Examining Crowd Work Through The Historical Lens of Piecework

Anonymized for Review

ABSTRACT

The internet is enabling 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 along three threads: 1) **??**?, 2) **??**?, and 3) **??**? 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.

ACM Classification Keywords

H.5.3. Information Interfaces and Presentation (e.g. HCI): Group and Organization Interfaces

Author Keywords

Crowdsourcing; on–demand labor; gig work

INTRODUCTION

The past decade has seen a flourishing of *on–demand work*, largely driven by the reformulation of work as the constituent parts of larger tasks. This framing of work into de–contextualized, modular blocks enables computation to hire workers at scale through open calls on the internet [**howe2008crowdsourcing**, **Bigham2014**, **crowdworkFuture**]. Distributed paid participants then engage in the work whenever their schedules allow, with little to no awareness of the broader context of the work, and with (often) fleeting identities and associations [**martin2014being**, **uberAlgorithm**]. In this paper, we use the term on–demand work to join a pair of related phenomena: 1) *crowd work*, on platforms such as Amazon Mechanical Turk (AMT) and other sites of (predominantly) information work; and 2) *gig work*, typically involving 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 like 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., [**bernsteinSoylent**, **vizwiz**, **paolacci2010running**]).

As on–demand work has grown far beyond information work, it has given rise to an increasingly complicated and conflicted culture amongst both the workers who enable it and the researchers who study it. **howe2008crowdsourcing** first described crowdsourcing in general terms as "outsourcing [work] to an undefined, generally large group of people in the form of an open call" [**howe2008crowdsourcing**]. However, for years its instantiation was limited to the utilization of human intelligence to process data, participate in scientific studies, and perform information work [**CrowdsourcingUserStudies**, **movieSummarizationWu**, **yuenSurvey**, **geiger2011managing**, **quinnbedersonTaxonomy**]. More recently, crowdsourcing of physically embodied work — driving and cleaning, for instance — has become a focus for on–demand labor markets [**uberAlgorithm**, **uberOfficial**, **zaarlyOfficial**, **taskrabbitOfficial**]. This growth prompted efforts to understand not just the work, but also the workers on these platforms [**Ross**, **whoareNOTtheTurkers**]. Some of this research has been motivated by the identification of the sociality of gig work, and the frustration and disenfranchisement that these systems embody [**turkopticon**, **martin2014being**, **takingAHITMcInnis**]. Other work has focused on the outcomes of this frustration, reflecting on the resistance workers express against digitally mediated labor markets [**uberAlgorithm**, **dynamo**].

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:

1. **??**? Specifically, (a) How complex are the goals that crowd work can accomplish?, and (b) What kinds of goals and industries may eventually utilize it? [**foundry**, **suzukiAtelier**, **KimStoria**, **yuanAlmost**, **YuEncouragingOutside**, **Nebeling:2016:WCW:2858036.2858169**, **Hahn:2016:KAB:2858036.2858364**];

ACM ISBN 978-1-4503-2138-9.
DOI: 10.1145/1235

2. **??**? [**embracingErrorKrishna**, **bernsteinSoylent**, **sensitiveTasks**, **LykourentzouPersonalityMatters**, **KucherbaevReLauncher**, **Law:2016:CKC:2858036.2858144**, **Cai:2016:CRI:2858036.2858237**, **Chang:2016:ACC:2858036.2858411**, **Newell:2016:OMA:2858036.2858490**]; and
3. **??**? [**turkopticon**, **storiesIraniSilberman**, **dynamo**, **crowdcollab**, **whyWouldAnyoneBrewer**, **takingAHITMcInnis**]

This research has largely sought to answer these questions by examining the present on–demand work phenomenon. So far, it has not offered a framing for holistically explaining the developments in worker processes that researchers have developed, or the emergent phenomena in social environments; nor has any research, to our knowledge, gone as far as 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 standalone contracts, wherein payment is made for work output, rather than for time. Piecework as a metaphor for crowd work is not new. Indeed, **crowdworkFuture** in **crowdworkFuture** referenced crowd work as piecework briefly as a loose analogy to the form of work emerging at the time [**crowdworkFuture**]. 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, empirically based research.

More concretely, by looking at on–demand work as an instantiation (or even a continuation) of piecework, and by looking for patterns of behavior that the corresponding literature predicts on this basis, we can 1) make sense of the phenomena so far as part of a much larger series of interrelated events; 2) reflect on differences in the factors that impacted piecework historically and impact on–demand work today; and finally, 3) to the extent that history repeats itself, 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 studying task decomposition, which was historically limited in scope by technological limits in measurement and instrumentation, and leverage that understanding to suggest how modern web technology reconfigures this measurement limit for on–demand crowd work.

We organize this paper as follows: we first review the definition and historical arc of piecework to lay groundwork and make clear the analogy to on–demand work (which we will refer to as *crowd work* subsequently, for consistency with prior literature). Then, 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 experience it today. Finally, 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 this reference has generally been offered in passing. As this paper principally traces a relationship between the historical piecework and the contemporary crowd work (or on–demand labor more generally), this casual familiarity with piecework may prove insufficient. We'll more carefully discuss piecework in this section in order to inform the the rest of the argument. Specifically, we will 1) define "piecework" as researchers in the topic understood it; and 2) trace the rise and fall of piecework at a very 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 crowd work's three questions: complexity limits, task decomposition, and worker relationships.

What is piecework?

Aligning on–demand work with piecework requires an understanding of what piecework is. While "piecework" has had multiple definitions over time, we can trace a constellation of characteristics that recur throughout the literature. We will follow this history of research, collecting descriptions, examples, and provided definitions of piecework, trying to trace the outline of a working understanding of *what piecework is*.

hughRaynbirdTaskWork offers a concise definition of piecework — which he variously also calls "measure work", "grate work", and "task work" — by contrasting the "task–labourer" 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 [emphasis added]" [**hughRaynbirdTaskWork**]. **10.2307/2338394** gives a more illustrative definition of piecework, offering 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" [**10.2307/2338394**]. This framing perhaps makes the most intuitive sense; "payment for results," as **10.2307/2338394** calls it, is not only common in practice, but well–studied in labor economics as well [**Figlio2007901**, **weitzman1976new**, **10.2307/3003414**, **BJIR:BJIR038**].

It's worth acknowledging that "this distinction [between piece–rates and time–rates] was not completely clear–cut" [**hart2013rise**]. Indeed, work adopted piece–rate compensation in some aspects and time–rate compensation in others. The "Rowan premium system", which essentially paid workers a base rate for time plus (the potential for) an additional pay dependent on output, was just one of several alternatives to stricter time– and piece–rate renumeration paradigms, which muddies the waters for us later as we attempt to categorize cases of piecework [**rowan1901premium**]. As **rowan1901premium**'s premium system guaranteed an hourly rate regardless of the worker's productive output *as well as* an additional compensation tied to performance, workers under this regime were in some senses "task–labourers", and in other senses (more conventional) "day–labourers".

It may be worth thinking about piecework through the lens of its *emergent* properties to help understand it. Returning to **hughRaynbirdTaskWork** several arguments for the merits of piecework crop up; he points 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." **hughRaynbirdTaskWork** highlight the freedom from control that "task–labourers" enjoy [**hughRaynbirdTaskWork**, **rowan1901premium**].

We see this sense of independence regardless of the time, locale, and industry. **10.2307/3827491** offers a look into the lives and culture of "match girls" — young women paid by piecework to assemble matchsticks generally in the late 19th century. Of particular interest was their independent nature, via their reputation ". . . for generosity, independence, and protectiveness, but also for brashness, irregularity, low morality, and little education" [**10.2307/3827491**]. **10.2307/27508091** documents piecework from 1850–1930 in Australia, finding similar assertions of the freedom compositors of newspapers experienced as pieceworkers: "If a piece–work compositor who held a 'frame' 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" [**10.2307/27508091**]. From these accounts we identify a sense of independence and autonomy that resonates across decades, industries, and locales where piecework is found.

Piecework opened the door for people who previously couldn't participate in the labor market — for example due to lack of training — to do so, and to acquire job skills incrementally. For example, women could receive training in narrow subsets of the general body of skills, enabling them to act in capacities similar to what conventional (male) apprentices would undertake [**hart2013rise**]. In addition, workers with specific slices of skills could be matched to suitable tasks. Workers without conventional training — like women, who had no such opportunities to engage in engineering and metalworking apprenticeships as men did — could be trained very narrowly on a very tightly constrained task, demonstrate proficiency, and become experts in their own ways.

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 freedom in when and how much to work; and
3. structured tasks such that people who didn't have the training to engage in the traditional labor force could still participate.

Viewing crowd 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 [**martin2014being**, **whyWouldAnyoneBrewer**]. 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 workflow [**noronha2011platemate**, **bernsteinSoylent**]. Given this alignment, many of the same properties of piecework historically will apply to on–demand work as well. In the next section, we perform this application to three of the major questions in crowd work and gig work, identifying similarities and differences between historical piecework and modern on–demand work.

A Piecework Primer

In this section we will offer a brief overview of the history of piecework; this should not be mistaken for a comprehensive background. Instead, this section will attempt to provide a sense of orientation when thinking about piecework. In other words, it will frame piecework in the contexts of the early days of the Industrial Revolution, through the political and economic turmoil of the early and mid–20th century, and into the 21st century. While the previous section provided a *definition* of piecework, this section attempts to shine a light on the *zeitgeist* of piecework.

Piecework's history traces back further perhaps than most would expect. **grier2013computers** 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 19th century [**grier2013computers**]. 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 off on in farm work [**hughRaynbirdTaskWork**], in textiles [**restructuringPieceworkBaker**, **riisOtherSideLives**], on railroads [**Brown01041990**], and elsewhere in manufacturing [**10.2307/3827491**]. 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. **hart2013rise** point out that the Second World War, which called millions of Americans to military service, necessitated the rapid training and employment of a labor pool that hadn't historically been utilized in industrial labor: women [**hart2013rise**].

The early proliferation of manual piecework led to discussion surrounding how best to manage pieceworkers [**norton1900textile**, **clark1908cotton**]. Despite this, workers' means were mostly ignored, leading to frustration over poor working and living conditions (famously documented by **riisOtherSideLives**) [**riisOtherSideLives**]. This led to industry organizations representing railway workers, mechanical engineers, and others beginning to speak out on pieceworkers' behalf [**american1921problem**, **richards1904anything**].

Piecework's popularity in the United States and Europe plummeted almost as quickly as it had climbed. **hart2013rise**'s work substantively explores the precipitous decline of piecework in the last third of the 20th century. In their work, **hart2013rise** offer a number of explanations for the sudden vanishing of piecework. The salient suggestions include: 1) the emergence of more effective, more nuanced incentive models — rewarding teams for complex achievements, for instance; 2) the shifting of these industries (manufacturing, clothing, etc. . .) to other countries; and 3) the quality of "multidimensional" work becoming too difficult to evaluate [**hart2013rise**].

RESEARCH QUESTIONS

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 [**bernsteinSoylent**, **foundry**, **crowdForgeKittur**]. 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) **??**, 2) **??**, and 3) **??**. 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 Crowd Work

A key question to the future of crowd 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 crowd 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 crowdsourcing can demonstrate viability for meaningfully complex tasks, the argument runs, it will be incapable of ensuring a pro–social outcome for work and workers [**crowdworkFuture**]. **crowdForgeKittur** first opened the question of whether crowdsourcing could be used for goals that are not simple parallel tasks [**crowdForgeKittur**]. 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 [**myers2000past**], researchers have since created additional proof–of–concept applications and techniques, including conversational assistants [**Lasecki:2013:CCC:2501988.2502057**], medical data interpreters [**Lasecki:2013:CCC:2501988.2502057**], and idea generation workflows [**YuEncouragingOutside**, **yu2014distributed**, **Yu2016a**], to name a few examples.

To achieve complex work, this body of research has often applied ideas from Computer Science to design new crowdsourcing workflows. Beginning with a goal that has presented significant challenges for computers, the researcher leverages an insight from Computer Science (for example, MapReduce [**crowdForgeKittur**] or sequence alignment algorithms [**lasecki2012real**]) 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 [**rittel1973dilemmas**]. As a first example, idea generation shows promise [**YuEncouragingOutside**, **yu2014distributed**, **Yu2016a**], but there is as yet no general crowdsourced solution for the broader goal of invention and innovation [**fuge2014analysis**]. Second, focused writing tasks are now feasible [**Kim2017**, **bernsteinSoylent**, **Nebeling:2016:WCW:2858036.2858169**, **writingMicroTasks**, **agapie2015crowdsourcing**], but there is no general solution to create a cross–domain, high–quality crowd–powered author. Third, data analysis tasks such as clustering [**chilton2013cascade**], categorization [**andre2014crowd**], and outlining [**luther2015crowdlines**] are possible, but there is no general solution for sensemaking. 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, **foundry** 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" [**cheng2015break**, **haas2015argonaut**], enabling the crowdsourcing of goals such as user–centered design [**foundry**], programming [**latoza2014microtask**, **Fast2016**, **Chen2016**], and mentorship [**suzukiAtelier**]. However, there remains the open question of how complex the work outcomes from expert crowds can be.

Piecework's perspective

grier2013computers gives early accounts of a piecework strategy in Airy's creation of the British Nautical Almanac [**grier2013computers**]. Airy's goal was complex — mathematical calculations to produce tables that would allow sailors to locate themselves by starlight from sea. Many of his contributors did not have high–level mathematical training, so Airy broke down the task into simpler calculations and distributed them by mail, accomplishing the complex goal through piecework tasks that paid little.

However, when piecework entered the American economy, it was not used for complex work. One reason for low complexity was workers' skills: it was infeasible to provide new pieceworkers with the comprehensive education that apprenticeships imparted [**hart2013rise**]. So, initially piecework arose for farm work, and as **hughRaynbirdTaskWork** and others discuss, the practice remained relatively obscure until it blossomed in the textile industry [**hughRaynbirdTaskWork**]. Complexity levels remained low at the turn of the 20th century as piecework saturated New York City [**riisOtherSideLives**]. However, writers of the time focused their attention on wage [**burton1899commercial**] and management regimes [**norton1900textile**] rather than training.

Measurement also limited the complexity of piecework: only tasks that could be measured and priced could be completed via piecework. When **Brown01041990** investigated what limited the adoption of piecework in industries that otherwise gravitated toward it (e.g., railway engineers), the homogeneity of tasks arose as a major contributing factor [**Brown01041990**]. **10.2307/23702539** concurs via a case study of the Santa Fe Railway, which used "efficiency experts" to develop a "standard time" to determine pay for each task at the company informed by "thousands of individual operations" [**10.2307/23702539**]. One might conclude from **10.2307/23702539**'s observations that complex, creative work — which is inherently heterogeneous and difficult to routinize — would be unsuitable for piecework.

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"' [**10.2307/23702539**]. **hart2016rise** 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" [**hart2016rise**]. Complex work, which is often subjective to evaluate, falls victim to this criteria.

This focus on measurement and tracking had consequences. **10.2307/23702539** 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 [**10.2307/23702539**]. 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 [**hart2013rise**].

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, **Brown01041990** argues that piecework "is less likely in jobs with a variety of duties than in jobs with a narrow set of routinized duties" [**Brown01041990**]. **SJOE:SJOE371** 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" [**SJOE:SJOE371**]. Second, complexity was limited by access to capital to create the necessary infrastructure. As **10.2307/23702539** reports, only the largest and most wealthy railroads had the resources necessary [**10.2307/23702539**]. 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 [**10.2307/2118435**]. These foremen were responsible for allocating resources and understanding when and how to modify work as necessary [**wray1949marginal**]. 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 [**10.2307/2338394**, **riisOtherSideLives**].

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 [**Brown01041990**]. 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 [**Maguire11042000**, **Maguire2894**, **Skok:1999:KML:299513.299625**, **skok2000managing**, **Woollett1407**, **woollett2011acquiring**]. 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 profesionally [**silva2013traffic**, **hind2014outsmarting**]. Other examples include search engines enabling information retrieval, and word processors enabling spelling and grammar checking. By augmentating the human intellect [**engelbart2001augmenting**], 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 [**turkitLittle**, **weld2010decision**], as well as direct their activities [**uberAlgorithm**], and act as "piecework clerks" [**10.2307/23702539**] to inspect, modify and combine work [**turkopticon**, **takingAHITMcInnis**]. In many cases, the intermediary function has been removed as well, leading workers to need to directly email requesters for clarification and feedback [**martin2014being**]. 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. **turkitLittle**'s vision was that any user with basic programming skills could tap into on–demand human intelligence. As better toolkits lower this threshold [**myers2000past**] and computational thinking diffuses, a broader population will be able to use crowd work.

Implications for crowd work

Technology's ability to support human cognition will enable stronger assumptions about workers' abilities, increasing the complexity of crowd 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 **hart2013rise** and **grier2013computers** described in their piecework examples of human computation [**grier2013computers**] and drastically reformulating macro–tasks given the constraints of piecework [**hart2013rise**]. 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 [**aguaded2013mooc**]. If we can overcome this obstacle, we might be able to empower more crowd workers to do complex work such as engineering and metalworking, rather than doom them to "uneducated" match girl reputations [**10.2307/3827491**]. However, many such experts are already available on platforms such as Upwork, so training may not directly increase the complexity accessible to crowd 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 afford crowd 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 foremen's responsibilities, most likely is a middle ground in which crowd work re–introduces the human element to management in a more targeted way (e.g., [**haas2015argonaut**, **kulkarni2012mobileworks**, **crowdguilds**]). This move will require resolving the tension between workers and perilously antagonistic managers, as **10.2307/2118435** suggest, to break a toxic cycle of mistrustful requesters [**MaliciousCrowdworkersGadiraju**].

Finally, the cost of creating piecework infrastructure has dropped. Expensive manufacturing equipment has been largely replaced by computer code [**lessig2006code**]. As with lowered costs of management, lowered infrastructure costs will make crowd 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 crowd 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 Tayloristic 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 [**crowdForgeKittur**, **bernsteinSoylent**, **writingMicroTasks**, **Nebeling:2016:WCW:2858036.2858169**]. These decompositions typically take the form of workflows, which are algorithmic sequences of tasks that manage interdependencies [**Bigham2014**]. Workflows often utilize a first sequence of tasks to identify an area of focus (e.g., a paragraph topic [**crowdForgeKittur**], an error [**bernsteinSoylent**], or a concept [**Yu2016a**, **Yu2016b**] 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 [**noronha2011platemate**], brainstorming [**siangliulue2015toward**, **yu2014distributed**], and accessibility [**lasecki2013chorus**, **lasecki2012real**, **Lasecki2011**].

If decomposition is key to success in crowd work, the question arises: what can, and can't, be decomposed? Moreover, how thinly can work be sliced and