Labor Scheduling and Twin Oaks Community

A Research Paper Submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia – Charlottesville, Virginia

In the Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

By

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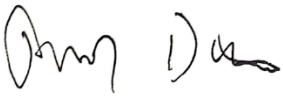
Fall, 2021

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed:  Date: 11/05/2021
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Introduction:

This thesis is about my development of an automatic labor assigner program for Twin Oaks Community. This was a difficult task. I hope that, through writing about this process, I can impart lessons I've learned to others who are hoping to make similar labor or work assigners. Hopefully they can learn from my mistakes. This also may be of interest to those who want to learn more about Twin Oaks Community. This work will detail its labor system and changes that have been made to it. I do so to set this new labor assigner into the broader context of changes that have been made to Twin Oaks's labor system.

Twin Oaks Community is an egalitarian, intentional commune of about 100 people. They all live and work together on a farm in central Virginia. One of the main things that sets them apart is that they hold almost all of their wealth in common. There is no one person's name on their deed as they all equally own and share the land. They also share income. A member cannot make money for themselves while living at Twin Oaks. Money goes to the collective and is divided among everybody.

Twin Oaks is also the place that I was born and raised. This both biases my view and gives me knowledge about its workings. Therefore, some facts about Twin Oaks are not accompanied with citations. I simply know these things to be true. The absence of citations does not mean that the information presented is not accurate.

This essay is broken into three sections. The first section is on the history of work scheduling. It will focus on the history of scheduling that pertains to Twin Oaks's system. The second section is on Twin Oaks's labor system and its scheduling. It also details the history of the system. And the third and final section is on the automatic labor assigner. It covers the specifics of how the algorithm works, lessons I've learned, how the program will change going forward.

Scheduling History:

Scheduling and project management have been around for a very long time. They had to be practiced to make things like the Pyramids of Giza, The Great Wall of China, The Hanging Gardens of Babylon, and more (Seymour & Hussein, 2014, p. 1-2). But, unfortunately, we don't have much information as to how these projects were scheduled (Seymour & Hussein, 2014, p. 2). This is for a few reasons. One reason is that managers would sometimes keep their techniques secret to all but those who were in their tribe or family so that their skills were more in demand (Seymour & Hussein, 2014, p. 2). Another is that some managers weren't very educated so did not know how to record their practices, even if they wanted to (Seymour & Hussein, 2014, p. 2). Also, they might not have kept records on this subject because they didn't have a concept of it. The concept of a project is a fairly abstract, and doesn't show up in ancient texts (Seymour & Hussein, 2014, p. 2). One text might say how they organized a bunch of workers to move a stone for a pyramid but the interconnection between that and running a kitchen so that those workers could eat could very well have escaped our ancestors. The main kind of representational method people used before the 18th century which was vaguely schedule related were models (Weaver, 2006, p. 3). However, these only showed what the end

product would look like, and maybe how the workers would get it done (Weaver, 2006, p. 3). It neither showed the sequence of tasks the workers would do to make the end product nor the time it would take to make it (Weaver, 2006, p. 3).

Factories were the main instigators for scheduling. However, early factories were small and only produced a single product (Herrmann, 2006, p. 3). They were so small that they only had one person, a foreman, who would direct people (Herrmann, 2006, p. 3). He was their schedule. It would be a long time before actual schedules were made however their progenitor was created about this time.

In the 18th century, people started formally making tools for scheduling. The first of these, at the time of its making, didn't actually have anything to do with scheduling. It was the bar chart. Joseph Priestley was an enlightenment era nobleman and scientist (Kingston). One of his best known accomplishments was the discovery of oxygen (Kingston) but, he also invented the bar chart in 1765 (Weaver, 2006, p. 3). It had time as an axis and charted the duration of various events with bars that varied in length (Weaver, 2006, p. 3). This chart idea was picked up by William Playfair, an engineer and political economist (*William Playfair: Biography on Undiscovered Scotland*, n.d.), who created a series of other graphs (Weaver, 2006, p. 4). These still weren't applied to scheduling. The core ideas were out there but were not developed for another hundred years or so.

In the early 20th century, scheduling and project management shifted from being a craft system to being an intricate system of study and business (Seymour & Hussein, 2014, p. 3). The main cause of this shift was the development of the planning office. It was created by Frederick Taylor who is known for his fundamental changes to the way scheduling occurs in factories (Herrmann, 2007, p. 6). The planning office made scheduling its own department and separated it from a side task that foremen did (Herrmann, 2007, p. 6). It housed many clerks whose job, among other things, it was to keep track of what job should be done when and by whom (Herrmann, 2007, p. 6). In some factories foremen still were in charge of scheduling but Taylor's planning office was widely adopted (Herrmann, 2007, p. 7). Another key feature of the planning office was a large bulletin board that tracked, for every workstation, the operation it was currently doing, the orders that it was currently processing, and future orders that would be processed there (Herrmann, 2007, p. 6-7). But this was not the only major development in scheduling that this era saw. It also saw the formation of graphical ways of tracking data via charts.

Charts played a pivotal role in the tracking of labor in factories. Much later, their influence would be echoed in the labor system at Twin Oaks. But long before this, by 1912, the modern bar chart for tracking work was developed in Germany (Weaver, 2006, p. 6). However, these only showed what activities needed to happen and when (Weaver, 2006, p. 6). They didn't show which jobs were interdependent or the sequence in which jobs should happen (Weaver, 2006, p. 6). The one who developed these ideas was Karol Adamiecki. Karol Adamiecki was a Polish economist, engineer, and management researcher (Weaver, 2006, p. 5). In 1896 he

developed a way, through charts, to indicate the ordering of jobs (Weaver, 2006, p. 5). They were supposed to harmonize people's work and so were called Harmonygraphs (Weaver, 2006, p. 5). One such graph looks shockingly like the schedules that Twin Oakers use to track their labor. Unfortunately, his works were published in Polish and Russian and so weren't widely disseminated (Seymour & Hussein, 2014, p. 3). The man who is credited with making these visual displays of work, and revolutionizing production scheduling is Henry Gantt. He was an American engineer and management consultant (Seymour & Hussein, 2014, p. 2). Between 1910 and 1915, he made the widely popular charts known as the Gantt Charts (Seymour & Hussein, 2014, p. 3). They gained popularity, and gained his name, because they were used in large projects during World War I and later they were also used in the construction of the Hoover Dam (Seymour & Hussein, 2014, p. 3). These charts were novel because they broke large tasks into smaller ones and indicated tasks' interdependencies (Seymour & Hussein, 2014, p. 3). They also showed a task's progress through a bar's length relative to the total amount of time allocated to the task (Herrmann, 2007, p. 9). This is echoed in today's loading bars. Also notably, and unlike Taylor's bulletin board, Gantt Charts were designed so that supervisors could carry them around with them (Herrmann, 2007, p. 8). This move away from a centralized board that everyone can reference to more personal schedules is mirrored in Twin Oaks's current labor system.

Twin Oaks's labor system departs from the history of scheduling at this point. The first paper copier was made by Xerox at this time (Seymour & Hussein, 2014, p. 3). This is the only major scheduling development that impacts Twin Oaks. In the period after the 1950s scheduling became computerized (Seymour & Hussein, 2014, p. 3). It started using complex mathematical equations to solve scheduling problems and this is absolutely not how it is done at Twin Oaks.

Unlike Twin Oaks's schedules, Gantt Charts are focused on the workstation and machine throughput. They measure things like how many deliverables each assembly task produces, what days specific machines should be working on what, and how long assembly tasks should take (Herrmann, 2006, p. 5, 8, 9). Whereas Twin Oaks schedules are much more people focused. Their purpose is not to maximize output but to make sure that people connect with each other at the right times. They are focused on giving power to the individual. Both Gantt and Twin Oaks's schedules are made for a similar purpose: to track labor. But they come at it from vastly different perspectives.

Twin Oaks Scheduling:

The most important component of Twin Oaks's labor system is Labor Credits, Oaks's internal currency (Kinkade, 1994, p. 29). For every hour you work you earn one labor credit. This isn't universally true. You must work doing tasks that Twin Oaks has deemed labor creditable/of benefit to the community. This includes tasks that make money for Twin Oaks as well as work in the garden or dairy, but it also includes a wide range of other tasks that you might not think of as strictly being work. A non-exhaustive list of these labor creditable tasks

that Kat Kinkade, one of the founders of Twin Oaks, made is, "house cleaning, shopping, childcare, laundry, cooking, mowing the lawn, doing house hold repairs, volunteer work for charitable organizations, going to the doctor, voting in local elections, writing letters to Congress, going to relatives' funerals, and repainting your room, in addition to virtually unlimited sick time" (1994, p. 29). Every week, each member of Twin Oaks must work more than 40 hours in some of these areas. The exact number of labor credits they must make varies with time. If you work and earn more than you're required to for a certain week, then you are said to work "overquota." These extra hours are stored in your labor balance, and you can use them to work less, or go on vacations for subsequent weeks (Kinkade, 1973). You can also use the hours in your labor balance to pay another member to do tasks for you although you cannot give them more hours than it took to complete the task (Kawatski, 2001). To record all your hours, and see what work you're scheduled, each week each member gets a personal schedule called a Labor Sheet.

The inspiration for Twin Oaks was a novel by B. F. Skinner called Walden Two. It describes a fictional utopia. It briefly mentions a labor credit system that Twin Oaks's is based on (Kinkade, 1994, p. 30). The community in Walden Two has a variable labor credit system (Skinner, 1948, p. 45): If you work one hour in the sewers then you'll get more than one labor credit and if you work an hour planting flowers then you'll get less (Skinner, 1948, p. 46). In Walden Two they have figured out just the right amount of labor credits to award each job so that all jobs are equally desirable (Skinner, 1948, p. 46). At one point, Twin Oaks had a similar system to this, although not when it first started.

When it first started, Twin Oaks had no labor system at all. This lasted for three weeks (Kinkade, 1973, p. 40). It changed when one of the women complained about doing all the housework and wanted others to help (Kinkade, 1973, p. 41). At first, they differentiated between those tasks that they enjoyed doing and ones that felt more like chores (Kinkade, 1973, p. 41). The ones that were chores they put on the labor credit system (Kinkade, 1973, p. 41). As time wore on and they got less excited about the various tasks they were doing, all work was eventually put on the labor credit system (Kinkade, 1973, p. 41).

After this Twin Oaks developed its first formal labor assigning system. In it, everyone would write job names and how long they thought they'd take on 3x5 cards (Kinkade, 1973, p. 42). They'd assemble these cards and sit in a circle (Kinkade, 1973, p. 42). Then, they'd deal all of them out to everyone (Kinkade, 1973, p. 42). People would keep the jobs that they liked and pass those they were less excited about to their right (Kinkade, 1973, p. 42). They'd all agree on how many hours each person was doing that week then, once a person had accumulated jobs with that many hours, they'd step out of the circle (Kinkade, 1973, p. 42). Those participating enjoyed this way of assigning tasks, but it was slow (Kinkade, 1973, p. 42).

For Twin Oaks's second system, they still had the same 3x5 cards but now they put them in a box (Kinkade, 1973, p. 42). People would write their initials on the job they wanted (Kinkade, 1973, p. 42). Then someone would go over each card, randomly pick a person's initials

who signed it, and that person would get the job (Kinkade, 1973, p. 42). Those who signed cards but weren't randomly picked would get the jobs that no one signed up for (Kinkade, 1973, p. 42). This was when the variable labor credit system entered the scene. If people competed for a job, then its labor credit value decreased by 10% and if nobody wanted a job its value increased by 10% (Kinkade, 1973, p. 42). They changed this system slightly, so that everybody had their own sheet and signed up for jobs at the same time to make it harder to game the system (Kinkade, 1973, p. 42). They called this process *simultaneous sign up* (Kinkade, 1973, p. 42).

They kept simultaneous sign up for about two years, until 1970 (Kinkade, 1973, p. 44). The motivation for the change was a large influx of members bringing their number up to about 40 (Kinkade, 1973, p. 44). They figured, with that many people, there had to be at least one person who enjoyed, or at least didn't dislike, doing each job (Kinkade, 1973, p. 44). So, they made a system where every member ranked all the jobs at Twin Oaks by how much they enjoyed doing them (Kinkade, 1973, p. 44). People would get more labor credits for the jobs the more they disliked them (Kinkade, 1973, p. 44). But there was a problem with this. Since the amount you were "paid" for each job was based on your enjoyment of it, two people could be working the same job at the same time and get vastly different amounts of labor credits (Kinkade, 1994, p. 31). So, in 1974, Twin Oaks set the value of a labor credit to one hour, no matter what the work was (Kinkade, 1994, p. 32). That's how it remains to this day.

The overquota system has changed over the years too. For most of Twin Oaks's history, if you worked overquota in a certain work area the work would not come out of that area's labor budget (K. Dakota & K. Dakota Henderson, personal communication, October 10, 2021). This incentivized people to work harder and allowed more work to be put into work areas with smaller budgets (K. Dakota & K. Dakota Henderson, personal communication, October 10, 2021). However, it was seen as devaluing work areas' budgets and was replaced by a system called *flex hours* (K. Dakota & K. Dakota Henderson, personal communication, October 10, 2021). It gave people 60 hours per year that they could work and not take out of work areas' labor budgets (K. Dakota & K. Dakota Henderson, personal communication, October 10, 2021).

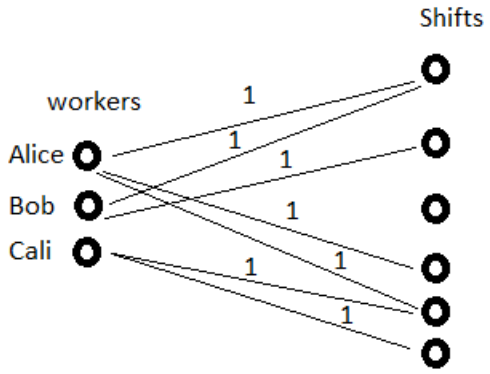
Sometimes people don't work enough at Twin Oaks. Just as someone can work more hours than their share and so can build up hours in their favor, they can also work less and so owe Twin Oaks labor credits. This is called being in the labor hole. Before 1987, people could coast by, doing less than their share of work, and Twin Oaks wouldn't do much about this (Kinkade, 1994, p. 34). That member would often have friends, who those in charge had to live with and so wouldn't want to make a fuss (Kinkade, 1994, p. 34). In 1987 the Labor Hole Policy was introduced (Kinkade, 1994, p. 34). It said that if someone was in the labor hole for seven out of the last twelve months that they'd go back to being a provisional member and have all their debt cleared (Kinkade, 1994, p. 34). A provisional member, after a certain period of time, is voted on and either becomes a full member or leaves (Kinkade, 1994, p. 34). If they continue not working it usually makes enough people upset that they are asked to leave (Kinkade, 1994, p. 34).

Conclusion - Automatic Labor Assigner:

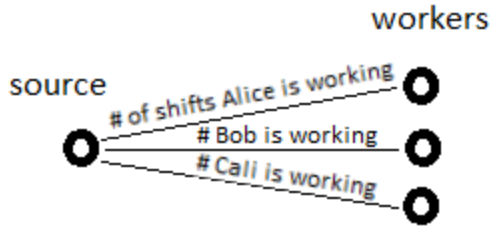
The automatic labor assigner is a program that would assign all the labor for people at Twin Oaks. It would take in, as input, all the work that needs to be done as well as the work preferences of Twin Oaks members and would output Labor Sheets for every member each week. Unfortunately, it has not yet been fully created. The algorithm that was meant to serve as the engine for the labor assigner is not flexible enough to support the intense variability of Twin Oaks's labor system. This algorithm is called Max-Flow.

Max-Flow is an algorithm that runs on graphs: a set of points called nodes or vertices and a set of lines that connect these nodes. The lines are called edges. For Max-Flow, each edge can only be traversed in one direction. Also, each edge has a capacity (Mützell & Josefsson, 2015, p. 9). An edge can only have "flow" going through it up to its capacity (Mützell & Josefsson, 2015, p. 9). One node is the source, or start, and another is the sink, or end (Mützell & Josefsson, 2015, p. 6). The source and sink can output and take in an infinite amount of flow respectively. Max-Flow finds the maximum amount of "flow" that can traverse from the source, through the graph, and to the sink (Mützell & Josefsson, 2015, p. 6). You can imagine this as water running through a series of pipes from some input to some output.

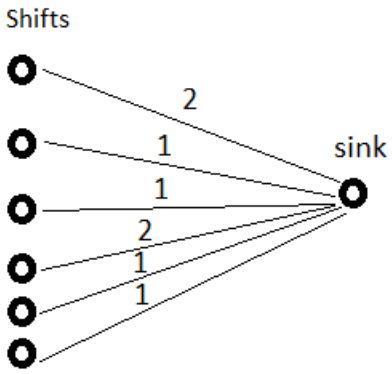
Max-Flow can be used to solve scheduling problems. This section describes a method that is very similar to the one I used to make the Twin Oaks labor assigner. First, divide all the nodes into two types: Worker nodes and shift nodes. The number of shift nodes represent the number of shifts each week that need to be filled. Each worker node is connected to each shift node that that worker is free and trained to do. The edge that connects them has a capacity of 1. The capacity and flow represent one worker working one part of that shift.



You connect each worker node to the source node. Those edges have a capacity equal to the maximum number of shifts that worker can work in a week.



So, if a person was working 5 shifts in a week, then you'd give that person's edge a capacity of 5. Finally, you connect each work node to the sink. These have a capacity equal to the number of people needed to work that shift.



You then run Max Flow. If a shift's edge that's connected to the sink is at full capacity (if it has flow running through it up to its capacity) then that shift can be scheduled for that week. Those workers who have flow running to that shift will work it. I assumed that this, or a very similar method could be applied to Twin Oaks. I was wrong.

The problem with applying Max Flow to Twin Oaks is just how variable the Twin Oaks system is. Not only do jobs not have fixed days that they happen on, but they also don't have fixed times of days that they happen. A job could happen at 2pm Friday or 8am Wednesday or at some other time entirely. And then some jobs can happen at literally anytime that people are free to do them. This requires a level of flexibility that Max Flow simply cannot support. Max-Flow requires fixed times.

Genetic algorithms offer a way to deal with Twin Oaks's flexible system: First, it will generate many configurations of job times. Then it will use Max-Flow to see how many of these jobs can be scheduled. This is the configuration's fitness, which represents how good of a solution it is. We combine configurations to produce another that has similar traits but possibly

with some mutations. Then we repeat this process until we find a configuration that meets some fitness criteria. This is the direction I hope to take the automatic labor assigner in. If it works, I will add my contribution to the history of scheduling and the development of Twin Oaks's labor system.

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