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SPHandler: Multi-criteria based intelligent stakeholder quantification system for value-based software

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ABSTRACT

Value-based is a popular term for software systems which deal with financial matters. For development of value-based software (VBS) systems the software requirements engineering (RE) process must be robust. The RE process is concerned with exploration, verification and validation of key software requirements for a given VBS system. Highly valuable requirements are required in order to design a VBS product. A set of highly valuable requirements can only be obtained from key stakeholders. Stakeholders are the entities considered as vital in success and failure of the software system. Different approaches are represented by researchers in the domain of stakeholders' analysis. The existing stakeholders' analysis approaches focus the problem in a diverse range of dimensions. The processes used in these approaches vary from each other and the use of stakeholder attributes is not uniform. The approaches are highly obscure in terms of guidelines for value quantification of stakeholders. In this research, a neuro-fuzzy inspired intelligent decision support system *SPHandler* is proposed for identification and quantification of VBS stakeholders using *stakeholder metrics*, *Neural Network* and *Fuzzy C-Means* in order to cope with issue of stakeholder quantification. The proposed system is efficient in terms of performance and reduces the bias induced by the experts during stakeholders' evaluation.

Keywords: software requirements engineering; value-based software; stakeholders; decision support system; artificial intelligence; neural networks; fuzzy c-means; clustering;

1. INTRODUCTION

The very term value-based is associated with value-based software engineering (VBSE). The value-based software (VBS) systems are the part of VBSE and are developed based on economic theory. Boehm states the term VBSE as "the explicit concern with value concerns in the application of science and mathematics by which properties of computer software are made useful to the people" [1]. The value of the VBS system is measured in terms of its economic worth or market leverage. The value of a VBS system is also taken into account based on its human services [2]. The economic aspect of the VBS systems distinguishes them from other traditional software applications. In VBS development, the value-based approaches are applied in order to understand the different economic aspects of the VBS system. "The value-based approach to software development integrates value considerations into current and emerging software engineering principles and practices, while developing an overall framework in which these techniques compatible reinforce each other" [3]. In VBS systems, an innovative idea is introduced for realization. Requirements engineering (RE) is a set of core software engineering (SE) practices related to software requirements. RE is a sub-domain of SE. In VBS development the value-based RE (VBRE) approaches are adopted. Brooks has said "the hardest single part of building a software system is deciding precisely what to build... Therefore, the most important function that the software builder performs for the client is the iterative extraction and refinement of the product requirements" [4]. Different researchers have defined RE differently. As stated by Zave "requirements engineering is the branch of software engineering concerned with the real-world goals for, functions of, and constraints on software systems. It is also concerned with the relationship of these factors to precise specifications of software behavior, and to their evolution over time and across software families" [5]. A requirement is written in a textual form, is elicited by the stakeholders and developers, and their interrelationships are managed manually [6]. Keeping in view the current business scenarios the stakeholders are seeking innovative business solutions for different software applications. Innovation is the cause of complexity in the design and development of innovative and value added systems. The complexity is the result of unclear user requirements and objectives. The complexity of the requirements can be determined through functional and non-functional aspects which are termed as function requirements (FRs) and the non-FRs (NFRs) or quality features [7]. Due to this trend of innovation different innovative RE techniques are considered as critical tools in order to remove ambiguity in the requirements [8]. Requirements elicitation phase (REP) is considered as highly significant in RE [4, 9]. RE is a challenging discipline in software development in order to make a software successful [10] and is associated with stakeholders' identification, requirements elicitation and then implementation of the elicited requirements [11].

The success of a VBS system is directly associated with a set of key FRs and NFRs. If a software application or system meets the basic requirements criteria, then the software project is successful and vice versa. The key set of valuable requirements can only be obtained from key stakeholders after applying core VBRE practices during different VBRE processes. The well managed requirements have an immense effect on the quality of the final software product [12, 13]. The well managed requirements can only be obtained after segregation of critical stakeholders from the whole universe in the domain of a given software project.

Tom Gilb defines a stakeholder as "any person or organizational group with an interest in, or ability to affect, the system or its environment" [14]. Stakeholders are key players in the RE process and possess an effective influence on the success of the software project. In order to make the project successful the functional features of the software must be in align with the critical needs or requirements of the users. The key functional aspects in case of VBS development can only be achieved by involvement of critical stakeholders in the RE process. Stakeholders usually belong to different cultures and domains. Hence, it is necessary to analyse and prioritize the stakeholders for professional software development [11, 15]. The users or stakeholders can only be satisfied if the system meets all the key needs of the stakeholders [16, 17]. A software system of good quality can only be achieved if the requirements will be of high value. Babar et al. state that "the software quality is measured based on the performance of the system, the services provided by the system and the acceptance of a system by the intended community" [18]. Different stakeholders interpret needs differently which makes the decision process complicated. Hence, it is required to find out and to add key stakeholders in the software development life cycle and they may play a vital role in adding value to the software project.

Rest of the paper is divided into 5 main sections. Section 1 is about related works in which the current literature about the research is analysed thoroughly. Section 2 is about problem formulation in which a solution is given for the stakeholder problem. Section 3 is a detailed description of the fuzzy c-means and proposed system. Section 4 describes the results. Section 5 concludes the whole study.

2. RELATED WORKS

Researchers have presented different SIQ approaches for identification of critical stakeholders. The existing SIQ approaches use different stakeholders' analysis processes and attributes for their identification and quantification. One of the most prominent theories in stakeholders' analysis is Mitchell's theory. Mitchell has divided the stakeholders into eight major categories based on stakeholders' attributes of power, legitimacy and urgency. The reported categories of stakeholders in this research are dominant stakeholders, discretionary stakeholders, dormant stakeholders, dependent stakeholders, demanding stakeholders, non-stakeholders, definitive stakeholders and dangerous stakeholders [19]. According to Mitchell's stakeholders' theory, the relationship of a stakeholder can be with any attribute or all of the three attributes of power, legitimacy and urgency [19]. "A group has power to the extent it has access to coercive, utilitarian or normative means for imposing its will in the relationship. Legitimacy is a social good and more over-arching than individual self-perception and is shared amongst groups, communities or cultures" [20]. Figure 1 depicts the Mitchells' Stakeholder Salience Theory.

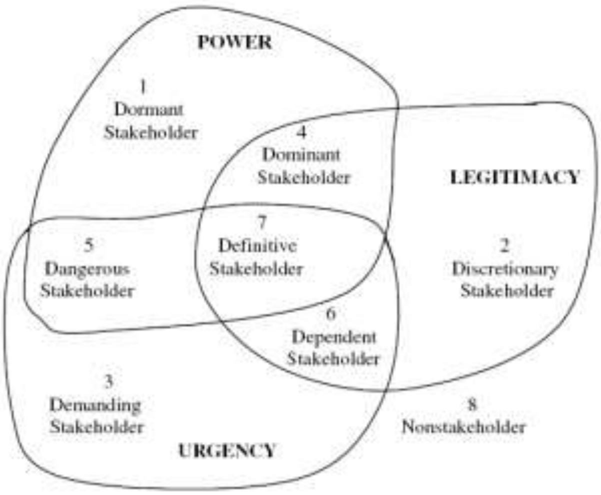

Figure. 1 Mitchells' stakeholder salience theory [19]

Pacheco and Garcia state "there is still no Stakeholder Identification Process (SIP) framework or uniform description" [21-23]. Among the current SIQ approaches, it is very difficult to decide that which approach is best for a given scenario. Among all stakeholder analysis approaches there are few approaches, may be one or two, which focus on prioritization of stakeholders while remaining focus on their identification. Using current approaches the identification and selection of valuable stakeholders is very difficult. The stakeholders' analysis approaches identify stakeholders based on their relationships, roles and influence [15, 19, 24, 25] without telling the details at process or activity level. They provide a very high level picture of the business entities. There are some approaches that do not take into account the aspects of relationships, roles and influence [26, 27].

The methods used in [28], for identification of stakeholders in an agile environment, are Freeman's method [29, 30] and Mitchell's model [19]. Freeman's method has divided stakeholders into two groups at a higher level of abstraction that are primary stakeholders and secondary stakeholders. In [31, 32] an approach is presented based on roles and types for identification and selection of stakeholders. An approach is proposed for identification and selection of stakeholders at inter-organizational level. The stakeholder's features which are considered in this approach are function, knowledge abilities, geographical position and level of the hierarchy. Though the approach is very powerful but the issue is how one will measure the level of competency among different stakeholders using these four features. A problem which is detected after implementation of the approach is associated with the profiles of different stakeholders. The four features are used to make the profiles of different stakeholders, but there are different stakeholders who have the same profiles with different ambitions or the FRs. The approach is proposed and implemented in order to find out all possible stakeholders for a given software system due to which lot of time is consumed. The approach is not cost efficient due to higher time consumptions. The selection of stakeholders is not based on their prioritization or quantification.

PisoSIA® (Stakeholder Identification and Analysis) approach is an extension in the existing approach called PISO® (Process Improvement for Strategic Objectives) [33]. The only suggestion which is given in PISO® framework is associated with the importance of stakeholders and their analysis. The extension in the PISO® framework is only supporting the stakeholders' identification and analysis and the impact of these identified stakeholders on the quality of the system. PisoSIA® is used to identify stakeholders after incorporating a change in an information system. Then the impact of that change on current stakeholders is analyzed or measured. The incorporation of change helps in identification of some new stakeholders or business entities who may add some value to the system. For stakeholder identification, Mitchell's model is integrated with PISO® that helps in the adoption of stakeholders' attributes for their selection. The focus of both PISO® and PisoSIA® is stakeholders' engagement without giving any consideration to their importance. The effectiveness of PisoSIA® approach is associated with the early findings if the early findings are correct then the approach will be effective or vice versa. In the case of PisoSIA® the early findings are incorrect due to which the actual efficiency of the technique is difficult to calculate.

A research called "ERP-implementation project from a stakeholder perspective" is conducted in [20]. In this research, Mitchell's model is used that helps in the classification of stakeholders at higher level of abstraction. Just like PisoSIA® a change is incorporated in order to identify new stakeholders and to measure the impact of change on existing stakeholders. There is no novel contribution regarding SIQP that may help in the selection of valuable stakeholders for VBS systems. A change is incorporated in an ERP system and the impact of this change is analyzed on the stakeholders. SIQP is not the focus of this research directly. The "stakeholder identification <process> precedes any other RE activity: we must first determine who they are and how important they are" [34]. The different features are presented by Glinz and Wieringa for identification of stakeholders that include interest in the system, must manage, introduce, operate, or maintain the system, involvement in the development, business responsibility, financial interest, constrain the system as regulators and negatively affected by the system. The stakeholders are quantified into three major categories that are critical, major and minor. For stakeholder identification and classification, the process level details are not given. Thus, it is difficult to adopt the model when a project or product requires an agile environment in terms of its execution, implementation or development.

A framework of stakeholder identification and selection is given in [35] and is comprised of three stages that are *identification, filtering and prioritization.* The framework is a conceptual overview of the necessary aspects that must be considered essential during SIQP and to make RE process effective. The proposed framework provides a very high level picture and "the framework may not be conclusive as it needs to be confirmed and refined further". The framework is generic and is not yet implemented in real scenarios. There are some other approaches that do not focus the SIQP itself rather they discuss the stakeholders in a casual way without due consideration. The overview of these approaches is given here.

In HyDRA [36] the too much stress is given on the viewpoints of the users in order to gain information about multiple requirements' resources and requirements' traceability links. There is no special consideration of stakeholders as such. In QSARA (Qualitative Systematic Approach to Requirements Analysis) the major stress is on the "stakeholders <who> have little knowledge or understanding of the domain or the initial document is poorly structured" [37]. The approach is helpful in identification of resource allocation and interdependencies. It also helps analysts to construct a complete description of system features. The approach lacks in providing a solid SIQP and focuses on the stakeholders who lack in domain knowledge.

The Activity Theory for Requirements Elicitation (ATRE) focuses on contextualized activities of the stakeholders and it defines general activities that are strongly based on the knowledge and skills of the stakeholders. ATRE is based on the concept of social property which presents knowledge from social sciences that can be useful in gaining new insights into the human context in a given software system. However the elaboration of social activities is very difficult because "they require the collaboration of heterogeneous teams on wide topics" [38]. The approach directly involves the stakeholders in order to negotiate the requirements without providing any mechanism for SIQ. Same is the case with the research performed by Kasirun and Salim that only focuses on the involvement of stakeholders during requirements elicitation based on the aspects like activity, environment and support of the tool [39]. SIQP is not the focus of this research. The research study conducted by Woolridge et al. is also based on major stakeholder categories and the SIQP is based on these high-level categories. The categories are financial supporters, customers, internal stakeholders, external stakeholders, special interest stakeholders, and influencer stakeholders [40]. In this research, the major stress is on the risk imposed by the stakeholders and the impact of stakeholder risk is calculated.

Williams et al. have presented a study in which a list of enterprise stakeholders is given who may involve in the commercial development. The framework is being proposed for enterprise software development coordination in which the stakeholders are identified based on "their role and their name (e.g. Bob Smith: director of marketing)". This framework helps in the enhancement of "collaboration across enterprises engaged in software development projects" [41]. For existing work practices, it is not a hard and fast rule.

A comprehensive literature review is conducted on the said problem of stakeholders for VBS development in [18]. Babar et al. have forced that there is a dire need of a new framework, based on stakeholders' metrics for VBS development due to their distinguished nature. However, there are two types of the SIQP problems that are process problems and technical problems. The four major process problems of the SIQP are highly complex, non-uniform, inconsistent, and time-consuming. The technical problems of the SIQP are non-existence of metrics, lack of low level details and use of limited stakeholders' attributes. In this research, fuzzy logic based intelligent system in order to identify and quantify the stakeholders of VBS systems. This research is in continuation of the research as presented in [42].

3. PROBLEM FORMULATION

In this section, the stakeholder problem is formulated in order to solve the stakeholder quantification issue. Currently the datasets about stakeholders do not exist in any database hence, for stakeholders' analysis data the metrics are proposed. In order to quantify the stakeholders the stakeholder metrics are used. The stakeholder value *Sv* is calculated based on the nine key stakeholder metrics called as stakeholder factors. These factors are risk factor, communication factor, skill factor, instability factor, interest factor, personality factor, hierarchy factor, legitimacy factor and environmental factor. Finally, Sv is calculated by subtracting value of γ factors from value of β factors. However, in this research we are not subtracting value of γ factors from value of β factors instead we will use the values of γ and β factors as an output during training of the BPNN. Later, the predicted values of γ and β factors will be given to fuzzy c-means algorithm in order to achieve a most critical cluster of the stakeholders which may add an economic leverage in the development of a VBS system. The values of the stakeholder metrics or factors are based on stakeholders' aspects which are described here.

Factor→F
Aspect→T

Definition: Here F is a notation for stakeholders' factor or metric and T represents the stakeholders' attribute or aspect. The stakeholders' aspects are evaluated on a ranking scale of 0 to 5.

The stakeholders' attributes considered for the two metrics are included after long discussions with industry professionals. Hence, we have two types of datasets the stakeholders' skill factor dataset and the interest factor dataset.

Stakeholders' Risk Factor (F_{SR})

The stakeholders' risk factor is comprised of the aspects like communication (T_{CM}), interpretation (T_{IT}), decision making (T_{DM}), cognitive load (T_{CL}), complexity (T_{CP}), language barriers (T_{LB}), time and geographic differences (T_{TG}).

$$F_{SR} = 0.2(T_{CM} + T_{IT} + T_{DM} + T_{CL} + T_{CP} + T_{LB} + T_{TG}) + 0.2$$

$$F_{SR} = 0.2\left(\sum_{i=1}^{n} F_{SR_i}\right) + 0.2 \tag{1}$$

In the equation 1, *i* is an element or aspect of the F_{SR} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SR} is in the range of 0.2 to 5.2.

Stakeholders' Instability Factor (F_{SI})

The stakeholders' instability factor is comprised of the aspects like immune to challenges (T_{CH}), cognitive load or workload (T_{CL}), and fatigue management (T_{FM}).

$$F_{SI} = 0.2\ (T_{CH} + T_{CL} + T_{FM}) + 0.2$$

$$F_{SI} = 0.2\ \left(\sum_{i=1}^{n} F_{SI_i}\right) + 0.2 \tag{2}$$

In the equation 2, *i* is an element or aspect of the F_{SI} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SI} is in the range of 0.2 to 5.2.

Stakeholders' Communication Factor (F_{SC})

The stakeholders' communication factor is comprised of the aspects like clarity (T_{CR}), objectivity (T_{OB}), and self-confidence (T_{SC}).

$$F_{SC} = 0.2(T_{CR} + T_{OB} + T_{SC}) + 0.2$$

$$F_{SC} = 0.2\left(\sum_{i=1}^{n} F_{SC_i}\right) + 0.2 \tag{3}$$

In the equation 3, *i* is an element or aspect of the F_{SC} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SC} is in the range of 0.2 to 5.2.

Stakeholders' Skill Factor (F_{SS})

The stakeholders' skill factor is comprised of the aspects like experience (T_{EX}), managerial abilities (T_{MA}), domain knowledge (T_{DK}), domain training (T_{DT}), and self-esteem (T_{SE}).

$$F_{SS} = 0.2\ (T_{EX} + T_{MA} + T_{DK} + T_{DT} + T_{SE}) + 0.2$$

$$F_{SS} = 0.2\ \left(\sum_{i=1}^{n} F_{SS_i}\right) + 0.2 \tag{4}$$

In the equation 4, *i* is an element or aspect of the F_{SS} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SS} is in the range of 0.2 to 5.2.

Stakeholders' Interest Factor (F_{SIT})

The stakeholders' interest factor is comprised of the aspects like domain scope knowledge (T_{DSK}), business knowledge (T_{BK}), and objectivity (T_{OB}).

$$F_{SIT} = 0.2\ (T_{DSK} + T_{BK} + T_{OB}) + 0.2$$

$$F_{SIT} = 0.2 \left(\sum_{i=1}^{n} F_{SIT_i} \right) + 0.2 \quad (5)$$

In the equation 5, *i* is an element or aspect of the F_{SIT} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SIT} is in the range of 0.2 to 5.2.

Stakeholders' Personality Factor (F_{SP})

The stakeholders' personality factor is comprised of the aspects like cooperative (T_{CO}), visionary (T_{VI}), inspirer (T_{IN}), performer (T_{PR}), knowledge sharer (T_{KS}), role model (T_{RM}), and influence (T_{IN}).

$$F_{SP} = 0.2\ (T_{CO} + T_{VI} + T_{IN} + T_{PR} + T_{KS} + T_{RM} + T_{IN}) + 0.2$$

$$F_{SP} = 0.2 \left(\sum_{i=1}^{n} F_{SP_i} \right) + 0.2 \quad (6)$$

In the equation 6, *i* is an element or aspect of the F_{SP} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SP} is in the range of 0.2 to 5.2.

Stakeholders' Hierarchy Factor (F_{SH})

The stakeholders' hierarchy factor is comprised of the aspects like executive position (T_{EP}), mid-career (T_{MC}), and entry-career (T_{EC}). The value of F_{SH} is taken account based on the current position of the stakeholders.

$T_{EP} = \text{High} = 5$

$T_{MC} = \text{Average} = 3$

$T_{MC} = \text{Low} = 2$

$F_{SH} = T_{Val}$

$T_{Val} = Value\ of\ Hierarcy\ Aspects$

Stakeholders' Legitimacy Factor (F_{SLG})

It is used to measure the intensity of legitimacy of a stakeholder in terms of needs and is described as high, average, and low.

$\text{High} = 5$

$\text{Average} = 3$

$\text{Low} = 2$

$F_{SLG} = T_{Val}$

$T_{Val} = \text{Intensity of Legitimacy}$

Stakeholders' Environment Factor (F_{SE})

The stakeholders' environment factor is comprised of the aspects like cognitive Load (T_{CL}), fatigue management (T_{FM}), inspirer (T_{IN}), and knowledge sharer (T_{KS}).

$$F_{SE} = 0.2\ (T_{CL} + T_{FM} + T_{IN} + T_{KS}) + 0.2$$

$$F_{SE} = 0.2 \left(\sum_{i=1}^{n} F_{SE_i} \right) + 0.2 \quad (7)$$

In the equation 7, *i* is an element or aspect of the F_{SE} and the total number of aspects is represented by *n*. The F_{SS} is calculated using values of aspects that are in the range of 0 to 5 and F_{SE} is in the range of 0.2 to 5.2.

$$S_V = (F_{SC} + F_{SS} + F_{SIT} + F_{SP} + F_{SH} + F_{SLG} + F_{SE}) - (F_{SR} + F_{SI})$$

$$S_V = \sum_{i=1}^{n} \beta_i - \sum_{j=1}^{m} \gamma_j \qquad (8)$$

$$\beta = \{F_{SC} + F_{SS} + F_{SIT} + F_{SP} + F_{SH} + F_{SLG} + F_{SE}\} \qquad (9)$$

$$\gamma = \{F_{SR} + F_{SI}\} \qquad (10)$$

In Equation 8 β and γ are the values of the factors which show the positive and negative aspects of a stakeholder. Two exceptions are given based on values of β factors and γ factors. If the value of β factors is low then the value of γ factors will be high and vice versa. From experimental data it is observed that in most of the cases the two exceptions are not going to be fulfilled in many cases. This results in complexity and equation 8 makes the decision process more complex, hence in this research equation 9 and equation 10 are used for stakeholder quantification. Initially, back-propagation neural network is used in order to predict the value of β and γ factors and these values are given as an input to Fuzzy C-Means algorithm in order to identify the stakeholders.

4. PROPOSED INTELLIGENT SYSTEM: SPHANDL

The proposed intelligent system *SPHandler* is comprised of stakeholder metrics, BPNN and FCM. Figure 2 describes the proposed intelligent system for SIQ. The interface is used as a means for input to the system. The input of stakeholders' parameters is of two types, which is based on values of β factors and γ factors for the BPNN and finally the predicted β and γ values serve as an input to fuzzy c-means. The stakeholders' parameters are given to the system in order to compute the values of F_{SC}, F_{SS}, F_{SIT}, F_{SP}, F_{SH}, F_{SLG}, F_{SE}, F_{SR} and F_{SI}. The computed values of the β factors and γ factors are stored in the database or in a text file. The β and the γ factor values are given as data input to the BPNN. The BPNN predicts the β and γ values for stakeholders' classification. The β and γ values are given as an input to fuzzy c-means in order to make the stakeholders' clusters for priority definition. For FCM initialization the required parameters are number of clusters *N*, the value of exponent or fuzzification parameter *E*, *I* is for total number of iterations and the parameter of initial centroid is also defined. After initialization the centroids are computed and membership values U_{ij} are modified. If the value of Euclidean norm ‖… ‖ is less than ε the algorithm is going to stop otherwise the centroids are updated again using equation 11 and the loop continues until the matrix norm value is not less than *ε*. Here, *ε* is the predefined accuracy or convergence criterion. If the threshold value of ε is achieved the system will show the results in the form of different clusters of the data otherwise the algorithmic loop will continue in order to achieve the optimal results of the problem.

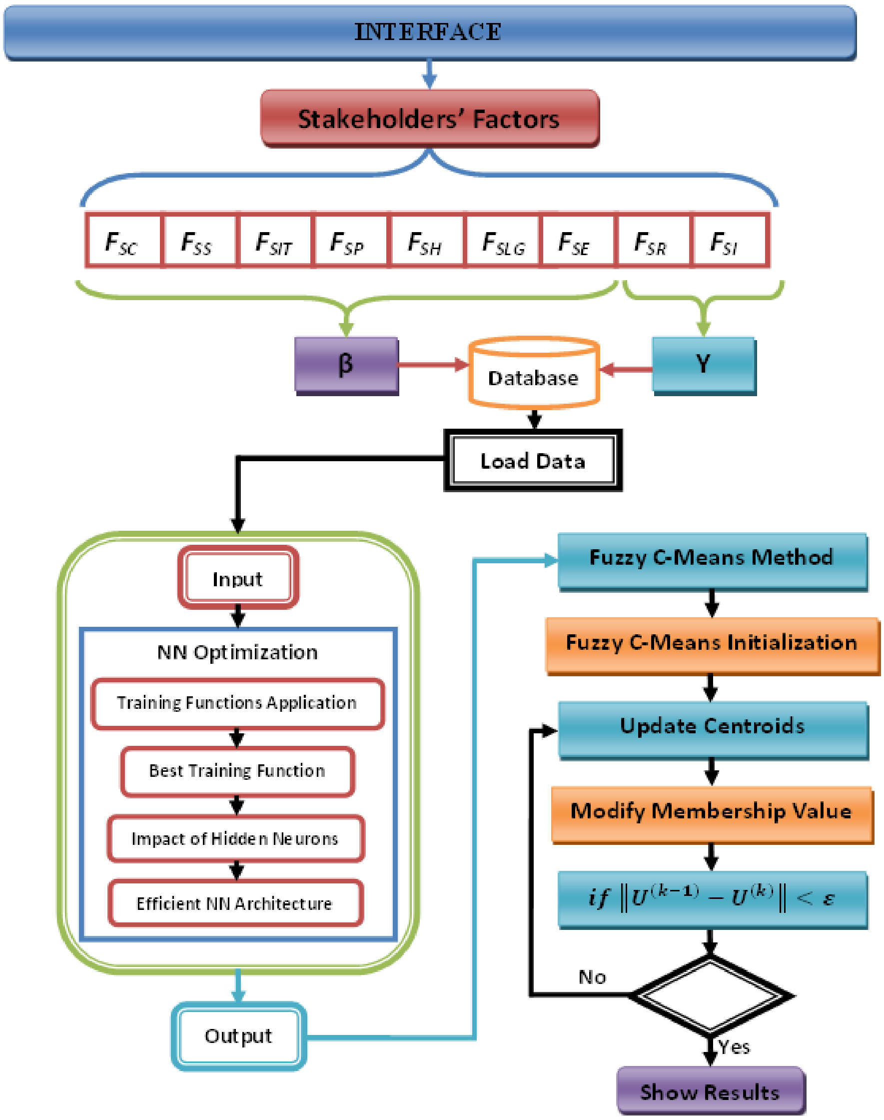

Figure. 2 Proposed intelligent system

5. EXPERIMENTAL SETUP

5.1 Back-propagation neural network

BPNN is a multilayer perceptron (MLP) normally comprised of one hidden layer [43]. The input layer serves as a backbone for neurons while the neurons in hidden and output layers perform computation. The signals in NN propagate in a feed-forward mechanism. The computational heuristics of the hidden and output layers cannot be observed. The very nature of neural networks is like information processing system and also possess similarity with biological nervous systems [44, 45]. Neural networks (NN) are used for prediction and to solve the highly complex and non-linear problems [46, 47]. In case of SIQP high level of uncertainty exists due to application of different opinions about stakeholders' attribute values. This thing makes the SIQP highly complex and non-linear. Currently, the research lacks in the application of heuristic approaches in the domain of SIQP. In *StakeMeter* SIQ framework the stakeholder value Sv is calculated manually by using different stakeholder factors. The manual application of *StakeMeter* framework parameters reduces the overall performance of the system, and induces the bias of experts. Moreover, it is non-scalable for projects with large number of stakeholders which is a big reason to propose an expert SIQ system. Figure 3 represents a 3-layered feed-forward BPNN. The bias **b** is added for learning purposes. The colourless circles on the most left side represent the weighted input to the input layer. The initialization of the multiplied weights *w* is random and the training of the network is carried out in order to reduce the mean squared error (MSE) for optimization of the results. The over training results in the reduction of the performance of the BPNN and its occurrence mainly depends on large number of training cycles [48]. The BPNN training consists of 4 major steps of initialization, activation, weight adjustment and iteration. The training in BPNN is an iterative process which reduces the MSE using back-propagation algorithm in order to acquire the optimized results.

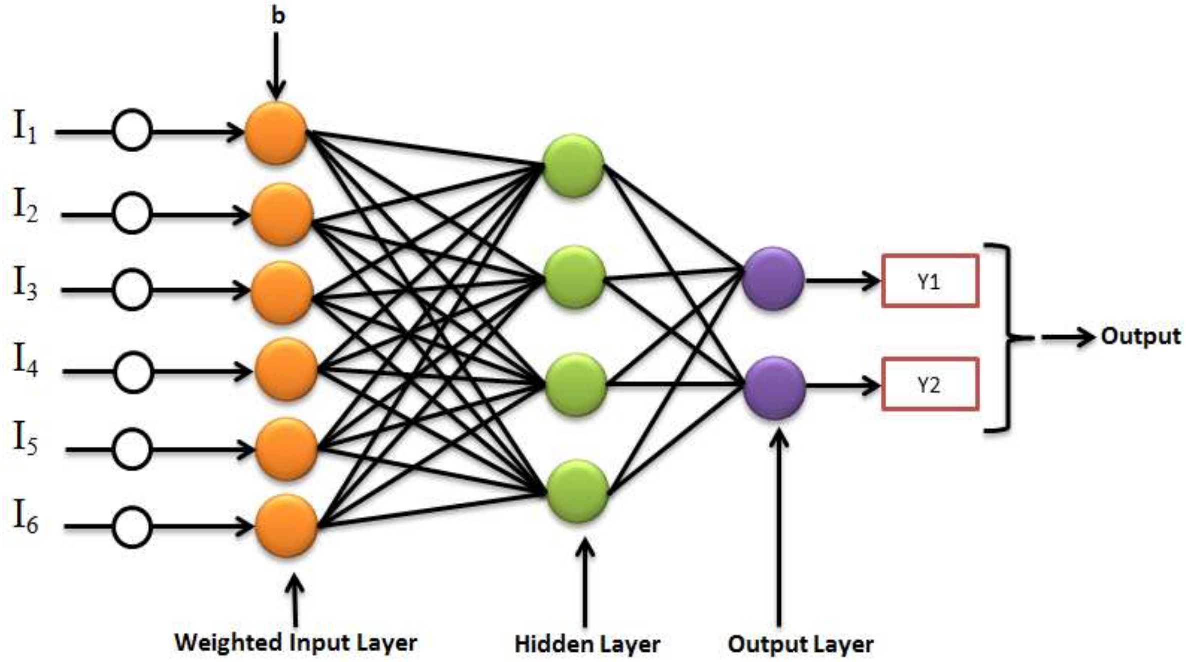

Figure. 3 Back-propagation neural network (BPNN)

For calculation of outputs in the hidden layer, based on the given inputs, the sigmoid activation function is used which is represented by following equation.

$$y_j(p) = sigmoid\left[\sum_{i=1}^{n} x_i(p).w_{ij}(p) - \theta_j\right] \quad (11)$$

In Equation 11 n is the total number of inputs for neuron j. For activation function the word *sigmoid* is a reserve word. Output layer calculates the final output by using the following equation.

$$y_k(p) = sigmoid\left[\sum_{j=1}^{m} x_{jk}(p).w_{jk}(p) - \theta_k\right] \quad (12)$$

In Equation 12, m is the total number of inputs to neuron k from the hidden layer.

5.2 Data collection

The supervised learning approach for BPNN is adopted in this research. Historical data is highly desirable in case of supervised machine learning approach. The historical data is comprised of cases, examples and all class instances. In supervised learning the data is used in order to predict an object's class [49]. As the data in case of stakeholders' quantification is not available hence, the StakeMeter framework's factors are used in this research. The training dataset is obtained from the proposed 9 factors which are F_{SC}, F_{SS}, F_{SIT}, F_{SP}, F_{SH}, F_{SLG}, F_{SE}, F_{SR} and F_{SI}. Each factor is comprised of different stakeholder aspects or attributes. The cardinal scale is used to rank these stakeholder aspects in the range of 0 to 5. Each stakeholder factor value is calculated using values of respective stakeholder aspects. The stakeholder values serve as an input to NN and are represented as:

$$p_i = \{p_1, p_2, p_3, \ldots, p_n\}$$

The stakeholder aspect values are selected by the experts as per defined ranking criteria of StakeMeter framework. The aspect values are used to calculate stakeholder factor values. The factor values are used to find out β factors value and γ factors value which serve as an input to BPNN. The β and γ values depict the positive and negative impacts of a stakeholder for a given VBS project. In StakeMeter the Sv is calculated by subtracting γ values from β values. However, such an approach makes the decision process complex and induces fuzziness. In the proposed intelligent system instead of computing the Sv only the values of β and γ are predicted using BPNN and later used as input for Fuzzy C-Means in order to obtain a cluster of highly prioritized stakeholders. Table 1 describes the partial data sample for β and γ values computation.

Table. 1 Partial data sample

β Factor Values							γ Factor Values		β Value	γ Value
F_{SC}	F_{SS}	F_{SIT}	F_{SP}	F_{SH}	F_{SL}	F_{SE}	F_{SR}	F_{SI}		
0.2	0.6	1.4	0.8	3	3	1.6	0.2	0.2	10.6	0.4
2.2	1.4	2.4	5.0	4	4	2.8	0.4	3.0	21.8	3.4
0.8	2.4	1.6	3.2	3	3	1.4	1.4	1.0	15.4	2.4
1.2	2.8	0.8	3.4	3	3	2.6	1.8	0.2	16.8	2.0
2.6	2.0	1.2	1.8	3	3	1.4	4.4	3.2	15.0	7.6
2.4	3.4	2.0	5.2	2	2	1.8	1.0	0.8	18.8	1.8
2.4	3.2	1.8	4.0	3	3	1.8	1.2	0.8	19.2	2.0
1.2	2.2	0.6	1.6	2	2	1.4	4.8	2.4	11.0	7.2

5.3 Neural network training

The two most common learning approaches are supervised and unsupervised learning. In BPNN the supervised learning approach is adopted for training purposed. Different training methods exist in order to train the BPNN like traingdx, trainlm, trainoss, trainbr, traincgf and some others. However, trainlm is the default, efficient and commonly used training function. In this research, we have used trainlm function in order to train the BPNN for our proposed expert system. The data is normalized in the range of -1 to 1 by applying functions of mean and standard deviation. The normalization helps in pre-processing of training data and in evenly distribution. For all possible classes of the target data a partial sample is purposely chosen and is shown in the Table 2. The training of BPNN is carried out using the default training function trainlm. The β factor values and γ factor values are given as target input while β and γ values are given as target output. NN is trained by applying different architectures and architecture of 9-16-2 (number of input – number of hidden nodes – number of output) is selected as an optimized solution for the said problem. Such an optimization process helps in resolving the stakeholder quantification problem.

Table. 2 Partial sample of results of NN training using trainlm

β Factor Values							γ Factor Values		β Value	γ Value	NN β Value	NN γValue
F_{SC}	F_{SS}	F_{SIT}	F_{SP}	F_{SH}	F_{SL}	F_{SE}	F_{SR}	F_{SI}				
0.2	0.2	0.2	0.2	2	2	0.2	0.2	0.2	5.0	0.4	5.0073	0.4029
0.2	0.4	0.2	0.2	2	2	0.2	0.2	0.4	5.2	0.6	5.1972	0.5995
0.2	0.6	0.2	0.2	2	2	0.2	0.2	0.6	5.4	0.8	5.3990	0.7999
0.2	0.8	0.2	0.2	2	2	0.2	0.2	0.8	5.6	1.0	5.6042	0.9994
0.2	1.0	0.2	0.2	2	2	0.2	0.2	1.0	5.8	1.2	5.8067	1.1977
0.2	1.2	0.2	0.2	2	2	0.2	0.2	1.2	6.0	1.4	6.0053	1.3987
0.2	1.4	0.2	0.2	2	2	0.2	0.2	1.4	6.2	1.6	6.2020	1.5993
0.2	1.6	0.2	0.2	2	2	0.2	0.2	1.6	6.4	1.8	6.3986	1.7976
0.2	1.8	0.2	0.2	2	2	0.2	0.2	1.8	6.6	2.0	6.5964	1.9956

…							…		…	…	…	…
3.2	5.2	3.2	7.2	4	4	2.6	5.6	3.2	29.4	8.8	29.4001	8.8112
3.2	5.2	3.2	7.2	4	4	2.8	5.8	3.2	29.6	9.0	29.5949	8.9781
3.2	5.2	3.2	7.2	4	4	3.0	6.0	3.2	29.8	9.2	29.7946	9.2224
3.2	5.2	3.2	7.2	4	4	3.2	6.2	3.2	30.0	9.4	29.9978	9.3863
3.2	5.2	3.2	7.2	4	4	3.4	6.4	3.2	30.2	9.6	30.2036	9.5940
3.2	5.2	3.2	7.2	4	4	3.6	6.6	3.2	30.4	9.8	30.4071	9.8226
3.2	5.2	3.2	7.2	4	4	3.8	6.8	3.2	30.6	10.0	30.6039	9.9736
3.2	5.2	3.2	7.2	4	4	4.0	7.0	3.2	30.8	10.2	30.7939	10.2145
3.2	5.2	3.2	7.2	4	4	4.2	7.2	3.2	31.0	10.4	30.9923	10.3945

Table. 3 Error difference

β Value	γ Value	NN β Value	NN γValue	Error Difference β Value	Error Difference γ Value
5.0	0.4	5.0073	0.4029	-0.0073	-0.0029
5.2	0.6	5.1972	0.5995	0.0028	0.0005
5.4	0.8	5.3990	0.7999	0.0010	0.0001
5.6	1.0	5.6042	0.9994	0.0006	0.0006
5.8	1.2	5.8067	1.1977	-0.0067	0.0023
6.0	1.4	6.0053	1.3987	-0.0053	0.0013
6.2	1.6	6.2020	1.5993	-0.0020	0.0007
6.4	1.8	6.3986	1.7976	0.0014	0.0024
6.6	2.0	6.5964	1.9956	0.0036	0.0044
…	…	…	…	…	…
29.4	8.8	29.4001	8.8012	-0.0001	-0.0012
29.6	9.0	29.5949	8.9881	0.0051	0.0019
29.8	9.2	29.7946	9.2024	0.0054	-0.0024
30.0	9.4	29.9978	9.3963	0.0022	0.0037
30.2	9.6	30.2036	9.5940	-0.0036	0.0060
30.4	9.8	30.4071	9.8026	-0.0071	-0.0026
30.6	10.0	30.6039	9.9736	-0.0039	0.0264
30.8	10.2	30.7939	10.2045	0.0061	-0.0045
31.0	10.4	30.9923	10.3945	0.0077	0.0055

The output predicted by trainlm function, along with error differences between the predicted and actual data values of β and γ, is shown in Table 3. The error difference is acceptable and the function trainlm provides an optimized solution for the problem. The results are taken after applying different architectures and the results found more optimized by applying the NN architecture of 9-16-2. The application of too many hidden nodes results in over-fitting problem hence it becomes difficult to generalize the results [50]. In this research we have chosen 4 different projects like online car showroom (OCSR), hospital management system (HMS), restaurant management system (RMS) and university web portal (UWP). There are 23 stakeholders of OCSR, 61 stakeholders of HMS, 121 stakeholders of RMS and 273 stakeholders of UWP. The stakeholder domain in case of UWP is comprised of a set of students and faculty members at university level. A total of 438 stakeholders are evaluated based on guidelines of StakeMeter. We have made 5 teams in order to evaluate the stakeholders and each team is comprised of 3 members. The values of all factors are computed and finally the β and γ values are predicted using NN based on the stakeholder factors which serve as an input to the NN. Table 4 shows the results of the validation data using selected NN architecture.

Table. 4 Partial validation data results using selected architecture

β Factor Values							γ Factor Values		β Value	γ Value	NN β Value	NN γValue
F_{SC}	F_{SS}	F_{SIT}	F_{SP}	F_{SH}	F_{SL}	F_{SE}	F_{SR}	F_{SI}				
2.4	2.8	1.2	4.0	3	3	2.6	0.4	0.4	19.0	0.8	18.9959	0.8003
2.8	3.0	2.2	3.4	3	3	2.2	0.8	1.2	19.6	2.0	19.6015	2.0008
2.0	2.6	2.6	3.0	2	2	1.6	1.2	0.8	15.8	2.0	15.7972	2.0008
1.8	3.2	1.8	2.4	3	3	1.8	1.0	1.4	17.0	2.4	16.9988	2.4002
2.2	1.6	0.8	2.6	2	2	1.2	3.8	0.8	12.4	4.6	12.3931	4.5943
1.0	2.0	1.6	1.8	2	2	1.6	3.6	1.8	12.0	5.4	11.9919	5.4089
1.4	2.2	2.0	2.4	3	3	2.0	2.2	1.2	16.0	3.4	15.9926	3.4028
2.4	1.8	1.8	2.6	3	3	2.2	1.0	2.0	16.8	3.0	16.8032	3.0018
1.2	1.4	1.0	2.2	2	2	1.4	3.6	1.6	11.2	5.2	11.1909	5.1938
1.4	2.0	2.6	3.4	3	3	2.4	1.8	2.2	17.8	4.0	17.8012	4.0005

5.4 Application of fuzzy c-means

In order to make the SIQP efficient the predicted values of stakeholders' metrics by BPNN are used as attributes in a fuzzy clustering technique. There are several clustering approaches of data however the data in the current research belongs to a fuzzy problem instead of the hard problem. Hence, based on fuzzy and hard problem the clustering can be divided into fuzzy clustering and hard clustering. In clustering the data possess two properties i.e. homogeneity and heterogeneity. In homogeneity the objects of one class or cluster are similar to each other while in heterogeneity the objects in one class are dissimilar to objects of other classes [51, 52]. The data points in fuzzy clusters possess a degree of fuzzification which shows their links with different clusters instead of showing their association with a single cluster.

a. Fuzzy c-means method

In order to get the prioritized clusters of the stakeholders we have applied fuzzy c-means (FCM) algorithm [53]. For software requirements prioritization FCM is used in VIRP approach [54]. For pattern recognition the improved FCM algorithm is used [55]. In FCM, the data objects are classified into different key clusters based on the attributes of the data objects. In FCM the position of the object is computed and is placed in the relevant cluster. The improved FCM consists of a fuzzification parameter m and the range of m is [1, n]. The fuzzification parameter m is used to measure the degree of fuzzification for a cluster. Normally, the value of m is 2. Initially, the centroid is based on a guess for FCM initiation and a centroid is a distance mean of a cluster. For distance matrix Euclidean distance formula is used as shown in equation 13.

$$d(x,y) = \sqrt{\sum_{i=1}^{d} |x_i - y_i|^2} \tag{13}$$

Each object in a cluster is given a membership rank. The update of the centroid and membership ranks is iterative and the position of centroid changes with respect to the dataset. The adjustment of the centroid depends on the objective function. The distance of an object from its respective centroid is measured by the objective function and the membership rank is weighted by it. A centroid is updated by Equation 14 and the Equation 15 is used to compute the membership rank.

$$C_j = \frac{\sum_i [\mu_j(x_i)]^m x_i}{\sum_i [u_j(x_i)]^m} \tag{14}$$

$$U_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{\frac{2}{m-1}}} \tag{15}$$

The objective function in the FCM is represented by Equation 16.

$$J = \sum_{i=1}^{N}\sum_{j=1}^{C} U_{ij}^{m} \parallel x_j - V_i \parallel^2 \quad (16)$$

The fuzzification parameter m, also called as exponent, plays a vital role in experimental results. The values of β and γ predicted by NN are passed as an input to the fuzzy c-means. The data is highly fuzzy due to the unclear scenarios. It is described in SFM that a stakeholder may have a higher β value with a lower γ value and vice versa. However, it is also observed that some stakeholders have higher β and higher γ values and in such cases the decision making is very difficult. Based on Sv, β, and γ values it is very difficult to quantify the stakeholders due to the induced fuzziness in the data values. Hence, in this approach fuzzy c-means is used to quantify the stakeholders based on β and γ values. Table 5 shows the partial dataset which is comprised of β and γ values for the said objects or stakeholders. After reducing the number of inputs to 2 the problem has become a 2-D problem.

Table. 5 Partial dataset sample for fuzzy c-means

Objects	*Β*	*γ*
	…	
Stakeholder 104	18.9959	0.8003
Stakeholder 105	19.6015	2.0008
Stakeholder 106	15.7972	2.0008
Stakeholder 107	16.9988	2.4002
Stakeholder 108	12.3931	4.5943
Stakeholder 109	11.9919	5.4089
Stakeholder 110	15.9926	3.4028
	…	

The values of the different parameters used in fuzzy c-means are described in Table 6. *N* represents the stakeholder sample, *d* is dimensionality, *m* represents the degree of fuzzification, *n* represents the iterations, *k* is the total number of clusters and the convergence criteria or performance is represented by *min_improvement*. The various combinations of parameters of *m* and *min_improvement* are applied in order to evaluate the performance. Different values of fuzzification parameter m are applied in a descending order in order to know the effect on the overall clustering results.

Table. 6 Fuzzy C-Means Parameters

	N	*d*	*m*	*n*	*k*	*min_improvement*
Stakeholder	438	2	2.5	**100**	2	10e-5
			2.5			10e-05
			2.5			10e-005
			2.0			**10e-5**
			2.0			10e-05
			2.0			10e-005
			1.5			10e-5
			1.5			10e-05
			1.5			10e-005

By applying different FCM parameters it is observed that the difference in clustering results is not prominent. Hence, the parameter values chosen in this research are *m* = 2.0, *k* = 2 and *min_improvement* = 10e-5. The iteration count is affected by the application of different parameters. Thus, for stakeholder quantification we have chosen the default parameters of FCM which produce most optimized results and are shown in bold in Table 6.

6. EXPERIMENTS AND RESULTS

Figure 4 shows the quantification of stakeholders of the 3 projects into 2 clusters. The cluster centroids are represented by * and o. The trends of the clusters delineate a high variation in the β and γ values of the stakeholders. It is obvious most of the stakeholders possess higher β values which show that the entry of these stakeholders, in requirements elicitation phase of VBS development, is highly vital and on the other hand they also possess higher γ values which make them risky for the VBS project. However, from the clusters it is easy to define an inclusion and exclusion criterion for the stakeholders. It becomes easier to separate a critical set of stakeholders from non-critical stakeholders. Based on values of β and γ we can decide that the few stakeholders in the 'o' cluster may not be vital at all due to their higher γ values. Hence, they may be excluded easily or we can place them in the second priority by keeping in view their β values. Figure 5 shows the total number of iterations in order to achieve the objective function.

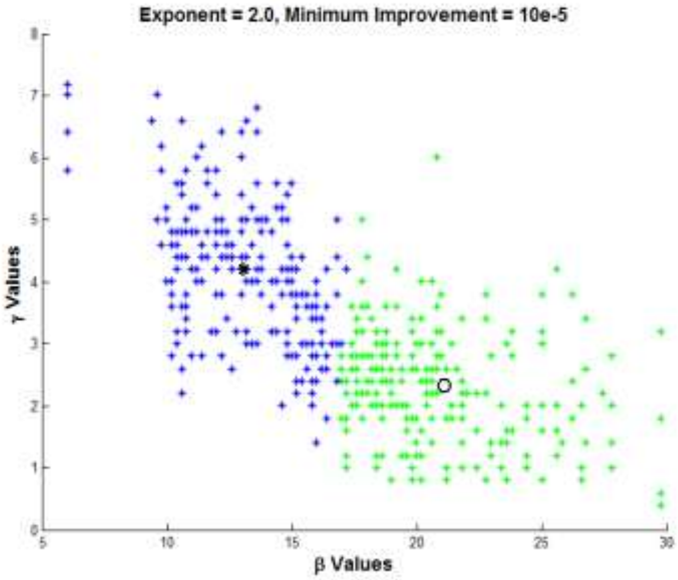

Figure. 4 Data with 2 clusters

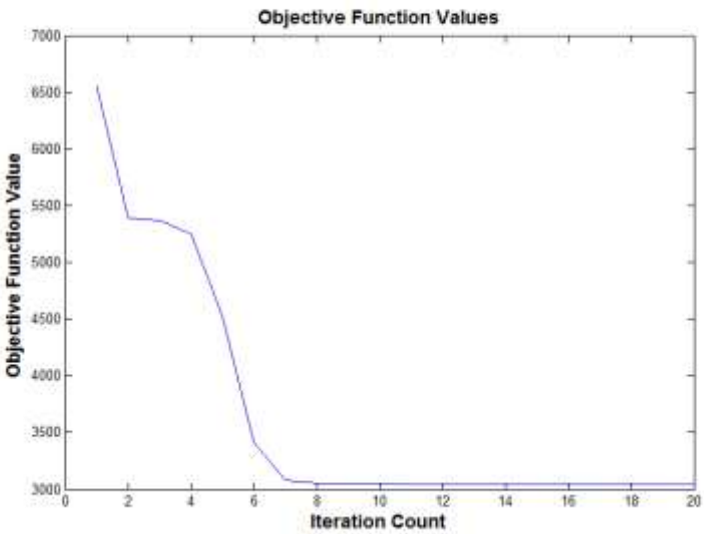

Figure. 5 Objective function for 2 clusters

In order to refine the stakeholder selection criterion there is the need to divide the stakeholders into more than 3 clusters and from the bunch of 2 clusters it is difficult to place the stakeholders in sub-priorities. Another issue which is associated with 2 clusters is selection of a stakeholder based on some expert biasness and induction of fuzzification. Hence, more clusters may help in elimination of expert biasness and fuzzification in order to define the inclusion and exclusion criterion. In Figure 6, data is divided into 3 clusters and only change which occurs in FCM parameters is $k = 3$ and the rest of the parameters are same. The cluster centroids in Figure 7 are represented by o, + and *. The cluster 'o' possesses high priority among all 3 clusters. The + cluster also possess key stakeholders hence the selection analysis is described in Figure 8. However, the stakeholders in the cluster '*' are discarded straightforwardly due to the imposed higher risk or greater γ values and higher β values.

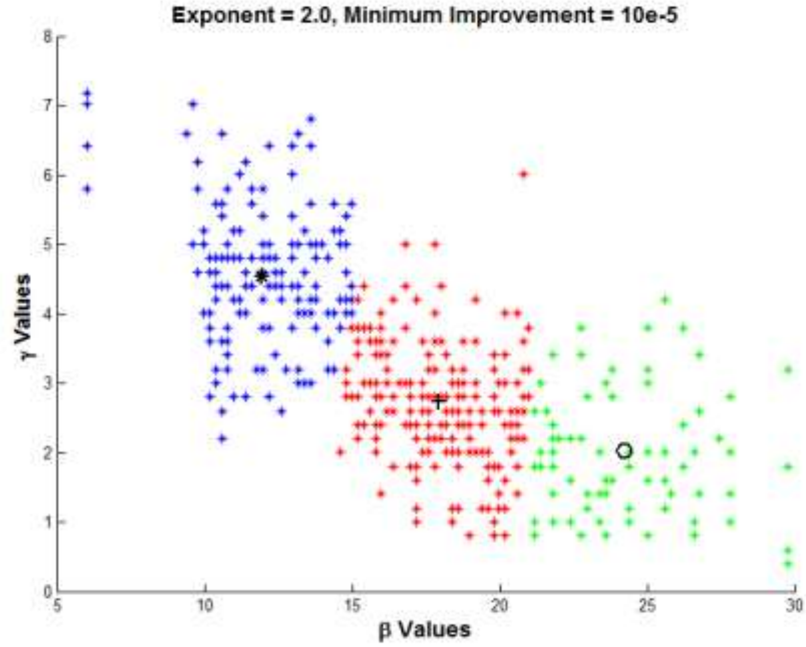

Figure 6: Data with 3 clusters

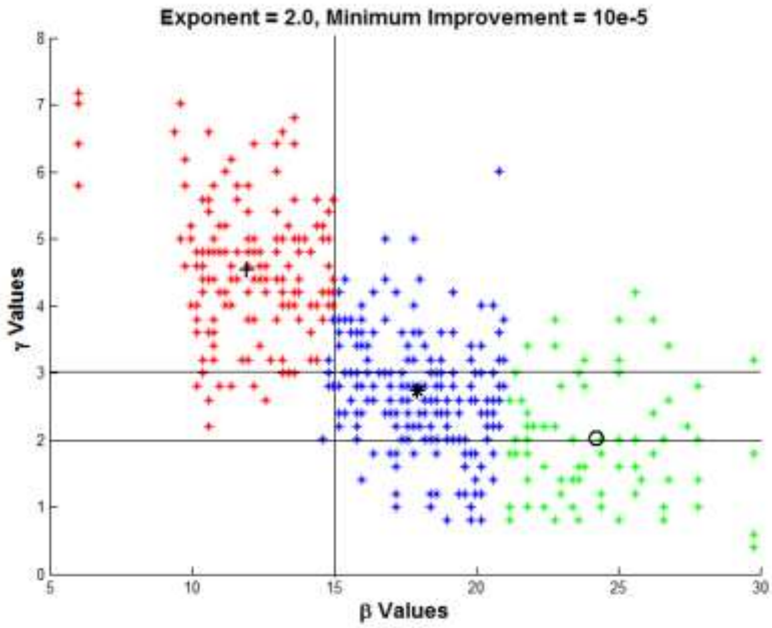

Figure 7: Data analysis with 3 clusters

In Figure 7, the stakeholder values in cluster 'o' are the key stakeholders that must be the part of RE process. However, there are some stakeholders which have higher γ values or possess higher risk. Initially if we define base value of γ as 2.0 and β as 15.0 then we get a more refined set of stakeholders. This set of stakeholders can be considered in the initial phase of requirements elicitation for VBS development. If we move higher on the y axis and select γ as 3 and β is same, then there will be few stakeholders from cluster 'o' who will become the part of critical stakeholders and more will be added from cluster '*'. The industry professional may also choose intermediate values between 2 and 3. All these stakeholders are considered as vital and the stakeholders in the cluster + are not considered as the vital entities for the requirements elicitation process. The stakeholders in green are the critical stakeholders for VBS development however the stakeholders in blue clusters are kept in second priority.

7. COMPARATIVE ANALYSIS AND DISCUSSION

Critical requirements play a vital role in the VBS development. Industry professionals apply different techniques in order to find out a key set of requirements from stakeholders. Stakeholders are the key entities in requirements elicitation step of RE. Different researchers have presented different approaches in order to identify and quantify the stakeholders based on different methods and parameters under different scenarios. The application of diverse methods makes the stakeholder identification process quite difficult and non-uniform. Based on the proposed metrics of StakeMeter an intelligent system is proposed in this research. Using said approach or system it becomes easy to assess the worth of a stakeholder for a VBS under development. The said approach reduces the effort of the analysts in order to predict the worth of a stakeholder based on the StakeMeter framework. A large number of attributes are considered in the StakeMeter for evaluation of the stakeholders which makes the SIQ process highly complex. The application of AI approaches like NN and FCM reduces the complexity and effort in terms of time. The application of NN helps in predicting the approximations of β and γ values though near to original values with less error. The application of NN also reduces the extent of bias as induced by the experts during manual evaluation of stakeholder β and γ values. From the StakeMeter inclusion and exclusion criteria it is difficult to define a base line for the Sv or stakeholder value. Hence, in this approach the Sv equation is not considered in order to overcome the issue of inclusion and exclusion. We have considered only the β and γ values in order to predict the priority of a stakeholder using FCM. The FCM approach is helpful in making clusters of the stakeholders based on β and γ values. Using these values an expert can easily define the priority of a given stakeholder for the VBS development. However, there are some limitations of this approach. Firstly, the large number of attributes reduces the overall efficiency of the NN during prediction of β and γ values of a stakeholder. Secondly, this approach is not applied in terms of global SE scenarios where the stakeholders are distributed across the globe.

8. CONCLUSION

RE is a key process in software development life cycle. During RE stakeholders play a vital role in elicitation of the requirements. The existing SIQ approaches focus the issue in diverse dimensions and do not provide a systematic way to quantify the stakeholders. The SIQ approaches are not uniform and it is difficult to adopt them as a standard or framework. These approaches are also not efficient in terms of time. VBS systems are associated with financial streams and an innovative idea is launched for market leverage. The quick implementation of the idea is highly desirable for VBS development. Hence, the suitability of current approaches is questionable for VBS development. In this research, a hybrid system is proposed in order to quantify the large number of stakeholders for VBS development. The stakeholder metrics are used to quantify the stakeholders and the stakeholder metrics values are used as an input to BPNN. BPNN predicts the value of a stakeholder and the predicted stakeholder values are given as an input to FCM. Later FCM classify the stakeholders into different clusters. The clustering approach helps in selection of highly critical stakeholders for VBS development.

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