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## Simulation Code - MATH 3020

Ncomputers=20 # Number of computer in the Network  
Nclean=5;  
N=1000 # Total Simulation  
prob=0.1 # Probability of infected  
  
save\_Days=rep(NA,N)  
save\_count\_infected=matrix(rep(NA,N\*Ncomputers),N,Ncomputers)  
  
for (j in 1:N)  
{  
 infected=rep(0,Ncomputers)  
 count\_infected=rep(0,Ncomputers)  
 Each\_infected<-NULL  
 # One computer becomes infected with a virus  
 a=sample(1:Ncomputers, 1,replace=TRUE) # Random number from 1 to 20  
 infected[a]=1 # One computer becomes infected with a virus  
  
   
 # Count the infected computer  
 count\_infected[a]=count\_infected[a]+1;  
   
 days=1;  
 h=1;  
 while(sum(infected)>0)  
 {   
 # Infected all network with Prob=0.1  
 k=length(a)  
 while(k<=length(a))  
 {  
 for(i in 1:Ncomputers)  
 {   
 if(sum(i==a)==0)  
 {  
 if(runif(1)<prob)  
 {  
 infected[i]=1;  
 count\_infected[i]=count\_infected[i]+1;  
 a=c(a,i)  
 }  
 }  
 }  
 k=k+1;  
 }  
   
 Number\_infected=  
 # Removes the virus from 5 computer  
 if(sum(infected)<=5){  
 infected=rep(0,Ncomputers)  
 } else {  
 remove=sample(a, Nclean, replace = FALSE);  
 infected[remove]=0;  
 a=a[!a %in% remove]  
 }  
days=days+1;  
 }  
save\_Days[j]=days  
save\_count\_infected[j,]=count\_infected  
}

* The expected time it takes to remove the virus from the whole network

mean(save\_Days)

## [1] 15.474

* The probability that each computer gets infected at least one

each\_infected=rep(1,N)  
for(k in 1:N){   
if(sum(save\_count\_infected[k,]==0)>0)   
 each\_infected[k]=0;  
}  
Probability=sum(each\_infected)/N  
Probability

## [1] 0.601

* The expected number of computers that get infected

Total\_computer\_infected=rep(0,N)  
for(k in 1:N){   
 Total\_computer\_infected[k]=sum(save\_count\_infected[k,])   
}  
mean(Total\_computer\_infected)

## [1] 70.694

We have a system of 20 computers connected in a network, some day in an unknown way a computer in the system is infected by a virus, due to the network connection, this infected computer can spread this virus to each of the remaining 19 with probability 0.1. Note that in case of spreading to a new computer (different from the initial one) it can spread the virus again to the non-infected one. In addition to this, the technician daily can only disinfect a maximum of 5 computers.

Next we break down the code into two parts:

* Infected all network with Prob=0.1

We know that an infected computer spreads the virus to another uninfected computer with probability 0.1. To simulate this, since we initially have one infected computer, we spread a **for** loop where we generate a random number between 0 and 1 (**runif(1)**) for each uninfected computer, where for each computer whose number is less than or equal to 0.1 then this computer is infected by the virus, otherwise it stays clean.

Note that when a new computer is infected, then it can spread the virus with probability 0.1, for this we use a **while** cycle which will stop if there are no new infected computers.

In this step of the simulation, the following results are obtained:

* **infected:** A vector of size 20, where each position represents a computer, if the value of position is 0 then the computer is not infected, if it is 1 then the computer is infected.

Example, output of one simulation:

infected= 1 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0

It means that computer 1,3,12 and 18 are infected, the rest are clean.

* **count\_infected**: A vector of size 20; where the value of position represents the number of times the computer has been infected. (Remember that a computer can be infected more than once before cleaning the entire network, since the technician cleans 5 computers daily.)

Example, output of one simulation:

count\_infected= 6 5 7 6 5 9 8 7 6 6 11 7 6 7 7 7 7 10 6 7

It means that for example:

* computer 1 was infected 6 times.
* computer 11 was infected 11 times.
* computer 20 was infected 7 times.
* **a:**: Vector that stores the computers that have been infected “in the morning”
* Removes the virus from 5 computer

In this part of the simulation, we randomly choose 5 infected computers to be disinfected, that is, we choose 5 values in the vector **a**, then these values are changed to 0 in the vector **infected:**. In case of only having 5 or less infected computers, they are disinfected and the simulation is ended.

using this simulation we can estimate:

* The expected time it takes to remove the virus from the whole network

The simulation is repeated N times, and in each time the numbers of days that take to clean the whole network is stored, so we generate a long sequence of random variables we compute the expectation by:

* The probability that each computer get infected at least one

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* The expected number of computers that get infected

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