Project 2
Plane-Simulation

班级：2016 级软件工程行政 7 班

徐伟元 16340261

杨泓臻 16340269

徐达烽 16340260

【题目要求】

用队列实现一个模拟飞机场调度飞机降落和起飞的程序。

P1、用飞机场模拟程序做若干次实验，调整准备着陆和起飞的飞机数的期望值，并找出在飞机不会被拒绝服务的条件下这些数字尽可能大的近似值。如果队列的长度增加或减少，那么这些值将会有什么变化？

P2、修改模拟程序，使飞机场有两条飞机跑道，其中一条总是用来着陆，另一条总是用来起飞。比较双跑道机场能服务的总飞机数和单条飞机跑道的飞机场的相应数字，前者是否为后者的两倍？

P3、修改模拟程序，使飞机场有两条飞机跑道，其中一条总是用来着陆，另一条总是用来起飞。如果某个队列是空的，那么两条跑道都能用于其他的队列。如果着陆队列总是满的，并且另一架飞机要到达着陆，那么将停止起飞，并将两条跑道都用于清理搁置的着陆飞机。

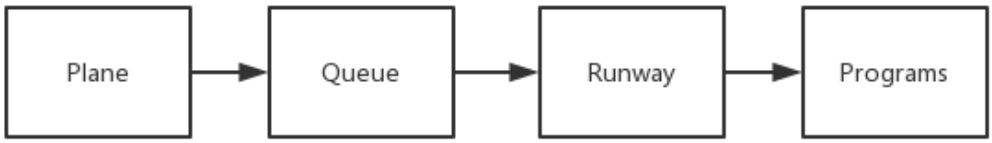
P4、修改模拟程序，使飞机场有 3 条飞机跑道，其中各保留一条总是用于着陆和起飞，第三条用于着陆，但在着陆队列为空的情况下，第三条亦可用于起飞。

P5、修改 P1 的模拟程序（单条跑道），使得当每架飞机到达着陆时，它将有一个随机的油量，以剩余的飞行时间为单位。如果飞机没有足够的油量在队列中等待，则允许它立即着陆。

P6、写一个占位程序来代替随机函数，这个占位程序既能用于调试程序又允许用户正确地控制每一个时间单元内每个队列到达的飞机数。

【数据结构与算法】

数据结构：



Plane 对象包含一架飞机的序号、时间，飞行状态等信息，可以有指挥其起飞、降落或拒绝请求等操作。

Queue 对象是 Plane 的队列，存有若干架飞机的信息，可以有出队，入队，清空队列，查看队列长度，查看队头等操作。

Runway 对象描述一条跑道，记录了这个项目大部分的重要统计信息，包括统计请求起飞/降落，成功起飞/降落，被拒绝起飞/降落的飞机数，跑道空置的时间，跑道利用率等。两个方法 can_land，can_depart 能告知当前新加飞机能否进入降落/起飞队列（如果某个队列已满就不能进入）。activity 方法则进行当前时刻的操作，即选择降落或者起飞一架飞机。

另外 Random 对象产生随机数，帮助程序模拟。

有了以上的类后，我们就可以根据各个问题的不同要求来实现飞机场的模拟了。

算法设计：

P1-P4，根据问题要求，将课本给出的所有代码组装好，并添加细节，模拟实现即可。

P5，降落队列的飞机对象加多一个属性，即油量。油量耗尽就可能坠毁。我是这么处理的，先根据飞机到达时间和油量，得出飞机的最晚着陆时间（当飞机超过

最晚着陆时间仍未着陆，就可能坠毁)。为了避免更多飞机坠毁，很明显，最晚着陆时间早的飞机应该优先着陆。如果最晚着陆时间相同，则先来先着陆。为了方便实现这个过程，我使用了优先队列（std::priority_queue)。并且在每一时刻处理更新下时间赶不及，已经坠毁的飞机。

P6，提供一个操作模式给用户选择，即用户可以选择手动或者自动模式，然后再选 P1-P5 进行模拟即可。

【测试数据、结果及分析】

P1

```
Enter the serial number of operation you want to do:
[0] change input mode(manual/auto). Current mode is auto
[1] an airport with only one runway.
[2] an airport with two runways, one always used for landingsand onealwaysused f
or takeoffs.
[3] an airport with two runways, one usually used for landings and one usually u
sed for takeoffs.If one of the queues is empty, then both runways can be used fo
r the other queue. Also, if the landing queue is full and another plane arrives
to land, then takeoffs will be stopped and both runways used to clear the backlo
g of landing planes.
[4] an airport with three runways, one always reserved for each of landing and t
akeoff and the third used for landings unless the landing queue is empty, in whi
ch case it can be used for takeoffs.
[5] an airport with only one runway, but the plane may run out of fuel and then
crash
Or Enter [Q] or [q] to exit the program
1
One plane can land or depart in each unit of time.
Up to what number of planes can be waiting to landor take off at any time?10
How many units of time will the simulation run?100
Expected number of arrivals per unit time?0.4
Expected number of departures per unit time?0.4
```

序列床度为 10，模拟一百次，到达与起飞飞机频率都是 0.4 的情况下的模拟结果：

```
Total number of planes processed 67
Total number of planes asking to land 31
Total number of planes asking to takeoff 36
Total number of planes accepted for landing 31
Total number of planes accepted for takeoff 36
Total number of planes refused for landing 0
Total number of planes refused for takeoff 0
Total number of planes that landed 31
Total number of planes that take off 34
```

```
Total number of planes left in landing queue 0
Total number of planes left in takeoff queue 2
Percentage of time runway idle 35%
Average wait in landing queue 0.0645161 time units
Average wait in takeoff queue 0.852941 time units
Average observed rate of planes waiting to land  0.31 per time unit
Average observed rate of planes waiting to take off  0.36 per time unit
```

此时没有飞机被拒绝服务。

将频率都提高到 0.5 试试：

```
One plane can land or depart in each unit of time.
Up to what number of planes can be waiting to landor take off at any time?10
How many units of time will the simulation run?100
Expected number of arrivals per unit time?0.5
Expected number of departures per unit time?0.5
```

```
Total number of planes processed 95
Total number of planes asking to land 48
Total number of planes asking to takeoff 47
Total number of planes accepted for landing 48
Total number of planes accepted for takeoff 47
Total number of planes refused for landing 0
Total number of planes refused for takeoff 0
Total number of planes that landed 48
Total number of planes that take off 42
Total number of planes left in landing queue 0
Total number of planes left in takeoff queue 5
Percentage of time runway idle 10%
Average wait in landing queue 0.229167 time units
Average wait in takeoff queue 3.83333 time units
Average observed rate of planes waiting to land  0.48 per time unit
Average observed rate of planes waiting to take off  0.47 per time
```

将频率一起提高到 0.6，就有起飞的飞机被拒绝了

```
Total number of planes processed 112
Total number of planes asking to land 59
Total number of planes asking to takeoff 53
Total number of planes accepted for landing 59
Total number of planes accepted for takeoff 44
Total number of planes refused for landing 0
Total number of planes refused for takeoff 9
Total number of planes that landed 59
```

```
Total number of planes that take off 38
Total number of planes left in landing queue 0
Total number of planes left in takeoff queue 6
Percentage of time runway idle 3%
Average wait in landing queue 0.40678 time units
Average wait in takeoff queue 10.1842 time units
Average observed rate of planes waiting to land  0.59 per time unit
Average observed rate of planes waiting to take off  0.53 per time unit
```

经多次实验，队列长度为 10 的情况下，不导致被拒绝情况发生的飞机最大频率大约在 0.55

队列长度修改为 20，频率为 0.6+0.6，模拟 150 次的情况，

```
Total number of planes processed 175
Total number of planes asking to land 90
Total number of planes asking to takeoff 85
Total number of planes accepted for landing 90
Total number of planes accepted for takeoff 75
Total number of planes refused for landing 0
Total number of planes refused for takeoff 10
Total number of planes that landed 90
Total number of planes that take off 57
Total number of planes left in landing queue 0
Total number of planes left in takeoff queue 18
Percentage of time runway idle 2%
Average wait in landing queue 0.455556 time units
Average wait in takeoff queue 19.3509 time units
Average observed rate of planes waiting to land  0.6 per time unit
Average observed rate of planes waiting to take off  0.566667 per time unit
```

少量飞机被拒绝起飞。

频率修改为 0.7+0.7

```
Total number of planes processed 205
Total number of planes asking to land 103
Total number of planes asking to takeoff 102
Total number of planes accepted for landing 103
Total number of planes accepted for takeoff 68
Total number of planes refused for landing 0
Total number of planes refused for takeoff 34
Total number of planes that landed 100
```

```
Total number of planes that take off 49
Total number of planes left in landing queue 3
Total number of planes left in takeoff queue 19
Percentage of time runway idle 0.666667%
Average wait in landing queue 0.66 time units
Average wait in takeoff queue 30.0204 time units
Average observed rate of planes waiting to land  0.686667 per time unit
Average observed rate of planes waiting to take off  0.68 per time unit
```

大量飞机被拒绝起飞。

经多次测试，队列长度为 20 时，大概 0.57 左右的频率是临界值。

总结：随着队列长度的增长，极限频率值会略有上升，但上升的幅度很小。而模拟的次数越多，飞机被拒绝的概率就越高。

P2

两条跑道的情况。

模拟 150 次，队列长度 20，频率 0.8+0.8 下的模拟结果：

```
Total number of planes processed 244
Total number of planes asking to land 121
Total number of planes asking to takeoff 123
Total number of planes accepted for landing 121
Total number of planes accepted for takeoff 123
Total number of planes refused for landing 0
Total number of planes refused for takeoff 0
Total number of planes that landed 121
Total number of planes that take off 123
Total number of planes left in landing queue 0
Total number of planes left in takeoff queue 0
Percentage of time runway idle 18.6667%
Average wait in landing queue 1.21488 time units
Average wait in takeoff queue 2.30894 time units
Average observed rate of planes waiting to land  0.806667 per time unit
Average observed rate of planes waiting to take off  0.82 per time unit
```

没有飞机被拒绝服务。

频率升高到 1+1 呢？

```
Total number of planes processed 294
Total number of planes asking to land 148
Total number of planes asking to takeoff 146
Total number of planes accepted for landing 148
Total number of planes accepted for takeoff 146
Total number of planes refused for landing 0
Total number of planes refused for takeoff 0
Total number of planes that landed 143
Total number of planes that take off 146
Total number of planes left in landing queue 5
Total number of planes left in takeoff queue 0
Percentage of time runway idle 3.66667%
Average wait in landing queue 5.73427 time units
Average wait in takeoff queue 2.9863 time units
Average observed rate of planes waiting to land  0.986667 per time unit
Average observed rate of planes waiting to take off  0.973333 per time unit
```

没有飞机被拒绝服务。并且可以看到，跑道闲置率稍有升高。

频率 1.2+1.2 试一下？

```
Total number of planes processed 294
Total number of planes asking to land 148
Total number of planes asking to takeoff 146
Total number of planes accepted for landing 148
Total number of planes accepted for takeoff 146
Total number of planes refused for landing 0
Total number of planes refused for takeoff 0
Total number of planes that landed 143
Total number of planes that take off 146
Total number of planes left in landing queue 5
Total number of planes left in takeoff queue 0
Percentage of time runway idle 3.66667%
Average wait in landing queue 5.73427 time units
Average wait in takeoff queue 2.9863 time units
Average observed rate of planes waiting to land  0.986667 per time unit
Average observed rate of planes waiting to take off  0.973333 per time unit
```

没有飞机被拒绝服务。

频率为 1.3+1.3 的情况

```
Total number of planes processed 391
Total number of planes asking to land 197
Total number of planes asking to takeoff 194
Total number of planes accepted for landing 168
Total number of planes accepted for takeoff 167
Total number of planes refused for landing 29
Total number of planes refused for takeoff 27
Total number of planes that landed 149
Total number of planes that take off 149
Total number of planes left in landing queue 19
Total number of planes left in takeoff queue 0
Percentage of time runway idle 0.666667%
Average wait in landing queue 13.8859 time units
Average wait in takeoff queue 13.3893 time units
Average observed rate of planes waiting to land  1.31333 per time unit
Average observed rate of planes waiting to take off  1.29333 per time unit
```

可见，两条跑道服务的飞机数量能达到一条跑道的两倍。经多次实验，两条跑道的极限频率大约是 1.25 左右。

P3

150 次模拟，队列长度 20，频率 1.3+1.3 的情况

```
Total number of planes processed 391
Total number of planes asking to land 197
Total number of planes asking to takeoff 194
Total number of planes accepted for landing 182
Total number of planes accepted for takeoff 167
Total number of planes refused for landing 15
Total number of planes refused for takeoff 27
Total number of planes that landed 164
Total number of planes that take off 149
Total number of planes left in landing queue 18
Total number of planes left in takeoff queue 0
Percentage of time runway idle 0.666667%
Average wait in landing queue 12.622 time units
Average wait in takeoff queue 13.3893 time units
Average observed rate of planes waiting to land  1.31333 per time unit
Average observed rate of planes waiting to take off  1.29333 per time unit
```

被拒绝的降落/起飞的飞机数为 15/27，比 P2 中略有下降，因为 P3 中两条跑道可以交叉使用，利用率更高。

P4

150 次模拟，队列长度 20，频率 1.2+1.2 的情况

```
Total number of planes processed 370
Total number of planes asking to land 193
Total number of planes asking to takeoff 177
Total number of planes accepted for landing 180
Total number of planes accepted for takeoff 168
Total number of planes refused for landing 13
Total number of planes refused for takeoff 9
Total number of planes that landed 162
Total number of planes that take off 149
Total number of planes left in landing queue 18
Total number of planes left in takeoff queue 0
Percentage of time runway idle 30.8889%
Average wait in landing queue 11.0741 time units
Average wait in takeoff queue 12.1879 time units
Average observed rate of planes waiting to land  1.28667 per time unit
Average observed rate of planes waiting to take off  1.18 per time unit
```

P5

显然是否有飞机会坠毁跟飞机油的余量大小有直接关系。

队列长度为 30，模拟时间为 200，降落/起飞频率为 4+4，油量 10 至 20，结果为：

```
Total number of planes processed 1558
Total number of planes asking to land 801
Total number of planes asking to takeoff 757
Total number of planes accepted for landing 391
Total number of planes accepted for takeoff 30
Total number of planes refused for landing 410
Total number of planes refused for takeoff 727
Total number of planes that landed 199
Total number of planes that take off 0
Total number of planes left in landing queue 28
```

```
Total number of planes left in takeoff queue 30
Percentage of time runway idle 0.5%
Average wait in landing queue 14.9698 time units
Average wait in takeoff queue -1.#IND time units
Average observed rate of planes waiting to land  4.005 per time unit
Average observed rate of planes waiting to take off  3.785 per time unit
164 planes crash!
```

164 架飞机坠机，减小频率到 2+2 时，坠机 137 架；频率为 1.5+1.5，坠机 55 架；频率为 1.2+1.2 时，坠机 30 架。

频率 1+2 时，坠机零架。

答案很显而易见，只要飞机到达的频率高于 1，那么就可能发生坠机事故。

P6

手动输入数据模式，在初始界面中输入 0 即可进行自动/手动的模式切换。

【分工、贡献%、自我评分】

人员	分工	贡献%	自我评分
徐伟元	基础代码+P1	40%	95
杨泓臻	题解思路+P2 P3 P4	30%	95
徐达烽	Debug+P5 P6	30%	85

【项目总结】

与项目一相比，这个项目更偏向于工程。在以往学习 C++的过程中，也很少接触这一级别的工程型代码。所以这次作业帮助我们重新复习了 C++的很多知识。如

果让我们自己从零开始实现，估计项目的组织会比较冗杂和凌乱，很难写得像课本给的框架那么清晰。课本提供的这种面向对象的编程方式，简洁而优美，也很值得我们仔细品味，吸收内化。

当然课本也不是十全十美的，代码中有错误的地方，修正也花了比较长的时间。P5 中需求做了比较大的改动（即加了油量这一重要属性），我在纠结用什么方法来做，可以实现大部分的代码重用而不失优雅。考虑了很多方案，最终想到用 priority_queue 取代 queue，因为如果 priority_queue 比较的是飞机的序号，那么就相当与一个普通的 queue 嘛，所以能够很方便地实现 P5 和 P1-P4 的代码重用。所以这次项目的最大收获时重温了 C++，C++不仅仅是 C with classes， 而是一门非常强大的语言。

我们另外的收获是获得了团队合作的经验。上一次项目只是一个简单算法题，单人即可完全全部代码。这次项目代码量很大，团队合作尤为重要。于是我们学习了将代码放到远程仓库 GitHub 时进行协作，这样可以大大提高协作效率。