



Cardiff University
Computer Science and Informatics

Using Optimisation Techniques on the Kidney Exchange Problem

Initial Plan

CM3203 One Semester Individual Project - 40 credits

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1 Ethics

The data for this project has been provided by preflib.org and contains 310 instances of synthetic kidney donor pools generated by a state of the art donor pool generation method described in “Increasing the opportunity of live kidney donation by matching for two-and three-way exchanges”. Transplantation 81(5), 2006 and was donated by John Dickerson [1][2]. As this data is synthetic, such that it does not correspond to real people, this project does not require ethical approval. However, if it becomes necessary to analyse or introduce another dataset, I will review the cause for ethical approval and apply for approval if required.

2 Project Description

2.1 Project Description

In this project, I will use various optimisation methods and algorithms to locate or approximate optimal or near-optimal solutions to the optimal matching problem. To achieve this, I will use the real-world application of the kidney exchange to model my solutions and analyse the performance of the chosen techniques. This project will include in-depth research into the optimal matching problem itself, research and implementation of different optimisation methods and techniques and analysis of the performance of each method with respect to the kidney exchange problem.

2.2 Introduction to the Optimal Matching Problem

In graph theory, a matching is defined as a set of paired edges, which do not share a set of common vertices. This means that each vertex in the set has either zero or one other edges paired with it. An optimal solution is found when the set contains the maximum number of matched pairs possible in the set or maximises the cost function with respect to the associated matching pairs. The optimal matching problem has many real-world applications, one such example is matching kidneys to patients waiting for a transplant.

2.3 Introduction to Kidney Matching

Chronic Kidney Disease (CKD) is a life-threatening health condition which prevents the kidneys from performing normally. Kidney failure may lead to harmful waste building up in the body, rising blood pressure and retention of excess fluid and without a transplant or dialysis, can be fatal. In the UK alone, around 3 million people suffer with CKD, and 63,000 are being treated for kidney failure (also known as stage 5 CKD, where kidney function is less than 15%)[3].

In the UK in 2019, 2283 kidneys were donated by deceased donors, and 952 by living donors. Often, living donors are part of a donor-recipient pair who may or may not be compatible with one another. In the case where they are incompatible, the pair may enter the UK Living Kidney Sharing Scheme (UKLKSS), to locate a compatible match for the recipient, and a compatible recipient for the donor [4].

In some cases, kidneys are donated anonymously as a non-directed altruistic donor (NDAD), which causes the case of an altruistic donor chain. This means that the donated kidney is allocated to a recipient of a pair in the UKLKSS. The donor registered to the chosen recipient donates and the chain continues until a kidney is donated to someone on the transplant waiting list.

3 Project Aims and Objectives

In this project I aim to:

- Create a tool to visualise the performance of different algorithms and optimisation methods of kidney exchange assignments.
- Analyse the performance of the chosen methods and consider the strengths and weaknesses of each.

Project Objectives:

- Study the optimal matching problem, in particular its application to the kidney exchange.
 - Produce a mathematical description of the problem.
- Research and implement algorithms which provide optimal solutions or matchings – or at least a good approximation to an optimal matching.
 - Implement chosen algorithms and visualise the results via a user-friendly interface.
- Conduct analysis of the chosen algorithms or methods using the application of the kidney exchange.
 - Produce a report explaining the chosen algorithms and offer analysis of their performance.

4 Work Plan

4.1 Deliverables

- Initial Plan - 08/02/2021
- Articulating the problem mathematically – w/b 08/02/2021
- Implementation of chosen algorithms – w/b 01/03/2021
- Literature review – w/b 03/05/2021
- Background research – w/b 03/05/2021
- Final Project Report – 14/05/2021

4.2 Meetings

Throughout the project, I plan to meet with my supervisor, Richard Booth, for 15-20 minutes on a weekly basis, every Friday. These meetings will be used to demonstrate my progress and to seek advice or guidance.

4.3 Work Plan

- **Week 1 – 01/02/2021**
 - Develop initial plan.
 - Begin background research on relevant topics such as the Kidney Exchange program and optimal matching techniques.
 - Download and install relevant software such as Gurobi.
 - Initial meeting with supervisor
- **Week 2 – 08/02/2021**

- Continue background research on relevant topics.
 - Gain clear understanding of the optimal matching problem and express the problem mathematically in my own words.
 - Familiarise myself with relevant software such as Gurobi.
 - Familiarise myself with the dataset.

Milestone: Submit Initial Plan (08/02/2021)

Deliverable: Articulating the problem mathematically
- **Week 3 – 5** (15/02/2021 – 01/03/2021)
 - Research and learn the theory of relevant matching algorithms/techniques.
 - Select 3/5 relevant algorithms and implement them.

Milestone: Implemented the chosen algorithms

Milestone: Supervisor meeting to review progress

Deliverable: Implementation of chosen algorithms
- **Week 6 – 8** (08/03/2021 – 22/03/2021)
 - Evaluate success of different algorithms and approaches.
 - Develop front-end to visualise the resulting matching.
- **Week 9** (19/03/2021)
 - Continue to develop front-end application.

Milestone: Complete front-end design and implementation.

Milestone: Supervisor meeting to review progress
- **Week 10 – 11** (26/04/2021 – 03/05/2021)
 - Write up of final report including analysis, literature review and background research.

Deliverables: Literature review and background research
- **Week 12** (10/05/2021)
 - Complete and submit final report.

Milestone: Complete final report.

Milestone: Submit all project deliverables (14/05/2021)

5 References

- [1] - <https://www.preflib.org/data/matching/kidney/>
- [2] - Optimizing Kidney Exchange with Transplant Chains: Theory and Reality. John P. Dickerson, Ariel D. Procaccia, Tuomas Sandholm.
- [3] - <https://www.kidneycareuk.org/news-and-campaigns/facts-and-stats/>
- [4] - <https://www.odt.nhs.uk/living-donation/uk-living-kidney-sharing-scheme/>