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Microtasking Activities in Crowdsourced Software Development: A Systematic Literature Review

MAIRA ZULFIQAR, MUHAMMAD NOMAN MALIK, (Member, IEEE), AND HUMA HAYAT KHAN, (Member, IEEE)

Department of Software Engineering, National University of Modern Languages, Islamabad 44000, Pakistan

Corresponding author: Maira Zulfiqar (mairazulfiqar461@gmail.com)

ABSTRACT With the utilization of crowdsourcing as a problem-solving approach, software industry has progressed tremendously in recent few years. Different models of crowdsourcing have been used depending on the nature of required outcome of the task, and have had varying levels of success to date. Microtasking is one of the lucrative models of crowdsourcing which penetrated the problem-solving strategy by facilitating the decomposition of complex tasks into short and self-contained microtasks which can be performed in few minutes. Regardless of considerable number of studies explored the kinds of microtasks, existing researches fall short when it comes to technical as well as non-technical tasks and the categorization of relevant microtasks. Thus, the aim of this research is to understand the context of microtasked related crowdsourcing and to explore the microtasks related to crowdsourced software development which exist in literature. Systematic literature review is conducted to identify the microtasking activities and expert review is conducted to validate the identified microtasking activities and their categories. The final publication sample to review the literature is composed of 42 research articles and the reviews of 4 experts are taken for validation. A total of 72 microtasking activities are found along with 11 categories. After validation applied, researchers came up with a list of 61 unique microtasking activities. This paper contributes to software industry by providing list of microtasks along with their categories which will be fruitful for researchers, microtasking platforms and their clients. It contributes to software industry by providing list of microtasks which will be fruitful for researchers and microtasking platforms.

INDEX TERMS Microtasks, activities, microtasking categories, crowdsourcing, software development.

I. INTRODUCTION

Microtasking is contemplated as one of remunerative model of crowdsourcing, which utilizes the shared cognitive efforts of online crowd [1], [2]. This model of crowdsourcing involves the decomposition of large and complex tasks into the number of simple, short and self-contained units (generally known as microtasks) [3], [4]. Microtasking is the process which involves the shared effort of large number of remote-workers (generally known as crowd) who participate to solve the problem for clearly defined and self-dependent tasks, by reducing geographical participation expenses and crowd workers mobility, thus saving time and expenses [5]–[7].

Different online platforms have been developed to provide the services to clients as well as crowd workers in terms of microjobs (another term for microtask), in order to reduce unemployment specially in developing communities [8]. These platforms support variety of tasks and provide different facilities to their users in terms of remuneration, social recognition, bonuses and e-gifts [9], [10]. Few platforms support the specific tasks (Quicktate and iDictate for call auditing and Topcoder for programming), while most of the platforms facilitate their clients with a variety of tasks related to designing, programming and development, testing and quality assurance, interpretation and analysis and content writing [11], [12].

With the frequent practice of distributed human computation in non-technical tasks, microtasking model of crowdsourcing is widely used to perform the technical tasks in software crowdsourcing [13]. In software engineering, microtasks are often known as microservices; a decomposed short, simple and well-structured web-based task which enables to be built independently, to deployed quickly

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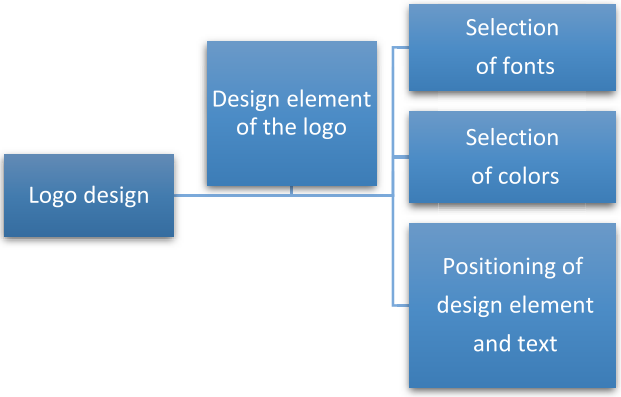

FIGURE 1. Decomposition of task 'logo design' into microtasks [21].

and independently and to reuse in future [14]. Dedicated online platforms have been developed for displaying the competitions, advertising, publishing, generating assigning and integrating the microtasks [15]–[17]. The microtasks are then published on the dedicated platforms to explore the best available crowd workers [18]. Moreover, the aims of dedicated online systems are to act as trustworthy intermediary platform and to resolve the disputes among clients and crowd workers [19], [20]. Figure 1 shows the decomposition of task into microtasks.

Figure 1. presents the decomposition of task into multiple microtasks. On a microtasking platform, logo design task is requested by a client. Depending on the managerial policies of the platform, copilot (experienced individual paid by the platform to perform the task) decomposes the task into multiple microtasks i.e., sketching of design element for required logo, selection of appropriate colors and fonts for specific logo and suitable positioning of design element along with text to achieve the final outcome.

Accusatively, microtasking supports the accomplishment of substantial digital tasks by decomposing the complex tasks into the number of microtasks which can be performed by diversified remote micro-workers available on microtasking platforms [4]. It has been noticed that published microtasks can be of technical (programming and development) as well as non-technical in nature [22]. Only a few noteworthy studies [18], [23], [24] have investigated different kinds and examples of microtasks which exist on web. However, their findings did not cover all the possible and existing microtasking areas.

As a consequence, without adequate knowledge of what type of microtasks can be generated from a complex task, clients and microtasking platforms may suffer in the terms of late completion of project and by assigning the task to inappropriate worker respectively. Thus, it is essential to investigate the microtasking tasks related to crowdsourced software development.

This research opens following research questions:

RQ1: What kinds of microtasking activities related to crowdsourced software development, are presented in research literature?

RQ2: What are the various categories for each of the identified microtasking activities?

The goal of the research questions is to understand the context of microtasked related crowdsourcing and to identify the microtasking activities which exist in crowdsourced related software development. Moreover, the aim of this research is to come up with the list of microtasking activities along with their categories which exist in literature.

The rest of the paper is organized as follows. Crowdsourcing definition, usage of crowdsourcing in software engineering, models of crowdsourcing, microtasking models, usage and platforms of microtasking is explained in section II. Methodology adopted to answer the research question followed by the guideline is presented in section III. Findings of the research are presented in section IV. Validation of findings is presented in section V. Limitations and future directions are explained in section VI and VII respectively. In the last, conclusion is presented in section VIII.

II. BACKGROUND

The utilization of crowdsourcing has become a new paradigm to solve complex problems [25]. It uses outsourcing model which involves the participation of all stakeholders by using a platform [26]. The term, crowdsourcing was first used by Jeff Howe in 2006, defined as ''the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call. This can take the form of peer-production (when the job is performed collaboratively), but is also often undertaken by sole individuals'' [27].

With the persistent development of computer applications and web-based platforms; academia and IT industry has been utilizing the stakeholder's cognitive capabilities, which makes the crowdsourcing as dominant approach for development of complex projects [23]. It is being used for different purposes i.e., information exchange and data transcription, product design and development, testing of products, creation of taxonomies, crowdfunding, consensus, designing of biomolecule and software development [21], [28].

Software crowdsourcing is rapidly growing problem-solving approach which utilizes the metacognitive efforts of online stakeholders; who are taken on-board by open call [25]. It eases the software development life cycle (SDLC) by decomposing and then; distributing the tasks to the best available crowd. It has been widely used in various applications e.g., Youtube, Wikipedia, Linux, reCAPTCHA, GoogleEarth and Yahoo Answers [28], [29]. Encyclopedia is another example of crowdsourced application, which was developed by 70,000 participants and supports 290 languages with 35 million articles [30].

Different crowdsourcing models are available which can be selected on the basis of requirements i.e., number of stakeholders required for accomplishment of specific project, best available platform for specific project and how open call method will be used [1]. Literature has revealed four models

of crowdsourced which are *peer production*, *competitions*, *investment* and *microtasking* model [30]. *Peer production* is one of the mature model of crowdsourcing in which collaborators (crowd workers of this model) contribute to the project to gain experience and knowledge, instead of any financial reward [31]. Open-source software e.g., Rails, Linux, Apache and Firefox are best known examples of peer production model of crowdsourcing, for which different programmers from the world developed and updates the latest versions [32].

Competitions model is related to the conventional method of outsourcing in which contestants (crowd workers of this model) post the required project on crowdsourcing platforms. A copilot (experienced individual paid by the platform for the accomplishment of the task) decomposes the project into multiple tasks known as competitions. Every contestant provides a best solution according to their expertise, hence the best solution provider get paid, which is selected by the copilot [33]. This model is suitable when high quality and diversified results are required by the client. Different crowdsourcing platforms implement competitions model e.g., Topcoder, 99designs, testbirds and uTests to crowdsource the development, designing, usability and system testing related tasks respectively [9], [12], [21].

Investments model is similar to the crowdfunding in which crowd workers (fundraisers and mostly entrepreneurs) collects the funds by using crowdsourcing platforms which facilitates them to access the market directly. Investors who contribute to the funds, take financial risks to support the development of software project and anticipate reimbursement [34]. Various platforms e.g., kiva, sandawe, fundable and kickstarter implement the investments model, which provides interaction between fundraisers and investors [35].

Microtasking model is related to the decomposition of complex task into the number of short, autonomous and less skill required tasks i.e., microtasks [6]. It supports the practice of distributed human computation by decomposing macrotask (generally complex in nature) into the self-contained short tasks which require less cognitive effort as well as less time [36]. In software engineering, microtasks often known as microservices; decomposition of complex web-based task into the number of short and independent tasks i.e., microservices [14].

Microtasking in crowdsourced software engineering can be achieved by two methods i.e., traditional method and behavior-driven development (BDD) approach [3]. In traditional method, each crowd worker performs the unique task e.g., an individual writes the test cases for all the behaviors of the system, and/or an individual implements the testing process for all the behaviors. It requires continuous communication between the crowd workers to accomplish the task and to ensure consistency. On the contrary, BDD approach is related to the accomplishment of a task by single crowd worker. An individual is responsible for writing the test cases for the behavior, implements and debug them by himself [14].

Microtasking can be achieved by implementing any of its two models. Selection of the model depends on the expected results of the task, nature of the problem, required skillset of the crowd workers, managerial challenges and monetary reward [37]. The first model is related to the accomplishment of non-sequential, independent and atomic units of tasks which require limited skills, less execution time, less cognitive effort and hence paid less [38]. Samasource is a platform which implements this model of microtasking which facilitates its users by providing the services related to image tagging, color and image identification. The second model is related to the accomplishment of sequential, interdependent and interactive tasks which are performed by multiple crowd workers. Tasks related to this model require special skillset, probably longer execution time and great cognitive effort. Literature has revealed that independent tasks are well defined, well mapped-out and well structured, and interdependent tasks require great collaborative effort and probably ill-structured and not well-defined [37].

With the persistent utilization of microtasking in recent years, different microtasking platforms have been developed to facilitate their users. Few platforms are specialized in specific niches e.g., Quicktate and iDictate only provides call auditing related services, TryMYUI provides user-interface related microtasked services and SurveyJunkie provides survey and sentiment analysis related microtasked services [8]. Few platforms e.g., My little job, click worker, field agent, swag bucks, rapid workers, ySense, prolific, PartTimeClicks, microworker and remotasks offer their users diverse services which are related to data manipulation, research, testing and quality assurance, graphic designing, tagging and labelling [39].

III. RESEARCH METHOD

The authors have followed Systematic Literature Review (SLR) methodology to identify the microtasking activities which exist in literature. In order to do so, SLR guidelines by B. Kitchenham [40] have followed as this is the detailed approach to conduct SLR in software engineering [41]. This SLR involves the comprehensive review of studies which are related to the microtasks and microtasked related crowdsourcing. The literature review was conducted with four databases (Science Direct, IEEE Xplore, Springer and ACM Digital Library) with using same search string. The details of steps followed in SLR are as follows.

A. SEARCH STRING FORMATION

The first phase of the search was the string formation. Following steps were taken to conduct the search:

- The authors derived the major terms from the RQ. The major terms are 1). microtasking, 2). activities and 3). crowdsourced software development.
- Synonyms and alternative terms were identified for the major terms. Microtasking: (microtask, small task, simple task, short task, decomposed task, micro-tasking, independent task, micro-task), Activities:

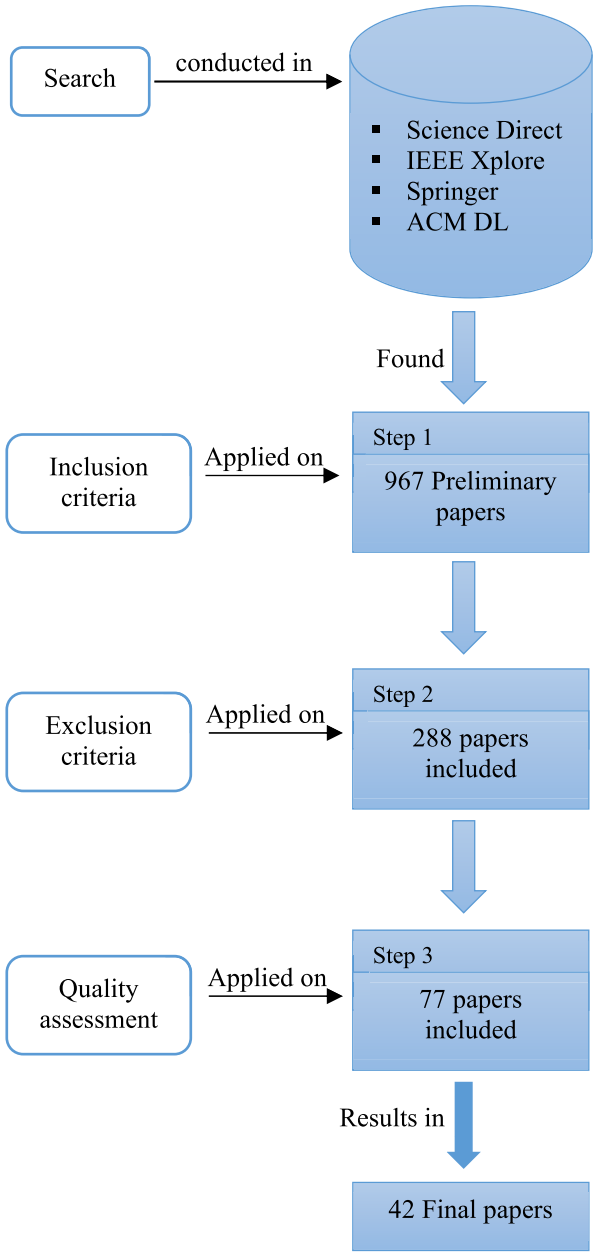

FIGURE 2. Search and selection process of studies to conduct SLR, to find the microtasking activities related to crowdsourced software development, which exist in literature.

(types, kinds, tasks, actions), Crowdsourced software development: (crowdsourcing, software crowdsourcing, software outsourcing, crowdsourced development, crowdsourced software, crowdsourced computing).

- ➢ The authors used wildcards in search terms, where required.
- ➢ The authors used Boolean operators (OR, AND) where required, for concatenation purpose.
- ➢ After applying search strategy, final search string was formulated which is follows:
("microtasking" OR "microtask" OR "small task" OR "simple task" OR "short task" OR "decomposed task" OR "independent task" OR "micro-task") AND ("activities" OR "types" OR "kinds" OR "tasks" OR "actions") AND ("crowdsourced software development" OR "crowdsourcing" OR "software crowdsourcing" OR "software outsourcing" OR "crowdsourced development" OR "crowdsourced software" OR "crowdsourced computing").

B. PAPER SELECTION

The paper selection procedure was performed in three steps. In first step, 197 from Science Direct, 381 from IEEE Xplore, 98 from Springer, 291 from ACM Digital Library and a total of 967 papers were found. Inclusion criteria were applied on preliminary papers on the basis of:

- ➢ Those papers are included in the search which either addressed microtasks in general, microtasking activities in crowdsourced software development or microtasks which exist in software development.
- ➢ Inclusion criteria was based on the availability of required keywords in paper title or keywords of the found articles.

After applying inclusion criteria, 288 papers were selected.

- ➢ In second step, exclusion criteria were applied on the basis of following parameters:
- ➢ Those papers were excluded which were only giving information of proceedings of conference or only have table of contents.
- ➢ Those papers whose title was in English but remaining content or full paper was in other language.

C. THOSE PAPERS WHICH WERE REPEATED IN DATA SOURCES

A total of 77 papers were included after applying exclusion criteria. In third step, quality assessment procedure was carried out to assess if required outcomes (microtasking activities) are presented in the paper. In order to do so, 77 papers were distributed among different researchers along with quality assessment checklist by Kitchenham. Quality assessment checklist is shown in table 1.

Questions mentioned in the checklist were answered by the researchers who were selected to read the papers for quality assessment. It was a collaborative process in which selected research articles were randomly allocated to the postgraduate students. In total, 77 research papers (after applying inclusion/ exclusion criteria) were randomly allocated among researchers. Each member was provided with 7 papers; hence papers were distributed to 11 respondents. The scoring scale was based on: Yes = 1, Partially = 0.5, No = 0. For each paper, scores of the questions mentioned in quality assessment checklist were accumulated. Those papers whose accumulated values were ranging between 0.5 to 1 were selected for final review. From 77 papers, accumulated score of 35 papers was below 0.5, hence remaining 42 papers were selected to find the microtasking activities.

TABLE 1. Quality assessment checklist.

S. No	Question	Answer
1.	Are the aims of the paper clearly stated?	Yes/ No /Partially
2.	Are the findings clearly stated, credible and important?	Yes/ No /Partially
3.	Are the prediction techniques used clearly described and their selection are justified?	Yes/ No /Partially
4.	Is the knowledge or understanding been extended by the research?	Yes/ No /Partially
5.	Is the diversity of perspective and context been explored?	Yes/ No /Partially
6.	Are the links between data, interpretation and conclusions are clear?	Yes/ No /Partially
7.	Does the detail/ depth/ complexity of the data is conveyed?	Yes/ No /Partially

TABLE 2. Data extraction information.

Field	Extracted data
Data Source	IEEE
Title	Human Beyond the Machine: Challenges and Opportunities of Microtask Crowdsourcing
Author	Ujwal Gadiraju, Gianluca Demartini, Ricardo Kawase, Stefan Dietze
Year of Publication	2015
Publication Type	Journal
Journal Name	IEEE Intelligent Systems (Volume: 30, Issue: 4)
Methodology	Experiment on AMT
Findings	Data verification and validation Audio translation Language translation

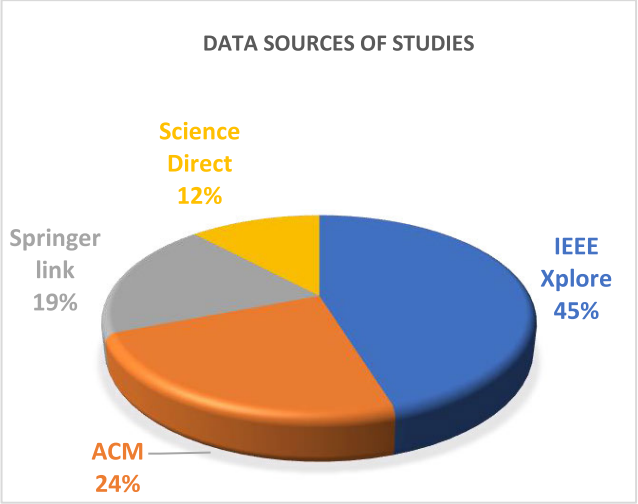

FIGURE 3. Percentage of papers taken from four databases.

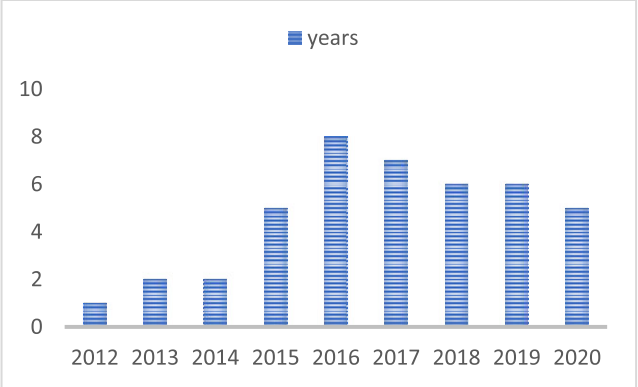

FIGURE 4. Publication years of studies.

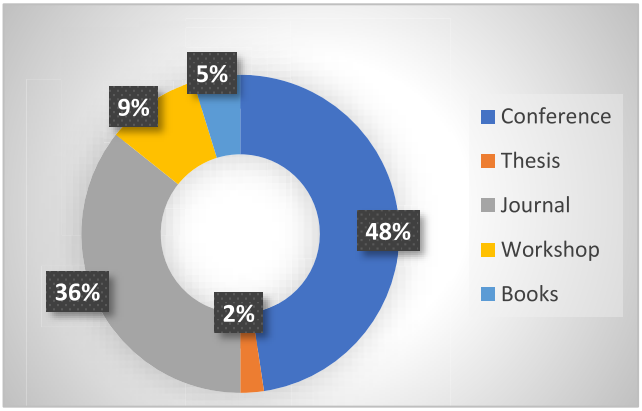

FIGURE 5. Publication type of studies.

D. INFORMATION EXTRACTION

Data from each selected paper was extracted on the basis of data source (database), title, publication type (journal, conference, book chapter, thesis), conference/ journal/ book/ thesis name, publication year, author's name, methodology applied in the paper and microtasking activities. Data extraction form is shown in table 2. On the basis of data extraction information, metadata of each paper is maintained which is shown in appendix B.

E. DATA SYNTHESIS

The authors extracted the data from each selected paper on the basis of mentioned fields (Table 2). Results obtained from

TABLE 3. Microtasking activities and their categories.

S. No	Microtasks	Categories	Description about microtasking categories	Papers	Frequency
1.	Metadata finding	Information finding	These tasks are related to the identification and finding of information. For example; finding the conference or journal name of the article where it has been published; or filter the data according to given requirements.	[36], [24], [42], [22], [43], [18], [32], [21], [45], [47], [48],	11
2.	Organizing the data				
3.	Information finding				
4.	Data collection				
5.	Information gathering				
6.	Filtration and synthesize the data				
7.	Content verification	Verification & validation	These tasks are related to the verification and validation of data e.g., verification of errors corrected by the crowd worker; or validation of the content if it is correctly translated from one language to another.	[22], [24], [49], [43], [44], [46], [6], [50], [51], [52]–[54], [47], [55], [56], [52]	16
8.	Product comparison				
9.	Data tagging				
10.	Data matching				
11.	Spam detection				
12.	Data collection	Content creation	Any type of microtask which is related to the creation of content. For example, gathering and selection of data and useful information to produce an article. In order to make a standardize document, microtasks can be; making an outline for specific topic (headings, subheadings), writing of information under each heading, selection of appropriate images, labelling of images, verification of relevance of images and content, and formatting of the document in a required format.	[49], [24], [36], [22], [42], [43], [44]–[46], [54], [28], [6], [50], [48], [52]	15
13.	Organizing the data				
14.	Listing of data				
15.	Documentation				
16.	Restructure the data into standardized reports				
17.	Addition of annotations				
18.	Data mapping				
19.	Pasting the data				
20.	Label an image				
21.	Dataset's module creation				
22.	Gathering of terms for taxonomy creation				
23.	Data selection				
24.	Data classification				
25.	Data enhancement				
26.	Data categorization				
27.	Video translation	Data transcription	These tasks related to the translation of content form one language to another. Furthermore, tasks related to conversion of a file to any other format also lie in this category. For example, transcription of audio file from English to Chinese.	[43], [6], [57], [36], [24], [42], [44], [49], [52]	9
28.	Language translation				
29.	Audio translation				
30.	Human Optical Recognition tasks				
31.	Digitizing local-language documents				
32.	Transcribing the speech's sentences				

TABLE 3. ***(Continued.)*** **Microtasking activities and their categories.**

33.	Image transcription				
34.	Data translation				
35.	Media transcription				
36.	Checking and listing of websites	Interpretation & Analysis	These microtasks are related to the personal and experience of the individuals regarding any product or service. For example, what do you interpret after watching given short video? Do you like new camera features launched in iPhone 13? These microtasks are related to the perception level, opinion, experience and intellectual level of the crowd workers.	[24], [42], [44], [49], [22], [46], [50], [6], [3], [51], [57], [58], [56], [23]	14
37.	Interpretation of visual data				
38.	Data interpretation				
39.	Data Analysis				
40.	Content moderation				
41.	Sentiment analysis				
42.	Conduct an interview	Surveys	These microtasks are related to the feedback of services and products; or to collect the information for educational or any other purpose. For example, how much time do you spend for social media?	[22], [24], [44], [6], [46], [53], [54], [57]	8
43.	Content feedback				
44.	Watch an online video	Content access	These microtasks are related to accessing the data by consuming the time and effort on task. For example, capturing the screenshots while using any application, or watching any video.	[22], [24], [49], [6], [43], [46], [51], [54], [47], [36]	10
45.	Logging of information onto a page				
46.	Sharing of data with different sites				
47.	Capture the photos				
48.	Content access				
49.	Copying of the data				
50.	Promotion e.g., webpages				
51.	Review of function behavior	Quality assessment	These microtasks are related to the testing and debugging to ensure the quality of a code. For example, testing of user interface, implementation of test cases to identify the errors.	[24], [59], [60], [3], [61], [51], [52], [54], [57], [62], [56]	11
52.	Locate known faults in code fragments				
53.	Identify, test, implement and debug behaviors in code				
54.	Implement a unit test				
55.	Delta debugging				
56.	Algorithmic debugging				
57.	Test a line of code				

TABLE 3. *(Continued.)* **Microtasking activities and their categories.**

58.	Debugging of UI				
59.	Debugging of program				
60.	Identification of design problems	Designing	These microtasks are related to the designing of interfaces of websites and web or cellular applications. For example, draw the design element for logo, design the icon for microphone, change the color of given icons etc.	[18], [21], [63], [64], [29]	6
61.	Sketching of small design related to interface				
62.	Selection of fonts				
63.	Designing a single component of logo				
64.	Human computation	Development	These microtasks are related to the programming, implementation and development of softwares. For example, write a piece of code according to the given instruction, modify the given function and implement it in an application, write the test cases for given application.	[3], [61], [62], [21], [57], [14], [24], [59], [60], [65], [66], [67], [64], [68], [58], [56], [37], [69]	19
65.	Implementing part of a function				
66.	Adding pseudo-code				
67.	Edit a function				
68.	Writing test-cases				
69.	Writing a piece of code				
70.	Identification of missing values in the dataset.	Identification	These microtasks are related to the identification of missing values or data from given content. These microtasks require clear understanding and great observation of the given system/process. For example, write the missing values in given dataset which will implement the system/program smoothly.	[59], [60], [14], [24], [65], [70], [68]	7
71.	Identification of alternative solution				
72.	Identification of main decision points from set of requirements				

each paper in the form of microtasking activities are discussed in section IV.

IV. RESULTS

In this section, authors presented the results. Initially, distribution statistics of studies according to databases, years and publication type are presented. In the later section, identified microtasking activities along with their categories are presented.

A. OVERVIEW OF FINAL PAPERS

The final papers are listed in Appendix A. The metadata extracted from each study is tabulated in Appendix B. As shown in figure 3, out of 42 final papers, 19 papers are from IEEE, 10 papers were published in ACM, 8 papers are from Springer link and remaining 5 papers were published in Science Direct.

As this systematic literature review covers the studies from 2011 to 2020. Figure 4 shows the publications of studies with respect to years. The newest papers were published in 2020 and the oldest papers were published in 2012.

In the perspective of publication type, out of 42 studies, 20 papers are from conferences, 15 articles were published in journals, 4 papers were presented in workshops. 2 articles are the parts of books and remaining 1 is PhD thesis. Figure 5 shows the visual statistics of papers according to publication type.

B. IDENTIFIED MICROTASKING ACTIVITIES AND THEIR CATEGORIES

Unique IDs are given to each paper which are shown in Appendix A. A total of 72 microtasking activities are found from systematic literature review. On the basis of execution process and nature of found microtasking activities, relevant microtasks are grouped into categories. Generic names are given to those categories e.g., each microtask which is related to the matching or verification of any product, is placed under the category of 'Verification and Validation'. Table 3 shows the identified microtasks along

TABLE 4. Validated microtasking activities and their categories.

S. No	Categories	Microtasking activities	Description about microtasking activities
1.	Information finding	Metadata finding	Any microtask which is related to finding the metadata of any article, image, audio or video. For example; author name of the article, email addresses of the authors, format of source file etc.
		Information finding	These microtasks are related to general information e.g., finding the information of an organization which is situated in any other country, identify authentic and unpaid Facebook pages which are providing services related to bitcoin.
		Data Filtration	These microtasks are related to filter the specific data or information from available vast data e.g., Make a list of kids related e-commerce websites which do not support payment by PayPal.
		Data synthesize	These microtasks are related to the grouping of different modules of data in order to make it specific information.
2.	Verification & validation	Content verification	Any microtask which is related to the verification of content e.g., verify the errors corrected in the code, or check if the particular website provides the required relevant information or not.
		Spam detection	These microtasks are related to verify if spam filter is working correctly e.g., send unsolicited or virus-infected email from another account and check if spam filter is preventing those emails from getting to an inbox.
		Data matching	These microtasks require the verification and matching of data from given or prescribed information. For example, review the client's comments to check if the most of the freelancers of specific niche are providing the exact services which they described in their offer list (gig for fiverr).
		Data tagging	Such microtask requires the crowd workers to give the suitable terms to particular product or service by organizing a piece of information to the relevant product or service. For example, 'give a suitable tagline for a given product to attract the audience of amazon'.
		Product comparison	Microtasks which are related to the comparison of different products e.g., compare the given products on the basis of their names, brand names, their quantity, their ingredients etc.
3.	Content creation	Data categorization	These microtasks are related to the categorization of same entities or same features, in order to create a content. For example, categorize the relevant features of the given product and give a suitable name for specific category.
		Data classification	The microtask which refers to the classification of data, entities and elements on the basis of predetermined criteria. For example, from given products and services, select the most appropriate service and product for each mentioned category.

TABLE 4. *(Continued.)* **Validated microtasking activities and their categories.**

	Data enhancement	These microtasks are related to the review of content or piece of content and then addition or removal of content according to their expertise to make the content more appropriate and to check if it is given in-depth knowledge. For example, this site likes to explore your area, write something interesting about your area.
	Data selection	These microtasks refer to the selection of words/terms, images, audio or video for the specific topic in order to create the content. For example, from given media (images and video), select the appropriate media which is related to 'child labor'.
	Gathering of terms for taxonomy creation	These microtasks are related to gather the terms and words for the development of taxonomy. For example, gather all the words and terms which are relevant to 'jurisprudence'.
	Dataset's module creation	These microtasks are related to the addition of entities or data in rows and columns of dataset, in case of missing data. Experts are required to accomplish these tasks. For example, add missing values in the given data set and create an extra row as small module of dataset.
	Label an image	The microtask which involves the description of the given product or service. For example, Give the description of given product in terms of its usability, reliability and customer feedback.
	Pasting the data	Such microtask involves the pasting of given data at appropriate position of the document or site and according to the arrangement or hierarchy of the content. For example, Place the given two paragraphs at suitable position of the given document.
	Data mapping	The microtasks which require the crowd workers to map the data fields from one site or database to another, in order to merge different databases or sites to their master copy and to manage it for content creation.
	Addition of annotations	These microtasks require the crowd workers to post the comments against any product, service or platform according to their experience. For example, 'we are creating a content, comment your ideas and experience regarding parasailing, to let the clients know about the service being provided by us'.
	Listing of data	The microtasks which are related to make the lists from given data. For example, from the given document, make a list of conferences which publish the articles related to e-commerce.
	Organizing the data	The microtask which are related to organizing the data according to flow of the content, hierarchy of thoughts, linkage of the content, categories and content under the categories. For example, organize the given document according to the mentioned criteria.
	Restructure the data into standardized reports	Such microtask requires the crowd workers to organize the given content into required formatting and convert them into given standardized document. For example, 'Template has been attached, convert the given content into required standard by checking the formatting of the content.

TABLE 4. *(Continued.)* **Validated microtasking activities and their categories.**

4.	Data transcription	Media conversion	These tasks refer to the conversion of media to their other file formats. For example, convert the given .jpeg image into .png format, Convert the .mp4 video into audio file etc.
		Media transcription	Such microtask involves the translation of audio or video from one language into other. For example, transcribe the given Chinese audio into English audio. .
		Data translation	These microtasks require the crowd workers to translate the text into other required languages. For example, translate the given piece of information into English.
		Human Optical Recognition tasks	Such microtasks are related to human computation regarding optical recognition. For example, 'Type what you see in the given captchas', 'transcribe the given scanned image into editable text file by using any OCR (optical character recognition) software'.
		Digitizing local-language documents	These microtasks require the crowd workers to transform such information which computer cannot process. For example, 'convert the given hand written text into digital form', 'transcribe the following analog audio recordings into digital form'.
5.	Interpretation & Analysis	Sentiment analysis	Such microtask involves the opinions and feelings of individuals regarding any product, service or platform on the basis of their experience. For example, do you like the 'product hunting' task on Amazon?
		Content moderation	These microtasks refer to the moderation of content i.e., check if the given content is according to the terms and conditions, if a content is inappropriate or violating the guidelines. Content moderators ensure that nothing offensive or irrational gets to specific site.
		Data Analysis and interpretation	These microtasks are related to the personal thinking of the individuals regarding any product, service, platform or comments. These tasks depend on the perception level, intelligence, expertise and experience of the crowd. For example, interpret the given graph according to your observation.
		Interpretation of visual data	These microtasks are related to the interpretation of image or video. For example, 'describe in few words about the duties performed by father shown in the video', 'describe the gestures shown by a kid in the given image'.
		Checking and listing of websites	These microtasks are related to check the websites if they are fulfilling the specific criteria or not. For example, identify the e-commerce websites which deals with kids toys in Pakistan and enlist them according to the fast delivery.
6.	Surveys	Content feedback	Microtasks which are related to take the feedback of the individuals against any product, service or online platform. For example, give your valuable feedback to improve our site.
		Conduct an interview	Microtasks which are related to interview the crowd workers about any product, service, platform or any specific day e.g., Mother's Day, Labor Day etc.

TABLE 4. *(Continued.)* **Validated microtasking activities and their categories.**

7.	Content access	Promotion e.g., webpages	These microtasks require the crowd workers to promote the content as well as to access the promoted content e.g., by clicking on the adds. For example, 'click the link given below to view the details', 'you can take information relevant to your interest by clicking on the links below'.
		Copying of the data	The microtasks which require the crowd workers to copy the data by simply accessing the content and use it in future tasks. For example, 'the following content is not copyrighted, you can save the data if it is of your interest'.
		Content access	The microtasks which require expert crowd workers to access the content by using content access softwares. These types of tasks are related to database management systems, inventory control systems or data warehouses.
		Capture the photos	These microtasks require the crowd workers to access the data, product label or tables of database by simply capture their images.
		Sharing of data with different sites	These microtasks involve the sharing of data (which can be in any format i.e., image, audio, video, text, your social media or freelancing account link) to other users and sites to let the viewers access the content provided by you.
		Watch an online video	These microtasks usually require the crowd workers to consume time to watch the given online video e.g., 'click on the given link to watch the animated video of human nervous system for further understanding'.
8.	Quality assessment & Testing	Debugging of program	Such microtask involves the crowd workers to ensure the quality of a program e.g., 'from a given piece of code, identify the errors and remove them'.
		Test a line of code	Such microtask involves the crowd workers to ensure the quality of line of code. For example, 'from a given line of code, identify the error(s), and remove them, if any'.
		Debugging of UI	These microtasks require the crowd workers to assess the quality of User Interface e.g., "Check if the color scheme, font face, font size, positioning of images with respect to text, white spacing and alignment are according to the design brief".
		Implement a unit test	Such microtask involves the crowd workers to ensure the quality of code by implementing a unit test.
		Algorithmic debugging	These microtasks involves the crowd workers to ensure the quality of an algorithm e.g., 'debug the given algorithm, if any error(s) exist, correct them'.
		Delta debugging	These microtasks usually require the workers to ensure the quality of program or piece of code by using given automated debugging tool.
		Identify, test, implement and debug the behaviors in code	These microtasks require the crowd workers to identify and remove the errors according to required programming behavior and implementation of program with amendments and debug again.

TABLE 4. *(Continued.)* **Validated microtasking activities and their categories.**

		Locate known faults in code fragments	In these microtasks, chunks of code which needs debugging are provided to the crowd workers and ask them to identify and remove the errors to ensure the quality of the given code fragments.
		Review of function behavior	Such microtasks involve the crowd workers to assess the behavior of the function which is being used in program in order to check if the program is performing the same functionality as it was intended to develop.
		Implementing part of a function	The microtasks which require the crowd workers to implement part(s) of a function to assess the quality of a code. For example, 'implement the required part of a function in a given code. (We are testing different functions and code to check if specific codes give smooth and required outcome in all machines, with or without plug-ins, operating systems and their versions).
9.	Designing	Designing a single component of logo	Such microtasks involve the crowd workers to design a component for logo. Experts are required to achieve the required outcome of such tasks. For example, 'draw the design element for logo of an airline'.
		Sketching of small design related to interface	The microtasks which are related to design any small component of an interface. Such type of microtasks is published on platforms to check the skills of the workers, if any platform wants to hire the designers. For example, 'draw 3D button with appropriate depth and shadows according to the given color scheme'.
		Selection of fonts	Such microtask involves the selection of suitable fonts by the crowd workers according to the nature of problem as well as demand of the client. For example, 'Select five appropriate fonts for logo of coffee shop'.
10.	Development	Writing a piece of code	Such microtask involves the crowd workers to write a piece of code according to given requirement, in order to develop the any system, or hire any individual. For example, 'write a piece of code to implement a given function'.
		Writing test-cases	These microtasks are related to the test cases which are written by the crowd workers, for the development of test suites. For example, 'write the maximum test cases for a given functionality'.
		Edit a function	The microtasks which are related to the modification of a given function(s) of a program e.g., 'Modify the function name and its parameters according to the client's requirement and check it if it is working properly'.
		Adding pseudo-code	Such microtask involves the addition of pseudo-code and comments in the code, to make the reviewers understand about the functionality performed by the code. For example, 'write the pseudo-code for the given requirement and then call the function to check the functionality'.
		Human computation	These microtasks usually involve the human computation in order to develop any (can be public) system which will check if the user is robot or not. For example, 'Mark the images in which birds are seen' or 'Identify the images which show green traffic signal'.

TABLE 4. *(Continued.)* **Validated microtasking activities and their categories.**

11.	Identification	Identification of main decision points	The microtask which usually involves the identification of main decision points from the set of requirements. For example, "Business plan document is given, you are required to identify the main decision points from it".
		Identification of alternative solution	These microtasks are related to find the alternative solutions of a given problem. For example, a problem related to designing a trifold flyer is discussed in the given document along with its one solution, you are required to provide the alternative solutions with comparatively low budget.
		Identification of missing values in the dataset	The microtask which refers to the identification of any missing data or information from the given dataset or the dataset's brief. These microtasks can be successfully performed by the experts of relevant fields. For example, a dataset related to patients of the hospital is attached in the document, you are required to fill the missing cells if any.

with their respective categories. In order to depict the functionality performed by microtask(s), brief description of each microtasking category is presented in table 3.

Table 3 shows the identified microtasking activities along with various categories for each identified microtasking activities. A total of 72 microtasking activities and 11 microtasking categories are found from literature which are related to crowdsourced software development. It has been observed that microtasking activities related to 'development' are higher in frequency i.e., 19 papers have discussed the microtasks related to software development. It has also been noticed that microtasks related to 'designing' are lower in frequency i.e., only 6 papers have highlighted the microtasks related to designing.

V. VALIDATION

Validation of identified microtasking activities have done by conducting the expert review. Microtasking activities and their categories are validated by four experts, two of them were from academia and two were from reputable software organizations. All experts possessed in-depth knowledge of microtasked related crowdsourcing. Experts validated the naming conventions i.e., if identified microtasks perform the unique functionality. Furthermore, experts also checked the consistency i.e., if the microtasks are positioned under its relevant microtasking category.

According to the experts, there were few duplications in the microtasks i.e., 'data collection' and 'gathering of terms' are same in nature. Experts recommended to give the brief description of each microtask. Furthermore, few activities were conveying same meaning, it was recommended to merge them and give a generic name to them. Moreover, experts suggested to create a link between each microtask to its relevant category in the form of short description.

A total of 72 microtasking activities were identified from SLR, after recommended changes applied, the authors came up with 61 unique microtasking activities along with their relevant categories. Validated microtasking activities are explained in table 4.

VI. LIMITATIONS

This research cannot be accomplished without limitations. One of the limitations is related to the selection of digital libraries to identify the microtasking activities. In this regard, researchers have selected four databases. However, there is a possibility that authors have missed many of the microtasking activities, as those studies are uncovered in this study. Besides, four experts have validated the findings of the study. However, it is possible that experts have missed any duplication or naming conventions of the microtasking activities or overlooked some of the microtasking activities. Another limitation is related to the selectin of keywords to create the search string for SLR. There is possibility that the selected keywords and search string is not well formulated with respect to the field of software engineering, especially in microtasked related crowdsourcing. Thus, it might generate the results which do not truly reflect the essence of the study.

VII. FUTURE FOCUS

As most of the software development is taking place by utilization of distributed human cognitive efforts. Experts are required to distribute and decompose the complex task into multiple microtasks. In this regard, future studies can be conducted to examine the pros and cons of automated and manual task decomposition systems. Moreover, a generic

model can be developed in future which can decompose all types of tasks into microtasks. Another research can investigate, if automated task decomposition system is developed in future, what will be its effects on microtasked related crowdsourcing and ultimately on crowdsourced software engineering.

Another research can be conducted in future to explore the remaining databases to identify the microtasking activities as well as microtasking categories which remain uncovered in this study. Besides, validation of the identified microtasking activities can be performed by using other methods. Moreover, different experiments on crowdsourcing platforms can be performed by using identified microtasking activities.

VIII. CONCLUSION

The authors have presented a systematic literature review to identify the microtasking activities related to crowdsourced software development which exist in literature. Four digital libraries (Science direct, ACM digital library, IEEE Xplore and springer link) were explored to accomplish the study. 42 studies were finalized to explore the microtasking activities and a total of 72 microtasks are identified which are related to different areas. Some microtasking activities are technical in nature i.e., write a piece of code or implement the given function behavior in the code' while others are non-technical in nature i.e., identify and remove the grammatical errors from a given paragraph. The authors have combined the similar and relevant microtasking activities into 11 categories and meaningful names are given to them. Moreover, an expert review is conducted in this regard to validate the identified microtasking activities. The purpose of expert review was to validate the naming conventions of identified microtasks, to check the duplication of identified microtasks (if any) and to check if the microtasks are placed under right category or not. Opinions of 4 experts are taken and recommended changes are applied to the findings. Finally, the authors came up with a list of 61 unique and validated microtasking activities along with 11 categories.

Focus of this research was to understand the context of microtasked related crowdsourcing and to highlight the microtasking activities related to crowdsourced software development which exist in literature. Comprehensive findings of the research will help the future researchers, microtasking platforms and their clients in terms of selection of right crowd worker to perform the specific task. As possible microtasking activities are presented under each category, it will help the microtasking platforms to scrutinize the expertise of crowd workers giving multiple tasks to them.

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MAIRA ZULFIQAR was born in Islamabad, Pakistan. She received the B.S. degree in software engineering from the National University of Modern Languages, Islamabad, in 2016, where she is currently pursuing the M.S. degree in software engineering. Her research interests include software crowdsourcing, micro-tasking, software risk management, and global software development. Her current research is on task decomposition in crowd-sourced software development.

MUHAMMAD NOMAN MALIK (Member, IEEE) received the Ph.D. degree in computer science from Universiti Teknologi Malaysia (UTM), Kuala Lumpur, Malaysia, in 2015. He is currently an Assistant Professor with the Department of Computer Science, National University of Modern Languages (NUML), Pakistan. His research interests include user experience (UX), software crowdsourcing, empirical software engineering, sustainable software engineering, and sustainable software projects.

HUMA HAYAT KHAN (Member, IEEE) was born in Attock, Pakistan, in 1985. She received the B.S. degree in computer science from the National University of Modern Languages, Islamabad, Pakistan, in 2007, the M.S. degree in software engineering from International Islamic University, Islamabad, in 2011, and the Ph.D. degree in software engineering from Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia, in 2015. She has been with the Department of Software Engineering, National University of Modern Languages, since 2015. She teaches several courses, including software process and quality, requirements, design, software project management, and software construction. She also directs the bachelor's and master's student projects. She is currently an Assistant Professor with the National University of Modern Languages. Her research interests include software engineering process and quality, software measurement, usability evaluation, software requirement engineering, and global software development. Her current research is on emotion-based requirement engineering in global software development.