Kidney Exchange Problems

1 Introduction

For patients suffering from renal failure, a kidney transplant is the preferred treatment option. Historically, such transplants were mostly from deceased donors. However, it is also possible for a kidney to be taken from a living donor and transplanted to a recipient. Such transplants lead to better long term health outcomes for the patient, and also circumvent the long wait for a suitable deceased donor. While there is only a limited long term impact on the (living) donors health, the operation and associated recovery time means that there are also few willing living donors, and usually these are only willing to donate to a close friend or family member. This can be an issue, since donor and recipient must be medically compatible, for example, a donor with blood type A can not donate to a recipient with blood type B.

Kidney exchange is a method to work around these medical incompatibilities. Suppose there is a patient with blood type A, who has a friend willing to donate with blood type B and a second pair where the situation is reversed (patient blood type B, recipient blood type A). In this case, an exchange can be set up, where the kidney of the donor of the first pair is transplanted to the recipient of the second pair, and vice versa. Such an exchange satisfies the requirement that the donors are only willing to donate if their friend is helped by it, even though they do not directly donate to them. Cycles like this could in theory be set up with an almost infinite number of donors and patients (A gives to B, gives to C, etc., finaly Z gives to A). In practice, this is restricted to a limited number of pairs for logistical reasons, and to minimize the impact if any donor or recipient would drop out at any point. Furthermore, we will consider non-directed donors in this project. These are donors that do not have an associated donor, but are willing to donate to any recipient. Such donors are powerful, because they are willing to donate without having to find a donor to help "their" recipient in return. They can set in motion a chain of transplants. We use "exchanges" to refer to cycles and chains collectively.

2 Problem Description

You are given a graph $G(V, A)$. In the graph, each vertex $v \in V$ represents either a donor-recipient pair (the subset $V^P \subset V$), or a non-directed donor ($V^N \subset V$). An arc $(i, j) \in A$ exists if the donor of i is medically compatible with the recipient of pair j. The goal of this problem is to find cycles and chains in this graph, such that the value of planned transplants is as large as possible. The maximum length of these cycles and chains are usually limited, you are encouraged to explore what happens as they vary from typical values (3 transplants) to larger exchanges.

The instance files will also contain some additional information on patients and donors, such as blood types. In practice, these are sometimes taken into account. For example, blood-type identical transplants can be preferred, or patients with fewer compatible donors receive some priority. You can explore alternate objectives where these things are taken into account, either through weighted solutions, or as tie-breakers.

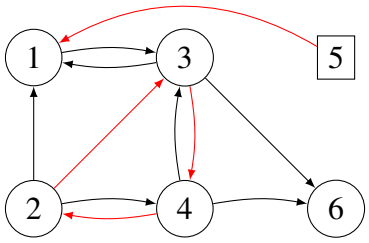

Figure 1: A graph representing a kidney exchange problem. Circles represent pairs, where the donor is only willing to donate if the recipient also receives a kidney. Squares represent non-directed donors. The red arcs show a possible (but not optimal) solution for this graph.

3 Data Files

Date Files will be made available through Canvas. These files contain instances of varying sizes, and generated through various procedures. This will allow you to investigate the impact instance characteristics have on the difficulty of the problem. More details on the file formats, generation methods, etc. will be added to the file folders.

Enjoy the puzzles!