CS1200: Intro. to Algorithms and their Limitations Prof. Salil Vadhan

Lecture 15: Ethical and Social Considerations

Harvard SEAS - Fall 2025 *2025-10-23*

1 Announcements

- Guest helping with today's class: Matthew Kopec, Program Director for Harvard's Embedded EthiCS program.
- My OH: today 1:30-2:15 SEC 3.327, Mon 5:30-6:15 Zoom (scheduled for DCE students!).

Recommended Reading:

- Hesterberg–Vadhan 16

2 Recap

Recall that, motivated by the problem of kidney exchange, we designed an efficient algorithm for the following problem.

Definition 2.1. For a graph $G = (V, E)$, a *matching* in G is a subset $M \subseteq E$ such that

Input: A graph $G = (V, E)$

Output: A matching $M \subseteq E$ in G of maximum size

Computational Problem Maximum Matching

3 Interrogating our Mathematical Models

Throughout this class, we have seen the power of mathematical modeling. Abstracting away inessential details to yield clean and precise formulations of computational problems allows us to more easily bring our algorithmic toolkit to bear and design solutions (i.e. algorithms and data structures) that apply to many different problems across different domains.

At the same time, when we perform this modeling, we should be cognizant of considerations that are relevant but might be lost in our model.

Q: What are some examples in the context of our modeling of kidney exchange as Maximum Matching?

Q: What are some potential *ethical* issues with our formulation of kidney exchange?

4 Specifying the Problem

We will spend the rest of class focusing on the problem of deciding *which patients ought to be prioritized* under a matching algorithm for kidney exchange.

Q: What factors ought to be incorporated into our metric? Which of those admit of a relatively straightforward numerical representation? How would you represent those?

As discussed earlier, some of the considerations associated with matching can be modeled by edge weights. Here, to keep things simple, we will focus just on the question of how to prioritize *patients* to receive donations, which can be captured by weights that we place on the vertices of the graph. This leads to two ethical questions:

How should we assign weights to vertices? For simplicity, we will start by attaching only a single weight $w(v)$ to each vertex v, but as we will see, there are often multiple ethically relevant features.

Definition 4.1. A *vertex-weighted graph* $G = (V, E, w)$ is a graph $G = (V, E)$ together with ____

For simplicity in the discussion below, we will assume that all donors are assigned the same weight (e.g. 0), as assigning and aggregating patient weights already raises challenging ethical questions.

How should we aggregate the weights of matched vertices to determine the "quality" of a matching? That is, given the vertex-weighted graph as input, what is our objective function? The simplest form of aggregation is:

Definition 4.2. For a vertex-weighted graph $G = (V, E, w)$, the *weight* of a matching $M \subseteq E$ is defined to be

$$w(M) =$$

This leads to the following computational problem:

Input: A graph $G = (V, E)$
Output: A matching $M \subseteq E$ in G of maximum weight $w(M)$

Computational Problem MAXIMUM WEIGHTED MATCHING

It is not necessarily the case that this is the "right" way to determine the quality of a matching, and different ethical principles may lead us to different aggregation methods.

In the following sections, we will study how different ethical theories suggest different choices of vertex weights for patients and different aggregation functions to optimize.

5 Utilitarianism

One common view in normative ethics is often referred to as *Utilitarianism,* which holds, roughly speaking, that the right action from a range of options is the one that is expected to yield the best outcomes. In classical Utilitarianism, the best outcome was believed to be the one that maximizes the aggregate sum total of *pleasure* the action generates across all individuals. In another common view, the best outcome is the one that maximizes total *welfare* across all individuals. For simplicity, we will focus on quantifiable measures of welfare for the kidney patients themselves. Furthermore, we will use summation as our aggregation function because that is the common interpretation of "total welfare" in Utilitarianism.

5.1 Equal Value of Life Years

One quantity with clear ethical relevance that is readily available in most kidney donation cases is the *estimated life years* gained for the patients. The *Equal Value of Life-Years (eVLYs)* metric treats each year of life for each individual as having the same value as any other. Fully egalatarian!

Q: Which of the following matchings would the eVLYs metric prefer?

Q: What are some circumstances in which we might prefer the other matching in the example above (i.e. not the one chosen by the eVLYs metric)? Any other problems with the eVLYs metric?

5.2 Quality-Adjusted Life Years

At the time of writing (October 2025) the most commonly used metric for assessing the value of health interventions is the "Quality-Adjusted Life Year" or "QALY" metric. This metric works by weighting life years according to a value that captures expected disease burden, where a weighting of 1 is given to each year in perfect health, and 0 for each year that is seen as being no better than being dead. There are various ways the precise weightings are constructed, but one common way is through public surveys where members of society are asked about their preferences between living a certain number of years in perfect health or some number of years with a specific health concern (e.g., having to go to regular kidney dialysis treatments for the remaining 10 years of one's life).

Q: How do QALYs address the problematic eVLYs example we saw?

Q: What might be some problematic consequences of using QALYs?

6 Prioritarianism

The previous two sections suggest that when matching organs to donors neither the aim of maximizing eVLYs nor the aim of maximizing QALYs puts the resulting algorithm on a secure normative footing. It seems that it doesn't only matter how many QALYs are gained, it also matters *to whom* those QALYs are going.

Class poll: If we had to choose one of the two following patients for a kidney donation, who should we choose?

- Patient A: Has lived 50 years in near-perfect health, and would gain 20 more years in near-perfect health with a kidney donation.
- Patient B: Has lived 20 years in near-perfect health, and would gain 19 more years in near-perfect health with a kidney donation.

Class poll: What about for the following two patients?

- Patient C: Has lived 20 years, most of which with childhood leukemia, which is now cured. Would gain 10 years in near-perfect health with a kidney donation.
- Patient D: Has lived 20 years in near-perfect health, and would gain 10 years in near-perfect health with a kidney donation.

Rawls' maximin principle: We should prefer the outcome where the individuals who are the worst off in the scenario fare the best. Applied to kidney exchange, we can mathematically model the maximin principle by seeking a matching M that first attempts to maximize:

Notice that this is a case where, in addition to using two weights per vertex, our aggregation function is also something different than summation.

Class exercise: Each side of the classroom will be assigned to come up with arguments for either Utilitarianism (formulated by maximizing the sum of QALYs) or the Maximin approach above. Discuss with your neighbor and try to come up with the best arguments possible.

Class poll: Do you think the Utilitarian or Maximin approach is preferable for kidney exchange?

Another view that arose out of such critiques is a view called "Prioritarianism"— a combination of "priority" and "Utilitarianism"— which suggests that we place greater weight on helping those who are worse off, while allowing that in some cases the right choice leaves some worst off individuals worse off than some other match would generate.

Q: How can we model Prioritarianism mathematically?

7 Takeaway

- The theory of algorithms does not provide an answer to the question "are we solving the right problem?"
- Think carefully about the relationship between the problems our algorithms are designed to solve and the sociotechnical systems in which they going to be deployed. There may be serious ethical or social implications!
- Engage with the humanities and social sciences.
- Often ethical or social considerations can be incorporated into the problem formulation, and you can use your algorithmic toolkit to address them.
- Sometimes algorithms are not the (whole) answer! (Project Donor, co-directed by Harvard CS 2024 grad Daniela Shuman, helps potential donors qualify for donation through health improvements.)