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*.

Raynbird 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]" [26]. Chadwick 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" [6]. This framing perhaps makes the most intuitive sense; "payment for results," as Chadwick calls it, is not only common in practice, but well–studied in labor economics as well [10, 33, 34, 14].

It's worth acknowledging that "this distinction [between piece–rates and time–rates] was not completely clear–cut" [13]. 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 [30]. As Rowan'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 Raynbird, several arguments for the merits of piece-

work 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." Raynbird highlight the freedom from control that "task–labourers" enjoy [26, 30].

We see this sense of independence regardless of the time, locale, and industry. Satre 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" [31]. J. Hagan 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" [16]. 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 [13]. 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 [21, 3]. 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 [23, 2]. 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'll discuss the history of piecework at a high level to contextualize the observations and conclusions we later make, rather than provide a comprehensive historical account. In other words, it will frame piecework, in 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; as close to a *thick description* of piecework as we can afford [11].

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 19th century [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 off on in farm work [26], in textiles [1, 28], on railroads [4], and elsewhere in manufacturing [31]. 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. Hart and Roberts 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 [13].

The early growth of piecework led to discussion surrounding how best to manage pieceworkers [24, 7]. Despite this, workers' needs were mostly ignored, leading to frustration over poor working and living conditions (famously documented by Riis [28]). Discontent reached a crescendo when industry organizations representing railway workers, mechanical engineers, and other industries began to speak out on pieceworkers' behalves [18, 27].

Piecework's popularity in the United States and Europe plummeted almost as quickly as it had climbed. Hart and Roberts's work substantively explores the precipitous decline of piecework in the last third of the 20th century. In their work, 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 these industries (manufacturing, clothing, etc. . .) to other countries; and 3) the quality of "multidimensional" work becoming too difficult to evaluate [13].

Case studies in piecework
We'll discuss the context and factual details of three instructive cases of piecework to inform the three questions we investigate later — first, railroad and other industrial workers across the United States; second, Airy's employment of *human computers*; and third, domestic and farm work (in particular, the "match–girls"). We'll approach this by looking at familiar cases of decomposed, distributed work (industrial workers), and make our way backwards through the 20th and then 19th century, tracing the origins of the ideas that

[al2: I'm coming out of this with a sort of structure that *loosely* describes piecework chronologically. Strictly speaking, I'm talking about each of these topics (let's call them **human computation**, **domestic and farm work**, and **industrial work**), and some of these things overlap with each other to some extent, but for the most part Airy and the human computers came in the mid–19th century, farm work and the "domestic" work (like making matches) came around at the turn of the 20th century, and the industrial work (railroad workers, the WWII war effort, and the rise of the labor union movement) unfolded from the early 20th century onward.]

Railroad and other 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. It was here that scientific management, Fordism, and Taylorism dramatically influenced how workers were managed and the ways in which workers were perceived and envisioned paradigmatically; it's here we'll start our overview of piecework's history through case studies.

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 [15], was a pieceworker [8].

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 [32, 20]. 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 [4]. Instead, managers conducted "stop watch time studies" [22], using completion times to inform per–task compensation.

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.

Domestic and Farmhand Labor

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 piece-workers with the comprehensive education that apprentice-ships imparted [13]. So, initially piecework in the United States arose for farm work, and as Raynbird and others discuss, the practice remained relatively obscure until it blossomed in the textile industry [26]. The complexity of the work remained low at the turn of the 20th century as piecework saturated New York City [28]. However, writers of the time focused their attention on wage [5] and management regimes [24] rather than training. Mass manufacturing, such as sewing garments [28] and making matchsticks [31], flourished under piecework systems in densely populated cities.

Workers' relationships with employers quickly soured. The match–girls strike of 1888 was one of the earliest and most famous successful worker strikes, and perhaps the beginning of "militant trade unionism" [31]. As Weyer, Webb, and Webb described, "the match–girls' victory turned a new leaf in Trade Union annals" [35]: in the 30 years after the match–girls strike, the Trade Union Movement enrollment grew from 20% of eligible workers to over 60%.

The match–girls strike foreshadowed both collective action victories and an emerging paradigm regarding worker management. Coal miners won a nationwide individual minimum wage after The Great Coal Strike of 1912 [29]. Garment workers in Philadelphia secured collective bargaining rights in 1915 after a prolonged strike and threat of a second [9]. It was in the midst of this time that Taylor published the work for which he would later be called "the father of scientific management" [19]. It was this framing on work & worker management that gave workers a concrete adversary — if not Taylor, then *Taylorism* — against which to rally [17, 25].

Airy's Computers

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' " [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.

[al2: THIS GOES LATER: 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.]