Identifying the Complexity Limits of Crowd Work

A key question to the future of on–demand work [al2: is this an old remnant of me being indecisive about terms?] 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 [26]. Kittur et al. first opened the question of whether crowdsourcing could be used for goals that are not simple parallel tasks [25]. 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 [36], researchers have since created additional proof–of–concept applications and techniques, including conversational assistants [28], medical data interpreters [28], and idea generation [55, 53, 54], to name a few examples.

This body of research has often invoked insights from Computer Science and applied them to human workflows. The crowd work literature typically identifies target milestones that have presented significant challenges for researchers, leverages an insight from Computer Science (for example, MapReduce [25] or sequence alignment algorithms [27]), and arranges humans as computational black boxes within those approaches. [al2: We could quote Irani and Silberman and say "human APIs", but that gets a little critique–y, and we might want to save that for later.] 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 approach works with focused complex tasks, but the broader wicked problems Rittel and Webber brings up remain unsolved [42]. As a first example, idea generation shows promise [55, 53, 54], but there is as yet no general crowdsourced solution for the broader goal of invention and innovation [14]. Second, focused writing tasks are now feasible [24, 5, 37, 48, 1], but there is no general solution to create a high–quality crowd–powered author across domains. Third, data analysis tasks such as clustering [12], categorization [4], and outlining [32] 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 and other crowdsourced goals such as addressing climate change [22].

Restricting attention to non–expert microtask workers limited the ambitions of research in the area. So, Retelny et al. 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. Researchers then apply similar Computer Science techniques but to expert "macro-tasks" [11, 18]. This approach has led to successful crowdsourcing of goals such as the user–centered design process [40], programming tasks [29, 13, 10], and mentorship [47]. However, there remains the open question of how complex the work outcomes from these approaches will be.

Piecework's perspective

Grier gives early accounts of a piecework strategy in Airy's creation of the British Nautical Almanac [17]. 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. Initially for farm work, as Raynbird and others discuss, the practice remained relatively obscure until it blossomed in the textile industry [39]. Complexity levels remained low at the turn of the 20th century as piecework saturated New York City [41]. However, writers of the time focused their attention on wage [8] and management regimes [38]. [al2: Hart and Roberts would later argue of this time that…? I'm beginning to notice that I'm really gravitating toward naming authors, which is totally weird when I read through conventional HCI papers.] The work remained low–skilled in part because it was infeasible to provide new pieceworkers with the comprehensive education that apprenticeships imparted [19]. [al2: I feel like this sort of jumps ahead without mentioning it (in my head it's a jump from Norton's 1900 to Hart and Roberts's 1940s), and I felt like this was a phenomenon that I'd like to shine in a positive(–ish?) light.]

Measurement limited the complexity of piecework: only tasks that could be measured and priced could be completed via piecework. When Brown 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 [7]. Graves concurs via a case study in 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" [16]. One might conclude from Graves's observations that complex, creative work — which is inherently heterogeneous and difficult to routinize — would be unsuitable for piecework.

Piecework was also limited to tasks that could be clearly evaluated. The roles required to facilitate piecework in the early 20th century included "piecework clerks, inspectors, and 'experts"' [16]. Hart argues for an ultimate complexity limit: at some point, evaluating multidimensional work for quality (rather than for quantity) becomes infeasible. In his 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" [20]. Complex work, which is often subjective to evaluate, falls victim to this criteria.

This focus on measurement and tracking had consequences. Graves argued 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 [16]. 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 [19].

Piecework researchers also argue that, in addition to constraints on the kind of *work* that's amenable to piecework, only certain kinds of *organizations* are 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" [7]. 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" (emphasis added) [2]. 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 to "pay the overhead involved in installing work reorganization" [16]. 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 worker [6]. Specifically, foremen were responsible for allocating resources and understanding when and how to modify work as necessary [51]. 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 intermediate management. [al2: will people understand the nuance here of "intermediate" meaning that the management act as *intermediaries*? I know that sounds stupid, but I feel like the wording has a connotation of just being "middle management", which doesn't communicate that these are bidirectional negotiators.]

The research seems to suggest that it was difficult to apply piecework to more skilled work, particularly because maximizing on the advantages of piecework seemed to reward smaller, more constrained, more narrowly trained tasks. 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 [9, 41].

Comparing the phenomena

Piecework makes a number of observations leading to the conclusion that piecework's complexity is fundamentally bounded by several limitations, chief among them the costs of managerial overhead and the transition thereto. Brown and Graves's claims that organizations can't adopt piecework unless they're sufficiently large to absorb the cost of transitioning to a piecework system; Boal and Pencavel and Wray's observations for the importance of competent, effective managerial oversight — a human resource, which made the scaling cost prohibitively expensive for many [6, 51, 16, 7].

Digital media have expanded the scope of viable piecework by pushing drastically on the limits cited by piecework researchers. The research on piecework tells us that we should expect piecework to thrive in industries where the nature of the work is limited in complexity [7]. 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 make it easier 1) to do complex work aided by computers and 2) to evaluate and manage workers as they do increasingly complex work, even observing their work to an otherwise unprecedented granularity.

[al2: maybe this should go away? **Technology has made it possible for non–experts to do work that was once considered within the domain of experts.** Yuan et al. builds on the work of others (*Voyant* and, more relevantly, *CrowdCrit*) to design workflows that yield "expert–level feedback" [56, 52, 31]. This body of work identifies ways to transform a variety of duties comprising complex tasks and distills them into "a narrow set of routinized duties", informed in part by researchers — acting as inspectors — and experts [quotations from 16]. Where Graves would call additionally for the identification of crowdsourcing's version of "piecework clerks", we point out that today algorithms manage workers as pieceworkers once did [30, 16].]

Technology facilitates the subversion of expertise requirements by giving non–experts access to information that would otherwise be unavailable. Taxi drivers in London endure rigorous training to pass a test known as "The Knowledge" — a demonstration of the driver's comprehensive familiarity. Researchers have identified significant growth of the hippocampal regions of the brains in veteran drivers, generally understood to be responsible for spatial functions such as navigation [34, 33, 45, 46, 50, 49]. Services such as Google Maps & Waze make it possible for people entirely unfamiliar with a city to know more about a city even than experts through the collective data generated by other users ranging topics such as police activity, congestion, construction, etc… [44, 21]. [MSB: what's the insight I should take away from this paragraph? what does this say about crowd work?] [al2: Maybe I'm burnt out but I feel like the topic sentence is the takeaway and I'm not entirely sure what else to put here. Maybe that digital media can make it possible for non–experts to do increasingly expert work, informed by "insider" or "expert" knowledge of work, the way Uber, Waze, etc…do?]

Implications for crowd work

We should consider exploring the limitations that algorithmic management bring along more carefully. While crowd work research has touched on this subject, we've yet to make out the bigger picture of this theme [30]. If we can resolve the tension between workers and perilously antagonistic managers, as Boal and Pencavel suggest, then we may be able to break a toxic cycle of mistrustful requesters [for example 15] and develop more considerate platforms as McInnis et al. advocate [35]. [al2: What will happen if we don't do this? Maybe this is where I should bring up the "market for lemons" metaphor

and say that the market will just continue to decline in quality until nobody is willing to rely on it either as a source of data/information (requesters), or a means of sustaining oneself financially (workers).]

Finally, and perhaps most importantly, we need to replicate the success of narrowly slicing education and training for expert work as Hart and Roberts and Grier described in their piecework examples of human computation [17] and drastically reformulating macro–tasks given the constraints of piecework [19]. [al2: If we can find better ways to train crowd workers for narrowly defined work, we can envision more complex applications and outcomes of crowd work, as in the case of metalwork breaking away from the historical requirements of lengthy, comprehensive apprenticeships.] 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 [3]. If we can overcome this obstacle, we might be able to empower crowd workers to do complex work such as engineering and metalworking, rather than doom them to match girl reputations: "brash, irregular, immoral, and uneducated" [43]. [MSB: how will that reduce any of the problems except the last one?] [al2: I was thinking of fleshing out that the antipathy in general ("brash, immoral, etc…") stems from these workers not being high–skill; we see similar descriptions used of Turkers when people talk about malicious and low–skill Turkers and getting them to "expert–level work". the historical counterexample is that metalworking pieceworkers didn't have these reputations, and we can suppose that this is because they *were* trained (albeit unconventionally), and therefore considered educated, regular, etc… Too much of a stretch?]

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