Crowd Intelligence in Requirements Engineering: Current Status and Future Directions

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Abstract. Software systems are the joint creative products of multiple stakeholders, including both designers and users, based on their perception, knowledge and personal preferences of the application context. The rapid rise in the use of Internet, mobile and social media applications make it even more possible to provide channels to link a large pool of highly diversified and physically distributed designers and end users, the crowd. Converging the knowledge of designers and end users in requirements engineering process is essential for the success of software systems. In this paper, we report the findings of a survey of the literature on crowd-based requirements engineering research. It helps us understand the current research achievements, the areas of concentration, and how requirements related activities can be enhanced by crowd intelligence. Based on the survey, we propose a general research map and suggest the possible future roles of crowd intelligence in requirements engineering.

Keywords: Requirements Engineering, Crowd Intelligence, User Feedback, Crowdsourcing

1 Introduction and Background

Software systems are engineered via interactive processes between multiple stakeholders in the developmental and operational environment. Depending on ones' command of design ability, and knowledge about the application domain, the creative process can happen either in the designer's mind or the user's mind or together [9]. The success of software product is measured by the degree it meets the intended design purposes and end-user needs [60]. Minimizing the cost and the speed in achieving that target is always desired. While conventional requirements engineering (RE) approaches often rely on limited number of stakeholders, e.g. through interviews and focus groups, it is made possible today to involve a large group of potential users and contributors distributed geographically and culturally. Therefore, RE for today's software, can benefit from novel techniques and tools to support converging crowd intelligence in requirements elicitation and decision [7, 70, 77]. Crowd intelligence arises from the cooperation, combined efforts, and competition amongst end users, who are interested to take part in requirements engineering activities.

To cater for the diversity of the crowd in requirements elicitation, some effort has been made in term of persona and adaptive feedback acquisition [3]. The foci are on software systems being developed in open environment and offered in open market more than dedicated products for specific customers [3, 63]. But these techniques can only provide initial segmentation which needs further support to cater for the many facets of diversity in the crowd including those found in their comments and feedbacks [12, 19, 32, 42]. Therefore, more scalable mechanisms are needed where users can actively participate in different feedback channels thus contributing to the future system design decisions [72, 73].

Crowdsourcing has existed as a business paradigm long before the Internet era. However, its integration with the internet has brought great popularities and successful applications in many disciplines [10, 38, 76, 78, 84]. An extensive analysis to the crowdsourcing literature has led to a crowdsourcing taxonomy, which is composed of four major concepts: crowd, client, task and platform [30]. In recent years, crowdsourcing has attracted much attention and was widely experimented in software engineering including requirements engineering [50]. One notable area is the engineering of crowdsourcing platforms to allow crowd intelligence to emerge, e.g. Wisdom of Crowd. The degree and focus areas of such crowd intelligence together with the facilities and algorithms built to allow it, are diverse. Also, it became apparent that activities like aggregation of crowd input and the derivation of collective decisions require the power of AI at the planning time and also production time.

In this paper, we explore such diversity and status of using crowd intelligence for requirements engineering and facilitating it through AI. We conduct a literature survey to evaluate the current status of the field of Intelligent Crowd-based RE. We describe our method in Section 2 and then our research findings in Section 3. We depict a map for the areas of research in Section 4, which fits the pieces into an integral picture and discuss possible future directions in Section 5.

2 Research Method

In this section, we describe our literature survey process including the research questions and the searching, filtering and analysis processes. In requirements engineering research, there is a growing interest in crowd-based RE. While crowd-based RE (CrowdRE) is considered promising, it is unclear what is the status of the research and practice in CrowdRE and what are the current challenges. Thus, we identified the main research questions of our literature survey as:

RQ1. What are the current foci of CrowdRE research?

RQ2. How traditional RE activities are mapped with CrowdRE activities and how crowd-based techniques support RE activities?

RQ3. What is a possible future role of intelligence in CrowdRE?

Search criteria required a paper title to meet the following search string and variations of it: (“CrowdRE” OR “Requirements Crowdsourcing” OR (“Crowd” AND “Requirements Engineering”) OR “Crowd-based Requirements Engineering” OR (“Crowd

intelligence" AND "Requirements Engineering"). The papers must be written in English and must have been published in peer reviewed conferences, journals, book chapters or be a refereed thesis. Snowballing approach was used to expand the search results.

Online libraries which were used for searching the research papers are: IEEE Xplore, ACM Library, ResearchGate, Springer Library, Elsevier Science direct and Google Scholar. The duration searched was between January 2010 and September 2018. Main conferences, workshops and journals whose title meet the search criteria were also searched in order to ensure important papers, while other major RE related conferences, workshops and journals are also included, e.g. IEEE RE conference, REFSQ, CrowdRE workshop, CAiSE, RCIS, REJ, IST and JSS.

The initial searching process led to 127 papers in total. Then a manual selection process was conducted and we excluded papers which were published in languages other than English, in unrecognized venues and meeting the search criteria but without being centered on the topic. For this, we read the title, abstract of each paper in order to check its relevance, if still relevant or uncertain, the introduction and even the whole paper is read. In total 97 papers where selected, out of which 77 papers are directly related to CrowdRE, while the remaining 20 papers are supportive papers to CrowdRE concepts like Crowdsourcing Taxonomy, books on crowd wisdoms, crowd motivations, software crowdsourcing companies case study etc. The final list of papers was validated again by the 2nd author of the paper, by looking at the title and reading the content if necessary. Also, the selection criteria were double checked, to ensure that no relevant papers were missed in the selection process. The major keywords from the title of the included papers were: requirements/ requirement engineering, software, crowd, requirements crowdsourcing, mining, users/user, feature, reviews, case study, approach, online, elicitation, collaborative, and so on. Taking a closer look at the nature of the studies included in our survey, the surveyed studies included visions and previews, case studies, data analytics studies, tools and demos, domain-specific studies and applications. The survey papers included in our paper were studies which collected data about usage of crowdsourcing requirements elicitations [28]. We analyzed each paper to identify its nature of study and then grouped them into the categories. There are 34 technical solutions papers, 3 empirical study papers, 7 data analysis papers, 4 papers are about domain applications, 7 case studies, 7 papers about RE tools, there are also 4 surveys, 3 research previews, and 8 vision papers.

3 RE Activities: Crowd Support and Main Issues

CrowdRE is mainly founded on the assumption that it is important to collect up-to-date observations and experience of the "crowd" about a system and predict the future requirements. Also, CrowdRE is still developing, therefore there are exploratory studies on CrowdRE models, activities and validation with expert software engineers, end users and researchers through surveys and questionnaires in order to find some relationship between crowdsourcing features and requirements elicitation to better understand the needs of end users and overcomes human cognitive limitations by monitoring users at run time [29, 28, 2, 68]. In this section, the results of our survey around the status of the field and how this role has been fulfilled so far, including the support from AI, will be presented.

3.1 The Crowd in the Requirements Engineering Activities

Requirements is pivotal in software engineering as it is fundamental to ensure product quality and customer satisfaction. Major requirements engineering activities, such as requirements elicitation, modeling, analysis and validation, prioritization, and runtime adaptation and evolution are all serving these two ultimate goals. The role of the crowd can vary according to the RE activity and also the RE technique and model used. For example, while we would expect requirements expressed as User Stories to be understood fairly by the crowd, requirements validation may need advanced simulation and scenario building skills, and hence tools to engage and get meaningful input from the crowd. We try to answer RQ1 through this section by highlight current CrowdRE research focus through literature.

Table 1. Requirements activities that crowd are involved

RE. Activities	Perspectives/Activities		No. of Studies
Elicitation	General requirements	[1,13,34,44,39,50,56,57,58,70,77,84,87]	70
	Features	[25,49,69,58,90,91]	
	NFRs	[4,5,23,51,72]	
	Run-time Feedback	[71,22,31,41,72,96]	
	Emerging requirements	[15,42,57]	
	Design Rationale	[37]	
Modelling & Specification	Use cases [27,46,], process models [12,26], Goals [61,68], *i**[59], feature models [19,68]		8
Analysis and Validation	By crowd [48,54,72], by textual data analysis [13,20,25,33,41,42,49,51,52,62,64,80,86,88,89], by prototyping [22], sentiment analysis [21,79], image and unstructured data analysis [21,73]		22
Prioritization	User rating and comments [14,43], developer voting [72], crowd members vote [70,72], statistical analysis [21], gamified approaches [36]		6
Run-time	Monitoring [2,20,73,75,93], adaption [3,26,55], evolution [25,45,66,85], discovery [81], context [21,42,48]		16

Requirements Elicitation. Requirements elicitation is the process of gathering user demand and needs to be addressed by the software. As we can see from Table. 1, 70 out of 77 paper covers requirements elicitation, using different approaches with different foci (type of requirements elicitation), where some of papers references are shown in Table 1. For this, we analysed each paper content to identify foci of requirements elicitation and grouped them into categories shown in Table 1. For example, there are works focusing on elicit general requirements, including: building personas for users profiling [3] and identify Personae Non Gratae (potential system attackers or abusers) [51], collecting runtime user feedbacks, or on extraction of novel or emerging functional or non-functional requirements [23], such as usability, user experience [4] and awareness [75], or security and privacy requirements [5,8], or building elicitation tools for crowd.

Requirements Modeling. In requirements modeling, graphical models such as use cases, sequence diagrams, *i**, goal, activity diagrams, etc. are typically used by developers and stakeholders to better understand and communicate about the requirements [27, 12, 1, 59]. Requirements modeling is considered as challenging for massive crowds, it is only possible to build collaborative modelling tools for small or medium

sized groups [27], or competition platforms for the crowd to bid for an award for best requirements specifications [1, 64]. For example, Almaliki et al [3] suggested clustering the crowd and their different styles of input, the crowd is being modelled linked to feedback acquisition process by a model-driven process. Specifically, linking the user's personas into associated goal models, then goal models are converted into use case models. Sherief et al [68] proposed an architecture and ontology for acquiring crowd feedback and linking it to requirements models.

Requirements Analysis and Validation. Requirements analysis focuses on parsing and understanding the elicited requirements. During requirements analysis, inconsistences, ambiguities, and incompleteness in gathered and documented and possibly modeled requirements are identified. Hosseini et al [31] propose a technique for feedback annotation, called CRAFT, which aims to harnessing the power and wisdom of the crowd. Stade et al [73] argue that CrowdRE process cannot be implemented ad-hoc and that much work is needed to create and analyse a continuous feedback and monitoring data stream. Similarly, Liu et al [46] propose to collect users click events in order to correlate user behavioral data with active feedbacks so that they can efficiently solves user issues. Almaliki et al [3], proposed persona-based feedback acquisition technique using quantitative and qualitative analysis to help engineers understanding the diverse behaviors of the users. Maalej et al [48] surveyed the state-of-the-art elicitation approaches of user input, and found that there is currently no unified model of user input. They proposed a development process enabling users to become "prosumers" of software applications and giving more continuous, direct and rich input. Requirements validation is the process of making sure that requirements gathered are aligned with the stakeholder's actual needs and are correct, consist and testable. As shown in Table 1, quite a few papers acknowledge that requirements validation in CrowdRE is challenging [28, 54, 68, 72, 73].

Requirements Prioritization. Requirements prioritization and negotiation play a pivotal role in CrowdRE [67]. A large number of stakeholders often result in a large set of requirements and preferences, but only a subset can be implemented in the software under design. Thus, prioritization and triage is required to solve this problem. Researchers have used approaches such as, user rating and comments, developer voting, crowd member's votes, statistical analysis, gamified approaches [36, 61]. Lim and Finkelstein [43] developed tool named StakeRare, which uses social networking and collaborative filtering to elicit and prioritize large set of requirements.

Requirements Evolution. In CrowdRE, user feedback loops can be obtained iteratively throughout the lifecycle of the product. New requirements are gathered at run time and referred to when planning for the next release of the software system. Therefore, user's activities need to be monitored or reported to capture the usage context and users' intentions in the form of user's behaviors log. There are existing works on runtime adaptation or evolution in CrowdRE [2, 15, 20, 21, 26, 45, 55, 81].

3.2 Utilities in CrowdRE

Based on our survey in CrowdRE, we found that researchers focus was on the following aspects: the crowd, the tasks delegated to the crowd, and the design of mechanisms,

such as those enabling crowd competition and collaboration, the media or channel for communication, the incentives for engaging the crowd, and ways to evaluate the quality of deliverables from the crowd.

Crowd. Crowd are the entities who will take part in the requirements processes. Crowds are mainly classified according to the following three properties: scale, level of skills, and roles. In the case of CrowdRE, we mainly deal with requirements approaches involving large crowd, but not necessarily unknown or random. *Level of knowledge and expertise* is the property representing the required skills of the crowd in a specific subject domain [65]. Stratified coverage could be specified to enable the acquisition of differences of viewpoints, e.g. from lowly and highly skills crowd. In the literature, there level of expertise of the crowd is one of the requirements of a crowdsourcing project. Techniques are proposed by Srivastava and Sharma [72], Levy et al [39] and Groen [22], where macro user communities were involved to elicit requirements using different media channels (LinkedIn, users forums and research workshops). Munante et al [55] gather preferences of both domain experts and end users in the form of personas and questionnaires about configuration requirements for adaptive systems. *Role* means which the remit and expectation of the crowd members involved in CrowdRE. In the literature, there are end users, domain experts, software engineers being involved for different purposes. Snijders [70], proposed a CrowdRE approach that gathered requirements are analysed and prioritized by involving crowd members. Similarly, in Groen et al [21] requirements gathered are validated by developers or third-party experts.

Task. Task is the requirement activity in which the crowd participates. Tasks in CrowdRE are categorized according to their type and complexity, as shown in Table 3. Task *type* refers to the nature of the task for which crowd will participate. In Table 1, it can be seen that task type is extraction of raw requirements [34], provide feedbacks [48, 39], bugs identification [21, 31, 20, 73], feature request identification [29, 52], non-functional requirements [31, 72]. Task *complexity*: means whether the task is simple, medium, or complex to complete. Complexity is inter-related with crowd role, level of skills and the time needed by the crowd to perform it.

Mechanisms. Mechanisms are the means by which CrowdRE approaches achieve their intended goals of participation, including the media or sources used to reach out for the crowd, the incentives to motivate crowd for participating in RE activities and crowd collaboration or aggregation mechanisms. Mechanisms are further decomposed into the following sub-heading, as can be seen in Table 3, which is sketched based on literature.

*Collaboration and Aggregation***.** Collaboration means that whether individuals in the crowd need to collaborate to complete a task. While aggregation means that individual's contributions are aggregated to present some useful information. In the literature, there are approaches requiring different types of collaborations to complete a task [50, 39, 28, 3, 83] and approaches to aggregate the individual contributions at the end [43, 55, 21, 73]. Groen et al [20, 21] proposed theoretical models for CrowdRE using concepts of crowdsourcing where individuals' tasks are aggregated to provide a final list of identified requirements. Only few approaches adopted competition among crowds to yield optimal solutions [1, 22].

Media/Channel: In order to gain access to massive crowd, we need certain media. CrowdRE uses different channels to achieve this. Many existing work uses a general purpose media to access a community of crowd, online forums and mobile application marketplaces [29, 56, 31,35], a few others uses social network tools to access crowd along with LinkedIn [72, 22], research workshops [39], mobile stores and twitter [6] [62, 79, 91], as in Table 3. Similarly, MuruKannaiah et al [56, 57], developed their own crowd requirements research dataset to research user communities and other diverse characteristics of crowd members, which can be used for analysis and prioritization of requirements using Amazon Mechanical Turk, which is a crowd-based platform. Details of media/channel used in literature are depicted in Table 2.

Table 2. Types of Media

Type of Media	Researchers used Media type
Twitter	Guzman et al [22, 25], Williams & Mahmoud [79]
User Forums	Bakiu et al [4] (epinions.com), Do et al [15] (Firefox, Lucene and Mylyn), Greenwood et al [19], Kanchev et al [34, 35] (Reddit.com), Li et al [41] (sourceforge.net), Qi et al [62] (Jd.com) , Xiao et al [80] (epinions.com), Shi et al [69] (JIRA)
LinkedIn	Groen [22], Srivastava & Sharma [72]
Mobile stores	Groen et al [23], Johann et al [33], Maalej and Nabil [49], Williams et al [87], Dhinakaran et al [88], Liu et al [91]
Amazon store	Groen et al [23], Kurtanovic and walid [37]
Issue Tracking	Merten et al [52] (GitHub ITS & Redmine ITS)
MTurk	Murukannaiah et al [56, 57] , Breaux et al [8], Gemkow et al [89], Khan et al [90]

Incentives/Motivation: To engage the crowd in feedback generation or requirements elicitation, certain motivation and incentives strategies are required. Most common motivations are rewards [1, 56] gamification and public acknowledgement [3, 70, 73] or multiple techniques in combination. Snijders et al [71], propose REfine, a game-based requirements elicitation technique which use gamification to constantly motivate the crowd members for giving feedback and keeping them involved. Srivastava and Sharma [72], Levy et al [39], Groen [22] and Munante et al [55] propose that rewards and acknowledgements can be used to motivate experts and non-experts crowd members. Piras et al [61] proposed to develop a framework for analyzing, modeling and accomplishing acceptance requirements for software application using gamification.

Quality: It is an important question to answer in CrowdRE to evaluate and ensure the quality of requirements obtained from the crowd either as individuals or as groups following some collective intelligence model. This problem remains largely uninvestigated in the literature. It is well argued in general crowd intelligence literature [94] that diverse, independent and decentralized crowd performs better than experts in certain circumstances and when communication and aggregation of knowledge is also done properly. We need to find out what are the necessary conditions and quality measures for crowd to deliver useful results. Getting knowledge from the crowd is by itself not a

guarantee for quality knowledge. Indeed, as discussed in [92], quality is relates to the way the crowd is approached and organized, but not only to the quality of their input. One the other hand, ideal solutions from experts may be either biased towards their own expertise, or too ambitious in reality. Researcher's needs to explore this part further in future research, as up to date, according to our knowledge there is less research study and needs further exploration.

4 A Research Map for Intelligent CrowdRE

To support crowd intelligence in RE, we have developed a research map, described in Table 3, mapping the current research work in CrowdRE in response to RQ2 and RQ3. The map describes each requirements engineering activity with respect to Crowd activities covering: crowd tasks and mechanisms. The columns show the crowdsourcing activities' while rows show RE activities. Possible techniques used for crowd motivation are given in Table 3 under the heading incentives/motivations.

Table 3. Research map for CrowdRE

RE Activities	Tasks		Mechanisms			
	Role/ Expertise	Types	Collaboration/ Competition	Media/ Channel	Incentives/ Motivation	Quality of requirements gathered
Elicitation	system user / Low	Feature Requests, New requirements	Collaboration between crowd/ aggregation in final outcome	Twitter, User forums, Facebook, websites, Mobile app stores	Gamification Vouchers, Social recognition, Cash	No individual guarantee, by statistical analysis
Modeling	Analysts & domain experts / Logs analysed by development team/ Medium-high	Co-modelling, goal modeling, feature modeling, process modeling, argumentation	Direct/indirect collaboration	Platform-based	Gamification, Assigned or obliged	Relying on Individual expertise
Analysis & Runtime adaptation / evolution		Feedbacks on Bugs, monitoring run time logs of exceptions, abnormal behaviors information retrieval, sentiment analysis, Language patterns, Recommender system	No collaboration between crowd/ aggregation in final outcome	Manual or automated text analysis, speech act recognition tools, Log analysis and mining tools	Gamification, Social recognition, cash, assigned or obliged	Relying on Individual expertise, Fairly reliable
Validation	Developer or 3rd party/ High	Annotation or walkthrough review		Validation need to check the influence		Relying on Individual expertise
Prioritization and Negotiation	system user/ Low	Preference elicitation, win-condition elicitation	Direct/indirect group decision making	Voting or group decision making tools	Gamification, Cash Vouchers, Social recognition	No individual guarantee, by consensus

There are diverse research efforts on crowd requirements engineering in the surveyed literature using AI techniques. For example, there are works on using natural language processing (NLP) techniques in classifying, clustering, categorizing users' feedback into feature requests, bugs, or simple compliments [16, 37, 41, 53, 69]. Analysis of user feedbacks and runtime human-computer interactions are experimented using NLP and text mining techniques. Maalej et al also highlighted the issues and emphases to use automated techniques to categorize users' feedbacks into different categories in crowd-based requirements engineering [49, 58]. We adhere not the possibility that users may give feedback in the form of images, audio or video, thus analysis is required to deal with such unstructured data. Also, AI techniques such as *swarm algorithms*, *case-based learning* and *collaborative filtering* can be used with crowd-generated data to get useful insights. As more recently, Sarro et al [86], used Case Based Reasoning (CBR) algorithm to predict mobile apps rating based on the features claimed for mobile apps in their description. Also, Gemkow et al [89], applied AI techniques to a crowd-generated dataset, to extract the domain-specific glossary terms, and Seyff et al [85], propose to use AI techniques together with crowd-generated data in order to observe the effects of requirements on sustainability. As CrowdRE generated a massive amount of candidate requirements, automated and AI techniques are required to validate the volume and diversity of test cases and contexts of use [85].

To support our proposed framework, we have identified some related studies in the literature which also focus on using crowd intelligence. Dabrowski et al [12] proposes that statistical techniques can be used to *maximize the capacity of crowd* in identifying new software requirements. Also, Liang et al [42] use requirements mining from crowd user's behaviors data to *recommend services to crowd users*. Recently, Seyff et al [85] proposed a crowd-based approach for *engaging stakeholders in a continuous cycle of negotiation* regarding the possible effects of requirements on sustainability. In their model, firstly, feedback regarding software services are gathered using crowd platform, then *machine learning techniques* are applied to *cluster and analyse feedback gathered*.

So far, there are few works been done in crowd *requirements modeling*. Khan et al [90], propose semi-automated goal modeling approach to model features identified from CrowdRE. For requirements *analysis and validation*, Mead et al [51] proposed that machine learning algorithms can be used to analyse individual Personae Non Gratae created by crowd users. To accommodate AI and exploit human intelligence in requirements analysis, Dhinakaran et al [88] proposed an active learning approach to classify requirements into features, bugs, rating and user experience. Recently, Williams et al [87] proposed that *automated social mining and domain modeling techniques* can be used to analyse mobile app success and failure stories to identify end-users' concerns of domain. Khan et al [90], applied *AI techniques* to a crowd-generated dataset to cluster relevant features and then draw a *semi-automated goal model* from the extracted features. Stade et al [73] proposed that automated approaches are required to combine monitored data with feedback data in crowd environment. To support continuous requirements elicitation Oriol et al [93], proposed a framework to simultaneously collect feedbacks and monitoring data from mobile and web users. Gamification can be used to keep the crowd motivated and engaged. Kifetew et al [36] developed gamification-based requirements prioritization tool to prioritize requirements. Moreover, our

proposed framework is not final, that could be changed, and that, it needs verification and validation before being put into practice.

Recently, Williams et al [87] proposed that automated social mining and domain modeling techniques can be used to analyse crowd-generated requirements. It can be seen in Table 3, possible AI techniques that can used for CrowdRE analysis, validation and modeling are, *information retrieval, sentiment analysis, language patterns, annotation, walkthrough, co-modeling, goal modeling, feature modeling and business process modeling, AI argumentation, CBR, Swarm algorithms and collaborative filtering* respectively. This lead to give answer to RQ2. These tasks are different nature but it can be overridden by introducing *automated algorithms* together with interactions with experts or knowledge base integrating crowd input and expert rules.

5 Discussion and Future Direction

Crowd participation are of potential aid for all RE activities. The size and significance of participation may vary but the added value is also the sense of participation itself where the crowd feel *relatedness* and *ownership* of the solutions all the way through the development process. *Relatedness* is a pillar of motivation as explained in self-determination theory (SDT) [11] [97]. Similar social principle can be adopted for motivating crowd members by integrating social media with crowd-based activities. Besides this, *fun and enjoyable* activities like visual effects, animations can be used to motivate and engage crowd members. *Aesthetics* in games are as important as level design and rewards. Continuous learning opportunities provided for user communities will also keep them interested in being involved. In fact, a one-size-fits all style for motivation would not work and personalization and cultural-awareness are needed [95, 96].

Much work has been done on requirements elicitation using the crowd. Requirements activities in CrowdRE are mostly focusing on user feedbacks. To cater for crowd intelligence, we can approach both experts (analysts, developers, domain experts) and non-expert users. Their input is then applied on the gathered feedbacks in different ways such as *sentimental analysis, information retrieval, co-modeling, goal modeling, usage mining, annotation, walkthrough reviews and prototyping*. User communities voluntarily contribute their data and intelligence by allowing run time monitoring of their behavior in order to identify recurring patterns. User logs are created from there feedback on usability issues, abnormal behaviors and run time exceptions, which are used as a media source. The nature of monitoring task is complex and required medium to high expertise.

For *requirements modeling*, we suggest direct or indirect collaboration support to incorporate crowd intelligence into requirements discoveries and decisions. Co-modeling scale shall be increased to cope with the volume and diversity of crowd. Semi-automated and fully automated goal-modeling techniques shall be used to model CrowdRE. Also, *Argumentation* can be used to model CrowdRE and capture requirements rationale. The current trend for collaborative modelling environments is more and more artefact-driven, as it embodied in the open software development platforms.

Our research map shows that multiple media channels are provided through which crowd input can be gathered. Different types of tasks can be delegated to the crowd using those media channels. The map suggests that for crowd intelligence to take effect, collaboration, competition or aggregation support is mandatory while there might be some projects which do not require collaborations amongst the crowd members. Mechanisms for collaborative tasks are provided to the crowd.

Similarly, input from different tasks can be aggregated to form the final outcome. For automated aggregation of individual contributions, data mining and analysis tools play an important role. To take maximum advantage of crowd intelligence in requirements gathering, certain incentives must be given to user communities in order to keep them motivated for actively and continuous feedback. For crowd intelligence to take effect, the crowd members have to be *independent*, *diversified* in terms of knowledge and skills [94]. Thus, we may look for differences rather than consensus when we collect raw requirements information, in particular, for paradigms like universal design and software product lines engineering (SPLE). When we analyse them and seek for creative ideas, we let the knowledge build up and form a continuation to better quality and better user experience by tracking and knowledge management tools [17, 18].

Harnessing the role of crowd in the validation is promising to cater for scalability and coverage of different user groups. In CrowdRE, raw requirements data come from end users are often massive in size, and are not generated by expert in RE, which leads to a threat. Therefore, automated requirements validation techniques are required for refining the set of requirements, reducing the complexity of task, or crowd sourcing the task back to the mass. Picking right requirements for the next release is important, which can be done through requirements prioritization and negotiation. *AI argumentation*, is best fit for eliminating ambiguity and decision making. Further work is required in CrowdRE for *preference elicitation* and *win-condition elicitation*. By considering the *users ranking*, *rating and comments* about current product features, adopt some *statistical analysis* could bring the state-of-the practice to a next level of success. Automated techniques, possibly supported by AI, are required to effectively prioritize the identify candidate requirements and keep as many stakeholders involved in the decision process as possible.

Once a list of candidate requirements is identified, they can be presented to the crowd members to elicit their preferences in prioritizing the potential requirements [80]. We can gather crowd intelligence in the form of preference elicitation and win-condition elicitation to support prioritization and negotiation. To support this, the proposed framework provides direct or indirect group decision making and voting mechanism. For requirements prioritization and negotiation, end users' participation is essential, thus it is necessary to keep them motivated by combining possible means, such as gamification, vouchers, social recognitions and monetary awards in order to achieve better user satisfaction and improved software usability.

Monitoring end users' behavior while interacting with the software system are very essential in CrowdRE. There is existing work in monitoring end user behavior by *mining user logs and mouse click events*. But it is only a start at a few minor points of the entire landscape. With the integration of crowd intelligence, we can collect feedbacks

on usability issues, abnormal behaviors and run time exceptions. *Intelligent Mechanisms* are required to correlate monitoring data with user feedbacks, so that developers can better interpret the user's feedback. Although Monitoring tasks are very complex but its handling costs can be minimized with the introduction of *automated tools*. With the support of log analysis and data mining tools, it is easier for the development team in understanding the user feedback.

One open problem is in managing privacy of users which may deter users from participating, e.g. in discussion in an open forum for employees of a large-scale company. Privacy can be tackled by certain motivation mechanisms, including assurance by the organization policies, and data protection measures, including the right of the crowd to know how their individual input was judged and by whom. We note here that such measures can become a burden on the organization to adopt CrowdRE, e.g. in responding to Freedom of Information requests and the right of citizens to Automated Decision Making in the GDPR in Europe.

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