

Graphical User Interface for Kidney Paired Donation Program

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Introduction

A **graphical user interface (GUI)** to visualize inputs and outputs from the **Kidney Paired Donation (KPD)** program is developed. KPD program is based primarily on micro-simulation models which enable us to evaluate and compare allocation strategies and effects of policy. There is no user friendly platform thus far that permits easy communications between inputs and outputs in the KPD program. Thus, the developed interface will facilitate the clinical research related to KPD program.

KPD Program and Optimization

1. Background

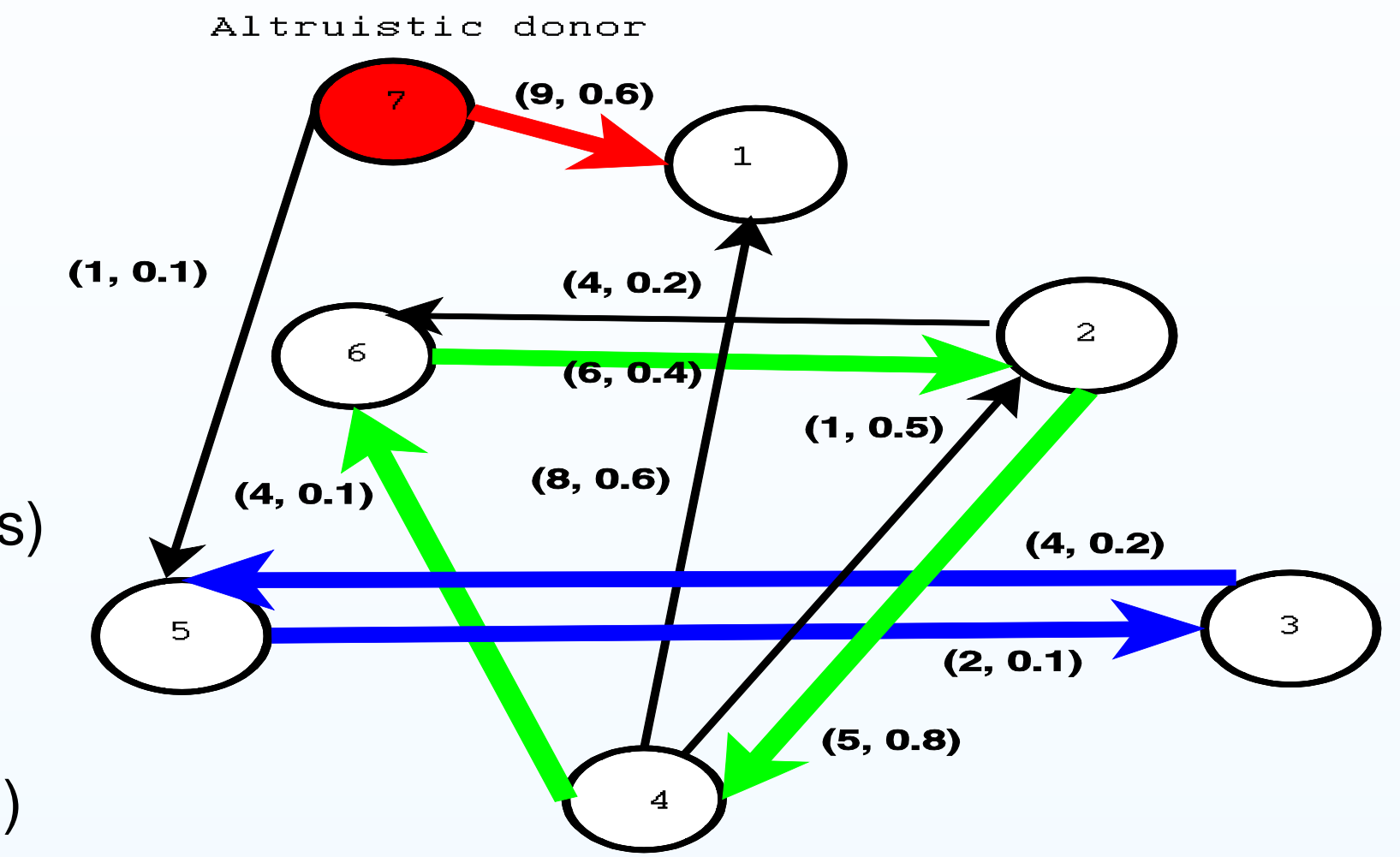
- 80,000 people awaiting kidney transplants, 16,000 transplants performed yearly. The availability of organs does not meet the excessive demand
- Donors incompatible with their recipients can still help their loved ones get live donor kidneys by matching with other incompatible pairs**

2. Objective

- Make **optimal** decisions to reach the **most mutual benefits** (e.g., more patients save life) from limited **resources** (kidney donors)

3. Solution: Optimized Matches via Constrained Graphic Optimization

- Graph: Each **node** represents an incompatible donor/recipient pair or altruistic donor, each **edge** represents a possible match
- Match: (1) Paired Donor-Patient Exchanges: 3⇔5, 2⇔4⇔6; (2) Chains for Altruistic Donors: 7⇒1; (3) Combination of (1) and (2)



Algorithm

Formulation: Integer Programming

$$\max \sum_{c \in C} y_c u_c,$$

$$s.t., y_c \in \{0,1\}, \forall c \in C,$$

$$\text{and } \sum_{c \in C(i)} y_c \leq 1, 1 \leq i \leq n$$

where C is the class of all cycles or chains of length three or less without or with altruistic donors, C(i) is the set of cycles or chains in C that contain vertex i and y_c is a vector of indicators representing if cycle or chain c is to be executed for transplant ($y_c=1$) or not ($y_c=0$), u_c is the expected utility of cycle c depending on edge utility e_{ij} and probability p_{ij} .

The solution to the above constrained maximization provides the optimal kidney exchange in a KPD program

System Configuration

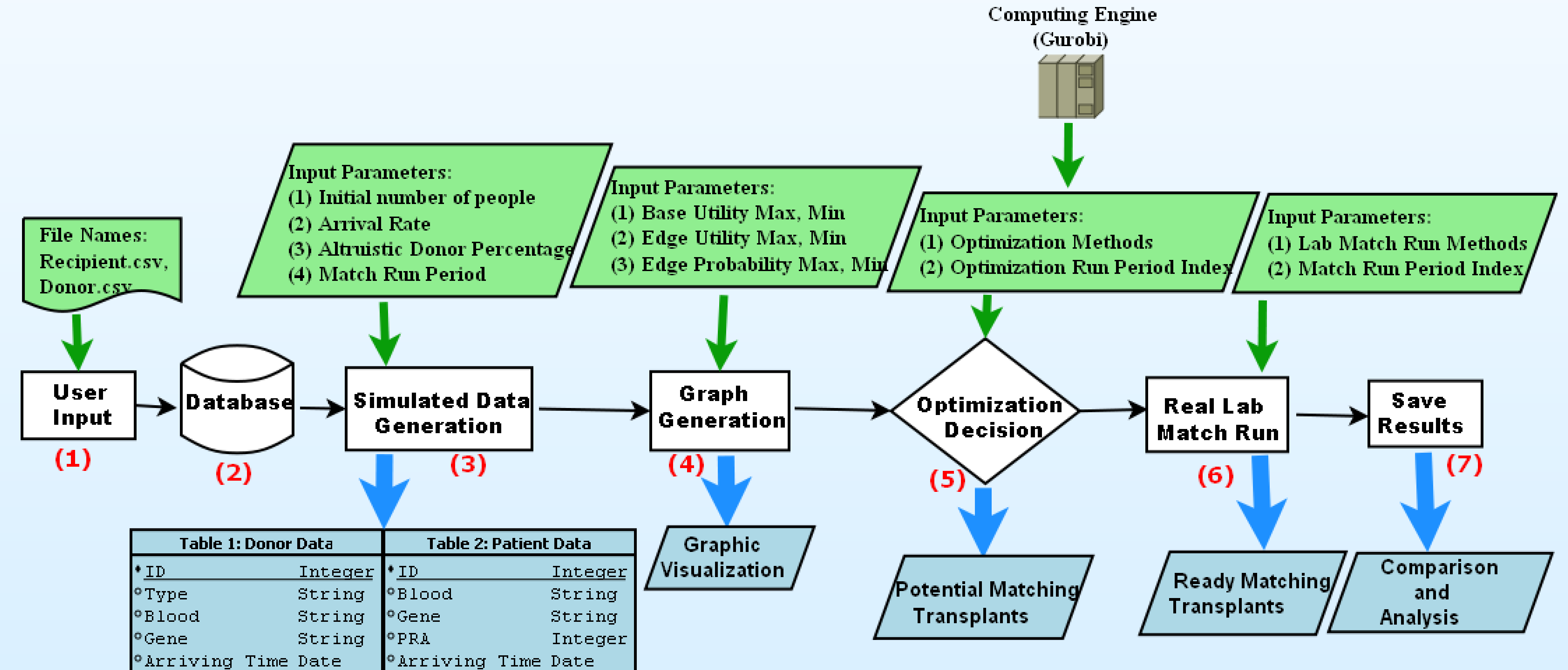
- The software consists of a comprehensive **frontend GUI** in Qt development environment and a **backend computing engine** powered by optimization integer programming software, such as Gurobi.

Computing Engine: the core of KPD program applies statistical data models and optimization functions to output matching results. It is written entirely in C++ and compiled into a binary executable code.

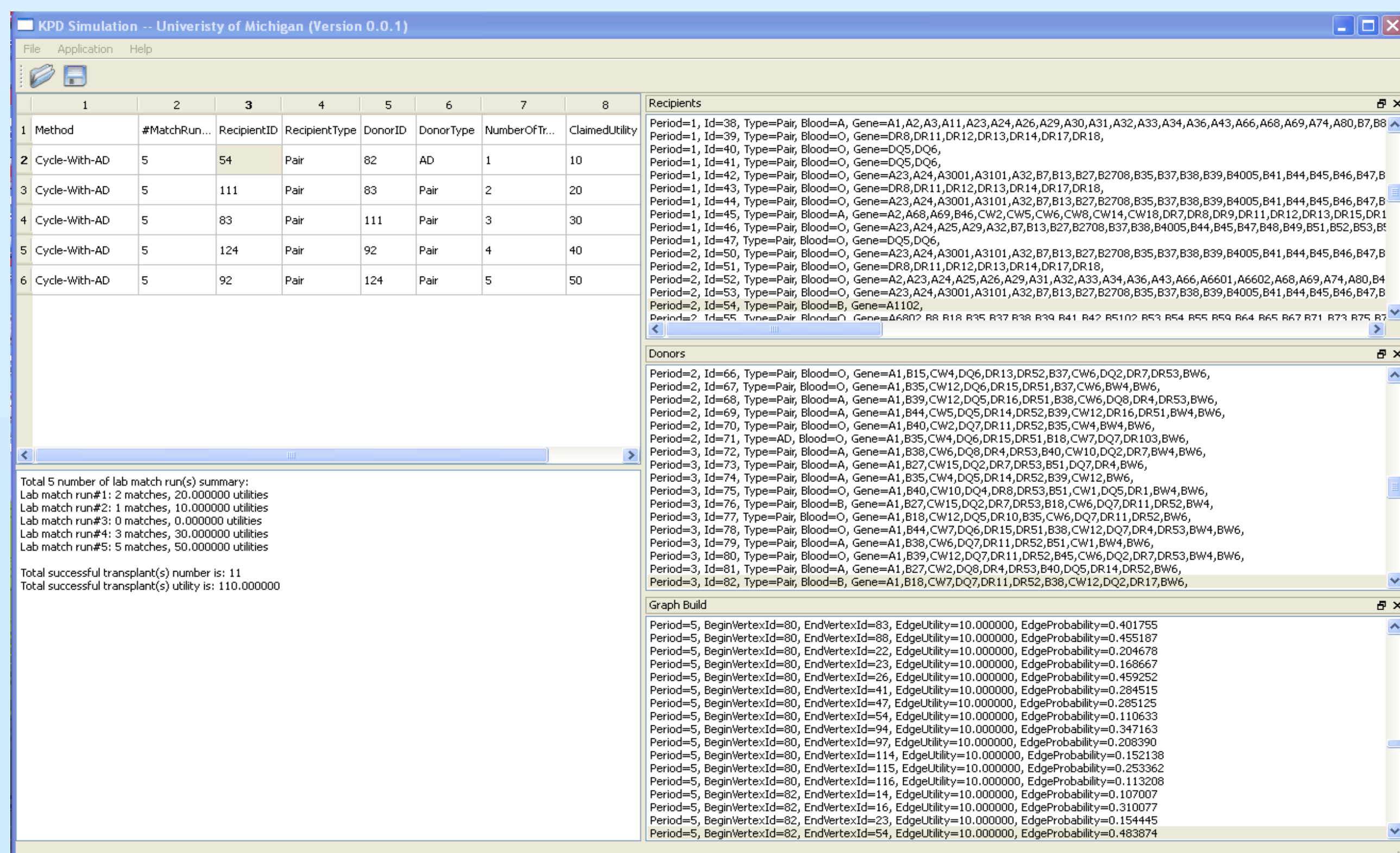
GUI's Primary Role: receive and process data from users, select modeling criteria and KPD parameters, and then to output results in easily accessible environments. GUI is developed in C++ too and also compiled into a separate executable program.

- Communication between the computing engine and the GUI is carried out through input and output files. Thus, the KPD software can be easily deployed across multiple platforms, such as Windows, Linux and Mac OS.

Micro-simulation Model Flowchart



GUI Software



Basic Components:

- Read data from users
- Build (secured) database
- Generate simulation data from database
- Generate graphic visualization
- Optimization decision: output potential matching transplants
- Real lab match run: output ready matching transplants
- Output and save results for analysis and comparison

Major Operations:

- Step 1:** Choose menu: **File** -> **Open** -> Input file names into **Read KPD Recipient and Donor File** dialog
- Step 2:** Select menu: **Application** -> **KPD Data Generation** -> Assign parameters in **KPD Data Generation Parameters** dialog -> Push **OK** to confirm the parameters -> Output the simulated recipients and donors data in the **Recipients** window and **Donors** window
- Step 3:** Select menu: **Application** -> **KPD Graph Generation** -> Assign parameters in **KPD Graph Generation Parameters** dialog -> Push **OK** to confirm the parameters -> Output the vertex and edge of simulated graph in the **Graph Build** window
- Step 4:** Select menu: **Application** -> **KPD Optimization Run** -> Choose method and period in **KPD Optimization Run Input** dialog -> Push **OK** to confirm -> Output the potential matching results in the **Central** window
- Step 5:** Select menu: **Application** -> **KPD Lab Match Run** -> Choose method and period in **KPD Match Run Input** dialog -> Push **OK** to confirm -> Output the ready matching results in the **Central** window
- Step 6:** Select menu: **File** -> **Save** -> Assign file name (.csv) for the current result -> Push **save** button to confirm

Future Work

- The system will allow to input data of patient/donor pairs and/or altruistic donors from three sources:
 - Existing secured database: BMTR (Bone Marrow Transplant Registry), APD (Allied for Paired Donation), NKR (National Kidney Registry), SRTTR (Scientific Registry of Transplant Recipients), Stanford (Stanford Medical School Blood Center), UM (University of Michigan KPD Program).
 - Statistical models that are trained from simulated data from the existing secured database
 - New inputs of patient/donor and/or altruistic donor data directly from users
- The system will build graphic visualization tools into the existing software for output analysis, which helps clinicians, donors and patients more easily visualize and assess the KPD program.

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