Examining Crowd Work through The Historical Lens of Piecework

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ABSTRACT
The internet is empowering the rise of crowd work, gig work, and other forms of on–demand labor. A large and growing body of scholarship has attempted to predict the socio–technical outcomes of this shift, especially addressing three questions: 1) What are the complexity limits of on–demand work?, 2) How far can work be decomposed into smaller microtasks?, and 3) What will work and the place of work look like for workers? In this paper, we look to the historical scholarship on piecework — a similar trend of work decomposition, distribution, and payment that was popular at the turn of the 20th century — to understand how these questions might play out with modern crowd work. We identify the mechanisms that enabled and limited piecework historically, and identify whether crowd work faces the same pitfalls or might differentiate itself. This approach introduces theoretical grounding that can help address some of the most pernicious questions in crowd work, and suggests design interventions that learn from history rather than repeat it.

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INTRODUCTION
The past decade has seen a flourishing of *on–demand work* driven by the reformulation of work as constituent parts of larger tasks. This framing of work into modular components has enabled the computational hiring & management of workers at scale [65, 16, 81]. Distributed workers then engage in work whenever their schedules allow, often with little to no awareness of the broader context of the work, and often with fleeting identities and associations [102, 92]. In this paper, we use "on–demand work" to capture a pair of related phenomena: first, *crowd work*, on platforms such as Amazon Mechanical Turk (AMT) and other sites of (predominantly) information work; and second, *gig work*, often as platforms for one–off jobs, like driving, courier services, or administrative support. The realization that complex goals can be accomplished by directing and managing crowds of workers spurred industry to flock to sites of labor such as AMT to explore the limits of this distributed, on–demand workforce. Researchers have also taken to the space in earnest, developing systems and designs that enable new forms of production (e.g. [12, 14, 117]).

As on–demand work has grown far beyond information work, it has given rise to scholarship exploring myriad facets of on–demand work. Howe first described crowdsourcing as "outsourcing to an undefined, generally large group of people in the form of an open call" [65]. However, for years its instantiation was limited to the utilization of human intelligence to process data, participate in scientific studies, and perform information work [79, 158, 165, 47, 118]. More recently, crowdsourcing of physically embodied work — driving and cleaning, for instance — has become a focus for on–demand labor markets [92, 145, 64, 140]. This growth prompted efforts to understand not just the work, but also the workers on these platforms [124, 134]. Some of this research has been motivated by the identification of the sociality of gig work [50], and the frustration and disenfranchisement that these systems embody [70, 102, 104]. Other work has focused on the outcomes of this frustration, reflecting on the resistance workers express against digitally mediated labor markets [92, 129].

This body of research has broadly sought to answer one central question: What does the future hold for on–demand work and those who do it? Researchers have offered insights on this question along three major threads: First, What are the complexity limits of on–demand work? Specifically, (a) How complex are the goals that crowd work can accomplish?, and (b) What kinds of goals and industries may eventually utilize it? [120, 138, 76, 164, 162, 110, 55]. Second, How far can work be decomposed into smaller microtasks [82, 12, 26, 98, 83, 90, 22, 28, 111]. And third, What will work and the place of work look like for workers? [70, 69, 129, 50, 20, 104].

This research has largely sought to answer these questions by examining extant on–demand work phenomena. So far, it has not offered a framing for holistically explaining the developments in worker processes that researchers have developed, or

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the emergent phenomena in social environments; nor has any research gone so far as to directly predict future developments.

Piecework as a lens to understand crowdsourcing

In this paper, we offer a framing for on–demand work as a contemporary instantiation of *piecework*, a work and payment structure which breaks tasks down into discrete jobs, wherein payment is made for work *output*, rather than for *time*. Piecework use as a lens on on–demand work is not new. Kittur in 2013 referenced crowd work as piecework briefly as a loose analogy [81]. But more than this, the framing of on–demand labor as a re–instantiation of piecework gives us years of historical material to make sense of this new form of work, and allows us to reflect on–demand work through a mature theoretical lens, informed by decades of rigorous, empirical research.

More concretely, by looking at on–demand work as an instantiation (or even a continuation) of piecework, and by interrogating patterns that the corresponding literature predicts on this basis, we can first, make sense of past events as part of a much larger series of an interrelated phenomenon; second, reflect on differences in the factors that impacted piecework historically and their impact on–demand work today; and third, to some extent, offer predictions of what on–demand work researchers, and workers themselves, might expect to see on the horizon. For example, we will draw on the piecework literature regarding task decomposition, which was historically limited by shortcomings in measurement and instrumentation, and leverage that understanding to suggest how modern technology affects this mechanism in on–demand work — namely, by enabling precise tracking and measurement of workers via algorithms and software. By doing so, on–demand labor will find ways to decompose tasks to unprecedented levels.

We organize this paper as follows: first, we review the definition and history of piecework to make clear the analogy to on–demand work (which we'll call *crowd work* hereon for consistency with the existing literature); second, we interrogate the three major research questions above using the lens of piecework. We will identify similarities and differences between piecework as historically understood and on–demand work as we know it today; third, we will make predictions of future developments based on how those similarities and differences influenced piecework; finally, we will offer implications for researchers and practitioners based on our results.

A REVIEW OF PIECEWORK

The HCI community has used the term "piecework" to describe myriad instantiations of on–demand labor, but researchers have generally made this allusion in passing. Since this paper traces a much stronger parallel between (historical) piecework and (contemporary) on–demand work (and, more generally, on–demand labor), a more comprehensive background on piecework will be useful. We will more carefully discuss piecework in this section to help make our observations and arguments with better familiarity with the topic. Specifically, first, we'll define "piecework" as researchers in its field understand it; and second, we'll trace the rise and fall of piecework at a high level, identifying key figures and ideas during this time. This section is not intended to be comprehensive: instead, it sets up the scaffolding necessary for our later investigations of on–demand work's three questions: complexity limits, task decomposition, and worker relationships.

What is piecework? A Primer and Timeline

Aligning on–demand work with piecework requires an understanding of what piecework is. While it has had several definitions over the years, we can trace a constellation of characteristics that recur throughout the literature. We'll follow this research, collecting descriptions, examples, and definitions, tracing an outline of *what piecework is* alongside piecework's contemporary developments in practice.

Piecework's history traces back further perhaps than most would expect. Grier describes the process astronomers adopted of hiring young boys to calculate equations in order to better–predict the trajectories of various celestial bodies in the 1830s [51]. George Airy was perhaps the first to rigorously apply piecework–style decomposition of tasks to work; by breaking complex calculations into constituent parts, and training young men to solve simple algebraic problems, Airy could distribute work to many more people than could otherwise complete the full calculations.

Piecework may have started in the intellectual domain of astronomical calculations and projections, but it found its foothold in manual labor. Piecework took hold in farm work [119], in textiles [10, 122], on railroads [21], and elsewhere in manufacturing [130]. Fordism and scientific management thrust piecework into higher gear, especially as mass manufacturing and a depleted wartime workforce forced industry to find new ways to eke out more production capacity.

By 1847 we find a concise definition of piecework in Raynbird's essay on piecework, particularly driven toward encapsulating the manual labor of farmwork. Raynbird does this by contrasting with the "day–labourer" — "the chief difference lies between the day–labourer, who receives a certain some of money ... for his day's work, and the task–labourer, whose earnings depend on the quantity of work done" [119]. Chadwick defines it through examples: "payment is made for each hectare which is pronounced to be well ploughed ... for each living foal got from a mare; ... for each living calf got" [27]. This framing offers an intuitive sense of piecework; "payment for results," as he calls it, is not only common in practice, but well–studied in labor economics as well [42, 150, 151, 61].

It's worth acknowledging that "this distinction [between piece–rates and time–rates] was not completely clear–cut" [58]. Employers implemented piece–rates in some aspects and time–rates in others. The Rowan premium system, for example, essentially paid workers a base rate for time plus additional pay dependent on output [125]. As Rowan's premium system guaranteed an hourly rate regardless of the worker's productive output *as well as* additional compensation tied to performance, workers were in some senses "task–labourers", but in other senses "day–labourers". This was just one of several alternatives to strict time– and piece–rate renumeration paradigms.

It may be worth thinking about piecework through the lens of its *emergent* properties to help understand it. Raynbird argues for the merits of piecework, pointing out that "piece work holds out to the labourer an increase of wages as a reward for his skill and exertion . . . he knows that all depends on his own diligence and perseverance . . . [and] so long as he performs his work to the satisfaction of his master, he is not under that control to which the day–labourer is always subject". The argument that "task–labourers" enjoy freedom from control crops up in Raynbird's and later Rowan's works [119, 125].

We see this sense of independence in myriad times, locales, and industries. Satre offers a look into the lives and culture of "match–girls" — young pieceworkers, mostly women, who assembled matchsticks in the late 19th century. Of interest was their reputation ". . . for generosity, independence, and protectiveness, but also for brashness, irregularity, low morality, and little education" [130]. Hagan and Fisher document piecework from 1850 through 1930 in Australia, finding similar notions of independence and autonomy among piecework newspaper compositors: "If a piece–work compositor . . . decided that he did not want to work on a particular day or night, the management recognised his right to put a 'substitute' or 'grass' compositor in his place" [54]. This sense of independence and autonomy appears to be an inherent component of piecework.

The early growth of piecework led to discussion on how best to manage pieceworkers, generally regarding workers antagonistically [113, 34]. This was a far cry from the earlier rhetoric on piecework, which promised that piece workers would gladly work as diligently and as hard as possible because incentive–based pay would reward workers directly for hard work [].

Piecework opened the door for people who previously couldn't participate in the labor market to do so, and to acquire job skills incrementally. During World War II, women received training in narrow subsets of more comprehensive jobs, enabling work in capacities similar to conventional (i.e. male) workers [58]. Workers with specific skill subsets could be matched to suitable tasks. Women previously had virtually no opportunities to engage in engineering and metalworking apprenticeships as men did; now, they could be trained quickly on narrowly scoped tasks, demonstrate proficiency, and become experts.

Piecework's popularity in the United States and Europe fell almost as quickly as it had climbed. Between 1938 and 1942, the proportion of metal workers under piecework systems had climbed steeply from 11% to 60% [57]. By 1961, that proportion dropped to 8% [25]. Carlson details that, from 1973 to 1980, the holdouts of piecework — where more than 50% worked under incentive wage plans — were principally in clothes–making (e.g. hosiery, footwear, and garments). Hart and Roberts's work substantively explores the precipitous decline of piecework in the last third of the 20th century.

In summary, piecework: 1) paid workers for *quantity* of work done, rather than *time* done, but occasionally mixed the two payment models; 2) afforded workers a sense of freedom and independence; and 3) structured tasks in such a way as to facilitate more narrowly scoped training and education.

Viewing on–demand work as a modern instantiation of piecework is relatively straightforward by this definition. First, platforms such as Mechanical Turk, Uber and TaskRabbit pay by the task, though some such as Upwork do offer hourly rates as well. Second, workers are attracted to these platforms by the freedom they offer to pick the time and place of work [102, 20]. Third, system developers as on Mechanical Turk typically assume no professional skills in transcription or other areas, and attempt to build that expertise into the work flow [112, 12]. Given this alignment, many of the same properties of piecework historically will apply to on–demand work as well.

Case studies in piecework

Throughout the rest of the paper, we will return to four case studies to frame our analyses: Airy's employment of human computers; domestic and farm work; the "match–girls" strike; and industrial and assembly-line work. In introducing these cases at a high level, we'll trace the history of piecework while also framing the later analysis of the major research threads we named earlier: complexity, decomposition, and relationships.

Airy's Computers

Industrial Workers

Piecework might be most familiar to the HCI researcher at the assembly line, which largely defined manufacturing through the 20th century. In the railroad industry and especially on the assembly line we see many of the mechanisms of work and worker management that later made their way into crowd work. Furthermore, it's from here the piecework literature draws most upon to find limits speaking to complexity and task granularity. We'll expose these facets of piecework very superficially in the context of industrial work to better speak to these research questions in on–demand labor later.

Railway companies adopted piecework regimes in the early 20th century; what followed was a flourishing in the management practices with pieceworkers, as railway companies struggled to find effective ways to motivate and evaluate this skilled workforce of engineers. Graves takes up a case study of the Santa Fe Railway, finding that they employed "efficiency experts" to develop a "standard time" to determine pay for each task at the company informed by "thousands of individual operations"; Graves goes on to list some of the roles required to facilitate piecework in the early 20th century — among them, "piecework clerks, inspectors, and 'experts' " [48].

This oversight, while controversial (especially among workers [72]), paved the way for piecework to grow substantially. With Taylor's formalization of scientific management in *Taylorism* (and Henry Ford's eponymously named *Fordism*), piecework in the early and mid–20th century surged, especially in industrial work. Scientific management promised that the careful measurement of workers would yield higher efficiency and output [141, 95]. While Brown points out that piecework dramatically advanced the instrumented measurement of workers, in Taylor's time highly instrumented, automatic measurement of workers was all but impossible [21]. Instead, managers conducted "stop watch time studies" [109], using completion times to inform per–task compensation, similarly to efficiency experts in the Santa Fe Railway, but substantially more precise.

Piecework through the 20th century centered around auto and other mass manufacturing, but found its way into the war effort during World War II. With the vast majority of men drafted into service, factories found themselves turning to a predominantly female workforce that had neither the formal training nor the years of apprenticeship experience that conventional workers would have had. Rather than attempting to train this new labor force in every aspect of industrial work, these women were trained for individual tasks and assigned to that task. One might reflect on the observation that "Rosie the Riveter", an icon of 20th century America who represented empowerment and opportunity for women [63], was a pieceworker [37].

The 1930s represented a boom for piecework on an unprecedented scale, especially among engineering and metalworking industries. Hart and Roberts characterize the 1930s — and more broadly the first half of the 20th century — as the "heyday" of the use of piecework. They attribute this to the shortage of male workers, who would have gone through a conventional apprenticeship process affording them more comprehensive knowledge of the total scope of work.

Some of the first systematic cases of what we would recognize as crowd work can be found in the study of astronomy. In the 19th century, the calculation of celestial bodies had become a competitive field with Airy needed to compute tables that would allow sailors to locate themselves by starlight from sea. This work ostensibly called for educated people who comprehensively understood mathematics. Airy realized that he could break the tasks down and delegate the constituent parts to "human computers" who "... possessed the basic skills of mathematics, including 'Arithmetic, the use of Logarithms, and Elementary Algebra' " [51]. As a result, many of Airy's computers had relatively rudimentary educations compared to the background of education that typically worked in the calculation of solar tables. Airy distributed tasks by mail, allowing work to be completed by a somewhat geographically distributed workforce, and paid for each piece of work completed. Airy also instituted a policy of firing his computers once they reached age 23.

The human computers captured several aspects of task decomposition that would become common. First, the work was designed such that it could be done independently and without collaboration. This enabled geographically-distributed workers to complete the tasks. Second, the work was designed so that intermediate results could be quickly verifiable as correct: Airy would have two workers each do the calculation, and a another person compare their answers. Third, Airy identified ways to decompose the large task into narrowly-trainable subtasks.

This practice ensured two outcomes that arguably disfavored workers. First, it eliminated any potential to advance professionally, as workers' careers in this area ended relatively early in their careers, and without formal education in mathematics they struggled to find work for which their experience was meaningful. Second, it limited workers' ability to organize by ensuring that workers hardly spent sufficient time to successfully rally their peers.

Domestic and Farmhand Labor

The application of piecework to farm work in the late 19th century and later to manufacturing of small goods, such as garments and matches, at the turn of the 20th century proved to be a formative period for piecework as we would come to know it. Piecework regimes in farms and in homes engaged workers in assembling clothing, where they were paid by the *piece* of output. Textile manufacturers found that they could deliver fabric to people at their homes, paying them to sew together clothing. The manufacturers would later return to retrieve the finished garments, paying these workers for each *piece* of clothing made. Farm work applied the idea of piecework by paying workers for things like picking bushels of fruit or bringing to birth animals [27].

Workers could, in principle, assemble as much or as little clothing as they wanted; the reality was more grim, as Riis documented in "*How the other half lives: Studies among the tenements of New York*" in 1901 [122]. He found that workers endured bleak living conditions and worked long hours attempting to scrape together a living.

The Match–Girls' Strike

Match–makers were some of the first workers in mass manufacturing to successfully rally for political causes. At the end of the 19th century, manufacturers employed women to assemble matchsticks in factories. These women rallied first in the form of a march on parliament in 1871 to protest a proposed tax, and later (more famously) in what was later called "the match–girls strike of 1888" [130].

The match–girls strike of 1888 was sparked by a worker's arbitrary docking of pay, but much deeper resentment had been boiling over for years. Match–girls were already frustrated with the arbitrariness of management, poor working conditions, and having to work with phosphoric materials (which was proving hazardous).

Regardless of the reasons, the lasting impact of the match–girls strike of 1888 was profound. This was one of the earliest and most famous successful worker strikes, and perhaps the beginning of "militant trade unionism" [130]. As Weyer, Webb, and Webb described, "the match–girls' victory turned a new leaf in Trade Union annals" [153]: in the 30 years after the match–girls strike, the Trade Union Movement enrollment grew from 20% of eligible workers to over 60%.

Match girls were the only group in 1903 to have formed a trade union, according to Booth's account at the time [19]. Satre noted that match girls "... pooled their resources to purchase their plumes and clothes ... and expressed their solidarity through small [and major] strikes" [19]. But they were also, as Satre confesses, known for "brashness, irregularity, low morality, and little education" [130]. These were workers who treasured their independence, but also fiercely protected one another, contributing to the common good. Their "brashness" for instance may have detracted from their public image, but almost undoubtedly contributed to their sense of solidarity, making their propensity to act against such unfair treatment and poor conditions understandable and maybe predictable.

Industrial Workers

Piecework might be most familiar to the HCI researcher in the context of industrial and factory work, which largely defined manufacturing through the 20th century. Before the factory assembly line arose, railway companies adopted piecework regimes in the early 20th century. What followed was a flourishing of piecework management practices, as railway companies worked to find effective ways to motivate and evaluate this skilled workforce of engineers. Graves takes up a case study of the Santa Fe Railway, finding that they employed "efficiency experts" to develop a "standard time" to determine pay for each task at the company informed by "thousands of individual operations"; Graves goes on to list some of the roles required to facilitate piecework in the early 20th century — among them, "piecework clerks, inspectors, and 'experts' " [48].

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RESEARCH QUESTIONS

Research in crowdsourcing has spent the better part of a decade exploring how to grow the limits of crowdsourcing, finding the boundaries of crowd work and microtasks. This has largely involved iteratively identifying barriers on complexity and overcoming them through novel designs of work–flows and processes (e.g. [12, 120, 80]). The question then has become *whether* there are limits to crowdsourcing, and if so, what factors determine them. To this question, a number of contributions to the field have pressed for answers.

The exploration of on–demand work's potential and limits has principally looked at manipulating and extending along three dimensions: First, what are the complexity limits of on–demand work. Second, how far can work be decomposed into smaller microtasks. And third, what will work and the place of work look like for 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.

Identifying the Complexity Limits of On–Demand Work

A key question to the future of on–demand work is *what* precisely will become part of this economy. Paid crowdsourcing began with simple microtasks on platforms such as Amazon Mechanical Turk, but microtasks are only helpful if they build up to a larger whole. So, our first question: how complex can the work outcomes from on–demand work be?

Crowd work's perspective

Crowdsourcing research has spent the better part of a decade proving the viability of crowdsourcing in complex work. Unless on–demand work as a whole can demonstrate viability for meaningfully complex tasks, the argument runs, it will be incapable of ensuring a pro–social outcome for work and workers [81]. Kittur et al. first opened the question of whether crowdsourcing could be used for goals that are not simple parallel tasks [80]. Their work demonstrated proof–of–concept crowdsourcing of a simple encyclopedia article and news summary — tasks which could be verified or repeated with reasonable expectations of similar outcomes. Seeking to raise the complexity ceiling [108], researchers have since created additional proof–of–concept applications and techniques, including conversational assistants [86], medical data interpreters [86], and idea generation work–flows [162, 160, 161], to name a few examples.

To achieve complex work, this body of research has often applied ideas from Computer Science to design new crowdsourcing work–flows. Beginning with a goal that has presented significant challenges for computers, the researcher leverages an insight from Computer Science (for example, MapReduce [80] or sequence alignment algorithms [85]) and arranges humans as computational black boxes within those approaches. This approach has proven a compelling one because it leverages the in–built advantages of scale, automation, and programmability that software affords.

It is now clear that this computational workflow approach works with focused complex tasks, but the broader wicked problems largely remain unsolved [123]. As a first example, idea generation shows promise [162, 160, 161], but there is as yet no general crowdsourced solution for the broader goal of invention and innovation [45]. Second, focused writing tasks are now feasible [77, 12, 110, 142, 2], but there is no general solution to create a cross–domain, high–quality crowd–powered author. Third, data analysis tasks such as clustering [32], categorization [7], and outlining [97] are possible, but there is no general solution for sense–making. It is not yet clear what insights would be required to enable crowdsourced solutions for these broader wicked problems.

Restricting attention to non–expert, microtask workers proved limiting. So, Retelny introduced the idea of crowdsourcing with online paid *experts* from platforms such as Upwork. Expert crowdsourcing enables access to a much broader set of workers, for example designers and programmers. The same ideas can then be applied to expert "macro–tasks" [31, 53], enabling the crowdsourcing of goals such as user–centered design [120], programming [89, 41, 29], and mentorship [138]. However, there remains the open question of how complex the work outcomes from expert crowds can be.

Piecework's perspective

Only tasks that could be measured and priced could be completed via piecework — a fact which fundamentally limited the potential complexity of piecework. Earlier we discussed Graves's and later Brown's analysis of railway workers; one might conclude from Graves's observations in particular that complex, creative work — which is inherently heterogeneous and difficult to routinize — would be unsuitable for piecework [48]. Brown's description of efficiency experts would corroborate this; "efficiency experts" can effectively gauge how long known tasks should take, but would find themselves overwhelmed if they attempted to assess creative work like design, which can take an arbitrary number of iterations before proceeding to a subsequent step .

Piecework was limited to tasks that could be clearly evaluated. For example, the roles required to facilitate piecework in the early 20th century included "piecework clerks, inspectors, and 'experts"' [48]. Hart argue that evaluation is the ultimate complexity limit: at some point, evaluating multidimensional work for quality (rather than for quantity) becomes infeasible. In their words, "if the quality of the output is more difficult to measure than the quantity [...] then a piecework system is likely to encourage an over–emphasis on quantity produced and an under–emphasis on quality" [59]. Complex work, which is often subjective to evaluate, falls victim to this criteria.

This focus on measurement and tracking had consequences. Graves suggests that the first sparks of scientific management could be found in piecework: the approach of paying workers for each piece of output necessitated the rigorous tracking, measurement, and training of workers for which scientific management became famous [48]. If true, the concurrent upswing of scientific management and Fordism through the first two–thirds of the 20th century alongside piecework was not only understandable, but predictable [58].

Piecework researchers also argue that, in addition to constraints on the kind of *work* that's amenable to piecework, only certain kinds of *organizations* were amenable to piecework. Researchers detail three organizational criteria. First, Brown argues that piecework "is less likely in jobs with a variety of duties than in jobs with a narrow set of routinized duties" [21]. Agell points out the phenomenon here as a market effect: "in an environment with multi–tasking, pay schemes based on tightly specified performance may induce workers to neglect tasks that are less easy to measure" [3]. Second, complexity was limited by access to capital to create the necessary infrastructure. As Graves reports, only the largest and most wealthy railroads had the resources necessary [48]. Third, organizations required capable managers in charge of the pieceworkers. The West Virginia mines, for example, hired foremen to be the intermediary between upper management and the workers [17]. These foremen were responsible for allocating resources and understanding when and how to modify work as necessary [157]. So, in sum, organizations historically could only take advantage of piecework if they had homogeneous work to be done, access to capital to purchase the necessary equipment, and the ability to hire people who could serve as intermediaries between pieceworkers and management.

The research seems to suggest that it was difficult to apply piecework to more skilled work, particularly because maximizing the advantages of piecework seemed to reward smaller, more constrained, more narrowly–trained tasks, and only in organizations that could pay for the equipment and people to enable it. For most of the 19th century, piecework was applied almost exclusively to farm and textile work. Work was simple and widely understood — farm workers didn't need to be trained on how to plow fields, or birth foals; seamstresses knew how to sew together denim [27, 122].

Comparing the phenomena

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 [21]. 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 because technology makes it easier 1) for workers to do complex work without training, 2) to manage workers in doing complex work, and 3) to create the infrastructure necessary to manage the workers.

Technology increases non–experts' levels of expertise by giving access to information that would otherwise be unavailable. For example, taxi drivers in London endure rigorous training to pass a test known as "The Knowledge" — a demonstration of the driver's comprehensive familiarity with the city's roads. This test is so challenging that veteran drivers develop significantly larger the regions of the brain associated with spatial functions such as navigation [100, 99, 136, 137, 156, 155]. In contrast, with on–demand platforms such as Uber, services such as Google Maps & Waze make it possible for people entirely unfamiliar with a city to operate professionally [135, 62]. Other examples include search engines enabling information retrieval, and word processors enabling spelling and grammar checking. By augmenting the human intellect [40], computing has shifted the complexity of work that is possible without training.

Algorithms have automated some tasks that previously fell to management. Computational systems hire workers [96, 152], as well as direct their activities [92], and act as "piecework clerks" [48] to inspect, modify and combine work [70, 104]. In many cases, the intermediary function has been removed as well, leading workers to need to directly email requesters for clarification and feedback [102]. These algorithms, however, are less able than human managers to manage contingencies that were not programmed into them.

Finally, the organizational limit on infrastructure creation is somewhat lessened. Writing web scripts takes fewer people and fewer hours than creating physical equipment for piecework. Little et al.'s vision was that any user with basic programming skills could tap into on–demand human intelligence. As better toolkits lower this threshold [108] and computational thinking diffuses, a broader population will be able to use on–demand work.

Implications for crowd work

Technology's ability to support human cognition will enable stronger assumptions about workers' abilities, increasing the complexity of on–demand work outcomes. Just as the shift to expert crowdsourcing increased complexity, so too will workers with better tools increase the set of tasks possible. Beyond this, further improvements would most likely come from replicating the success of narrowly–slicing education for expert work as Hart and Roberts and Grier described in their piecework examples of human computation [51] and drastically reformulating macro–tasks given the constraints of piecework [58]. 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 [4]. If we can overcome this obstacle, we might be able to empower more of these workers to do complex work such as engineering and metalworking, rather than doom them to "uneducated" match girl reputations [130]. However, many such experts are already available on platforms such as Upwork, so training may not directly increase the complexity accessible to on–demand work unless it makes common expertise more broadly available.

Will the shift from human managers to Turing–complete algorithms raise the complexity ceiling? By the Turing test, the algorithms would be at best indistinguishable from human piecework clerks and foremen. So in terms of enabling coordination, algorithmic management is unlikely to directly raise the ceiling beyond what piecework could achieve. However, as a resource constraint, algorithms are a fixed cost and not a per–person cost like human managers. So in terms of accessibility, algorithms will allow a broader class of organizations and individuals to benefit from soliciting on–demand work. This shift may enable complex goals that were not cost–effective before to become feasible. However, because algorithms remain far from replicating all of the foreman's responsibilities, most likely is a middle ground in which on–demand work re–introduces the human element to management in a more targeted way (e.g., [53, 84, 154]). This move will require resolving the tension between workers and perilously antagonistic managers, as Boal and Pencavel suggest, to break a toxic cycle of mistrustful requesters [46].

Finally, the cost of creating piecework infrastructure has dropped. Expensive manufacturing equipment has been largely replaced by computer code [93]. As with lowered costs of management, lowered infrastructure costs will make on–demand work accessible to a broader set of people and organizations. This in and of itself does not raise the complexity ceiling, but by broadening the potential market for on–demand work, it may enable a new set of goals and needs take part.

Decomposing Work

At its core, on–demand work has been enabled by decomposition of large goals into many small tasks. As such, one of the central questions in the literature is how to design these microtasks, and which kinds of tasks are amenable to decomposition. In this section, we place these questions in the context of piecework's Taylorist evolution.

Crowd work's perspective

Many contributions to the design and engineering of crowd work consist of creative methods for decomposing goals. Even when tasks such as writing and editing cannot be reliably performed by individual workers, researchers demonstrated that decompositions of these tasks into workflows can succeed [80, 12, 142, 110]. These decompositions typically take the form of workflows, which are algorithmic sequences of tasks that manage interdependencies [16]. Workflows often utilize a first sequence of tasks to identify an area of focus (e.g., a paragraph topic [80], an error [12], or a concept [161, 163] and a second sequence of tasks to execute work on that area. This decomposition style has been successfully applied across many areas, including food labeling [112], brainstorming [133, 160], and accessibility [86, 85, 87].

If decomposition is key to success in on–demand work, the question arises: what can, and can't, be decomposed? Moreover, how thinly can work be sliced and subdivided into smaller and smaller tasks? The general trend has been that smaller is better, and the microtask paradigm has emerged as the overwhelming favorite [143, 144]. 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, preventing a single errant submission from impacting the agenda of the work as a whole fully exploiting the abstracted nature of each piece of work [68, 88, 146]. In this sense, finer decompositions are seen as more robust — both to interruptions and errors [31] — even if they incur a fixed time cost. At the extreme, recent work has attempted demonstrated microtasks that take seconds [147, 23] or even fractions of a second [82]. However, workers perform better when similar tasks are strung together [88], or chained and arranged to maximize the attention threshold of workers [22]. Despite this, we as a community have leaned *into* the peril of low–context work, "embracing error" in crowdsourcing [82].

The general lesson has been that the more micro the task, and the more fine the decomposition, the greater the risk that workers lose context necessary to perform the work well. For example, workers edit adjacent paragraphs in inconsistent ways [12, 77], interpret tasks in different ways [73], and exhibit lower motivation [78] without sufficient context. Research has sought to ameliorate this issue by designing workflows help workers "act with global understanding when each contributor only has access to local views" [148], typically by automatically or manually generating higher–level representations for the workers to reflect on [32, 148, 77].

As the additional context necessary to complete a task diminishes, the invisible labor of *finding* tasks [102] has arisen as a major issue. Chilton et al. illustrate the task search challenges on AMT. Workers seek out good requesters [102] and then "streak" to perform many tasks of that same type [33]. and some work has gone into ameliorating the problems specific to this work site (*ReLauncher*),

Researchers have reacted by designing task recommendation systems [e.g. 35] and others focused on minimizing the amount of time that people need to spend doing anything other than the work for which they are paid [24].

Piecework's perspective
Brown inquired from another direction, asking what limited the adoption of piecework in industries that otherwise gravitated toward it (in the case studies he examined, this mostly focused on railway engineers), ultimately arguing that factors such as the nature of the work design (specifically, the homogeneity of tasks) and the costs associated with adopting a piecework model were the major contributing factors that determined the use of piecework [21].

The research community relating to piecework and labor has been wrestling with the decomposition of work for the better part of a century. The beginnings of systematic task decomposition stretch back as far as the 19th 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 astronomical phenomena [51]. The work that Airy solicited resonates with modern crowd work 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. Third, workers could be trained on a very narrow subset of mathematical skills to be sufficiently qualified to do this work.

Piecework researchers enumerate a number of problems with the decomposition of work, and the conflicting pressures managers and workers put forth. Bewley in particular points out that the approach of paying workers by the piece is "... not practical for workers doing many tasks, because of the cost of establishing the rates and because piecework does not compensate workers for time spent switching tasks". Ultimately, Bewley argues that "[piecework is] infeasible, because ... total output is the joint product of varying groups of people" [13].

Comparing the phenomena
Where measurement and instrumentation were limiting factors for historical piecework, computation has changed the situation so that a dream of scientific management and Taylorism — to measure every motion at every point throughout the workday and beyond — is not only doable, but trivial [149]. Where Graves directly implicates measurement as preventing scientific management from being fully utilized, no longer exists modern crowd work is measuring and modeling every click, scroll, and keyboard event [128, 127]. The result is that on–demand work can articulate and track far more carefully than piecework historically could.

A second shift is the relative ease with which the metaphorical "assembly line" can be changed. Historical manufacturing equipment could not quickly be assembled, edited, and redeployed [66]. In contrast, today system–designers can share, modify, and instantiate environments like sites of labor in a few lines of code [93, 96]. This opportunity 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 manipulate as few as 20 years ago [36, 22, 31, 30, 82].

Third, modern crowd work has sliced work to such small scales that the marginal activities — things like finding work and cognitive task switching — have become large relative to the tasks themselves [33]. 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 [58]. The result is that on–demand workers are more free agents than historically was the case. However, because they spend significant time searching for tasks, the piece rate is less a good estimate of take–home earnings than before.

Implications for crowd work
If measurement precision limited the depth of decomposition for piecework historically, as Graves argues, then modern on–demand work stands to become far more finely–sliced and highly decomposed than ever before. Online tools make measurement and validation so easy [128] that these aspects of piecework are solved, or near enough that they no longer limit task decomposition. Now, not just tasks, but entire workers' histories [60], can be collected and analyzed in detail.

However, decomposition has hit a second bottleneck: cognition. Task switching costs and other cognitive costs make it difficult to work on tasks so far decontextualized from their original intention [88]. There will of course be tasks that can be decomposed without much context, and these will form the most fine–grained of microtasks. However, other tasks cannot be freed from context — for example, logo design requires a deep understanding of the client and their goals. In part due to this limitation, 99designs workers often recycle old designs rather than make new ones for each client [9].

So, ultimately, the levels of decomposition are likely to follow the contours of context required. Low–context work will be extremely highly decomposed. High–context work will continue to be limited.

The Relationships of Workers to Work, Peers, and Others
HCI and CSCW have framed themselves around supporting work rather than becoming an infrastructural layer enabling it. While all artifacts have politics, this shift into computational labor systems has directly impacted the lives and livelihood of workers. So, it is important to understand: what will the future look like for the workers who use these systems?

Crowd work's perspective
One of the initial questions that researchers asked was, who are the crowd workers and what draws them to crowd work? Early

literature emphasized motivations like fun and spare change, but this narrative soon shifted to emphasize that many workers use platforms such as Amazon Mechanical Turk as a primary source of income [74, 67, 8]. Despite this, Mechanical Turk is a low-wage affair for most workers in the United States [67, 102, 52]. Thus, those who choose to opt out of the traditional labor force and spend significant time on Mechanical Turk are especially motivated by the opportunity for autonomy and skill variety [74]. Due to valuing autonomy, it is tempting to ascribe attitudes of "pity the workers" to Turkers, but this frame is increasingly rejected by workers and designers as patronizing [69].

Workers' relationships with requesters are fraught. Workers are often blamed for any low-quality work, regardless of whether they are responsible [102, 104]. Some research is extremely open about this position, blaming unpredictable work on "malicious" workers [46] or those with "a lack of expertise, dedication [or] interest" [132]. Workers resent this position — for good reason. Irani and Silberman highlighted the information asymmetry between workers and requesters on AMT, leading to the creation of *Turkopticon*, a site which allows Turkers to rate and review requesters [70]. Dynamo then took this critique on information asymmetry and power imbalances a step further, designing a platform to facilitate Turkers acting collectively to bring about changes to their circumstances [129]. This unbridled power that requesters have over workers and the resultant stress and frustration that this generates has been part of the undercurrent of research into the tense relationships between workers and requesters [49, 129].

Researchers have also begun to appreciate the sociality of crowd workers. Because the platforms do not typically include social spaces, workers instead congregate off-platform in forums and mailing lists. There, Turkers exchange advice on high-paying work, talk about their earnings, build social connections, and discuss requesters [102]. Many crowd workers know each other through offline and online connections, coordinating behind-the-scenes despite the platforms encouraging independent work [50, 159]. However, the frustration and mistrust that workers experience with requesters does occasionally boil over on the forums. This behavior has come to be known as "mega–drama" amongst such workers [129]. Still, the study of these communities is made challenging because most of these platforms do not themselves include social affordances for workers [107].

Piecework's perspective

We discussed earlier that observers believed that workers were strongly motivated by the piecework model [34], but the emergent trend contrasted with this early rhetoric, when workers began instituting "The Fix", deliberately slow work to game efficiency experts [126]. Workers, Roy found, formed even more starkly antagonistic relationships with their managers.

As managers became increasingly onerous in their management of pieceworkers, workers began resisting piecework regimes and the methods that came along with it. Soon, many worker organizations were weighing in on (or, more precisely, against) piecework and the myriad oversights it made in valuing workers' time [72, 121]. As mounting attention increasingly revealed problems in piecework's treatment of workers, workers themselves began to speak out about their frustration with this new regime. Organizations representing railway workers, mechanical engineers, and others began to mount advocacy in defense of workers [72, 121]. Pieceworkers' relationships with their employers eventually developed a pattern of using laborer advocacy groups [94, 5, 103, 71]. Collective action grew to become a central component of negotiating with managers [56, 115].

There's a noticeable dearth of information on the inter–personal relationships among pieceworkers beyond the match–girls at the end of the 19th century. Nevertheless, we can offer some observations: primary sources indicate that labor organizations wished for workers to identify as a collective group, "not only as railroad employees but also as members of the larger life of the community" [72]. Doing this, Ostrom and others later argued, would facilitate collective action and perhaps collective governance [116, 56, 115]. Riis also contributed to this sense of shared struggle and endurance by documenting pieceworkers in their home–workplaces, literally bringing to light the grim circumstances in which pieceworkers lived and worked [122].

Comparing the phenomena

While historical pieceworkers could be looked down on, as the match-stick girls were characterized by "brashness, irregularity, low morality, and little education", there was generally less written about quality concerns for historical pieceworkers than there is in modern on–demand work. Why the difference? One possibility is that, through writing web scripts and applying them to many tasks, it is possible for a small number of spammers have an outsized influence. Historically, it was much harder for such workers to move and get new jobs — today, they can simply accept a different task on Mechanical Turk. Another possibility: online anonymity breeds distrust [44], and where pieceworkers could be directly observed by foremen, online workers are known by little more than an account ID.

The relationship between workers and employers has also shifted: while historically the management of workers had to be done through a foreman (who necessarily had an intuitive — perhaps sympathetic — relationship with workers), the foreman of the 20th century has largely been replaced by algorithms of the 21st century [92]. The result of this change is that the agents managing work are now cold, logical, and unforgiving. Where a person might recognize that the "attention check" questions proposed by Le et al. ensure that malicious and inattentive workers are stopped, some implementations of these approaches only seem to antagonize workers. More than 30 years ago, Anderson and Schmittlein wrote: "When performance is difficult to evaluate, imperfect input measures and a manager's subjective judgment are preferable to defective (simple, observable) output measures" [6]. This frustration has only grown as requesters have had to rely on automatic management mechanisms. Only a few use the equivalent of human foremen [53, 84].

Relative to the mature state of collective action for pieceworkers offline, crowd workers have struggled to make their voices heard [129, 69, 70]. Both pieceworkers and on–demand workers have struggled at times to form a collective identity necessary to organize. With workers joining and leaving the crowd labor force continuously, and with many part-time members, it is extremely difficult to corral the group to make a collective decision [129]. However, even when they can: whereas pieceworkers could physically block access to a site of production, online labor markets provide no facilities for workers to change the experience of other workers. This is a key limitation — without it, workers cannot enforce a strike.

Implications for crowd work

The decentralization and anonymization of on–demand work, especially online crowd work, will continue to make many of its social relationships a struggle. While some workers get to know each other well on forums [102, 50], many never engage in these social spaces. Without intervention, worker relationships and collectivism are likely to be inhibited by this decentralized design. One option is to build worker centralizing points into the platform, for example asking workers to vote on each others' reputation or allowing groups of workers to collectively reject a task from the platform [154].

The history of piecework further suggests that relationships between workers and employers might be improved if employers engaged in more human management styles. Instead of delegating as many management tasks as possible to an algorithm, it might be possible to build dashboards and other information tools that empower modern crowd work foremen [84]. If the literature on piecework is to be believed, more considerate *human* management may resolve many of the tensions we've discovered among among crowd workers.

Reciprocally, crowd work may be able to inform piecework research. There exists far less literature about pieceworkers' relationships than there does today about on–demand workers' relationships. Research into on–demand labor benefits from both the accessibility of digital platforms as well as the firmer theoretical basis of Anthropology than existed at the turn of the 20th century, when piecework began to emerge. Malinowski, Boas, Mead and Boas and other luminaries throughout the first half of the 20th century effectively defined Cultural Anthropology as we know it today; *participant–observation*, the *etic* and the *emic* understanding of culture, and *reflexivity* didn't take even a resemblance of their contemporary forms until these works [101, 18, 106]. On–demand labor today may give us an opportunity to revisit open questions in piecework with a more refined lens.

DISCUSSION

In our analysis of on–demand work via the piecework lens, three issues arose: 1) the hazards of predicting the future, 2) utopian and dystopian visions, and 3) a research agenda. We will attempt to grapple with these questions here explicitly.

The Hazards of Predicting the Future

The past can't be a perfect predictor for the future; as Scholz points out, "it would be wrong to conclude that in the realm of digital labor there is nothing new under the sun" [131]. Our analysis is limited by the differences, foreseen and unforeseen, between historical piecework and modern on–demand work. For example, many of the challenges that *Dynamo* overcame in crowd collective action, such as designing for trustworthiness and ensuring anonymity, were relatively unique challenges precipitated by the affordances of the internet. For example, unlike physical work environments, people can (and often do) contribute to online communities in a one–off manner [105]. The internet makes this kind of loose affiliation feasible. While we have attempted to understand the likely overlaps and differences between history and modern day, no analysis is perfect.

But this does not mean that attempting to draw meaningfully from historical scholarship would be folly; enough of piecework can and does inform on–demand work that HCI and CSCW might seek out historical framings for other phenomena of study as well. While we can only speculate one of (perhaps many) possible futures, history does allow us to articulate and bound which futures appear more likely.

In particular, the predictions that have emerged surrounding crowd work have run the spectrum from deep pessimism [43] to exuberant optimism [81]. In the next section, we will use the piecework foundation which informed our case studies to trace out possible dystopian and utopian futures for on–demand labor.

Utopian and Dystopian Visions

An easy narrative is to characterize the future of on–demand labor at one of two extremes. On one hand, crowd work researchers imagine the application of crowdsourcing as a potentially bright future that enables the achievement of near–impossible goals and career opportunities [139, 81, 14, 138]. On the other hand, researchers warn that on–demand labor will create exploitative sites of dispossession [131], racial discrimination [39], and invisible, deeply frustrated workers [70, 15].

A uniquely challenging facet of this topic of inquiry is the public attention that this domain has attracted. Activists have described speculative work as having "essentially been turned into modern–day slaves" [11]. Meanwhile, advocates describe it as "a project of sharing aimed at providing ordinary people with more economic opportunities and improving their lives" [38].

Piecework teaches us that, without appropriate norms and policy, the dystopian outcome has happened and will happen again. The piecework nature of on–demand work induces us "to neglect tasks that are less easy to measure" [3], rewarding us not for creativity but predictability; payment for this work may ultimately be determined by an algorithm that fundamentally doesn't understand people; the layers between us and our managers might increasingly become "defective (simple, observable)" algorithms [6], just like those which already frustrate on–demand workers [92, 129, 70]. However, social policy has advanced since the early 1900s, so as on–demand work gains popularity a repeat of *How the Other Half Lives* [122] seems less likely.

On the other hand, while piecework's nascent years were grim, they precipitated a century of extremely strong labor advocacy [58, 103]. Even today, the geist that came out of the labor union revolution inspires collective action and worker empowerment around the world: in India, workers across the nation recently engaged in the largest labor strike in human history — perhaps as many as 150 million [1]. If labor advocacy groups can find ways to permeate on–demand labor markets as some have called for [75], then the future of on–demand labor may follow the same trajectory of worker empowerment that piecework *later* found.

The history of piecework suggests that the utopian and dystopian outcomes will *both* occur, in different parts of the world and to different people. When piecework plummeted in the United States, outsourcing rose — creating major labor issues around the world. It is entirely possible that we will create a new brand of flexible online career in developed countries, while simultaneously fueling an unskilled decentralized labor force in developing nations. As designers and researchers, this prompts the question: which outcome are we attempting to promote or avoid for who?

A Research Agenda

Piecework also helps bring into focus the areas of research that might bear the most fruit. We return to the three questions that motivated this paper: 1) "what are the complexity limits of on–demand work?" 2) "how far can work be decomposed into smaller microtasks?" and 3) "what will work and the place of work look like for workers?".

While we have arguably outpaced piecework with regard to the limits on the complexity of work, the most complex and open-ended wicked problems [123] remain the domain of older human collectives such as governments and organizations. In addition, we can learn from the piecework literature as it relates to the stymieing effect that mismanagement has on workers; research into the complexity limits should emphasize on finding new ways to manage workers, in particular using humans — perhaps other crowd workers — to act as modern foremen.

Piecework researchers looking into decomposition pointed out long ago that piecework is saddled by a lower limit on decomposition: "piecework does not compensate workers for time spent switching tasks" [13]. We've since studied this phenomenon in crowd work to great length both observationally [33] and experimentally [88]. We should consider whether this remains a worthwhile area to explore; unless the work we put forth directly affects the costs of task–switching — for instance, the cost of suboptimal task search, or the cognitive burden of changing tasks — we may only make incremental advances in micro–task decomposition. When the cognitive cost of understanding a task and its inputs outstrips the effort required to complete the task, decomposition seems a poor choice.

Finally, we turn to the relationships of crowd workers. The crowd work literature here can convincingly speak back to the piecework scholarship perhaps more than in the other sections. The tools that are available to us today — not just technical, but *methodological* — make it possible to discover, study, and partner with crowd workers in ways that were unimaginable to piecework researchers. A professor engages in crowd work [15] not just because it's possible, but because our community appreciates the importance of approaches such as participant–observation and ethnography as a whole [114].

CONCLUSION

On–demand work is not new, but a contemporary instantiations of piecework. In this paper, we reconsider three major research questions in on–demand work using the lens of piecework: 1) "what are the complexity limits of on–demand work?"; 2) "how far can work be decomposed into smaller microtasks?"; and 3) "what will work and the place of work look like for workers?" To do so, we draw on piecework scholarship to inform analyses of what has changed, what hasn't, and may change change soon. Reciprocally, we believe that modern on–demand work will teach us about the broader phenomenon of piecework as well. If history really does repeat itself, the best we can do is be prepared.

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