Multi-level Optimization Problems for Kidney Exchange

Doctoral defense

Danny Blom

15 december 2023
Kidney transplantation

End-stage renal disease (ESRD):
- Undergoing dialysis
- Kidney transplantation (preferred treatment)

<table>
<thead>
<tr>
<th>Waiting list</th>
<th>Transplants</th>
<th>Registered</th>
<th>Removals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>deceased</td>
<td>living</td>
<td></td>
</tr>
<tr>
<td></td>
<td>donors</td>
<td>donors</td>
<td></td>
</tr>
<tr>
<td>9,939</td>
<td>2,970</td>
<td>1,232</td>
<td>5,466</td>
</tr>
</tbody>
</table>

Data from Eurotransplant Statistics Report Library (2022)
Kidney Exchange

Can be generalized to multiple pairs!

Danny Blom
15 december 2023
Kidney Exchange

Henk \rightarrow \text{Kidney} \rightarrow \text{Kidney} \rightarrow \text{Ingrid}

Can be generalized to multiple pairs!
Kidney Exchange

A = (I, H)
B = (A, F)

Can be generalized to multiple pairs!
Kidney Exchange

Henk

Ingrid

Fatima

Ahmed

$p_A = (I, H)$

$p_B = (A, F)$

Can be generalized to multiple pairs!
Kidney Exchange

Can be generalized to multiple pairs!
Kidney Exchange

Can be generalized to multiple pairs!

Danny Blom  
Doctoral defense  
15 december 2023
Kidney Exchange

Can be generalized to multiple pairs!

Danny Blom

Doctoral defense

15 december 2023
Kidney Exchange

Can be generalized to multiple pairs!

\[ p_A = (I, H) \]

\[ p_B = (A, F) \]
Kidney Exchange

$p_A = (I, H)$

$p_B = (A, F)$

Can be generalized to multiple pairs!
Kidney Exchange Programs (KEPs)

- Each donor can donate at most one kidney!
- Donor donates kidney $\Rightarrow$ Patient receives kidney
- Restricted number of pairs in an exchange
Kidney Exchange Programs (KEPs)

- Each donor can donate at most one kidney!
- Donor donates kidney $\rightarrow$ Patient receives kidney
- Restricted number of pairs in an exchange
Kidney Exchange Programs (KEPs)

- Each donor can donate at most one kidney!
- Donor donates kidney $\Rightarrow$ Patient receives kidney
- Restricted number of pairs in an exchange

Note: there is no exchange option for pair $p_9$!
**Reality:** many pairs remain unmatched in a single iteration
**Reality:** many pairs remain unmatched in a single iteration

**Idea:** merge pools of multiple programs!
Part 1: Collaborations in Kidney Exchange

**Reality:** many pairs remain unmatched in a single iteration

**Idea:** merge pools of multiple programs!
**Reality:** many pairs remain unmatched in a single iteration

**Idea:** merge pools of multiple programs!
**Reality:** many pairs remain unmatched in a single iteration

**Idea:** merge pools of multiple programs!
Issues with Collaboration

However, not everyone benefits equally from collaboration

- Conflict of interest: personal welfare versus social welfare
- Strategic choices (internal exchanges, withholding pairs)
Chapter 2: computing an “optimal withholding strategy” is (theoretically) difficult

Chapter 3: new mechanism for KEP collaborations
- Reporting all pairs often better than greedy withholding
- Outcomes very close to those obtained by merging pools
Part 2: Uncertainty in Kidney Exchange

Stage 1: proposal for a set of exchanges
Uncertainty: unexpected incompatibilities, pairs leaving prematurely
Stage 2: reconsider exchanges (*recourse*)

- Take into account stage 1 decision when reoptimizing
- Minimizing disappointment for stage 1 exchange patients
Part 2: Main Results

Optimization involves computing the worst-case failure scenario?

- New algorithm for this subproblem (Chapter 4)
- *Downward monotone interdiction games* (Chapter 5)
Conclusion

You get a kidney!
You get a kidney!

And YOU get a kidney!

EVERYBODY GETS A KIDNEY!
Multi-level Optimization Problems for Kidney Exchange

Doctoral defense

Danny Blom

15 december 2023