REU Projects about Kidney Exchange

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1 Organ Exchange

The preferred treatment for kidney failure is a transplant; however, demand for donor kidneys far outstrips supply. *Kidney exchange*, an innovation where willing but incompatible patient-donor pairs can exchange organs—via barter cycles and altruist-initiated chains—provides a life-saving alternative. Patients who are fortunate enough to find a willing living donor must still contend with *compatibility* issues like blood type, tissue type, and other medical or logistical factors (as we discuss later in the paper). If a willing would-be donor is incompatible with a patient, the kidney cannot be transplanted.

Kidney exchange is a recent innovation that allows patients to swap willing but incompatible donors. Figure 1 shows a graphical representation of a small pool consisting of three patient-donor pairs, where an arrow from pair i to pair j means the patient at j is compatible with the donor at i. Also shown is an altruistic donor; such donors do not come with paired patients and are willing to donate a kidney without asking for one in return. The basic kidney exchange problem is then to recommend an optimal—according to some social welfare function—set of disjoint cycles and altruist-initiated chains in the graph.

1.1 Learning QALYs

Not all kidneys are created equal. Indeed, some kidneys are worse than others globally, while other kidneys might be a better match for me than they are for you. One measure of this is *graft survival rate*, the length of time a donor organ continues to work in its recipient before requiring replacement. This, along with the recipient's health at the time of transplant, gives an

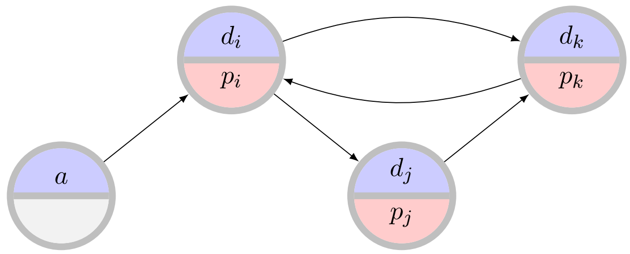

Figure 1: Tiny example kidney exchange pool with three patient-donor pairs and one altruistic donor.

estimate of how many "QALY"s a kidney is worth to a potential recipient. QALYs—quality-adjusted life-years—are a generic measure of disease burden, including both the quality and the quantity of life lived. It is used in economic evaluation to assess the value for money of medical interventions. One QALY equates to one year in perfect health. The more QALYs, the better.

In this project, you will use machine learning to estimate QALYs for potential donor organs and recipients. You will use a large dataset covering all live kidney donations in the US since 1987—roughly 100000 or so—to learn a classifier that maps potential donor organs to a QALY score. Once that classifier is learned, you will add this classifier to a large kidney exchange codebase used to do sensitivity analysis at the UNOS kidney exchange. How much does optimizing with respect to QALYs help relative to the status quo?

Paper: `http://jpdickerson.com/pubs/dickerson15futurematch.pdf`
OPTN data: `https://optn.transplant.hrsa.gov/data/request-data/`
Codebase: `https://github.com/JohnDickerson/KidneyExchange`

1.2 Greedy Packing

Finding the maximum cardinality disjoint set of small cycles and long chains in a directed graph is NP-hard. Lots of research has gone into solving this problem to optimality in practice. Still, solving the problem is quite slow. There is value in finding approximate solutions—that is, creating algorithms that *quickly* find a good, but maybe not the best, packing. These algorithms could be deployed in dynamic optimization packages that are only now starting to be used in real exchanges.

In this project, you will design heuristic methods for packing cycles and chains in real kidney exchange graphs. You will compare them against some state-of-the-art optimal packing algorithms. How close do you get to optimal, and with what variance? How much time do you save versus optimality? Can you prove anything about your heuristics?

Optimal packer paper: `https://arxiv.org/abs/1606.01623`

Base code: `https://github.com/jamestrimble/kidney_solver`