Cairo University, Faculty of Engineering
Computer Engineering Department
Data Structures and Algorithms

Data Structures and Algorithms
Project Requirements

Physiotherapy Center

Objective

To develop a system to efficiently manage patient appointments, therapist schedules, and the utilization of treatment devices within a ***physiotherapy center***. You are expected to design and implement a system that simulates the real world system. You should pick the most appropriate data structures and apply efficient algorithms to handle the system.

Project Phases

Phase	*%*
Phase 1.1	**10%**
Phase 1.2	**30%**
Phase 2	**60%**

Late Submission is not allowed.

Sharing your code with others through GitHub (for example) is counted as cheating. You are NOT allowed to publish your code publicly before the final exams.

Project Phases details and deliverables are released in another document.

Simulation Time (timestep)

Any reference to time means timestep. It is a counter starting at 1. At each timestep, some actions may occur, like a patient arriving, assigning a patient to a treatment, etc. After performing all actions of the current timestep, increment it.

Main Entities

Patients: For each patient, the system should store at least the following info:

- **Patient ID (PID):** A unique identifier for each patient.
- **Patient Type:** Either a normal or a recovering patient.
- **Appointment Time (PT):** The scheduled appointment time.
- **Arrival Time (VT):** The timestep the patient arrives at the center.
- **Required Treatments List:** **A list** of required treatments for that patient. For each treatment, you store its **duration** and some later assignment info.
- **Patient Status:**
  - **IDLE:** a patient who doesn't arrived yet (VT > current timestep)
  - **ERLY**: a patient arriving before PT. (i.e., VT < PT)
  - **LATE**: a patient arriving after PT. (i.e., VT> PT)
  - **WAIT**: a patient who is waiting for a treatment to start.
  - **SERV**: a patient being served (i.e., in a treatment session.)
  - **FNSH**: a patient who has finished ALL treatments

There are 3 types of **Treatments** and each type needs an available **Resource**:

- Electro-therapy **(E-therapy)**: the needed resource is an *electro device*.
- Ultrasound-therapy **(U-therapy)**: the resource is an *ultrasound device*.
- Exercises in a gym room **(X-therapy)**: the resource is a *gym room*.
  Note: A gym room may accommodate more than one patient (***Capacity***).

There are two types of **Patients**:

- Normal Patient (**N-Patient**): this patient must perform the required treatments in the same order given in the input file.
- Recovering Patient (**R-Patient**): this patient is almost recovered, so he can perform the required treatments in any order.

Important Definitions:

Assignment Time (ST): the timestep a request is picked for treatment.

Total Waiting Time (TW) for a single patient: a patient that is not in a treatment session is counted as waiting.

$$TW = \sum all\ time\ durations\ a\ patient\ is\ waiting$$

- **Total Treatment Time (TT) for a single patient:**

$$TT = \sum all\ time\ durations\ a\ patient\ is\ in\ treatment$$

- **Finish Time (FT):** The time when a patient is done with ALL his treatments.

$$FT = VT + TW + TT$$

Lists & Resources Assignment Criteria

Lists:

The **system lists** are:

1. ALL Patients: to be uploaded from the input file at startup.
2. Early Patients, Late Patients, Waiting Patients, In-treatment Patients, Finished Patients.
3. Available Treatment Resources: to pick from to serve the waiting patients.

Each **patient** has a Required-treatment **list**.

Rules:

- A patient can have at most 3 treatment types and cannot have the same treatment type more than once.
- Lists of waiting patients should be ordered by appointment time, so that the earliest appointment is first. (*Do you really need a priority queue here?*)
- To assign a patient to any treatment type, the needed resource should be available at the current timestep. Otherwise, the patient has to wait until the needed resource is available.
- A room can accommodate more than one patient at the same time, depending on the room capacity, which is loaded from the input file.

- **Early Patients:**
  Early patients are the patients with VT < PT. Once arrived, they should be added to a separate list. This list is sorted by appointment time, so that the earliest appointment is first. When the appointment time comes, the patient is moved to the appropriate waiting list.

- **Late Patients:**
  Late patients are the patients with VT > PT. Once arrived, they should be added to a separate list. They must wait in the list half of their late duration as a late penalty before being added to the appropriate waiting list. BUT when adding him to a waiting list, place him sorted according to his actual **PT+penalty.**
  Example: if PT=10 and VT=16, then late penalty = 3.
  Then at timestep 19 (16+3), he will leave the "Late" list and join a waiting list but should be placed sorted so that he should precede all patients with PT > 13 (10+3).

- **Treatment Cancellation:**
  A patient is allowed to cancel only if:
  - He is currently waiting in the X-therapy waiting list (exercises).
  - The exercises are his last required treatment.

  There is a probability (***Pcancel***) that a patient in this list cancels and leaves the center (**goes to the finish list**). **Pcancel** should be loaded from the

input file. Each timestep, you should generate a number from 0 to 100 and if it is less than **Pcancel**, pick a ***random*** patient (not always the first patient) from this X-therapy waiting list to cancel and leave.

- **Treatment rescheduling**
  A patient is allowed to reschedule to a **new PT** only if:
  - He is currently in the early list.
  - The new PT is greater than his original PT.

  There is a probability (***Presc***) that a patient in this list asks for a new PT. ***Presc*** should be loaded for the input file. Each timestep, you should generate a number from 0 to 100 and if it is less than ***Presc***, pick a ***random*** patient (not always the first patient) from the early list to reschedule. The new PT should be generated randomly and be greater than the old PT. (*Think: Where should you place that patient after rescheduling?*)

Patients Assignment example scenario for NP

Assume we have a **normal** patient (**NP**) with [*PT= **50**, VT = 40* and 2 required treatments *{U 10, E 5}*] i.e. He needs U-therapy for 10 timesteps, E-therapy for 5.

1. At 40, the patient should be moved from "ALL" list to "Early" list. The priority in the Early list is related to **the appointment time PT** (50).
2. At time 50, he should be moved to the "Ultra waiting" list as it is the first treatment in his list.
3. After that, when this patient is picked to be assigned to an ultrasound device, he should be moved to "In-treatment" list for 10 timesteps.
4. Then the patient should be moved from the in-treatment list to the "Electro waiting" list.
5. After that, when this patient is picked to be assigned to an electrotherapy device, he should be moved to the "In-treatment" list again for 5 timesteps.
6. Then he should be moved to the "Finish" List.

What about Recovering Patient (RP)

The same assignment algorithm applies, but remember that for RP, the assignment order doesn't matter. So, before he joins ANY waiting list, he should check the treatment latency (***TL***) for each waiting list **he may join** and then join the waiting list with the minimum TL. For example TL for Ulrta-Wait list

TLu = $\sum$ all **ultra** treatment durations for ALL patients in Uwait list

A note about room assignment.

As long as the room has vacancies, more patients could be assigned to it. Once full, the room should be moved from the available rooms list. The first patient leaving a full room should return it back to the available list again.

Input/Output File Formats

The Input File Format

- Line 1 contains **NE** (the number of all E-therapy devices), **NU** (the number of all U-therapy devices), **NG** (the number of all X-therapy Gym rooms).
- Line 2 contains the capacity of each ***NG*** room.
- Line 3 contains the cancel and rescheduling probability **Pcancel** and **Pres*c*** %, two integers from 0 to 100.
- Line 4 contains ***P*** (the number of all patients).
- Then ***P*** lines, where each line represents the information of a patient.
- Each of the ***P*** lines contains:
  1. Patient Type: one char, ***N*** for normal, and ***R*** for recovering.
  2. Appointment time (**PT**) and Arrival time (**VT**).
  3. Number of required treatments by this patient (**NT**), then for each required treatment, input its **Type** and **Duration**. Each treatment type is one char: ***E*** for E-therapy, ***U*** for U-therapy, and ***X*** for X-therapy. **Note:** each patient can have **at most** 3 treatment types and cannot have the same treatment type more than once.
- Note: All the info of the same patient is in the same line.

  Example 1:
  N 50 40 **2** U 10 X 5
  This patient is normal (N), has an appointment at timestep 50, will arrive at timestep 40, and has **2** required treatments: a U-therapy for 10 timesteps (duration) then an X-therapy for 5 timesteps (treatment order matters).

  Example 2:
  R 30 35 **3** U 6 E 5 X 10
  This patient is recovering (R), has an appointment at 30, will arrive at 35 (late), and has **3** required treatments: a U-therapy for 6 timesteps, an E-therapy for 5 timesteps, then an X-therapy for 10 timesteps.

- NOTE: The input lines of all requests are sorted by **the arrival time (VT)** in ascending order. Think about how to use this note appropriately.

Sample Input File

3 1 2	☐ 3 E-therapy devices, 1 U-therapy device, **2** X-therapy gym rooms.
10 5	☐ For the 2 gym rooms, capacity of 1st is 10 patients, and 2nd is 5.
10 30	☐ Pcancel = 10% and Presc = 30%.
4	☐ 4 patients, then we have 4 lines next, one per patient.
N 30 25 **3** E 5 U 12 X 10	
R 30 35 **3** U 6 E 5 X 10	
R 50 40 **1** X 5	
N 40 40 **2** X 15 U 10	

The Output File Format (Phase2)

- The output file you are required to produce contains **P** output lines (a line for each patient) in the following format:
  1. Patient ID (**PID**) and Patient Type (**PType**).
  2. Appointment time (**PT**) and Arrival time (**VT**).
  3. Finish time (**FT**).
  4. Total waiting time for this patient (**WT**).
  5. Total treatment time for this patient (**TT**).
  6. Whether doing an accepted cancel (one char: ***T*** if true, ***F*** if false).
  7. Whether doing an accepted reschedule (one char: ***T*** if true, ***F*** if false).
- **Important Note:** The output lines of patients **must be sorted** by finish time **FT** in **descending** order. Do we need to perform a sorting approach? Is there a better way?
- Then the following statistics should be shown at the end of the file.
  1. Total number of timesteps.
  2. Total number of all, N, and R patients.
  3. Average total waiting time for all, N, and R patients.
  4. Average total treatment time for all, N, and R patients.
  5. Percentage of patients whose cancellation is accepted (%).
  6. Percentage of patients whose rescheduling is accepted (%).
  7. Percentage of early patients (%).
  8. Percentage of late patients (%).
  9. Average number of timesteps of the late penalty applied for all late patients.

Sample Output File

The following numbers are just for clarification and not produced by actual calculations. **Make sure to use the same format with all sentences**.

PID	PType	PT	VT	FT	WT	TT	Cancel	Resc
P4	N	50	40	80	20	20	**T**	F
P1	R	20	20	50	14	16	**T**	F
P3	R	10	12	40	8	20	F	**T**
P2	R	10	8	30	5	17	F	F

Total number of timesteps = 80
Total number of all, N, and R patients = 4, 1, 3
Average total waiting time for all, N, and R patients = 11.75, 20, 9
Average total treatment time for all, N, and R patients = 18.25, 20, 17.67
Percentage of patients of an accepted cancellation (%) = 50 %
Percentage of patients of an accepted rescheduling (%) = 25 %
Percentage of early patients (%) = 50 %
Percentage of late patients (%) = 25 %
Average late penalty = 1 timestep(s)

Program Interface

The program can run in one of two modes: **interactive,** or **silent mode**.

1. Interactive Mode: Allows the user to monitor the system. In this mode, the program prints the current time then pauses for an input from the user ("Enter" key for example) to display the output of the next timestep.

```
Current Timestep:  85
==============  ALL List  =================
512 patients remaining:  P100_90, P101_90, P102_92, P103_93, P104_97, .....
—>  Print ONLY the first 10 patients currently in the ALL list
============== Waiting Lists  =================
2 E-therapy patients: 2, 7
4 U-therapy patients: 13 ,15 , 45, 12
5 X-therapy patients: 5, 10, 4, 6, 9
==============  Early List  =================
4 patients: 22, 33, 44, 55
==============  Late List  =================
2 patients: 17, 52
==============  Avail E-devices ==============
3 Electro device: 4, 21, 90
==============  Avail U-devices ==============
2 Ultra device: 2, 7
==============  Avail X-rooms ==============
2 rooms: R3[3, 10],  R6[8, 9]
============  In-treatment List  ==============
20 ==> P13_E2, P3_U5, P8_R2 ..... print all
-----------------------------------------------------
5 finished patients: 89, 33, 57, 18, 1 (Recently finished patients are printed first)
Press any key to display next timestep
```

Output Screen Explanation

- ❑ First, a part of the "ALL" list is printed. P100_90: Patient 100 arrives at 90.
- ❑ Counts and IDs of patients in waiting lists, early list, and late list are printed.
- ❑ Then lists of available devices are printed.
- ❑ Then for each non-full room, print Room ID followed by **[**current number of patients inside this room, then room capacity**].**
- ❑ Then print in-treatment list. For each patient, print ID, assigned resource.
- ❑ Then the finish list.

The above screen is just for explanation and is not generated by actual simulation.

2. Silent Mode, the program produces only an output file. It does not print any simulation steps on the console, just prints

```
Silent Mode, Simulation ends, Output file created
```

NOTE: No matter what mode of operation, **the output file** should be produced.