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, a more comprehensive background on piecework will be useful. 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, to develop a working understanding.

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 [12]. 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 [22], in textiles [1, 23], on railroads [5], and elsewhere in manufacturing [26]. 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" [22]. 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" [7]. 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 [10, 28, 29, 16].

It's worth acknowledging that "this distinction [between piece–rates and time–rates] was not completely clear–cut" [15]. 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 [24]. 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 [22, 24].

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" [26]. 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" [13]. This sense of independence and autonomy appears to be a common component of piecework.

Since workers could now choose their own schedule and style, there arose a discussion on how best to manage pieceworkers. This conversation generally regarded workers antagonistically [25], 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 rewards hard work [8]. [al2: Norton talks about guarding against collusion among workers, hence the instinct to include it, but with Clark's paper coming out in 1908 and Norton in 1900, I guess the timing looks weird.]

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 (male) workers [15]. 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% [14]. By 1961, that proportion dropped to 8% [6]. 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 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 piecework industries such as manufacturing and textiles to other countries; and 3) the quality of "multidimensional" work becoming too difficult to evaluate [15].

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 [19, 4]. 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 [20, 2]. 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 workers; the "match–girls" strike; and industrial and assembly-line 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

In the 19th century, the calculation of celestial bodies had become a competitive field, and 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, or people who could compute basic functions. These human computers "… possessed the basic skills of mathematics, including 'Arithmetic, the use of Logarithms, and Elementary Algebra' " [12]. 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. Second, the work was designed so that intermediate results could be quickly verified: Airy would have two workers each do the calculation, and another person compare their answers. Third, Airy identified ways to decompose the large task into narrowly-trainable subtasks.

This practice ensured two outcomes that disfavored workers. First, it eliminated any potential to advance professionally, as workers' careers 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 were barely in communication with each other.

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. Textile manufacturers found that they could deliver fabric to people at their homes, asking them to sew together clothing. The manufacturers would later return to retrieve the finished garments, paying these workers for each piece of clothing completed. Farm work applied the idea of piecework by paying workers for tasks like picking bushels of fruit or bringing to birth animals [7].

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 [23]. 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" [26].

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

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" [26]. As Webb and Webb described, "the match–girls' victory turned a new leaf in Trade Union annals" [27]: 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 [3]. Satre noted that match–girls "… pooled their resources to purchase

their plumes and clothes … and expressed their solidarity through small [and major] strikes" [3]. But they were also, as Satre confesses, known for "brashness, irregularity, low morality, and little education" [26]. 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 in the context of industrial and factory work, which largely defined manufacturing through the 20th century. Before the factory assembly line arose, however, 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' " [11]. This oversight, while controversial (especially among workers [18]), paved the way for piecework to grow substantially.

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.

Piecework 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. "Rosie the Riveter", an icon of 20th century America who represented empowerment and opportunity for women [17], was a pieceworker [9].