SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number:	**CA15210 – European Network for Collaboration on Kidney Exchange Programmes**
STSM title:	**Near-Optimal Algorithms for Stochastic Matching Problems in Kidney Exchanges**
STSM start and end date:	**25/03/2018 to 30/03/2018**
Grantee name:	**Paul Duetting**

PURPOSE OF THE STSM/

The purpose of this short-term scientific mission was to fund a one-week to initiate joint work between the grantee, Paul Duetting, Assistant Professor at London School of Economics, and the host, Ioannis Caragiannis, Associate Professor at University of Patras, on the algorithmic and strategic aspects of stochastic matching problems as they arise in the context of kidney exchanges. Particular emphasis will be on enhancing existing static models of stochastic matching with a temporal component, and on designing algorithms that are provably near-optimal for this enhanced set up. The proposed research although theoretical in nature is likely to have practical importance by informing the design of novel practical algorithms with improved performance.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

During the one-week visit the host, Iannis Caragiannis, and the grantee, Paul Duetting, worked on formulating a mathematical model and efficient algorithms for integrating deceased donors into kidney-paired donation programmes.

The proposed model starts from the observation that existing kidney-paired donation programmes periodically find cycles along which kidney exchanges can be performed. After these exchanges have been carried out, the remaining incompatible donor-recipient pairs induce a directed acyclic graph in which each donor-recipient pair is a vertex and there is a directed edge from donor-recipient pair A to donor-recipient pair B if the donor of pair A can donate to the recipient of pair B. Now when a potential kidney donator deceases his or her kidney can be given to a subset of the remaining recipients. Abstractly, the deceased donor becomes a vertex in the directed acyclic graph, with edges pointing to all donor-recipient pairs with compatible recipients. The idea is now that the deceased donor's kidney can be used to initiate a chain of donations along a directed path in the directed acyclic graph.

Typically there will be more than one possible path and the algorithmic question is which path should be chosen if there is more than one possible path, so that overall the number of donations through chains is maximized.

The host and the applicant have examined this question under three different computational models:

(1) An offline model in which it is known in advance which donors will decease. The optimal algorithm for this model serves as a benchmark for the other two models.

(2) An online model in which the sequence of donors that decease is determined by an adversary. Algorithms for this model can be deterministic, in which case the adversary gets to see which chains the algorithm has chosen, or randomized, in which case the adversary gets to see the code of the algorithm but not the outcome of the random choices. In both cases the quality of an algorithm is measured by means of the competitive ratio, the worst-case ratio between the total number of donations in the optimal offline algorithm and the algorithm at hand.

(3) An online model with probabilistic assumptions on the sequence of donors that decease. Algorithms in this model are assumed to know the distribution over input sequences, and may base their choices on this knowledge. The quality of an algorithm in this model is again measured by means of the competitive ratio, the relative loss vis-à-vis the optimal offline algorithm.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

In addition to formulating a formal mathematical for incorporating deceased donors into paired kidney donation programmes and computational models that enable the design and analysis of algorithms with provable performance guarantees for selecting deceased donor-initiated chains the host and the applicant have obtained the following results:

(1) A polynomial-time algorithm for the offline problem that given a pool of donor-recipient pairs that form a directed acyclic graph and a set of deceased donors finds the maximum number of donations that are possible through chains.
(2) A hardness result (NP-hardness and APX-hardness) in the same offline model when there is a cap on the maximum length of allowed chains.
(3) An upper bound on the competitive ratio of the deterministic polynomial-time online algorithm that always picks the longest possible chain in the adversarial model.
(4) A matching lower bond on the competitive ratio of any deterministic online algorithm, which shows that the simple greedy algorithm is best possible.
(5) A parametrized property of online algorithms in the probabilistic online model, which implies an upper bound on the competitive ratio.
(6) Several ideas on how a competitive online algorithm in the probabilistic online model could look like. Roughly: Given the expected arrival sequence precompute a distribution over routing trees, then pick a routing tree according to this distribution, and for each donor in the actual sequence of arrivals pick the longest possible path in that tree.

FUTURE COLLABORATIONS (if applicable)

The host, Iannis Caragiannis, and the grantee, Paul Duetting, decided to follow-up on the short-term scientific meeting through (a) weekly Skype meetings and (b) a follow-up visit in London in July/August with the goal of writing an article about the results obtained. As possible venues for publication the host and the applicant considered computer science conferences such as the ACM-SIAM Symposium on Discrete Algorithms (whose submission deadline is in August) or the ACM EC Conference on Economics and Computation (whose submission deadline is in February). They also plan to follow-up on the publication of an extended

abstract in the proceedings of a computer science conference with a publication in an econ, operations research, or medical journal.