MAJOR RESEARCH QUESTIONS

We look at lots of papers that use the term "crowdsourcing" or "crowd work" in the abstracts and titles of their papers, especially the papers that we cited earlier, to try to answer the questions that we posed in the introduction. Then we look to the piecework literature to see whether and to what extent piecework answers the questions we, crowdsourcing researchers, have asked. We then see whether and how crowdsourcing as we know it has differed from piecework, and how that affects the predictions and conclusions made in the piecework literature.

What are the limits of crowdsourcing?

Research in crowdsourcing has spent the better part of a decade exploring how to grow the limits of crowdsourcing and find the boundaries of crowd work and microtasks. This has largely involved identifying challenges to this form of labor, overcoming them through novel designs of work–flows and processes, and repeating the process [e.g. 2, 44, 28]. The question that has emerged among these researchers and through the work that they have produced then has been driving at *whether* there are limits to crowdsourcing (and, if so, what factors determine those limits). Through this lens, we can point to a number of contributions to the field that have extended the boundaries of crowd work.

The exploration of crowdsourcing's potential and limits has principally looked at manipulating and extending along three dimensions: 1) finding crowd work's limits, 2) the decomposition of work, and 3) the relationships of workers. We'll explore these aspects of crowdsourcing, discussing the extents to which work can be decomposed, contextually abstracted, and made more resilient to attrition of various forms. We'll also point to corresponding piecework literature addressing these aspects. Finally, we'll discuss how these elements will serve to constrain the upper and lower bounds of crowdsourcing as it relates to the question of the furthest limits of crowdsourcing.

Achieving greater complexity

crowd work's perspective. **Crowdsourcing research has spent the better part of a decade attempting to prove the viability of crowdsourcing in increasingly complex work.** Kittur et al. map the discussion toward this goal in their work on crowdsourcing complex work [28]. The broader body of work has varied significantly in type — providing conversational assistants, interpreting medical data, and telling coherent and compelling stories, to name a few examples [32, 40, 26].

This body of research has involved similar approaches to problems, often involving insights made in Computer Science and applied to human work–flows. The crowd work literature typically identifies target milestones in CS that have presented significant challenges for researchers, leverages some of the approaches and insights that Computer Science researchers have already made (for example, MapReduce in the case of Kittur et al.'s *CrowdForge*), and arranges humans as computational black boxes within those approaches and processes [28, 44, and others]. This approach has proven a compelling one because it leverages the in–built advantages that technology and digital media afford. *Foundry*'s tools for managing and arranging expert groups into a cohort allow researchers to convincingly argue that expert teams can be rapidly formed, just like non–expert teams [44].

Piecework's perspective. **The research into piecework makes the case that piecework has been limited principally by the challenges of human management and oversight.** Graves describes a case study in Santa Fe Railway, which deployed scientific management and a piecework regime in an attempt to stymie rising repair costs [15]. Returning to Hart's reflections on piecework's limitations, we recall the multidimensional problem — tasks comprising of numerous, sometimes conflicting, goals [19]. It would be reasonable, then, to infer that work like this — reasonably highly skilled work where quality is difficult to assess — would be unsuitable for piecework.

Hart and Graves, without acknowledging one another, seemingly corroborate one another's conclusions at different levels of observation. Graves enumerates some of the roles required to facilitate piecework in the early 20th century: "… piecework clerks, inspectors, and 'experts'…" [19, 15]. Graves and Hart may seem to be making differing claims about the limitations of piecework, but we argue that Graves is simply making a more concrete observation illustrating the insight that Hart later makes. Graves recognizes that it's necessary for a successful piecework shop to employ clerks, inspectors, and other experts to properly design and evaluate complex work. Hart argues an ultimate limit to how far this can go; at some point, evaluating multidimensional work output for quality (rather than for quantity) becomes infeasible.

This isn't to say that complex work is outside of the realm of piecework; indeed, we've discussed complex applications of crowd work already. As Hart and Roberts described, the 1930s saw a flourishing of clever piecework job design out of necessity due to the fact that it was infeasible to provide new workers with the comprehensive education that was familiar to men [18]. This constraint led to much more tightly scoped work, and (perhaps surprisingly at the time) more efficient allocations of workers, who could now specialize in extremely narrowly defined roles. The same could be said of Airy and his *computers* — young boys whose preparations consisted principally of a relatively specific mathematics curriculum [17].

Piecework researchers also make claims regarding the organizations that benefit from piecework in the first place. Brown discusses the factors necessary for piecework to thrive: "… incentive pay is less likely in jobs with a variety of duties than in jobs with a narrow set of routinized duties" [5]. Graves adds further, that successful cases of piecework owed themselves in part to the fact that "… only [the largest and most wealthy railroads] had the resources to …pay the overhead involved in installing work reorganization" [15]. Together, Graves and Brown make a persuasive argument that piecework is limited in complexity by managerial overhead and the fixed cost of adopting a piecework payment regime.

There are other characteristics to effective complex piecework institutions, such as appropriately designed management practices. Boal and Pencavel describe the role of the

foreman in West Virginia coal mines under the piecework model: "The foreman had the power to hire and fire workers and allocate workplaces, but then left the face–worker largely free to his own efforts so that often he went all day without seeing the foreman" [4]. The general approach adopted by these West Virginia mines was, as in other factories with active foremen, to let the foreman be the intermediary between management and the worker. Specifically, foremen were responsible for allocating resources and understanding when and how to modify work as necessary [59].

What's different about crowd work. **Digital media have expanded the scope of viable piecework by pushing drastically on the limits cited by piecework researchers.** The research on piecework tells us that we should expect piecework to thrive in industries where the nature of the work is limited in complexity [5]. Given the flourishing of on–demand labor platforms such as Uber, AMT, and others, we ask ourselves what — if anything — has changed. We argue that the Internet has trivialized the costs and challenges of the earlier limiting factors for two reasons: 1) Technology make it much easier to do complex work aided by computers; and 2) The Internet allows us to leverage the benefits of "economies of scale" at very little cost to the system–designer [35, 42].

Technology has made it possible for non–experts to do work that was once considered within the domain of experts. Yuan et al. builds on the work of others (*Voyant* and, more relevantly, *CrowdCrit*) to design workflows that yield "expert–level feedback" [61, 60, 37]. This body of work identifies ways to transform a variety of duties comprising complex tasks and distills them into "a narrow set of routinized duties", informed in part by researchers — acting as inspectors — and experts [quotations from 15] Where Graves would call additionally for the identification of crowdsourcing's version of "piecework clerks", we point out that today algorithms manage workers as pieceworkers once did [34, 15].

Furthermore, technology more directly facilitates the subversion of expertise requirements by giving non–experts access to information that would otherwise be unavailable. Taxi drivers in London endure rigorous training to pass a test known as "The Knowledge" — a demonstration of the driver's comprehensive familiarity. Researchers have identified significant growth of the hippocampal regions of the brains in veteran drivers, generally understood to be responsible for spatial functions such as navigation [39, 38, 49, 50, 58, 57]. Services such as Google Maps & Waze make it possible for people entirely unfamiliar with a city to know more about a city even than experts through the collective data generated by other users ranging topics such as police activity, congestion, construction, etc. . . [48, 20].

Implications for crowd work research. **The piecework literature gives us a template for pushing the boundaries of complexity in piecework, but it also signals some of the ultimate limitations of crowd work and piecework in general.** While the threshold preventing task requesters from utilizing piecework has dropped thanks to affordances of the Internet, the ceiling on task complexity hasn't moved significantly. If we're to make use of Brown's prescriptions, we would benefit from finding ways to decompose varied tasks into homogeneous microtasks.

We should also consider exploring the limitations that algorithmic management bring along more carefully. While research has touched on this subject, we've yet to make out the bigger picture of this theme [34]. If we can resolve the tension between workers and perilously antagonistic managers, as Boal and Pencavel suggest, then we may be able to break a toxic cycle of mistrustful requesters [for example 14] and develop more considerate platforms as McInnis et al. advocate [41].

Finally, and perhaps most importantly, we need to replicate the success of narrowly slicing education and training for expert work as Hart and Roberts and Grier described in their piecework examples [18, 17]. That is, we need to identify new ways to train crowd workers for uniquely narrowly defined work. To some extent, an argument can be made that MOOCs and other online education resources provide crowd workers with the resources that they need, but it remains to be seen whether that work will be appropriately valued, let alone properly interpreted by task solicitors [1]. If we can overcome this obstacle, we might be able to empower crowd workers to do complex work such as engineering and metalworking, rather than doom them to match girl reputations: "brash, irregular, immoral, and uneducated" [46].

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The Decomposition of Work

crowd work's perspective. **The crowdsourcing research into work decomposition has largely focused on minimizing the additional context necessary to do tasks, and making it easier to do tasks with less time.** This first thread is perhaps best described by Verroios and Bernstein as making crowd workers "... able to act with global understanding when each contributor only has access to local views" [55]. With the exception of a few cases (specifically, Kinnaird, Dabbish, and Kiesler's work which finds that greater work context fosters more reliably high–quality work), the micro task paradigm has emerged as the overwhelming favorite [51, 52, 9, 27].

As the additional context necessary to complete a task diminishes, the marginal cost of finding and *doing* tasks has increasingly become the focus of research. Chilton et al. illustrate the challenges on AMT, and some work has gone into ameliorating the problems specific to this work site (*ReLauncher*), while other work designs tasks around gap time (*Twitch Crowdsourcing* & *Wait–Learning*) [10, 31, 54, 7]. Cosley et al. attempts to address this by directing workers to tasks through "intelligent task routing" [11]. Much of this work and the work at the periphery of this space, then, has focused on minimizing the amount of time that people need to spend doing anything other than the work for which they are paid.

Earlier we discussed Cheng et al.'s work measuring the impact that interruption has on worker performance [9]. This work illustrates a broader sentiment in both the study and practice of crowd work, that microtasks should be designed resiliently against the variability of workers, fully exploiting the abstracted nature of each piece of work [22, 33, 53]. That is to say, micro–tasks should be designed such that a single worker's poor performance, or a good worker's sudden departure, does not significantly impact the agenda of the work as a whole. While Cheng et al. found costs with breaking tasks into smaller components in the form of higher cumulative time to complete (albeit much shorter real time to complete, owing to parallelization), Lasecki et al. found that at least *some* performance can be recouped by stringing similar tasks together [9, 33, respectively].

Yet more work looks at the general framing of tasks, chaining and arranging them to maximally exploit the attention and stress threshold of workers [6]. Rather than attempt to minimize the error rates in micro–tasks, as Kinnaird, Dabbish, and Kiesler suggested, we as a community have leaned *into* the peril of low–context work, "embracing error" in crowdsourcing [30].

Piecework's perspective. **The research community relating to piecework and labor has been wrestling with the decomposition of work for centuries.** The beginnings of systematic task decomposition stretch back as far as the 17th century, when Airy employed young boys at the Greenwich Observatory who "possessed the basic skills of mathematics, including 'Arithmetic, the use of Logarithms, and Elementary Algebra' " to compute, by hand, astronomical phenomena [17]. These workers became the first *computers*.

The work Airy solicited was interesting for several reasons. First, work output was quickly verifiable; Airy could assign variably skilled workers to compute values, and have other workers check their work. Second, tasks were discrete — that is, independent from one another. Finally, knowledge of the full scope of the project — indeed, knowledge of anything more than the problem set at hand — was unnecessary.

The insight of breaking tasks down into smaller components didn't find its audience until the early 20th century, with the rise of Fordism and scientific management (or Taylorism). From scientific management, we found that we could measure work at unprecedented resolution and precision. As Brown points out, piecework most greatly benefits the instrumented measurement of workers, but certainly in Ford and Taylor's time — and certainly in Airy's time — highly instrumented, automatic measurement of workers was all but impossible. As a result, the distillation of work into smaller chunks ultimately reached a limit of usefulness.

What's different about crowd work. **A number of factors in crowd work are different from piecework, chief among them being the relative ease with which the metaphorical "assembly line" can be changed.** Computers make it possible to switch from one task to another unlike any arbitrary manufacturing factory possibly could; a worker could do any number of different *types* of tasks in the span of just a few minutes, driven in particular by the power Lessig points to — that system–designers can share, modify, and instantiate environments like sites of labor in a few lines of code [33, 35]. This has spurred an entire body of work investigating the effects of ordering, pacing, interruptions, and other factors in piecework that would have been all but impossible to measure consistently as few as 20 years ago [9, 8, 30].

Further, we've sliced work to such small scales that the marginal activities — things like finding work, cognitive task switching, etc. . . — have become relatively large compared to the tasks themselves [10]. In the historical case of piecework, moving metallurgical tools, mining equipment, or other industry materials would have been prohibitively difficult and slow; workers were encouraged to specialize in a single set of tasks, allowing pieceworkers to sequence their tasks optimally on their own [18].

Rather than fall into the trap that Irani warns of, — one which where crowd workers are rendered as "modular, protocol–defined computational services" — we may yield better results from crowd work if we think of workers as similar to specialized, repurposable tools [23]. [al2: feeling meh about this argument. . .]

Finally, instrumentation has reached a sufficiently advanced and ubiquitous point that the dream of scientific management and Taylorism — to measure every motion at every point throughout the workday and beyond — is not only doable, but trivial [56]. One of the major challenges Graves cites as preventing scientific management from being fully utilized, the difficulty of tracking work & workers, no longer exists [15].

Implications for crowd work research. crowd work research today is on the right track to investigate pipelining and meta–task design. That is, investigating better work discovery methods, producing tools for workers to make more informed decisions [see, for example, 24]. It's not clear how much benefit there is in the further decomposition of work, given that we've hit bottlenecks with the cognitive stresses of switching between tasks as Lasecki et al. highlight [33].

The Relationships of Workers to Work, Peers, and Others

crowd work's perspective. **The relationships of workers with their work, peers, and with others are complex and still emerging.** Researchers have only begun to appreciate the sociality of crowd workers in labor markets that we've been otherwise studying for years [16]. Nevertheless, a number of interesting findings have already emerged in the crowd work literature, which we can report here.

A number of ethical questions surrounding the increasing complexity of crowd work and the hazards have increasingly arisen. Silberman, Irani, and Ross bring some of these issues at stake — working for increasing amounts of time on tasks of growing complexity, only to discover that requesters are not willing to pay, for instance — but these and other dangers range an enormous landscape [29, 47, 43, 45].

Some research already looks at research such as investing in workers, and informally, we know that this happens among in-

dustry requesters [21, 12]. AMT, meanwhile, offers requesters the ability to create tasks which are not just hidden from unqualified workers by default, but completely. Requesters have taken to using lists of worker IDs which reference workers who have proven their reliability, representing a sort of proto–organization of loosely connected workers.

Piecework's perspective. The rise of labor unions in the 20th century seems to have been precipitated by egregiously unjust conditions imposed on workers in factories and elsewhere [13]. Incidents broadly describing this dynamic can be found in research on AMT [24, 45]. If these are prototypical labor advocacy organizations of contemporary on–demand work, the next question we should look to is if — and indeed *how* — these institutions might face challenges in the future.

For insight on this, we return to 2009's study of labor unions, and identify that "Scholars who evaluate union governance by procedural criteria generally find that oligarchy tends to arise and persist even when democratic procedures are in place" [36]. Indeed, Levi et al. writes about the general perception that labor unions were either This perception already appears to be emerging in digitally mediated peer–governed organizations, as Keegan and Gergle and others have illustratively documented [3, 25]. If these organizations and others are to avoid the same fate that labor unions faced, they should take care to study this phenomenon and attempt to avoid it.

What's different about crowd work.

Implications for crowd work research.

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