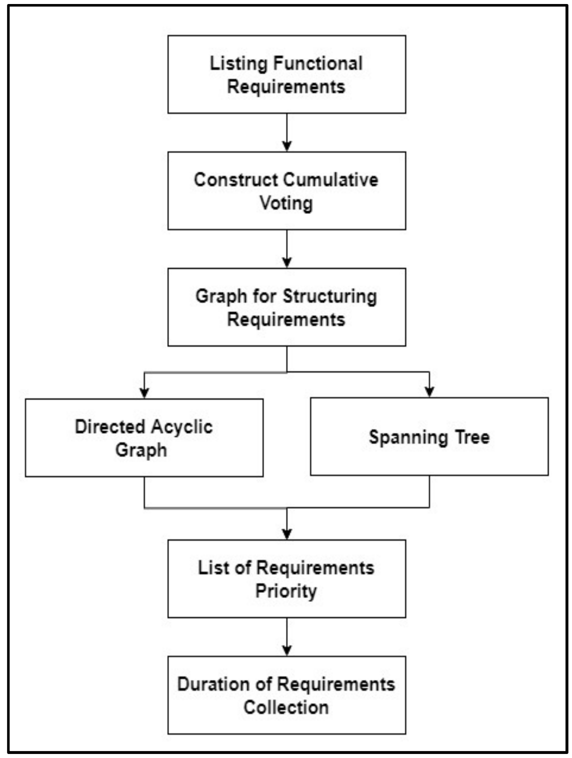

Figure 2: Research Design Process

The user identifies and lists all the requirements as shown in Table 1 below. The FR collected from the user is represented in the node symbols FR1, FR2, FR3, FR4, FR5, FR6, FR7, FR8, FR9, FR10, FR11, FR12, FR13, FR14 and FR15. After listing all the requirements, the next step is to prioritize all these requirements according to the urgency of the requirements. Then a series of questionnaires is set by the developer to construct the priority of the functional requirement listed.

Table 1: Listing of FR

List of FR	FR ID
Utilities	FR1
Bank / Students Receipts	FR2
Invoice Generation	FR3
Debit/Credit Notes	FR4
Sub-ledger	FR5
Exemption for Students	FR6
Payment for SGS	FR7
Discount Notes	FR8
Refund Payments	FR9
Sponsorship	FR10
Sponsorship – EPF	FR11

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Advanced Payments	FR12
Deduction Salary (Tuition Fees) – SPSM	FR13
Bad Debt	FR14
Update Payments	FR15

To construct the Requirement Priority (RP), the ratio scale Cumulative Voting (CV) method technique is being applied based on the rating scale as depicted in Table 2 below. Each stakeholder is given a constant amount of imaginary units that they can use for voting in favor of the most important issues [29]. In this case, the number of imaginary units assigned to an issue represented the respondent's relative preference (and therefore prioritization) concerning to the other issues is defined as a rating scale as shown in Table 2.

Table 2: Rating Scale

Rating scale	Definition
1-3	Least important
4-6	Much more important
7-10	Absolute most important

CV is more suitable for medium to large size requirements and more effective where determining the priorities of requirements is too difficult compared to when the size of requirements is too large, it becomes difficult to prioritize with a voting method. This technique is user-based as it is referred to the inputs of users [4]. The points given by each user are then accumulated, thus it's called a cumulative voting point. In this research, the algorithm to compute the cumulative voting is being developed.

Algorithm to compute the cumulative voting (CV) of FR:

Step 1: All user is responsible to provide a value of the rating for each requirement listing based on the Rating Scale in Table 2.

Step 2: As soon as all the rating values are assigned, then compute the sum of the rating scores and store it in the TOTAL column as shown in Table 3.

Step 3: Sort the FR based on the total sum of the rating scale from the highest to the lowest value. The result is shown in Table 4.

The algorithm above proves to show that Cumulative Voting (CV) is a straightforward technique for determining the priorities of requirements [29].

Next, FR priority will be assigned using the presented node symbols as shown in Figure 3 below. The priority of each FR is based on the cumulative voting decided by the users in Table 3. All FRs connected using the Directed Acyclic Graph (DAG) and converted possible numbers of Spanning Tree results as shown in Figure 4 below. DAG is a simple yet effective means of discussing causal issues in clinical and epidemiologic research, and it can assist in the design of studies and the statistical analysis of data [35]. In this study, the Spanning Tree within the DAG is used to assess the need for prioritization. It will display a complete track for a specific need, via which all other requirements must be established. Depth First Searching (DFS) or Breadth-First Searching (BFS) can both produce Spanning Trees.

The Depth–First Search (DFS) algorithm starts at the root of the tree (or an arbitrary node in a network) and explores each branch as far as feasible before returning to the root. Whereas the BFS algorithm likewise starts at the root of the tree (or any random node of a graph), unlike DFS, it first investigates the neighbor nodes before moving on to the next level neighbors. In other words, BFS investigates vertices in order of their distance from the source vertex, where distance is defined as the shortest path between the source vertex and the node [4].

Finally, after the list of requirements priority has been set, the duration for requirements is planned. The durations are determined from the discussions with the users, to set the priority of the requirement and take into consideration the complexity of the requirements.

Table 3: Cumulative Voting for functional requirements

Functional Requirement	FR Id	User 1	User 2	User 3	User 4	TOTAL
Utilities	FR1	9	8	9	9	35
Bank / Students Receipts	FR2	9	9	8	8	34
Invoice Generation	FR3	8	7	8	8	31
Debit/Credit Notes	FR4	7	7	7	7	28
Sub-ledger	FR5	7	5	6	7	25
Exemption for Students	FR6	8	8	8	8	32
Payment for SGS	FR7	4	4	4	5	17
Discount Notes	FR8	7	6	7	7	27
Refund Payments	FR9	6	6	5	5	22
Sponsorship	FR10	7	6	5	6	24
Sponsorship - EPF	FR11	6	5	6	6	23
Advanced Payments	FR12	5	4	4	5	18
Deduction Salary (Tuition Fees) - SPSM	FR13	4	4	4	4	16
Bad Debt	FR14	4	4	4	3	15
Update Payments	FR15	5	5	5	5	20

Table 4: Functional Requirement Priority

Functional Requirement	FR Id	Priority	Chain / Parallel	Successor / Required For
Utilities	FR1	1		All
Bank / Students Receipts	FR2	2		FR5
Exemption for Students	FR6	3		
Invoice Generation	FR3	4	a	FR4, FR8
Debit/Credit Notes	FR4	5	a	FR3, FR8
Discount Notes	FR8	6	a	FR3, FR4
Sub-ledger	FR5	7		
Sponsorship	FR10	8	b	FR11
Sponsorship - EPF	FR11	9	b	
Refund Payments	FR9	10		
Update Payments	FR15	11		FR2
Advanced Payments	FR12	12		
Payment for SGS	FR7	13		
Deduction Salary (Tuition Fees) - SPSM	FR13	14		
Bad Debt	FR14	15		FR3, FR4, FR8

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4. FINDINGS AND DISCUSSION

[37] stated that requirements prioritization (RP) is known as giving a higher priority needs or higher order and it is a crucial activity for effective requirements management. They also revealed that Functional Requirements (FRs) are those specifications that the system must meet to function. Prioritizing FRs is especially important when concurrent team members will implement the requirements. For requirements to be supplied on time, it is required to give some requirements prominence and priority over others [37].

From the preliminary discussion with the users, there are 15 FRs needed for the system development as shown in Table 1. The total cumulative voting given by the users of the system is shown in Table 3. From this table, it shows that FR1 got the highest cumulative voting point with 35 points. It's followed by FR2, FR6 and FR3 with 34, 32 and 31 points respectively.

The table shows that FR4, FR8, FR5, FR10, FR11, FR9 and FR15 can be grouped into the middle cumulative voting point ranging from 20 to 28 points.

The least cumulative voting points are grouped by FR12, FR7, FR13 and FR14 with cumulative voting points between 15 to 18 points. Table 4 shows the sorted priority order for the FR with the detail chain and successor level. It shows that Utilities (FR1) is the most important task as it is the top priority, and it is also required for all other tasks. Three tasks, Invoice Generation (FR3), Debit/Credit Notes (FR4) and Discount Notes (FR8), seem to be paralleled (chain *a*) despite being ranked differently. This situation also happens to Sponsorship (FR10) and Sponsorship-EPF (FR11) which are parallel (chain *b*) to each other.

Figure 3 shows that FR1 is a requirement that is needed for FR2, FR6, FR3, FR4, FR8, FR5, FR10, FR11, FR9, FR15, FR12, FR7, FR13 and FR14 for its implementation. This relationship demonstrates that FR1 must be implemented and completed before the other FRs may be implemented.

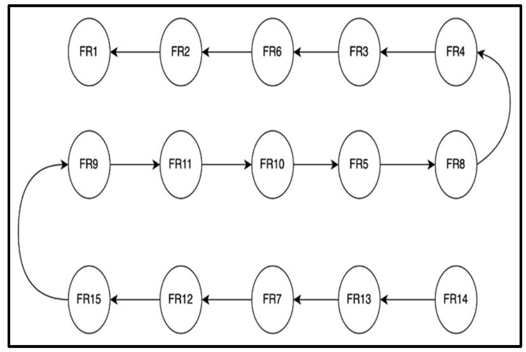

Figure 3: Assigning priority to Requirements in Graph

On the stack, a record of any visiting node or demand will be kept. Begin traversing the complete leaves of a given branch with DFS. When the branch's dead point is reached, the branch's prerequisites will be popped out one by one until the branch's start point is reached. The same procedure will be followed for the following branch. The term "dead point" refers to the point at which requirements are no longer required for any reason.

[12] stated that a spanning tree makes prioritizing simple to determine how important a given demand is with other requirements.

According to [28], to construct the Minimal Spanning Tree method there are three phases of a prioritization session are involved:

1. As preparation, outline n - 1 distinct pair of requirements in advance so that a minimal spanning tree can be built.
2. As execution, utilizing the scale in Table 2, compare each pair of requirements listed.
3. As a presentation, determine the relevance of the missing intensities by averaging the current intensities over all potential connections.

Due to the drastically decreased amount of pairwise comparisons, the minimal spanning tree method is highly quick. On the other hand, because all redundant information has been eliminated, it is more susceptible to judgment errors [6, 28].

The Spanning Tree in Figure 4 above, shows all potential trees in which the starting point will be the requirement required for other needs, so that the pre-requisite requirement will rise to the top as a parent, and all requirements that require pre-requisite requirements will appear as children and sub children. It shows that all the trees will end with FR1.

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Figure 4 also demonstrates that FR1 is required for all process trees thus making it the top priority. This figure also shows that trees 1 to tree 5 will start from FR6, FR9, FR12, FR 7 and FR13; and end with FR1 as FR1 is not required from any other requirement. This means that those processes are more straightforward. As for tree 6, it shows that despite having a lower priority, FR14 is much required for three other tasks which are FR4, FR3 and FR8.

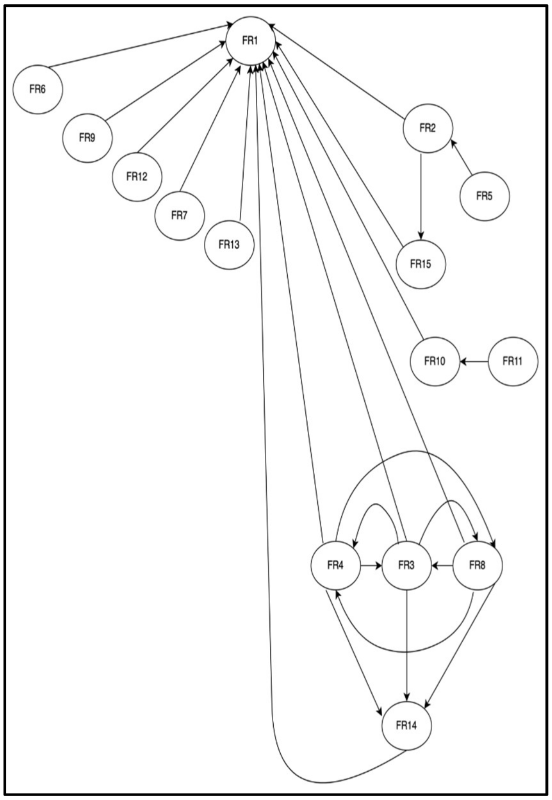

Figure 4: Directed Graph Connecting Different Requirements

On the other hand, trees 7, 8 and 9 show that FR4, FR3 and FR8 are required among each other at a simultaneous time for each task to be completed. Tree 10 shows that FR10 and FR11 are parallel to each other but FR10 is required by FR11 and not vice versa.

As in tree 11, it shows that FR15 which required FR1 is also required for FR2 in tree 12 whereby in tree 12 it shows that FR2 is also required for FR5.

To see the level of priority clearer, the spanning tree from Figure 4 can be broken into separate spanning trees as shown in Figure 5 below.

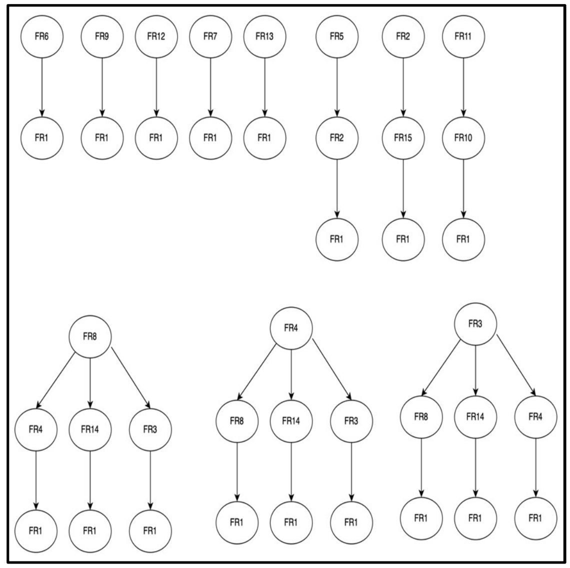

Figure 5: Spanning Trees from Graph of Figure 4

Based on Figure 5, the priority of FR8 will be greater than FR4, FR14 and FR3. Whereas the priority of FR4 will be greater than FR8, FR14 and FR3. Lastly, the priority of FR3 will be greater than FR8, FR14 and FR4.

Details summary of the priority for each FR as compared to the others is as below,

1. FR1 > FR6
2. FR1 > FR9
3. FR1 > FR12
4. FR1 > FR7
5. FR1 > FR13
6. FR1 > FR2 > FR5
7. FR1 > FR15 > FR2
8. FR1 > FR10 > FR15
9. FR1 > FR4 > FR8
10. FR1 > FR14 > FR8
11. FR1 > FR3 > FR8
12. FR1 > FR8 > FR4
13. FR1 > FR14 > FR4
14. FR1 > FR3 > FR4
15. FR1 > FR8 > FR3
16. FR1 > FR14 > FR3
17. FR1 > FR4 > FR3

Lastly, the duration needed in collecting the requirements (in days) was decided together with the users as shown in Table 5.

Table 5: Duration (Days) Spend for Requirements Collection

Tasks	Task Id	Priority	Duration (Days)
Utilities	FR1	1	10
Bank / Students Receipts	FR2	2	6
Exemption for Students	FR6	3	2
Invoice Generation	FR3	4	4
Debit/Credit Notes	FR4	5	4
Discount Notes	FR8	6	2
Sub-ledger	FR5	7	3
Sponsorship	FR10	8	17
Sponsorship - EPF	FR11	9	4
Refund Payments	FR9	10	6
Update Payments	FR15	11	5
Advanced Payments	FR12	12	3
Payment for SGS	FR7	13	3
Deduction Salary (Tuition Fees) - SPSM	FR13	14	3
Bad Debt	FR14	15	4

Table 5 above shows the duration for FR1 and FR10 take a longer time to settle the requirement process compared to other FRs. FR1 required 10 days to get the whole idea of system development. Whereas for FR10, the process is more complicated because the developers need adequate information from various departments such as the International Office, Loan and Sponsorship Unit, Bursary Unit, and Islamic Center.

Table 5 analysis reveals that the method used for this development performs better with the combination of Cumulative Voting (CV) and Spanning Tree in terms of the following:

1. ***Duration:*** a rather simple, and easy to use in producing priorities during developing the system.
2. ***Speed:*** the speed CV technique is relatively quick and the fastest method for producing priorities. CV techniques that are used can prioritize the requirements in each group independently of other groups before Spanning Trees is applied.
3. ***Accuracy:*** the most accurate of methods in developing this system.
4. ***No. of requirements:*** CV technique is fit for a medium to a large number of requirements, and the same for ordinal scale,
5. ***Scalability***: Scalability in the CV technique is high. Therefore, this CV technique can be more suitable for this development of the system.
6. ***Granularity***: The CV technique can ensure fine prioritization of the requirements in this system.
7. ***Complexity***: The CV technique is considered a complex technique according to the literature. CV technique can simplify the prioritization of requirements by reducing the number of requirements in each group.

Overall, the findings show that by using Cumulative Voting and Spanning Tree method for students' financial systems the developer can set the priority of every requirement. It shows that for other tasks to be completed, they must start with the Utilities (FR1). Not only FR1 received the highest Cumulative Voting point, but it was also given the top priority. Therefore, it can conclude from the findings that FR1 which is Utilities is the most crucial task for developing this student's financial system.

Findings also show that some tasks can be worked independently without requiring pre-requisite from other tasks except FR1. It can be seen from Figure 4, these tasks are F6, F7, F9, F12 and F13. Other tasks can be seen to require pre-requisite from other tasks up to the maximum of two other tasks.

The findings show the priority does not reflect the duration needed to complete the tasks. This can be seen from Table 5 where some tasks needed longer duration despite being fewer priorities. This is due to the complicatedness of the process for each task.

[36] stated that the Cumulative Voting (CV) method stands out for being simple to comprehend. Compared to AHP, stakeholders take less time to become comfortable with the technique. So long as fuzzy values are not taken into consideration, CV is faster than AHP at carrying out tasks.

5. CONCLUSION

The proposed approach aims at prioritizing the requirements of a system under development considering the inputs from stakeholders and developers. The user, which is the main stakeholder provides their inputs as intuitionistic values especially in providing and rating the votes for each requirement listing [2].

In conclusion, the RP combination technique can be significantly applied in identifying the priority of FR for the case of developing a student finance system. This case study approach was based on real-life practices and processes at the Private Institute of Higher Learning Education in Malaysia. The principal finding of this study is that the combination of cumulative voting and the spanning tree technique can be applied in identifying the priority of FR. The detailed summary of priority for each FR can be determined from the CV Priority techniques and by the separate spanning tree. Hence, priority and duration needed in days were established for each FR. These results will be beneficial to student financial system developers to schedule their development tasks effectively.

It is also confirmed that this technique can also be applied to different system development such as Academic Management Systems (AMS) and Students Affairs Management Systems (SAMS) to identify the priority requirements in the future.

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