Identifying Design Features using Combination of Requirements Elicitation Techniques

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***Abstract*—Requirements elicitation (RE) is the explanatory development activity of helping users figure out what they want. However, acquisition of requirements is challenging and inappropriate requirements might lead to unncessary project development cost. It is important to validate the requirements with various possible techniques to design a software solution. It is equally important to choose appropriate techniques for RE. To understand the importance of RE, *Energy feedback* or *visualization of electricity consumption* application had been chosen which would help in reducing household electricity consumption by motivating the residential end-users. To design an effective and innovative solution for *visualization* application, this article used a combination of three RE techniques, viz., systematic literature review (SLR), crowdsourcing survey and user-centred design (UCD) based design activity. The SLR assessed 22 studies, while the crowdsourcing survey and the design activity had 137 and 6 participants respectively. The RE techniques were interdependent and the results from each technique was fed to design the subsequent phases. Each of the RE techniques' motivation, procedure and its results were discussed and were statistically compared with each other forming the top seven features of the system to be developed. This study also analyzed the effectiveness of the requirements elicitation by conducting retrospective on the RE techniques. The retrospective analyzed things that went well, things that did not go well, and things that can be improved. It led to the discussion on how effectively can this process be improved to collect the requirements.**

***Index Terms*—systematic literature review, crowdsourcing, user-centred design, energy savings, requirements elicitation**

I. Introduction

Requirements elicitation (RE) is one of the first and foremost step in software engineering [1]. There are several ways to collect the requirements by user-centred techniques [2], but it is important to understand the significance of such an analysis. A software engineering expert, Steve McConnell says that "*The most difficult part of requirements gathering is not the act of recording what the user wants, it is the explanatory development activity of helping users figure out what they want*". The RE techniques should be UCD (user-centred design) based and be able to help the users to identify the requirements. Some of the popular RE techniques are surveys, focus groups, interviews, observations, etc.

We used three RE techniques to design a software application for energy feedback: systematic literature review (SLR), crowdsourcing survey and UCD interviews. Our main aim was to explore how a combination of these three RE techniques can help capture the software requirements of residential energy users and to motivate them to reduce household energy consumption.

RE is critical to the success or failure of a system or software project [3]. A major emphasis in early 1990s was that the identification of stakeholder is the pre-requisite of RE. In UCD based RE, the stakeholders are asked to list down the requirements suitable for the application to be developed and are prioritized based on their expectations. The users are involved at all the stages of the software development. These features of RE are expected to help understand the residential users' expectations and prioritize the functionalities of the *visualization* application.

The structure of this article is as follows: Section II explains the related works followed by the description of the system under development in Section III. Section IV explains the RE process followed by retrospective on RE and conclusion in Section V and VI respectively [4].

II. Related Works

This section discusses the use of several RE techniques in collecting the requirements of innovative software systems. There are several RE techniques mentioned in the literature and some of the techniques suitable for the application to-be-developed are mentioned below.

One of the interesting stories behind the rise of *crowdsourcing* in 2006 was when the project director at the National Health Museum, Washington DC, needed some photographs of sick people and instead of paying for the professional photographer, he found pictures for $1 at iStockphoto [5], which is a crowdsourcing platform to buy inexpensive pictures. The crowdsourcing became popular day by day and the use of crowdsourcing for software engineering application arose in the year 2010 [6]. Further more, the use of crowdsourcing for requirements engineering came into existence [7]. With the introduction of requirements engineering crowdsourcing platform, CrowdREquire [8], and crowd-centric requirements engineering [9], the field became more popular. Some of the applications that used crowdsourcing to engineer the requirements were StakeSource [10], StakeSource 2.0 [11], enterprise business intelligence app store [12], etc.

In a similar way, several *design thinking activities* were done to collect the requirements, which integrated innovation, customer experience and brand value [13]. The importance of understanding how the designers think and work and how to

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TABLE I
APPLIANCE AND SENSOR INFORMATION

Room Id	Room Name	Appliances	Sensors*
R1	Kitchen	Oven, refrigerator, microwave, light, powerplug, ventilator, dishwasher, stove	L, H
R2	Bed room 1	Light, television, heat pump, 2 power plugs	L, H, T
R4	Bed room 2		
R3	Bath room 1	Power plug, water heater, exhaust fan, light	L, H
R5	Bath room 2		
R6	Living room	3 lights, television, 2 power plugs, heat pump	L, H, T
R7, R8	Utility room and balcony	2 lights, washer/dryer, powerplug	L, H

*L - light intensity sensor, H - human presence sensor, T - temperature sensor

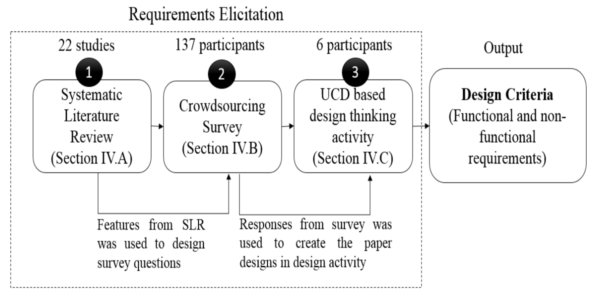

Fig. 1. Requirements Elicitation (RE) Techniques

collect the requirements based on that understanding was an added value [14]. Though a framework to choose techniques for requirements acquisition had been created [15], using more than two techniques to gather the requirements and validate those was very uncommon.

III. System Under Development

To elicit the requirements using a combination of RE techniques, we consider a system which helps residents in reducing their household electricity consumption. One of the important ways of reducing electricity is through the feedback rendered to the users. Hence, an important objective of the system is to visualize the household electricity and thereby motivating energy users to save unnecessary energy consumption. This system considered a single household with 8 rooms, 29 appliances and upto 3 sensors (human presence, light intensity, temperature) in each room. Table I describes the room, appliances and sensor information. The household is assumed to have 4 occupants using the system to be developed. The household electricity consumption would be simulated for 29 appliances every minute and to be stored in the database. The software system data from the database has to be converted into useful information to be visualized in a website in the form of real-time energy information, energy information by each appliance, energy saving tips/recommendations, remote appliance control, etc.

IV. Requirements Elicitation

To develop this system, the first and foremost step is to identify the requirements, which is very crucial for software system development. The most appropriate definition of requirements gathering is “designing the right thing” [16]. The primary goal of the requirements analysis is to identify the functional and non-functional design criteria of system under development using user-centred techniques [2]. The requirements elicitation (RE), in this study, uses the combination of SLR, crowdsourcing, and UCD based design thinking approaches. It was anticipated that the RE process would be (a) easy to cross validate the system features across various RE techniques, (b) easy to ‘deliver the right thing’ as the requirements were user centred, (c) easy to locate motivated stakeholders through internet to help identify the requirements (crowdsourcing), and (d) easy to identify the requirements through design thinking activities carried out with stakeholders as observation and involvement were the important means of identifying the user requirements.

Fig. 1 depicts the RE techniques as we applied it. For the system to be developed, the requirements were gathered by three different techniques: (a) systematic literature review (SLR), (b) crowdsourcing survey/questionnaire, and (c) design thinking activity. The SLR assessed 22 studies, while 137 and 6 participants took part in crowdsourcing survey and design thinking activity respectively. The result from each technique is then fed as the input to the subsequent techniques to improve the quality of design [4]. For instance, the features from SLR were used to design survey questions and the responses from the survey were used to create paper designs for designing. The output from the RE techniques was the design criteria for visualization of household electricity consumption which included functional and non-functional requirements. The RE techniques are described in the following subsections below.

A. Systematic Literature Review

The systematic literature review (SLR) is a process of identifying the literature, extracting the papers based on inclusion/exclusion criteria, and synthesizing the primary studies to answer relevant research questions [17]. The research questions aim to understand the existing research on visualizing tools for household electricity consumption. The features derived from SLR would then be used to create the crowdsourcing survey questions.

1) Motivation: The primary motivation was to extract the functional and non-functional requirements from research literature and use those knowledge to design the procedure and activities of the other two RE techniques.

2) Method: The search terms were devised to answer the research questions which aimed to understand the current research on visualization and the information that motivated the stakeholders to save household electricity. The search terms identified were ((visualization OR data visualization OR information visualization) AND (energy consumption OR energy cost OR energy conservation)). These terms were used to access published papers, technical reports, relevant thesis from various databases, journals, conference proceedings and

TABLE II
RESULTS OF SLR - DESIGN CRITERIA BASED ON GROUNDED THEORY

Design Criteria	Categories
Functional Criteria	Information displayed in the visualization
	Techniques in visualization
	Modes of visualization
Non-Functional Criteria	Non-functional software considerations
	Non-functional hardware considerations

research websites. A total of 232 papers from popular reputed academic databases such as Scopus, ScienceDirect, IEEE Xplore, ACM digital library, SpringerLink and INSPEC. In the first round of data extraction, duplicates were removed resulting in 218 studies. The second round of extraction analyzed the article title and abstract resulting in 25 primary studies. Applying the inclusion/exclusion criteria resulted in 22 studies from the third round of data extraction.

3) Results: Data synthesis were done by employing Grounded Theory (GT) [18] as an approach for discovering patterns within the datasets [19], which resulted in identification of design criteria for visualizing household energy consumption. Table II summarizes the functional and non-functional criteria along with the categories as identified by GT's open coding technique. The results are briefly discussed below and detailed results can be found in [20].

a) Functional Requirements: The functional criteria identified three categories, (a) information displayed in visualization, (b) techniques in visualization, and (c) modes of visualization.

Information displayed in visualization included real-time electricity consumption, peak energy consumption in a day/month/year, scheduling of appliances to avoid peak pricing, unnecessary energy consumption, comparison of energy consumption among homologous periods, i.e., hours, days, months, years, etc., comparison/ranking of energy consumption with neighbourhood homes, prediction of electricity bills, context aware electricity monitoring, and remote control of household appliances.

Techniques in visualization included 2D and 3D visualization. Traditional 2D visualization included charts/graphs, cluster maps, component planes, time log, spiral display, etc., whereas the modern 2D visualization included corolog, hive design, phyllotaxis design, pin wheel design, and some 2D user interfaces. 3D visualization included chloropeth maps, hit maps, 3D mapping and 3D user interfaces.

Modes of visualization explained the ability of end-users and energy managers to visualize the household energy consumption with the modes of their choice. For instance, if the end-users wanted to visualize the comparison of aggregated electricity consumption over 2 days, the modes selected would be days (instead of months, weeks, or years) and the type of visualization would be aggregated electricity consumption (instead of disaggregated or real-time) in comparison mode (instead of display mode). Similarly, various combinations can be used.

b) Non-functional Requirements: The non-functional criteria identified two categories, (a) non-functional software considerations, and (b) non-functional hardware considerations.

Non-functional software considerations were summarized under the acronym PAFUSE. They are (a) portability - ability to work on multiple devices, (b) accessibility - ease of finding, downloading and using the application, (c) flexibility - ability to toggle among the modes of visualization, (d) understandability - ease in recognition of visualization by human mind, (e) scalability - ability of application to expand to accommodate future information, and (f) extensibility - ease for developers to extend the application.

Non-functional hardware considerations depicted the issues pertinent to the visualization display, which included positioning of the visualization display, viewing distance, size of the display, storage capacity of the display, etc.

B. Crowdsourcing Survey/Questionnaire

Crowdsourcing, according to Brabham [21], can be defined as "a strategic model to attract an interested, motivated crowd of individuals capable of providing solutions superior in quality and quantity to those that even traditional forms of business can". Crowdsourcing, in this study, had been achieved by inviting the stakeholders to answer the survey. The difference between the normal survey and the crowdsourcing survey is that the respondents of the normal study is usually from a small closed group, who use large amount of effort, whereas the crowdsourcing is open to large group of non-experts, who use small amount of effort to solve a problem under consideration

The crowdsourcing survey was created by using the results of the SLR described in Subsection IV-A3.

1) Motivation: The primary motivation behind using crowdsourcing survey was to obtain the requirements from various stakeholders through internet, as survey is one of the easiest ways to meet stakeholders than any other means of communication. Using the crowdsourcing survey, it was plausible to engineer requirements from various participants in short period of time at their convenient schedule.

2) Method: Online crowdsourcing survey was created using a free online tool, *eSurv*[1] and was requested to be answered by the potential stakeholders identified through various sources such as Facebook groups, E-mail groups, and paper advertisements in church, supermarkets, etc. The survey questions were related to four major categories. They are (a) demographic information (e.g., age, gender, etc.), (b) energy usage information (e.g. number of people in home, bill payer, etc.), (c) current system and motivation (e.g. information from electricity bill, devices used to view electricity information), and (d) user preferences (e.g. preferred metrics ($, kWh) to view electricity information and the frequency of electricity information to be delivered). To validate the survey, a pilot testing was conducted with 6 participants and the survey was redesigned according to their feedback. A total of 137 stakeholders participated in the crowdsourcing survey and the

[1]https://esurv.org

responses were recorded to identify the functional and non-functional requirements of the system.

3) Data Analysis and Synthesis: The survey tool, *eSurv* has the ability to analyse the multiple choice question formats. The open-ended questions were analyzed and synthesized using another software tool, *nVivo*[2] and the results of the crowdsourcing survey were categorised as functional design requirements and non-functional design requirements.

4) Results : The primary functional requirements after analysing the crowdsourcing survey were (a) real-time aggregated electricity consumption, (b) real-time disaggregated electricity consumption (i.e., electricity consumed by individual appliances), (c) archived aggregated electricity consumption, (d) energy saving recommendations/tips, and (e) remote household appliance control. The non-functional requirements of the system were portability, understandability, accessibility, flexibility, scalability, modularity and security. The results are briefly discussed below and the detailed results are currently under review process.

C. UCD based Design Thinking Activity

User-Centred Design (UCD) is a process in which the end-users of the product or service are involved in every stage of the software development [22], [23]. For example, the end-users are involved in collecting the project requirements, designing the project, validating the assumptions made by the designers, etc. [24]. Some of the important advantages of UCD are (a) increased user satisfaction, (b) reduced redesign costs, and (c) improved performance [25]. UCD can be applied to obtain the design decisions or design criteria by means of various techniques such as user centred surveys, focus groups, interviews, design workshops, etc.

The third way of identifying the requirements of the system was UCD based design thinking activity (DTA). The DTA is the best way of accessing the personal experiences of the participants in their natural context and would help in obtaining the detailed particulars of system under development.

1) Motivation: The primary motivation of DTA was to make the participants design their expectations of the features of the system. The participants were also been provided with sample paper designs as shown in Fig. 2 to analyze the features. Also, they were asked to mention their preferences and the features that might motivate them to save energy at home.

2) Method: The important sources/inputs for the DTA were the results of the SLR and the crowdsourcing survey.

The samples of paper designs for the functionalities of the research FR1, FR2, FR3, FR4, FR9, FR10 are shown in Fig. 2. Similarly, the designs for FR5 to FR8 were also issued to the participants. There were 10 features and each of the feature was explained to the participants for interpreting the use of those in reducing their electricity consumption. The functionalities of the system were

- FR1: Current day's total electricity consumption in kWh.

[2]http://www.qsrinternational.com/

TABLE III
QUESTIONS ASKED IN DESIGN BASED ACTIVITY

Type of Design	Questions related to the designs
None (General Questions)	(a) What are the information would you notice from the paper electricity bill? (b) What are the information would you notice from the online electricity bill?
Aggregated and Disaggregated electricity consumption designs	(a) Do you think this design would save energy? (b) Would you prefer it with comparison or without comparison? (c) How often would you like to see the information (daily/weekly/monthly)? (d) How can this design be improved?
Real-time and remote control designs	(a) Do you think this design would save energy? (b) How can this design be improved?
Energy saving tips or recommendations	(a) How do you want to be notified about the energy saving tips? Email or text message or software application notifications or anything else?

- FR2: Current day's/week's/month's total electricity consumption in kWh.
- FR3: Comparison of daily electricity consumption with 2 previous days.
- FR4: Comparison of daily/weekly/monthly electricity consumption with 2 previous days/week/month.
- FR5: Current day's total electricity consumption by each appliance.
- FR6: Current day's/week's/month's total electricity consumption by each appliance.
- FR7: Comparison of daily electricity consumption by each appliance with 2 previous days.
- FR8: Comparison of daily/weekly/monthly electricity consumption by each appliance with 2 previous days/week/month.
- FR9: Design showing the appliances mapping them into a home's blueprint displaying the electricity consumption by each appliance (real-time electricity consumption).
- FR10: Design showing the appliances mapping them into a home's blueprint displaying recommendations (energy saving tips) for each appliance and can be controlled remotely (remote control).

FR1 to FR4 paper designs discussed aggregated energy consumption, while FR5 to FR8 discussed disaggregated energy consumption.

The participants were asked four questions after aggregated and disaggregated electricity consumption functionalities were described. (a) Do you think this functionality would save energy? (b) Would you prefer it with comparison or without comparison? (c) How often would you like to see the information (daily/weekly/monthly)? and (d) How can this design be improved? For the real-time and remote control designs, the participants were asked only about whether these functionalities would help them save energy and how the design can be improved. Apart from these questions, some of the general questions were asked which can be found in Table III.

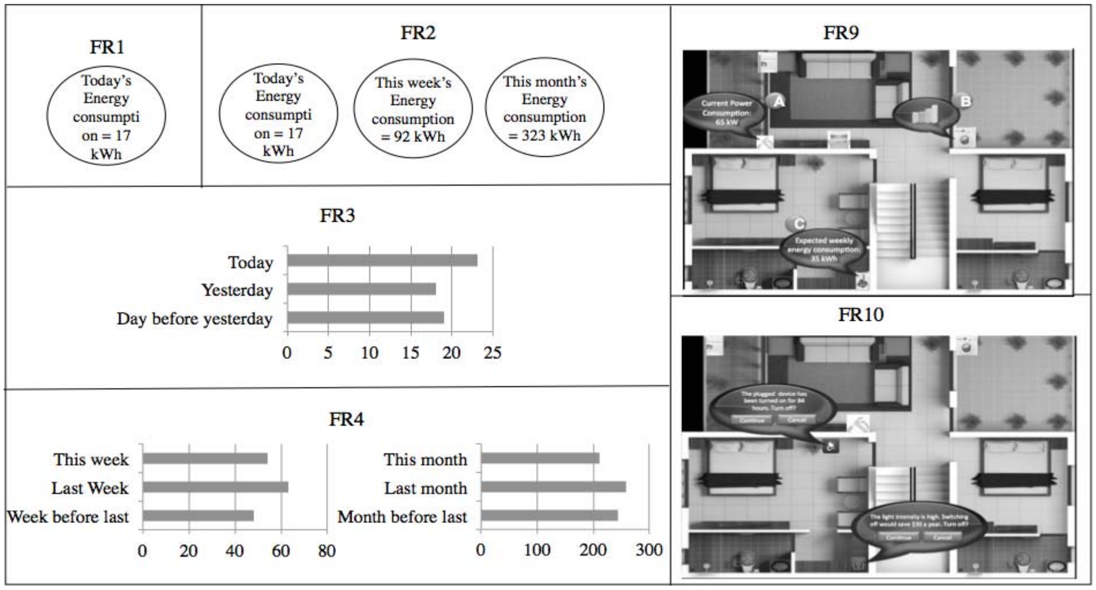

Fig. 2. Designs used in UCD design activity

3) Participants: The targeted participants of DTA are the residents of New Zealand who are aged 18 years and above. The participants were invited through E-mail groups. Six people accepted to participate in the research. One of the participants aged between 18 and 30, and 5 of them aged between 31 and 40. The selection of participants are random and are based on their willingness to participate. The participants are identified by PID (Participant IDentification) as P1to P6.

4) Results:

General Questions: The information that most of the participants (P1, P2, P3, P4, P6) read from the paper electricity bill were price, and comparison of electricity with the previous months. Also, one of the participants (P3) said that he would go through the details of the electricity bill when the price was more than the normal. One other participant (P2) said that they would look through peak energy consumption in a day and the total energy usage (in kWh) from the online electricity bill. She also said that she found it easier to turn off appliances if they are not in use.

Aggregated and Disaggregated Electricity Consumption: Current day's total electricity consumption in kWh: The participants felt that it would be better to connect it to the monetary benefits, that is to represent the electricity in dollar ($) amount (P1, P6). P2 said that they would use the information to reduce the consumption on the next day. But, P3 and P4 felt that the information was not useful by itself and might have to keep its record in their memory.

Most popular appliance to be monitored: The participants were asked about the appliance that they wanted to be monitored. Some of the appliances mentioned by the participants were dishwasher, water heater, heat pump, electric stove and power plugs.

Frequency of energy comparison: In most of the cases, the participants liked the comparison to be done weekly (P2, P3, P6, P4) and only one participant mentioned monthly comparison (P1).

Top Preferences by the Participants: The participants were asked to list their top 5 preferences among the 10 functional requirements. The most votes were received by FR6, which shows the disaggregated electricity consumption along with its frequency, followed by FR4 (Comparison of daily/weekly/monthly electricity consumption with 2 previous days/week/month) and FR8 (Comparison of daily/weekly/monthly electricity consumption by each appliance with 2 previous days/week/month). This clearly shows that the participants are muh interested in the comparison of electricity consumption over day/month/year over electricity feedback without any comparison. They felt that this might motivate them in saving electricity.

D. Features of the Proposed System

Table IV summarizes the functionalities of the system along with the percentage of studies/participants that supported it and are arranged in the order preferred by a majority of the studies (in case of SLR) and participants (from survey and design thinking activity). For instance, the functionality that was preferred by maximum studies/participants was 'aggregated energy consumption' and it was supported by 11 (50%) out of 22 SLR studies, 72 (63.72%) out of 137 participants in crowdsourcing survey, and 3 (50%) out of 6 participants in design activity with an average of 54.57%. The second highest preference was comparison of aggregated energy consumption among homologous periods such as days/weeks/months/years with 31.82%, 63.72% and 66.67% support from SLR, crowdsourcing survey and design thinking activity respectively.

Based on the top system features specified in Table IV, the top four features would be accessible in just a click away in a

TABLE IV
TOP SYSTEM FEATURES - COMPARISON FROM REQUIREMENTS ELICITATION TECHNIQUES

S.No.	Functionalities of the system	SLR	Crowdsourcing survey	Design thinking activities	Average
1	Aggregated energy consumption	50%	63.72%	50%	54.57%
2	Comparison - aggregated energy consumption	31.82%	63.72%	66.67%	54.07%
3	Remote appliance control	4.55%	NA	83.33%	43.94%
4	Energy saving tips	13.64%	69.03%	33.33%	38.67%
5	Disaggregated energy consumption	13.64%	73.81%	16.67%	34.71%
6	Comparison - Disaggregated energy consumption	0%	NA	66.67%	33.34%
7	Real-time energy consumption	22.73%	NA	33.33%	28.03%

dashboard followed by other three features in a different menu. All other preferences/settings would be few more clicks away from the top preferences.

V. RETROSPECTIVE ON REQUIREMENTS ELICITATION

Retrospective is a review activity that enables critical reflection on a process . Retrospective is very popular among the agile software development projects [26]. The important aspect of retrospective is to answer three important questions at the end of every software project completion. They are (a) What went well? (b) What didn't go well? and (c) What can be improved? [27].

A. What went well?

To achieve improvements in the RE process, it's usual to discuss the pain points; but, to keep the right thing being done, it is important to discuss the things that went well. RE process had several activities along the way which yielded good results.

We employed a combination of various techniques such as systematic literature review, crowdsourcing surveys and design thinking approaches to identify the requirements of the visualization system that saves household electricity. The results of the first RE technique, Systematic Literature Review (SLR), were fed into the next, i.e., crowdsourcing survey and Design Thinking Activities (DTA), resulting in the identification of top system features (see Table IV).

We accessed both research literature and commercial solutions' literature, which helped in analyzing the state-of-the-art techniques and features of the system which inturn helped us analyze the advantages and disadvantages and to come up with a clearly designed crowdsourcing survey.

In the crowdsourcing survey, we distributed the questions into four categories as mentioned in Subsection IV-B2. This was easily readable for the respondents to the survey.

During the DTA, the users were given ten different design options to choose their top preferences for energy feedback application. Also, ample amount of time was given to help the participant think and understand the suitable option(s) for household energy feedback.

The system features were arranged based on the average score of the three RE techniques as summarized in Table IV. It is hoped that this will help the end-users in viewing the highly preferred features in just a click away.

B. What didn't go well?

The response rate for the crowdsourcing survey is low and almost 12.5% (17 responses) of the surveys remained incomplete. The responding time should have been kept as minimum as possible by keeping the number of questions low because survey respondents typically dislike long surveys. Also, the survey should have had less to no open-ended compulsory questions and shouldn't have taken more than 5 minutes to complete.

During the DTA, some of the paper designs confused the participants as they did not know the overall picture of the system to be developed. So, a brief overview was given to the participants during the activity; however, apparently this was not enough. Intense pilot testing should have been done before the actual activity, which would have identified such issues and allowed us to improve the quality of the DTA instructions.

The number of participants for the crowdsourcing survey and DTA was rather low, which restrained us from drawing effective conclusions. We should have employed more effective advertisement to attract more participants and we should have released the advertisement far in advance.

C. What can be improved?

According to our observations, the design thinking activities should have been a group activity instead of an individual event. The group activity would have been informative to each of the participants technically and the outcome of the activity would have been more useful to us. Although the participants were given an overview of the project, a lot of assumptions were held and so an extended overview would have been helpful. Moreover, this could have reduced the duration of the design activity, as more time would have been spent on the activity rather than clarifying participant questions.

The design activity should have been video recorded to make effective observation of the participants. This would have added a completely different perspective to the observations by analysing the non verbal communication made by the participants and thereby help in improving the features of the system.

The keywords for SLR should have included several other specific terms such as 'electricity', 'electricity savings', 'household electricity', 'energy conservation', and 'energy feedback'.

VI. Conclusion and Future work

To solve the universal problem of reducing domestic electricity consumption, an innovative software system was planned to be designed, which might serve as the motivation for the end-users to save energy. The first phase of the software development, requirements elicitation was carried out using three major RE techniques one by one. They are (a) systematic literature review, (b) crowdsourcing survey, and (c) design thinking activity. Each of these techniques were interdependent and the results from each techniques were fed to design the subsequent techniques. Each technique had pilot testing and feedback was effectively utilized at every stage.

The motivation, method, results were discussed for each technique along with the retrospectives on requirements elicitation. The retrospectives included three major questions and discussed the advantages and disadvantages of the techniques used to engineer the requirements. The study was exposed to the statistical analysis to identify the top feature preferences was highly effective. The combination of RE techniques effectively helped to identify the system requirements. If these requirements are converted into useful and usable visualization, the system would be able to reduce the unncessary electricity consumption in the household.

Finally, there is an immediate attention required for designing visualization to balance between aesthetic appeal and practical usefulness, to balance between accuracy and clarity, and to balance between comfort and cost effectiveness. The application would be cross-platformed and developed using agile software development methodology. The implementation would be evaluated at every stage with atleast 20 - 25 participants and the feedback will then be incorporated to further enhance the application.

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