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) crowd 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 crowd 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. **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 1830s [**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 hold 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. [MSB: I think a sentence here to characterize the height of piecework would be helpful — how big a deal was it at its peak?] [al2: I'm not sure; I'll look for some data.]

update: hard to find anything saying "piecework represented eleventy billion dollars of the U.S. economy", which is what I'd like to say, but I can say something like "at its height, *k%* of garment workers were pieceworkers" or something. that seems a bit wishy–washy though; I'd like to say something like "*k%* of the *entire U.S. workforce* was working under some sort of piecework regime".]

By **hughRaynbirdTaskWork** we find a concise definition of piecework in **hughRaynbirdTaskWork**'s essay on piecework (where he also calls it "measure work", "grate work", and "task work"), particularly driven toward encapsulating the manual labor of farmwork. [al2: I just made the line "Raynbird's essay on piecework"; is that enough to make it sound less important?] **hughRaynbirdTaskWork** 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" [**hughRaynbirdTaskWork**]. **10.2307/2338394** 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" [**10.2307/2338394**]. 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 [**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, employers 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, potentially, an additional pay dependent on output [**rowan1901premium**]; this was just one of several alternatives to categorical time– and piece–rate renumeration paradigms. As **rowan1901premium**'s premium system guaranteed an hourly rate regardless of the worker's productive output *as well as* additional compensation tied to performance, workers under this regime were in some senses "task–labourers", but in other senses "day–labourers".

It may be worth thinking about piecework through the lens of its *emergent* properties to help understand it. **hughRaynbirdTaskWork** 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 **hughRaynbirdTaskWork**'s and later **rowan1901premium**'s works [**hughRaynbirdTaskWork**, **rowan1901premium**].

We see this sense of independence in myriad times, locales, and industries. **10.2307/3827491** 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" [**10.2307/3827491**]. **10.2307/27508091** 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" [**10.2307/27508091**]. This sense of independence and autonomy appears to be an inherent component of piecework.

[al2: I think now that this is moved to this area there's a good opportunity to frame this more as "now that workers could choose their own schedule, style, etc..., newfound interest in how to manage these workers emerged". Thoughts?] The early growth of piecework led to discussion on how best to manage pieceworkers, generally regarding workers antagonistically [**norton1900textile**, **clark1908cotton**]. 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 [**hart2013rise**]. 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 plummeted almost as quickly as it had climbed. Between 1938 and 1942, the proportion of metal workers who were pieceworkers had climbed steeply 11% to 60% [**hart2005piecework**]; by 1961, that proportion dropped to as little as 8% [**carlson1982time**]. **carlson1982time** details that, from 1973 to 1980, the remaining bastions of piecework — where more than 50% worked under incentive wage plans — were principally in clothes–making (e.g. hosiery, footwear, and garments). **hart2013rise**'s work substantively explores the precipitous decline of piecework in the last third of the 20th century.

[al2: ", ultimately arguing that..."?]

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 3) structured tasks such that people who didn't have the training to engage in the traditional labor force could still participate.

[MSB: If you want to make the argument in the last paragraph of this subsection that piecework assumed no professional skills, it's worth calling that out slightly more visibly throughout the subsection.][al2: I don't want to suggest that, actually, at least not ultimately; in the beginning, sure, but by WWII it definitely required certain specialized training (arguably in Airy's case too)]

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 plat-forms 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 work flow [**noronha2011platemate**, **bernsteinSoylent**]. 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 three major case studies to frame our analyses: Airy's employment of *human computers*; domestic and farm work; the "match–girls" and their strike; and railroad and other industrial workers. 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

[MSB: This one seems way thinner than the others? Maybe it should be merged with the earlier description of Airy.] 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' " [**grier2013computers**]. 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 [**10.2307/2338394**]. [MSB: cutting this next part, it seems irrelevant to the paragraph:]

Workers could, in principle, assemble as much or as little clothing as they wanted; the reality was more grim, as **riisOtherSideLives** documented in **riisOtherSideLives** [**riisOtherSideLives**]. He found that workers endured bleak living conditions and worked long hours attempting to scrape together a living.

These movements decentralized the work, for example, into individual homes. However, the next major step would be to re-centralize the pieceworkers into factories.

Industrial Workers

Piecework might be most familiar to the HCI researcher in the context of 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.

Railway companies adopted piecework regimes in the early 20th century. [MSB: What was pieceworky about this? They were paid per meter of railroad that they laid down?] What followed was a flourishing in the management practices with pieceworkers, as railway companies worked to find effective ways to motivate and evaluate this skilled workforce of engineers. **10.2307/23702539** 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"; **10.2307/23702539** goes on to list some of the roles required to facilitate piecework in the early 20th century — among them, "piecework clerks, inspectors, and 'experts' " [**10.2307/23702539**].

This oversight, while controversial (especially among workers [**american1921problem**]), paved the way for piecework to grow substantially. With **taylor1914principles**'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 [**taylor1914principles**, **towardsGlobalFordism**]. While **Brown01041990** points out that piecework dramat-

ically advanced the instrumented measurement of workers, in **taylor1914principles**'s time highly instrumented, automatic measurement of workers was all but impossible [**Brown01041990**]. Instead, managers conducted "stop watch time studies" [**nadworny1955scientific**], 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 automobile 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 [**honey1985creating**], was a pieceworker [**davies2014origins**].

The 1930s represented a boom for piecework on an unprecedented scale, especially among engineering and metalworking industries. **hart2013rise** 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.

[al2: some things I didn't cover:

- research finding that task variability is bad for piecework, but worker variability is good
- talk about the foreman
- worker advocacy groups

should I be making a serious effort to get that stuff in here? this section is kind of long already (and it'll definitely be much longer than the other case studies).]

The Match–Girls' Strike

Piecework played a role in early mass manufacturing during the Industrial Revolution, as well as the early years of worker collective organization and action. At the end of the 19th century, manufacturers employed women to assemble matchsticks in factories. These match–makers were some of the first workers in mass manufacturing to successfully rally for political causes, 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" [**10.2307/3827491**].

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). [al2: I might need to add some info

here, and certainly citations, but there'll be overlap with the other citations here]

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" [**10.2307/3827491**]. As **weyer1894history** described, "the match–girls' victory turned a new leaf in Trade Union annals" [**weyer1894history**]: in the 30 years after the match–girls strike, the Trade Union Movement enrollment grew from 20% of eligible workers to over 60%.

To understand how these women became such influential, if underreported, figures in labor advocacy's history, we should shine a light onto the reputation that had formed for these workers. Match girls were the only group in **booth1903life** to have formed a trade union, according to **booth1903life**'s account at the time [**booth1903life**]. **10.2307/3827491** noted that match girls "... pooled their resources to purchase their plumes and clothes ... and expressed their solidarity through small [and major] strikes" [**booth1903life**]. But they were also, as **10.2307/3827491** confesses, known for "brashness, irregularity, low morality, and little education" [**10.2307/3827491**]. 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.

[al2: I want to discuss a few things here:

- there were protests about something sort of like surge pricing in crop–picking, but i don't know how to make that a paragraph (maybe merge it with match–girls?)

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