

Simulating a doctor's waiting room

Goal: Simulate the queuing behavior at a doctor's office.

Assumptions:

1. Patients arrive on the minutes between 9:00 am and 11:59 am.
2. At most one patient arrives during any minute.
3. The probability that a patient arrives in any one minute is 0.075.
4. Each patient needs to meet with the doctor for 15 minutes.

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Expectations:

1. How many patients does the doctor expect to see in the day?
2. How much time does the doctor expect to spend with patients?

Simulating a doctor's waiting room

How do we simulate the arrival of patients?

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$i = \underline{\quad}$ occurs at time 11:59 am.

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$i = \underline{\quad}$ occurs at time 11:59 am.

We set up a For loop:

```
For[ $i = 0$ ,  $i$  _____,  $i$  _____,
  newPatient = If[RandomReal[] <= 0.075, 1, 0] ]
```

Dealing with the waiting

How do we simulate “waiting” in a “waiting room”?

An arriving patient will wait when _____.

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An arriving patient will wait when _____.

We will keep track of the following variables:

`nwait` = The number of patients waiting.

`endTime` = The time when the current patient finishes with the doctor.

`busy` = $\left\{ \begin{array}{l} 1 \text{ if the doctor is busy} \\ 0 \text{ if the doctor is free} \end{array} \right\}$

Simulating a doctor's waiting room

Now translate the flowchart into an algorithm:

Pseudocode:

- ▶ Zero out the counters.
- ▶ For `i` from 0 up to 180,
 - ▶ If the doctor is finishing with a patient at time `i`, then set `busy=0`.
 - ▶ Determine if a new patient arrives (random, probability 0.075).
If so, set `newPatient` to 1; otherwise set `newPatient` to 0.
 - ▶ If `newPatient == 1`, add one to the number waiting (`nwait++`)

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If so, set `newPatient` to 1; otherwise set `newPatient` to 0.
 - ▶ If `newPatient == 1`, add one to the number waiting (`nwait++`)
 - ▶ If the doctor is not busy AND there is a patient waiting,
 - ▶ Subtract one from the number waiting (`nwait--`)
 - ▶ Set the doctor to be busy (`busy = 1`)
 - ▶ Set the time when the doctor is not busy (`endTime = i + 15`).

Dealing with the waiting

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
]
```

- ▶ For i from 0 up to 180,
 - ▶ If the doctor is finishing with a patient at time i , then set `busy=0`.
 - ▶ Determine if a new patient arrives (random, probability 0.075).
If so, set `newPatient` to 1; otherwise set `newPatient` to 0.
 - ▶ If `newPatient == 1`, add one to the number waiting (`nwait++`)
 - ▶ If the doctor is not busy AND there is a patient waiting,
 - ▶ Subtract one from the number waiting (`nwait--`)
 - ▶ Set the doctor to be busy (`busy = 1`)
 - ▶ Set the time when the doctor is not busy to $i + 15$.

What does the simulation tell us?

We did the simulation, but what was the point?

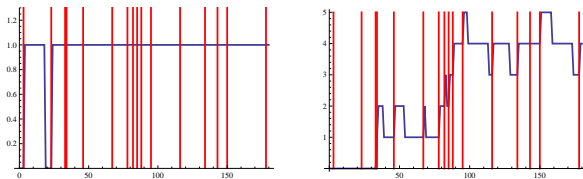
- ▶ How much of the day will the doctor will be busy?
- ▶ What is the average number of patients in the waiting room?
- ▶ How many people are in the waiting room at noon?
- ▶ How late will the doctor stay after noon?

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- ▶ How much of the day will the doctor will be busy?
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- ▶ How late will the doctor stay after noon?

What statistics do we need to keep track of to answer these questions?



This is just one instance; the power of simulation comes from running the model many times and understanding the average behavior.

Gathering data

- ▶ How many people are in the waiting room at noon?

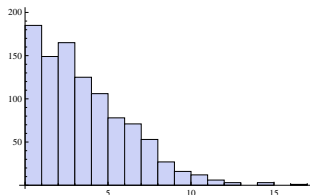
```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
];
nwait ← [Outputs the value after the loop ends.]
```

Running many trials

- ▶ How many people are in the waiting room at noon?

Simulate 1000 times using a Table command, generate a histogram.

```
trials = Table[
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
];
nwait ], {j,1000}]
Mean[trials] ← [Average: 3.105]
Histogram[trials]
```



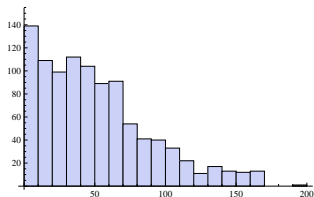
Gathering data

- ▶ How late will the doctor stay after noon?

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
];
```

↑ [*How to calculate how long
the doctor has to stay after noon?*]

Mean: 51 minutes (does this make sense?)



Gathering data

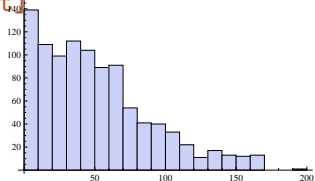
- How late will the doctor stay after noon?

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
];
```

```
If[busy == 0, 0, endTime + 15 * nwait]
```

↑ *[How to calculate how long
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Mean: 51 minutes (does this make sense?)

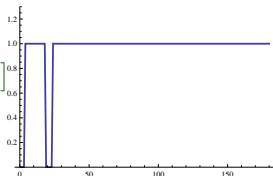


Gathering and plotting time-dependent data

- How much of the day will the doctor will be busy?

Keep track of if the doctor is busy by using a variable `isBusy`.

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
  isBusy[i]=busy; ← [this copies busy into isBusy[i].]
];          ↓ [Puts data into a list.]
busyList=Table[isBusy[i],i,0,179]
Total[busyList] ← [Total time busy.]
ListLinePlot[busyList]
```



Gathering and plotting time-dependent data

- What is the average number of patients in the waiting room?

Keep track of number of waiting patients by using a variable numWait.

```
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
  If[endTime == i, busy = 0];
  newPatient = If[RandomReal[] <= 0.075, 1, 0];
  If[newPatient == 1, nwait++];
  If[busy == 0 && nwait > 0,
    nwait--; busy = 1; endTime = i + 15];
  numWait[i]=nwait; ← [this copies nwait into numWait[i].]
];          ↓ [Puts data into a list.]
waitList=Table[numWait[i],i,0,179]
m=Mean[waitList] ← [Average patients.]
p1=ListLinePlot[waitList];
p2=Plot[m,x,0,179];
Show[p1,p2]
```

