Controlling Third World Ebola Outbreaks

New Mexico
Supercomputing Challenge
Final Report
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Executive Summary: Our program tries to model actual work being done to combat Ebola. Our goal was to gather information that could guide politicians in their decisions regarding allocation of money and Ebola support for third world countries. The programs that we modeled for the allocation of funds are: isolation facilities for sick people, testing facilities, sick patient transport services when needed, and dead body collection services. According to our results, the most effective investment would be into sick patient transport crews coupled with test facilities and at least one quarantine facility, because according to our results this has the most impact on the spread of Ebola

Problem Statement: The model that we designed determines how to most effectively quarantine patients. In our model we show how investments into quarantine facilities, simple test facilities, deceased body cleanup crews and identified sick patient transport crews effect an outbreak, in such a way that one could clearly say that one facility or crew is a preferable investment to the others.

Problem Background: At the time that we were choosing our project, EVD, more commonly known as Ebola, had an outbreak raging in West Africa, an outbreak that has been consistently on the news. Third world countries are not only the most prone to an outbreak, because of a lack of health care, but also in poor West African countries those who can not afford much food eat bushmeat, which comes from a combination of monkeys, fruit bats and other small rodents. It is from this bushmeat that Ebola enters a population.

Ebola is a rare and deadly disease caused by infection with a strain of Ebola virus. It is highly contagious but can only be transmitted from human to human contact. EVD First appeared in 1976 in 2 simultaneous outbreaks one in Nzara, Sudan and the other in Yambuku. The latter occurred in a village near the Ebola River, from which the disease takes its name. Ebola was named after the river to draw the attention away from the town it was first discovered (Yambuku). Ebola is believed to come from bats, however the CDC (centers for disease control) says that North American bats do not carry it. The bats that do carry it are fruit bats which can be found in Liberia, Nigeria, and Sierra Leone, which are the three hardest hit countries in the West African Ebola outbreak. It is also suspected that monkeys now carry and transfer the virus.

Especially in poor communities, wild meat is used to supplement diets, fruit bats and monkeys are eaten and included in the bush meat. Currently the only cure for EVD is for the patient to undergo a series of very costly blood transfusions, which are not affordable in third world countries. Hence in third world countries where EVD outbreaks occur most often the only way for an outbreak to cease is a) everyone dies or b) sick patients are identified and quarantined, and possibly contagious bodies are removed to stop the spread. With this in mind, we created our model to identify the most effective means to allocate funds for the quarantine and clean up process.

Methods Used to Evaluate Problem: We evaluated our problem by creating a complex model in which we included as many factors as was reasonable, and maybe a few more. Factors were included such as population, chance of death, initial number infected, number of facilities, and the programs already described. This model took a lot of work due to the complexity, altogether we had 11 procedures, each designed to do a specific task, such as infecting people, walking, breeding, dying, healing, transportation, and cleanup.

Verification and Validation of Model: We validated our model by only including real world statistics. This was done by ensuring that natural death rates, birth rates, and other variables were statistically accurate. One possible weakness in our model may have been the variable for how contagious the disease is. We were not able to find exact data on this. This led to very high rates of infection, so in our model very few people ever survived, and the majority of the population would die. However this did not prove to be a problem because we only needed the results to say whether one facility or crew was better than another. Overall, our populations would be too low, but we could still see which combinations of programs were being the most effective.

Results:

In the following charts OB means outbreak.

In this chart we are using a baseline of 10 test and 2 quarantine facilities. Then we increase to 20 test facilities and 3 quarantine facilities for all columns. The columns are different because in each column we calculate the impact of the addition of the 10 test facilities and one quarantine facility, but we use different assumptions about whether there are sick patient transport crews or body cleanup crews. In each case the column heading is held constant, and only the increase in test and quarantine facilities is calculated.

	Includes both sick patient trans. and body cleanup crews	All programs except sick patient transport	All programs except body cleanup crews	No sick patient transport or body cleanup crews
time of OB	24% increase	32% increase	11% increase	2% increase
survivors from OB	3% decrease	42% increase	11% increase	22% increase
total dead from OB	7% increase	1% decrease	1% decrease	1% decrease

In this next chart we hold the test and quarantine facilities constant. The baseline assumes that there are no body cleanup crews and no sick patient transport crews. We then model the addition of both body cleanup crews and sick patient transport crews together and independently.

	includes body cleanup crews and sick patient transport	body cleanup crews but no sick patient transport	sick patient transport but no body cleanup crews
survivors from OB	440% increase	33% increase	441% increase
total dead from OB	4% decrease	1% decrease	5% decrease

Conclusions: After several hours of tests with many different parameters we were able to conclude that the most effective way to combat the spread of Ebola is to have sick patient transport programs with test facilities and at least one quarantine facility. Moving sick patients to quarantine lowers the spread of infection, helps maintain political order by lowering the time span of an outbreak, while allowing for a higher survival rate of 441%. When we include crews for moving all dead bodies instead of sick patient transport, the survival rate is much lower. If we include both body cleanup crews and sick patient transport crews, we do not see an improvement. It may be the case that the results with both crews were a little bit skewed, also the difference in percentage is small considering the fact that the percentages are so high (mid four hundreds). It is important to note that to make use of sick patient transport, one needs to have test facilities and quarantine facilities.

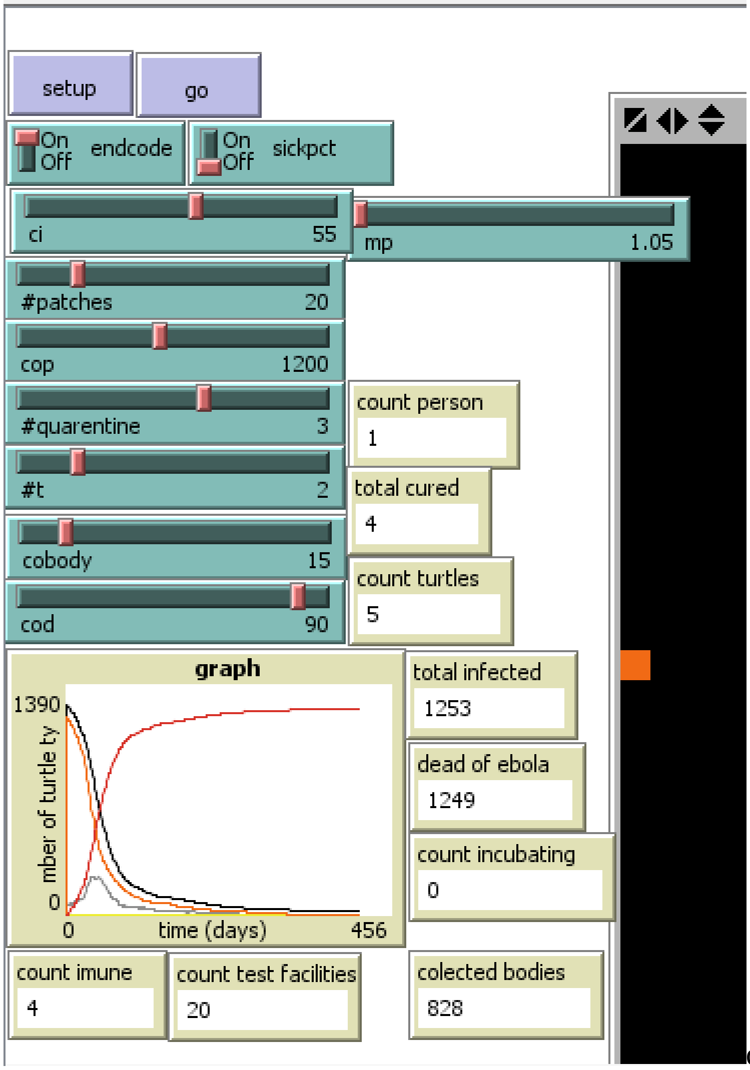
The Most Significant Achievement: Actually completing a relatively accurate model in a programming language that we had never used before. It was relatively accurate because it only had one statistical error, an error that we feel did not affect the validity of our results. Creating the model was really challenging at times, kind of like trying to swim upstream on a fast flowing river. However thanks to encouragement from both teachers and parents, we were able to finish it. Another significant achievement was to complete experimentation as we did 300 trials.

Acknowledgements: Both Kobe Bellas and Noe Garcia helped troubleshoot the code and develope it when our head coder, Rowan Kinney came to a standstill.

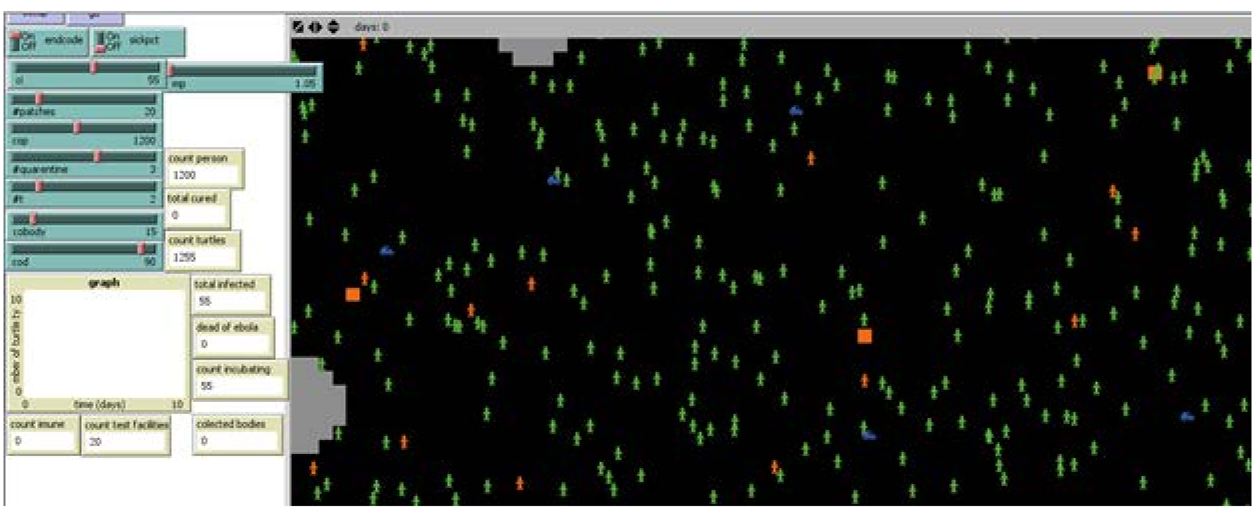
References:

1. "Ebola(virus Disease)." *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 31 Mar. 2015. Web. 01 Apr. 2015.
2. "Ebola Virus: Symptoms, Treatment, and Prevention." *WebMD*. WebMD, n.d. Web. 01 Apr. 2015.
3. "Ebola Virus Disease." *Wikipedia*. Wikimedia Foundation, n.d. Web. 01 Apr. 2015.
4. "Ebola: Mapping the Outbreak." *Www.bbc.com/world/news*. N.p., n.d. Web.
5. "Ebola." *MSF USA*. Doctors Without Borders, n.d. Web. 01 Apr. 2015.

Screenshots from our model:



our interface tab



our interface

WHAT IS IT?

This model is meant to model the spred of ebola in a town of about 5 thousand people, and with this model find the perfect number of test facilities and quarentine facilities while trying to conserve as much resorces as possible.

HOW IT WORKS

(what rules the agents use to create the overall behavior of the model)

HOW TO USE IT

slider cod = chance of death
slider cop = count of initial healthy people
slider ci = count of initial people with Ebola
slider #patches = number of test facilities (may not be exact)
slider #quarentine = number of cuarentine facilities
slider cobody = number of body crews
slider mp = max population (mp value * cop is max population)
slider #t = number of tes facilities

THINGS TO NOTICE

(suggested things for the user to notice while running the model)

THINGS TO TRY

(suggested things for the user to try to do (move sliders, switches, etc.) with the model)

part of our info tab

Our completed code:

```
globals
[
 qwerty
 asdf
]
breed [person people] ;;make breed people
breed [incubating incubation] ;;make ebola
breed [imune imunate] ;;make immune poeple
breed [dead deader]
breed [imunedy imunedie]
breed [body bodycrew]
breed [verydead verydeader]
to setup
 clear-all
 reset-ticks
 set qwerty #patches
```

```
 while [qwerty > 0]
 [
  ask patch random 201 random 201
  [set pcolor orange]
  set qwerty qwerty - 1
 ]

 set asdf #quarentine
 while [asdf > 0]
 [
  ask patch random 201 random 201
  [
   set pcolor grey
   ask neighbors4
   [
    set pcolor grey
    ask neighbors4
    [
     set pcolor grey
     ask neighbors
     [set pcolor grey]
    ]
   ]
  ]
  set asdf asdf - 1
 ]
 ask patch 0 0
 [
  set pcolor red
 ]
 create-incubating ci ;;spawn ebola
 [
  scatter set shape "person"
  set color orange
 ]
 create-person cop ;;spawn 500 people
 [
  scatter set shape "person"
  set color green
 ]
 create-body cobody
 [
  scatter set shape "car"
  set color blue
 ]
end

to scatter ;;place people during start
 setxy random-xcor random-ycor
 if pcolor = grey [ scatter ]
 if pcolor = red [scatter]
end

to go
 while [ count turtles > 0 and count person + count imune <= cop * mp and endcode = true and count incubating > 0]
  [
```

```
   ask turtles ;;have turtules move
    [
     if breed = person [ walk ]
     if breed = imune [ walk ]
     if breed = incubating [ infected-walk ]
     infect
    ]
   if count incubating >= 50 ;;make an emergency plan
    [
     ask turtles [ emergency ]
    ]
   if count imune + count person > 1 ;;make people mate
    [ spawn ]
   tick
  ]
end

to walk ;;teach people how to walk
 right random 30
 left random 30
 forward 1
 if random 19711 = 19710
 [
  if breed = imune
  [
   imudy
  ]
  if breed = person [ die ]
 ]
 if [ pcolor ] of patch-ahead 1 = grey
  [
   right 180
   forward 1
  ]
 if [ pcolor ] of patch-ahead 1 = red
  [
   right 180
   forward 1
  ]
end

to drive
 if count dead > 0
 [
 repeat #t
 [
  move-to one-of other turtles with [ shape = "dot" ]
  if count dead-here > 0
  [
   ask dead-here
   [
    set xcor 0
    set ycor 0
    set breed verydead
    set shape "dot"
   ]
```

```
  ]
 ]
 ]
end

to infected-walk ;;teach people with ebola how to walk
 right random 30
 left random 30
 forward 1
 if [ pcolor ] of patch-ahead 1 = red
  [ right 180 forward 1 ]
 if random 22 = 1
  [
   becomedead
  ]
 if [ pcolor ] of patch-here = grey ;;let ebola cure or die at heath facility
  [
   forward 0
   if random 20 > 10
    [
     set breed imune
     set color yellow
     set shape "person"
    ]
   if breed = incubating
    [ if random 20 <= 18
     [
      becomedead
     ]
    ]
  ]
 if [ pcolor ] of patch-here = orange
  [
   ifelse sickpct = true
   [
    move-to one-of other patches with [ pcolor = grey ]
   ]
   [
    set heading towards one-of other patches with [ pcolor = grey ]
   ]
  ]
end

to emergency ;;explain the emergency plan
 if breed = body
 [
  drive
 ]
 set heading towards one-of other patches with [ pcolor = orange ]
 if breed = person
  [ walk ]
 if breed = imune
  [ walk ]
 if breed = incubating [ infected-walk ]
end
```

```
to infect
 if breed = dead
 [
  if count person-here > 0 and random 101 <= cod
  [
   ask person-here
    [
     set breed incubating
     set color orange
     set shape "person"
    ]
  ]
 ]
 if breed = incubating
 [
  if count person-here > 0 and random 101 <= cod
  [
   ask person-here
    [
     set breed incubating
     set color orange
     set shape "person" ]
  ]
 ]
end

to spawn ;;teach people how to mate
 ask turtles
 [
  if random 55 < 25
   [
    if random 20076 <= 8
     [
      if breed = person
      [
       hatch 1
      ]
      if breed = imune
      [
       hatch 1
       [
        set breed person
        set color green
        set shape "person"
       ]
      ]
     ]
   ]
 ]
End

to becomedead
 if [ pcolor ] of patch-here = orange
  [
   set breed dead
   set color orange
```

```
   set shape "dot"
  ]
 if [ pcolor ] of patch-here = black
  [
   set breed dead
   set color black
   set shape "dot"
  ]
 if [ pcolor ] of patch-here = grey
  [
   set breed dead
   set color grey
   set shape "dot"
  ]
end

to imudy
 if [ pcolor ] of patch-here = orange
  [
   set breed imunedy
   set color orange
   set shape "bug"
  ]
 if [ pcolor ] of patch-here = black
  [
   set breed imunedy
   set color black
   set shape "bug"
  ]
 if [ pcolor ] of patch-here = grey
  [
   set breed imunedy
   set color grey
   set shape "bug"
  ]
end
```