Clustering Stakeholders for Requirements Decision Making

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Abstract. [Context and motivation] Novel web-based requirements elicitation tools offer the possibility to collect requirements preferences from large number of stakeholders. Such tools have the potential to provide useful data for requirements prioritization and selection. **[Question/problem]** However, existing requirements prioritization and selection techniques do not work in this context because they assume requirements ratings from a small number of stakeholders groups, rather than from a large number of individuals. They also assume that the relevant groups of stakeholders have been identified a priori, and that all stakeholders within a group have the same preferences. **[Principal ideas/results]** This paper aims at addressing these problems by applying cluster analysis techniques used in the area of market segmentation for identifying relevant groups of stakeholders to be used for requirements decision making. **[Contribution]** We describe a clustering analysis technique that can be used in this context and evaluate its adequacy on a pilot case study.

Keywords: Stakeholder segmentation, cluster analysis, web-based requirements elicitation, requirements prioritization and selection.

1 Introduction

There is a trend towards using web-based application such as forums, wikis, and recommender systems to elicit and prioritizing requirements from very large number of stakeholders [1], [2]. For example, StakeSource is a web-based requirements elicitation tool that allows stakeholders to recommend other stakeholders, submit requirements, and rate each other's requirements [3]. Such systems help collecting large amount of data that can be used for understanding stakeholders' preferences, identifying conflicts, and guiding requirements selection and prioritization.

There exists a wide range of qualitative and quantitative techniques for identifying the best tradeoffs among the preferences of multiple stakeholders [4]. Cost-value based requirements prioritization techniques rely on eliciting the relative costs and value of each requirements for each stakeholders group [5]. By assigning weights to the groups, one can compute the overall value of a requirement as the weighted sum of its value for each stakeholders group, and rank the set of requirements accordingly. Different variants of this approach are used in practice [6], [7], [8]. However, generating a full ranking of requirements based on a single numerical value hides conflicts between stakeholders instead of exposing them. More recent requirements selection

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techniques have therefore looked at the problem as a multi-criteria decision problem and developed support for exploring the space of optimal solutions and reasoning about the fairness of the requirements selection [9], [10], [11].

All these techniques have been developed in a context where requirements values are elicited for a small number of stakeholders groups only. They do not scale to the context of online requirements elicitation tools where values are elicited from a large number of *individual* stakeholders (for example, hundreds of individuals instead of five groups, which is roughly the number of groups that can be handled by multi-objective group decision-making techniques [11]). Furthermore, they assume that homogenous groups of stakeholders can be identified a priori, and that all stakeholders within a group agree on the value to be given to each requirement. An additional difficulty specific to online elicitation tools is that some groups of stakeholders are likely to be under-represented or over-represented in the collected ratings. For example, stakeholders who have more time to express their preferences online are likely to be over-represented compared to more busy stakeholders whose opinion may be no less important to the project success.

The objective of our work is to study the application of clustering techniques for identifying homogenous groups of stakeholders that can be used as input to existing requirements selection and prioritization techniques.

Our technique takes as input individual stakeholders' values for a set of requirements to be evaluated, and generates as output a set of stakeholders groups together with the value assigned to each requirement by each group. These group values can then be used by existing decision-making techniques to rank the requirements or generate a Pareto front and fairness diagram. A good grouping is one where all groups are composed of stakeholders with similar ratings so that the group values for each requirement are close to the ratings of its group members. Using group values that are close to the individual ratings as input to the decision-making techniques will result in decisions that better reflect the collected individual preferences than if the values used as input are further from the individual ratings. As a simple example, if a requirement is given very high rating by half the stakeholders and very low by the other half, splitting the stakeholders into two groups with a very high and very low group value for the requirement for each is better than having a single group where the requirement is given a medium group value. In the latter case, the group value fails to represent anyone's preference accurately and the result of decision-making techniques using this value will possibly satisfy no one. When generating groups, there is a conflict between minimizing the number of groups and maximizing their homogeneity. An extreme situation in which each stakeholder forms a single group would be very homogenous but would not help decision making.

Our approach relies on clustering techniques used in market segmentation for product development and marketing [12]. In this area, one distinguishes between a customer's characteristics that are product-independent such as his age, location and revenue, characteristics that are product-dependent such as his perceptions, benefits and loyalty for the product. Our approach groups stakeholders based their ratings which are product-dependent characteristics, instead of grouping them according to product-independent characteristics such as their job title or age.

This paper describes our approach and illustrates its use on a pilot case study conducted at UCL where we explore the impact of using different group size and compare clustering approaches.

2 Using Cluster Analysis to Group Stakeholders: An Example

Similarity between stakeholders' ratings is determined by their Euclidian distance. Given two stakeholders S_i, S_j and their ratings r_i, r_j for n requirements, the distance between their ratings is given by

$$d(ri, rj) = \sqrt{[(r_{1i} - r_{1j})^2 + (r_{2i} - r_{2j})^2 + \ldots + (r_{ni} - r_{nj})^2\ ]}$$

where r_{ki}, r_{kj} denote the ratings of S_i and S_j for requirement k, respectively. We generate stakeholders groups using the weighted average linkage clustering algorithm [12], [13]. This agglomerative hierarchical clustering algorithm allows one to form group hierarchies where small, highly homogenous groups at the bottom of the hierarchy are incrementally merged to form larger groups. This clustering algorithm has other properties that are highly desirable in our context: it is deterministic, not prone to reversal and chaining problems and it considers the size of the clusters when merging them [13].

To test our approach, we have carried out a survey at UCL asking 50 potential stakeholders to rate 5 requirements R1, R2, R3, R4 and R5 for an online calendar on a 10 point scale. We obtained responses from 47 stakeholders, labeled S1 to S47. Our product-specific characteristics are the values of each requirement to the stakeholders. We have also gathered a few product-independent characteristics related to the stakeholders like their position at UCL, number of years at UCL, and average number of hours spent online per day. Table 1 shows a sample of the data collected.

Table 1. Sample data collected from survey carried out at UCL

Stakeholder	Position	Time spent on internet daily (hrs)	No. of years at UCL	Ratings				
				R1	R2	R3	R4	R5
S1	Admin	6	4	5	3	10	10	10
S2	Research	10	7	3	10	3	3	3
..	…………	…..	….	….	….	….	….	….
S9	Postgraduate	8	1	1	2	3	4	8
..	…………	…..	….	….	….	….	….	….
S47	Academic	4	3	4	4	9	4	2

Figure 1 shows the dendrogram representing the clusters generated by the weighted average linkage clustering algorithm on these ratings. A dendrogram is a two-dimensional diagram that depicts how the agglomeration or division are done at the different stages of the cluster analysis [13]. The Y-axis depicts the distance among the ratings while the X-axis lists the stakeholders. At the topmost level of the hierarchy at cut off 10, we have a single cluster with all 47 stakeholders. When we move to the next level at a cut off 9 we have 3 clusters. The first one consists of stakeholders S26 to S31 in the dendrogram, the second one consists of stakeholders S2 to S34 and the third one consists only of stakeholder S9. As we decrease the distance along the Y-axis i.e. increase similarity, we have an increasing number of clusters which are smaller in size. We can see that in some cases, individual stakeholders are added to a

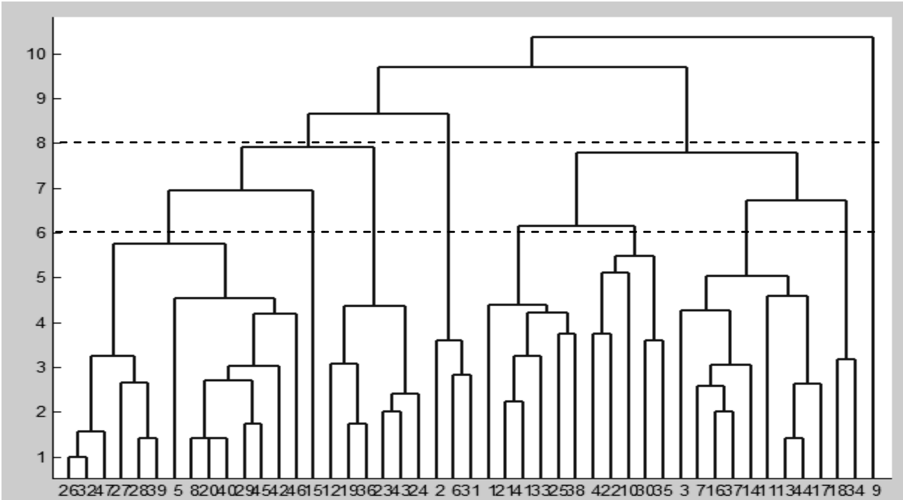

Fig. 1. Dendrogram for cluster analysis using weighted average linkage

cluster very late (at a greater distance) and these are outliers whose ratings could either be discarded or investigated in more depth depending on the importance and expertise of the particular stakeholder. One such example is stakeholder S9.

When using our technique, requirements engineers need to define where they want to cut off the hierarchy to get the optimal clusters in their context. To explore the impact of such decisions, we have decided to cut off the dendrogram at two places, that is, at distance 8 and 6. At cut off 8 we have 4 clusters and at cut off 6 we have 9 clusters. In each group, the value given to a requirement is taken to be the median value for all stakeholders in the group.

To assess the quality of the generated groups and their associated requirements value, we compare for each stakeholder the distance between the requirement values for the group to which the stakeholders belong and the actual values given by the stakeholder. For comparison purposes, we will also compute the distance of the actual ratings from the median of ratings with no clustering (i.e. all stakeholders are put in a single group) and when the stakeholders are grouped by their position at UCL. The results of this comparison are shown in Figure 2 for stakeholders S1 to S20 (the others are not shown to save space). The figure shows that the median values used to represent the stakeholders with no clustering and grouping by role are generally farther from the actual ratings of the stakeholders than when clustering is used at all. With clustering, it can be seen that with a cut off at a lower difference results in a median value closer to the actual rating of the stakeholder. Stakeholder S9 is an outlier as it is a cluster on its own and the median values with clustering will be the actual ratings of the stakeholder.

To further demonstrate how the overall decision process is improved, we fed the median for the clusters (labeled G1 to G3) at cut off 8 into the Volere prioritization template [6] giving equal weight to all of the clusters. We have dropped the ratings of outlier S9, so we are left with 3 groups each having a weight of 33%.

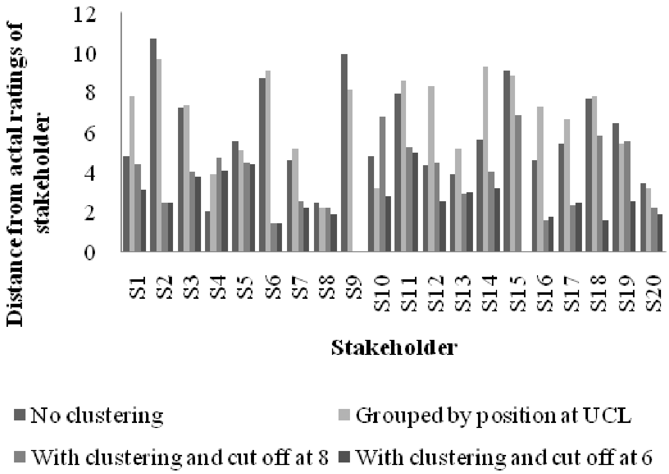

Fig. 2. Distance between the actual ratings of stakeholders and the median ratings for their group using different cluster sizes and approaches

The critical question of how to determine the weight of each group is currently left to the decision makers. The simple approach of estimating these weights by counting the number of stakeholders in each group will generally not be the best approach as some important stakeholders' views may be under-represented in the collected ratings and some important requirements such as legal or security requirements may be given low values by everyone except a few individuals who are experts in that area. Clustering stakeholders according to their ratings can mitigate these problems by highlighting these situations and allowing decision-makers to adjust the group weights or decide that some requirements must be implemented independently from the ratings. Standard prioritization techniques like AHP can also be used to help determining the group weights.

Figure 3 shows the requirements ranks after running Volere prioritization using median ratings with and without clustering. The requirements values and rankings are different in the two approaches. For example, when stakeholders are first grouped in clusters, requirement R2 moves above R1 and R5 in the ranking order. As we have shown in Figure 2, this ranking is obtained by using median requirements values for

Without Clustering

	Requirements Value	Rank
R1.	6	3
R2.	5	5
R3.	9	1
R4.	9	1
R5.	6	3

With Clustering at cut off 8

	G1	G2	G3	Weighted Sum Value	Rank
	0.33	0.33	0.33		
R1.	7	3	5	4.95	4
R2.	4	9	7	6.6	3
R3.	9	4	8.5	7.095	1
R4.	7	5	9.5	7.095	1
R5.	3	3	9	4.95	4

Fig. 3. Extract from results of Volere Prioritization with and without clustering

each cluster that are closer to the actual values given by each stakeholder than the overall median value when no clustering technique is used. Thus, assuming the weights given to the groups are valid, we can claim that moving R1 from 3rd to 4th better reflects the choice of the stakeholders because it relies on using requirements values that are globally closer to the individual ratings than if all stakeholders are viewed as forming a single group. Furthermore, grouping stakeholders as we have done also opens up the possibility of applying more elaborate group decision-making techniques based on multi-objective optimization and fairness analysis [11].

3 Conclusion

Identifying stakeholders groups is essential for applying requirements prioritization and selection techniques when requirements values are collected from large number of individual stakeholders. Our approach consists in forming such groups from stakeholder's ratings using a hierarchical clustering analysis technique. We have applied our technique on a pilot case study at UCL for which we have shown that there is an improvement in overall closeness of the ratings used to make decisions when using cluster analysis. Our future work includes implementing a tool to enable requirements engineers to use this technique. We aim to enhance the technique with methods to describe the profiles of stakeholders belonging to a group and help decision makers assessing the weight to be assigned to each group. Divergences among stakeholders rating within a group might also be used to detect ambiguous requirements. Our immediate future plan is to test our technique on large independent data sets collected using StakeSource [3].

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