

With Registered Reports Towards Large Scale Data Curation

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ABSTRACT

The scale of manually validated data is currently limited by the effort that small groups of researchers can invest for the curation of such data. Within this paper, we propose the use of registered reports to scale the curation of manually validated data. The idea is inspired by the mechanical turk and replaces monetary payment with authorship of data set publication.

CCS CONCEPTS

• **General and reference** → **Computing standards, RFCs and guidelines.**

KEYWORDS

data curation, mechanical turk, research turk, registered reports

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1 INTRODUCTION

Data from software repositories or other sources is the backbone of many techniques that researchers are developing, e.g., automated program repair [2] and defect prediction [7]. We can divide the data into three categories: raw data that has been scraped from repositories that is published without change, e.g., GHTorrent [3]; automatically processed data in which researchers enrich raw data through automated (heuristic) algorithms, e.g., with software metrics or with defect labels computed with the SZZ algorithm [10]; and manually processed data, where researchers curate manually enriched data with additional information, e.g., by correcting issue tracking data [6] or manually untangling changes [8, 9].

The different kinds of data have different advantages and drawbacks. While raw data is largest in scale, working with this data requires careful and often time-consuming downstream processing by researchers. Automatically processed data can often directly be used for analysis by researchers, but carries the risk of noise in case heuristics were used. Manual data is similar to heuristic data without noise, but often smaller in scale due to the amount of manual effort required to enrich the data.

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Within this paper, we propose the research turk as a new approach for the scaling of research projects that require manually enriching data. The concept of the research turk is based on the mechanical turk, a method for distributing simple task of manual labor to a workforce [4]. In comparison to the mechanical turk, the research turk also works if expert knowledge is required and replaces monetary payment with scientific credit in form of authorship. Publications that want to use the research turk make use of registered reports to define the study protocol. The pre-registration defines which data are collected, which task researchers must solve, what the requirements for participation are, and how much effort is required to become an author.

The remainder of this paper is structured as follows. We briefly introduce registered reports and the mechanical turk in Section 2. We present the research turk in Section 3 and discuss ethical issues in Section 4. We present an example for how the research turk may be used in Section 5 and discuss applications other than manual data in Section 6. Section 7 concludes the paper.

2 FOUNDATIONS

Our proposed approach builds on two concepts, which we explain in this section: registered reports and the mechanical turk.

2.1 Registered Reports

The Center for Open Science states that with a registered report “you’re simply specifying to your plan in advance, before you gather data.”¹ The pre-registration of the report defines the study protocol before the actual research project is conducted. While this concept is not yet established in software engineering research, there are already first results from other disciplines that demonstrate that registered reports can improve the quality of scientific results [1]. To the best of our knowledge, the first chance for registered reports in software engineering will be a special track at the International Conference for Mining Software Repositories 2020² in cooperation with the Empirical Software Engineering³ journal.

2.2 The Mechanical Turk

Amazon conceptualized the idea of the mechanical turk to crowd source decision making in the internet [4] with the MTurk⁴. The MTurk describes two different kinds of users: *Employers* and *Turkers*. The *Employers* post *Human Intelligence Tasks* (HITs) on the MTurk website. Such a task could, e.g., be the identification of all images that contain a certain object. The *Employers* define a payment rate for the fulfillment of the HIT. *Turkers* can browse among

¹<https://cos.io/prereg/>

²<https://2020.msrfconf.org/track/msr-2020-Registered-Reports>

³<https://link.springer.com/journal/10664>

⁴<https://www.mturk.com/>

the HITs and perform the tasks to earn money. To ensure quality of the results, the same HIT can be solved by multiple Turkers⁵.

A key requirement for effective work with a platform like the MTurk is that the HITs do not require expert knowledge. The ideal tasks for HITs are too complex for state of the art algorithms, but simple for humans. Unfortunately, this means that such a crowd working approach can only be used in a limited way to create research data. For example, it would be highly unlikely to find Turkers that could untangle commits [8, 9] or manually label bug reports [6]. Moreover, people that have this kind of expert knowledge would command relatively high rates for solving the tasks, which would be economically challenging for most research projects.

3 THE RESEARCH TURK

The research turk is our approach to create a mechanical turk that would work for research tasks that require expert knowledge and that can, therefore, not be performed by the general public but only by researchers. The general concept for the research turk is the same as for the mechanical turk, we only replace the employer with a Principle Investigator (PI)⁶ and the turkers with researchers: the PI defines HIT as research task which shall be solved by qualified researchers. However, there are two underlying problems with the research turk:

- How and where does the PI define the HIT?
- How are researchers motivated to solve the HIT?

In the following, we describe how registered reports can solve both problems, enable meta analysis of the work conducted in a research turk project, and why registered reports are better than simply advertising for the research turk on a website.

3.1 Definition of the HIT

Registered reports provide the means to define the HIT, i.e., the PI would pre-register the research and define the research protocol in advance. The description of the research protocol for a research turk project must cover the following aspects.

- A description of the HIT that shall be solved.
- A strong motivation for the research project and the importance of the HIT for the community, including the reasons why the PI believes that a sufficient amount of researchers contribute by solving the HIT.
- An estimation of the effort for solving the HITs that demonstrates the need for distributing the task within the community and allows researchers to estimate the effort their contribution would require.
- A description of how the PIs ensure the quality of the results produced by the participating researchers.
- A description of when and where the data will be shared publicly and under which license. This description shall also contain information what happens with the data in case not enough researchers participate in the crowd working to fully address the research proposal.

Because there is no direct relationship between the PI and the researchers that conduct the HITs, the quality assurance of the results is an important aspect that should not be neglected. The PIs should define sanity checks for produced data, e.g., by spot checking the solution of the HITs by the PIs or by requiring multiple solutions for each HIT.

3.2 Motivating Researchers

Motivation can be provided to researchers by giving them the chance to become authors of the study by participating in the HIT. The path to authorship needs to be defined in the pre-registered research protocol. The venue where the report is registered must allow for changes in the group of authors between the registration of the report and submission of the results. To address this, the research protocol must cover the following aspects.

- A description of how researchers can sign up for the participation in the registered report. The registration procedure should cover potential data privacy and ethical concerns, e.g., which data from researchers is stored as part of solving the HIT, including why this data is required and how the data will be used.
- A description of the minimal level of experience required to solve the HITs, e.g., specified by an academic degree, years of experience, or similar measures. This may also include exclusion criteria that the PIs may apply to reject requests for participation.
- A description of the minimal requirements for becoming authorship of the report, e.g., how many HITs must be solved by a researcher.
- A description of what happens if researchers participate, but do not meet the minimal requirements for co-authorship. This could, e.g., result in an acknowledgement.
- A description of how the order of authors will be determined, e.g., alphabetically or based on the number of HITs that are solved.
- The starting date and the end date for the crowd working phase.

We believe that offering authorship is an effective incentive for a sufficiently large amount of researchers to contribute by solving HITs, if the venue where the results will be published is respected and the expected impact of the resulting publication is high. For graduate students such a way to authorship of publications can be highly interesting, e.g., for improving their chances of a better grade, to improve their CV, to gain experience in conducting research tasks, or because they would directly benefit from the outcome of the research because they can exploit the results produced. Senior researchers may also participate, but we believe that this only happens if they would directly benefit from the outcome of the research, e.g., because they planned similar or related projects themselves.

3.3 Gamification

Prescribing minimal criteria for authorship carries the risk that researchers only solve exactly that amount of HITs, even though they could contribute more to the project by solving additional HITs. While this is a completely valid approach and we cannot fault any

⁵<https://blog.mturk.com/tutorial-understanding-hits-and-assignments-d2be35102fbd>

⁶While we use the singular of the term PI in the following, this may also be a group of researchers.

researcher for acting that way, many research projects would benefit from researchers solving more than the minimal amount of HITs. We believe that there is a gamification element that may be used for this purpose. The simplest approach would be to show a (potentially anonymized or pseudonymized) ranking of researchers showing who currently solved the most HITs. This may motivate researchers to raise “higher” in the ranking.

Such a ranking approach may directly be combined with the ordering of the author list. Many publications order the authors by some measure of their contribution to the work. The more someone contributed, the higher the ranking. Thus, researchers may be motivated to solve more HITs, if they move up in the author list and, thereby, gain a higher level of visibility.

3.4 Meta Analysis

While the solution of the HITs is the main objective of a study that is performed using the research turk, there are also opportunities for a meta analysis of the results. For example, the meta-analysis may cover the following aspects.

- Descriptive statistics about the number of HITs solved by each researcher.
- Demographic analysis, e.g., regarding the educational background of the researchers, their prior experience, or their geographical location.
- Relations of the above with the results of the quality assurance measures, e.g., between the number of HITs solved and the outcome of the quality assurance.

All meta-analysis that shall be performed should be specified as part of the registered report.

3.5 Advantages of Registered Reports

The research turk could also be used without registered reports, e.g., by creating a website that specifies the research protocol. However, we believe that using registered reports provides multiple advantages over the website approach.

The registered report may already be peer reviewed at the time of the registration. This can help to ensure both the importance of the project, as well as to avoid invalid results due to mistakes in the design of the HIT or the evaluation procedure. Thus, researchers have an assurance that the research protocol of the research turk study is valid and will not be rejected later due to mistakes. This removes a big risk from the participants side that the effort they invest does not lead to the expected payoff, i.e., the contribution to a successful research project and the authorship of the related publication.

Moreover, the pre-registration assures that there is a public and unchangeable record of the research protocol, which may be important in case there are conflicts. By defining the rules for the research turk in a peer reviewed and public forum, the PIs put their reputation at stake if they try to change rules after starting the study or to unfairly exclude researchers from authorship. On the other hand, the PI has the assurance that researchers cannot unfairly claim authorship, even though they do not meet the previously defined criteria. Thus, the registered report is similar to a contract between the PI and the researchers.

4 ETHICAL CONSIDERATIONS

Since a concept like the research turk involves human participants, there are important ethical considerations that affect the quality of the scientific work, the use of authorship as “payment”, and potential side-effects of such a way to become author of scientific publications.

First, we have to consider whether offering authorship for contributing a specified amount to a research project may lead to rushed or invalid results, because researchers may participate with less care in such a setting. This is a general question of any research project and, in the end, must be handled responsibly by the PI. The PI must ensure that there are sufficient measures for ensuring the quality of the registered report, e.g., by letting each HIT be solved multiple times and using majority votes and/or doing a meta study to assess threats to the validity of the results. How the quality will be ensured, including counter measures in case of quality problems, should be described as part of the pre-registration.

Second, it may be unethical to offer authorship because solving HITs may not be a sufficient contribution to a research project that warrants authorship. The IEEE defines three criteria for authorship. “(1) *Made a significant intellectual contribution to the theoretical development, system or experimental design, prototype development, and/or the analysis and interpretation of data associated with the work contained in the article;* (2) *Contributed to drafting the article or reviewing and/or revising it for intellectual content;* (3) *Approved the final version of the article as accepted for publication, including references.*”⁷ The ACM adds one additional criterion. (4) “*Agree to be held accountable for any issues relating to correctness or integrity of the work.*”⁸

The criterion (1) is fulfilled, because the solving of the HIT contributes to the “analysis and interpretation of data”. The criteria (2) and (3) can be fulfilled, by explaining that one of the requirements for authorship is a review of the draft of the report, including signing off on the final version of the report. This may involve significant effort for the PI, i.e., distributing the draft to all authors and incorporating all comments. However, this will only improve the quality of the work due to the large amount of internal reviewing effort. The criterion (4) can also be fulfilled by stating this responsibility as a pre-requisite for participating the research project as part of the registered report as well as by signing off on the final draft. In case there are researchers who fail to review the draft of the report, they may only be mentioned in the acknowledgements of the paper, but not as authors.

Third, we believe that the gamification element we propose does not add any additional ethical considerations, other than those we have discussed above. In the end, it is the responsibility of the PI to ensure that the order of authors is fair. Solving more HITs means that more effort was spent, warranting a higher ranking. The PI has to ensure that this does not impact the quality of the research using the same methods as we discussed at the beginning of this section.

⁷<https://journals.ieeeauthorcenter.ieee.org/become-an-ieee-journal-author/publishing-ethics/definition-of-authorship/>

⁸<https://www.acm.org/publications/policies/authorship>

Researchers	Validations	Commits	Effort
1	1	10,000	208.3–312.5
5	1	2,000	41.7–62.5
10	1	1,000	20.8–31.2
50	1	200	4.2–6.2
100	1	100	2.1–3.1
5	3	6,000	125.0–187.5
10	3	3,000	62.5–93.8
50	3	600	12.5–18.8
100	3	300	6.2–9.4

Table 1: Estimation of the effort per researcher for the untangling of 10,000 bug fixing commits. The effort is given in working days (8 hours per day).

5 EXAMPLE

We use the untangling of bug fixing commits to demonstrate the potential of the research turk. Just *et al.* [8] and Mills *et al.* [9] manually validated which part of a bug fixing commit were actually part of a bug fix and reduced the data to these changes, thereby untangling the bug fixing from other changes in the commit. This manual analysis improves the quality of data for different research directions, e.g., program repair [2], bug localization [9], and defect prediction [7].

The drawback of this data is the scale: Version 1.5 of the Defects4J data from Just *et al.* [8] contains data for 438 bugs from 6 different projects, the data from Mills *et al.* [9] is for 620 bugs from 13 different projects. We contacted the authors to get an estimate of the effort that was required for the manual validation. Mills *et al.* [9] estimate the effort per commit as 10–15 minutes.

Table 1 shows the estimated effort in working days per researcher required for the manual validation of the file changes for 10,000 commits. The table depicts two estimates for different amounts of participating researchers: every commit is validated by a single researcher and every commit is validated by three researchers to improve the data quality. A group of five researchers would have to work full-time for at least 125 days to create such a data set with three validations. With a large group of 100 researchers, each researcher has less than 10 days of work. Thus, this example shows how improbable it is that a single group of researchers can invest the effort required for the manual validation of such a large data set and how this is easily possible if a large amount of people can be motivated to collaborate.

We believe that this example could attract a sufficient amount of researchers. Defects4J has already been cited 362 times since the publication in 2014⁹. If only one author from every third publication that cited Defects4J would participate, there would already be over 100 contributors to the research turk effort.

6 BEYOND DATA CURATION

While data curation is the motivating example we used throughout this paper, we believe that the research turk may also be a great tool for replication studies that compare algorithms. For highly active research topics with multiple new approaches every year,

it is challenging to evaluate which approaches are currently the best within the state of the art, especially if the evaluation criteria differ between publications, e.g., due to differences between the benchmark data sets or performance indicators. As a consequence, new approaches are often only compared against the “perceived” state of the art, e.g., recent approaches or very popular approaches that were often used by others for comparison. Due to this, it may become unclear what the actual state of the art is. A large replication study is then the only way to resolve this issue and identify differences in performances between the different approaches, e.g., as by Herbold *et al.* [5] for defect prediction. Currently, such replication studies require a large amount of effort by a small group of researchers.

The research turk would offer another solution: a benchmark protocol for approaches could be pre-registered as a research turk study, including a list of algorithms from publications that need to be replicated. The protocol would need to specify which data is used for the benchmark and how the implementations of the algorithms should provide their results. Researchers could then participate in this group effort by providing the implementations of the algorithms. This effort could, e.g., be managed via pull requests on GitHub. This would enable code reviews of the algorithms to ensure consistent quality. Alternatively, the protocol could prescribe that each algorithm should be implemented several times and the implementations are tested against each other. This would add another dimension to the replication study, as it would be possible to evaluate by experiments if the descriptions of the algorithms by publications are sufficient.

We believe that such replication efforts could attract a large number of interested researchers, because such a project could help researchers get started in a new research direction.

7 CONCLUSION

Large sets of manually validated data require a massive effort that cannot be handled by research groups on their own. Within this paper, we propose the research turk to scale research efforts. The research turk is based on the idea that a collaborative research effort is defined using a registered report and that researchers can participate by contributing to this research effort in a defined way to gain authorship for that research. In future work, we want to instantiate the research turk for the validation of bug fixing commits we discussed as example.

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⁹According to Google Scholar on 2019-10-14

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