Microtasking Activities in Crowdsourced Software Development: A Systematic Literature Review

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ABSTRACT With the utilization of crowdsourcing as a problem-solving approach, software industry has progressed tremendously in recent few years. It is a powerful approach which supports distributed human intelligence to solve complex problems in the field of software development, machine learning, linguistics, medical, interpretation and other considerable fields of study. 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, crowdsourcing.

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], [6], [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 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], [16], [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.** Decomposition of task ‘logo design’ 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 [21]. Only a few noteworthy studies [18], [22], [23] 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 question:

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

The goal of the research question 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 [24]. It uses outsourcing model which involves the participation of all stakeholders by using a platform [25]. 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” [26].

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 [22]. 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 [27], [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 [24]. 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 crowdsourced the
development, designing, usability and system testing related
tasks respectively [9], [12], [34].
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 [35]. Investors who
contribute to the funds, take financial risks to support the
development of software project and anticipate reimbursement
[36]. Various platforms e.g., kiva, sandawe, fundable and
kickstarter implement the investments model, which provides
interaction between fundraisers and investors [37].
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 macro-
task (generally complex in nature) into the self-contained short
tasks which require less cognitive effort as well as less time
[38]. 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 [39]. 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
努力和 hence paid less [40]. 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 [39].
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
[41].

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 [42] have followed as this is the detailed
approach to conduct SLR in software engineering [43]. 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, microtasking, independent task, micro-task).
- Activities: (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.

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.

C. 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.

| 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                        |

C. DATA SYNTHESIS

The authors extracted the data from each selected paper on the basis of mentioned fields (Table 2). Results obtained from each paper in the form of microtasking activities are discussed in section IV.

IV. RESULTS

In this section, authors presented the results. Unique IDs are given to each paper which is shown in Appendix. 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 with their respective categories. In order to depict the functionality performed by microtask(s), brief description of each microtasking category is presented in the table 3.
| 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.                                                                 | [38], [23].     | 11         |
| 2.    | Organizing the data                |                             |                                                                                                                                                                                                                                                                                               | [44], [21].     |            |
| 3.    | Information finding                |                             |                                                                                                                                                                                                                                                                                               | [45], [18].     |            |
| 4.    | Data collection                    |                             |                                                                                                                                                                                                                                                                                               | [32], [34].     |            |
| 5.    | Information gathering              |                             |                                                                                                                                                                                                                                                                                               | [47], [49].     |            |
| 6.    | Filtration and synthesize the data |                             |                                                                                                                                                                                                                                                                                               | [50]            |            |
| 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.                                                                 | [21], [23].     | 16         |
| 8.    | Product comparison                 |                             |                                                                                                                                                                                                                                                                                               | [51], [45].     |            |
| 9.    | Data tagging                       |                             |                                                                                                                                                                                                                                                                                               | [46], [48].     |            |
| 10.   | Data matching                      |                             |                                                                                                                                                                                                                                                                                               | [6], [52].      |            |
| 11.   | Spam detection                     |                             |                                                                                                                                                                                                                                                                                               | [53], [54].     |            |
| 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. | [51], [23].     | 15         |
| 13.   | Organizing the data                |                             |                                                                                                                                                                                                                                                                                               | [38], [21].     |            |
| 14.   | Listing of data                    |                             |                                                                                                                                                                                                                                                                                               | [44], [45].     |            |
| 15.   | Documentation                      |                             |                                                                                                                                                                                                                                                                                               | [46]–[48].      |            |
| 16.   | Restructure the data into          |                             |                                                                                                                                                                                                                                                                                               | [54], [28].     |            |
|       | standardized reports               |                             |                                                                                                                                                                                                                                                                                               | [6], [53].      |            |
| 17.   | Addition of annotations            |                             |                                                                                                                                                                                                                                                                                               | [50], [55]      |            |
| 18.   | Data mapping                       |                             |                                                                                                                                                                                                                                                                                               | [59], [38].     |            |
| 19.   | Pasting the data                   |                             |                                                                                                                                                                                                                                                                                               | [23], [44].     |            |
| 20.   | Label an image                     |                             |                                                                                                                                                                                                                                                                                               | [46], [51].     |            |
| 21.   | Dataset’s module creation          |                             |                                                                                                                                                                                                                                                                                               | [55]            |            |
| 22.   | Gathering of terms for             |                             | These tasks related to the translation of content from one language to another. Furthermore, tasks related to conversion of a file to any other format also lie in this                                                                                                                                  | [45], [6].      | 9          |
|       | taxonomy creation                  |                             |                                                                                                                                                                                                                                                                                               | [59], [38].     |            |
| 23.   | Data selection                     |                             |                                                                                                                                                                                                                                                                                               | [23], [44].     |            |
| 24.   | Data classification                |                             |                                                                                                                                                                                                                                                                                               | [46], [51].     |            |
| 25.   | Data enhancement                   |                             |                                                                                                                                                                                                                                                                                               | [55]            |            |
| 26.   | Data categorization                |                             |                                                                                                                                                                                                                                                                                               | [23], [44].     |            |
| 27.   | Video translation                  | Data transcription          |                                                                                                                                                                                                                                                                                               | [38], [23].     | 11         |
| 28.   | Language translation               |                             |                                                                                                                                                                                                                                                                                               | [45], [6].      |            |
| 29.   | Audio translation                  |                             |                                                                                                                                                                                                                                                                                               | [51]            |            |
| 30.   | Human Optical Recognition tasks    |                             |                                                                                                                                                                                                                                                                                               | [55]            |            |
|   | Description                                                                                     | Interpretation & Analysis | References                                                                 |
|---|-----------------------------------------------------------------------------------------------|----------------------------|----------------------------------------------------------------------------|
|31.| Digitizing local-language documents                                                              |                            |                                                                             |
|32.| Transcribing the speech’s sentences                                                            |                            |                                                                             |
|33.| Image transcription                                                                            |                            |                                                                             |
|34.| Data translation                                                                              |                            |                                                                             |
|35.| Media transcription                                                                            |                            |                                                                             |
|36.| Checking and listing of websites                                                               | Interpretation             | [23], [44], [46], [51], [21], [48], [53], [6], [3], [52], [59], [60], [58], [22] |
|37.| Interpretation of visual data                                                                  |                            |                                                                             |
|38.| Data interpretation                                                                            |                            |                                                                             |
|39.| Data Analysis                                                                                  |                            |                                                                             |
|40.| Content moderation                                                                            |                            |                                                                             |
|41.| Sentiment analysis                                                                             |                            |                                                                             |
|42.| Conduct an interview                                                                          | Surveys                    | [21], [23], [46], [6], [48], [54], [56], [59]                              |
|43.| Content feedback                                                                              |                            |                                                                             |
|44.| Watch an online video                                                                          | Content access             | [21], [23], [51], [6], [45], [48], [52], [54], [49], [38]                 |
|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         | [23], [61], [62], [3], [63], [52], [55], [54], [59], [64], [58]         |
|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 |
| 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], [27], [65], [66], [29], [34] |
| 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], [63], [64], [27], [59], [14], [23], [61], [62], [67], [68], [69], [66], [70], [60], [58], [39], [71], [64] |
| 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. | [61], [62], [14], [23], [67], [72], [70] |
| 71. | Identification of alternative solution |
| 72. | Identification of main decision points from set of requirements |

V. VALIDATION

Validation of identified microtasking activities have been 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.
| 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. |
| Microtask                                      | Description                                                                                                                                                                                                 |
|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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.’ |
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 microtasks involve the translation of audio or video from one language into another. 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.
| 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’.

Copy 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.

|
| Category                      | Description                                                                                                                                                                                                 |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Locate known faults in code  | 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.         |
| 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       | 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). |
| function                      |                                                                                                                                                                                                              |
| 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    | 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’.           |
| related to interface          |                                                                                                                                                                                                              |
| 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’.                                           |
| 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’. |
| 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.

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 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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### APPENDIX A

Unique paper IDs of each selected paper of SLR to find the microtasking activities

| S. No | Paper ID | Paper Title |
|-------|----------|-------------|
| 01    | PID1     | A Taxonomy of Microtasks on the Web |
| 02    | PID2     | Break It Down: A Comparison of Macro- and Microtasks |
| 03    | PID3     | The Effect of Peripheral Micro-tasks on Crowd Ideation |
| 04    | PID4     | Estimating Conversational Styles in Conversational Microtask Crowdsourcing |
| 05    | PID5     | ReLauncher: Crowdsourcing Micro-Tasks Runtime Controller |
| 06    | PID6     | SimilarHITs: Revealing the Role of Task Similarity in Microtask Crowdsourcing |
| 07    | PID7     | A Profile-Aware Microtasking Approach for Improving Task Assignment in Crowdsourcing Services |
| 08    | PID8     | Exploring Microtask Crowdsourcing as a Means of Fault Localization |
| 09    | PID9     | Microtask Crowdsourcing Marketplace for Social Network |
| 10    | PID10    | Large-Scale Microtask Programming |
| 11    | PID11    | A Crowd-in-the-Loop Approach for Generating Conference Programs with Microtasks |
| 12    | PID12    | Human Beyond the Machine: Challenges and Opportunities of Microtask Crowdsourcing |
| 13    | PID13    | Microtask Programming |
| 14    | PID14    | Toward Microtask Crowdsourcing Software Design Work |
| 15    | PID15    | Task assignment in microtask crowdsourcing platforms using learning automata |
| 16    | PID16    | Microtasking: redefining crowdsourcing practices in emergency management |
| 17    | PID17    | Implementing Microservices through Microtasks |
| 18    | PID18    | Crowdsourced Reverse Engineering: Experiences in Applying Crowdsourcing to Concept Assignment |
| 19    | PID19    | Quality Assurance Strategies in Microtask Crowdsourcing |
| 20    | PID20    | Motivation of Workers on Microtask Crowdsourcing Platforms |
| 21    | PID21    | Crowdsourcing Platforms: Objective, Activities and Motivation |
| 22    | PID22    | Efficient Task Decomposition in Crowdsourcing |
| 23    | PID23    | A Task Decomposition Framework for Surveying the Crowd Contextual Insights |
| 24    | PID24    | Crowdsourced Microservices: Behavior-Driven development Applied to Microtask Programming |
| 25    | PID25    | Efficient Task Decomposition for Sequential Crowdsourced Task Solving |
| 26    | PID26    | Ask the Crowd: Scaffolding Coordination and Knowledge Sharing in Microtask Programming |
| 27    | PID27    | A Dynamic MicroTask Scheduling Approach for SLO based Human-augmented Computing |
| 28    | PID28    | Priming for Better Performance in Microtask Crowdsourcing Environments |
| PID | Title |
|-----|-------|
| 29  | Toward Microtask Crowdsourcing Software Design Work |
| 30  | Microtasking models and managerial challenges |
| 31  | Can Microtask Programming Work in Industry? |
| 32  | A Brief Perspective on Microtask Crowdsourcing Workflows for Interface Design |
| 33  | Adaptive Task Assignment for Crowdsourced Classification |
| 34  | Age-Based Task Specialization for Crowdsourced Proofreading |
| 35  | SLADE: A Smart Large-Scale Task Decomposer in Crowdsourcing |
| 36  | A workload-dependent task assignment policy for crowdsourcing |
| 37  | A network-based mechanism for managing decomposable tasks via crowdsourcing |
| 38  | Personalized and Diverse Task Composition in Crowdsourcing |
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| 40  | Two-sided Online Micro-Task Assignment in Spatial Crowdsourcing |
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