Utilizing Decision Trees to Formulate a Winning Strategy in Plague Inc. Evolved

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***Abstract*—Simulation games are becoming more and more realistic every year. They are also becoming more and more varied, from city builders, truck drivers, even global pandemic. With realism, comes difficulty and complexity. Plague Inc. Evolved is no different. This global pandemic simulator provides a semi-realistic depiction of how a disease can spread and cause a global pandemic. However, this game also simulates how stubborn humans are. How we humans will try everything we can to stay alive, and that is reflected on the difficulty of the game. Fortunately, there is always a strategy to win every game, no matter how difficult. As games are made to be played and won.**

***Keywords*—Difficult, Game, Simulation, Strategy.**

I. Introduction

In the recent years, video games have enjoyed a gradual increase in their popularity. This made playing video games an increasingly common hobby among the people. With the recent COVID-19 pandemic forcing people to stay at home, many more take up gaming as their hobby.

Ofcourse like other entertainment media, video games came in various forms. Ranging from big triple-A open world games such as the newly released Cyberpunk 2077, all the way to indie titles such as Hollow Knight and Slay The Spire.

Due to the recent pandemic, one of the indie titles that has been recieving increased attention is Plague Inc. Evolved. This is because Plague Inc. Evolved simulates, quite realistically, how easily a disease can turn into a global pandemic and wipe out humanity. This in turn attracts the attention of people seeking to find out more about how diseases spreads and understand the complexities of a viral outbreak.

While it does provide a semi-realistic simulation, Plague Inc. Evolved is at its core still a video game, perhaps a difficult one. Without understanding the game mechanics and the winning strategy, it is difficult to win consistently. With the increase in new players, it is to be expected that atleast some of them will struggle to even win in normal difficulty.

Image 1.1 Plague Inc. Evolved Title Screen (Source: https://www.ndemiccreations.com/en/25-plague-inc-evolved)

At its core, Plague Inc. Evolved is strategy/simulation game with a set of fixed mechanics. While there are a lot of options and strategies that the game offers, given enough time, a player is bound to find a consistent winning strategy on their own. However, not everyone have the time and perseverance to keep looking for that winning strategy. Newer players might find themselves irritated from constantly losing and decided to drop the game before they got to experience the game fully.

This paper aims to use decision trees to provide basic generalized strategies for most plague types to help newer players or returning players win more consistently. By doing so, players will slowly learn the game mechanics and can eventually devise their own strategy, perhaps derivating from the decision trees provided here, and ultimately experience the game fully.

II. Theoretical Bases

A. Graph

A graph is defined as a tuple of two sets, a non-empty set of vertices and a set of edges. Graphs are used to represent the discrete objects and the relation between said objects. The objects are represented as the vertices, while the edges represent the relation between the objects. Mathematically, it is usually represented as G = (V, E), where G is the graph itself, V is the non-empty set of vertices and E is the set of edges.

There are several ways of classifying graphs, one way to do it is to look at the directional orientation of the edges. Based on the directional orientation of the edges, graphs are classified into two types:

1. Undirected graph

   This type of graph does not have any directional orientation on its edges. Examples of this type of graphs:

Image 2.1 Undirected graph (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Graf-2020-Bagian1.pdf)

2. Directed graph or digraph

Every edges in this type of graph is given directional orientation. Examples of this type of graph:

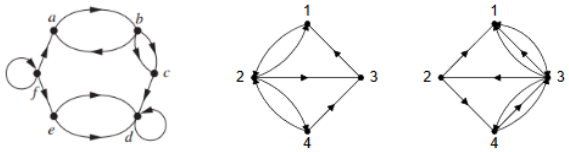


Image 2.2 Directed graph (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Graf-2020-Bagian1.pdf)

There are several terminologies for graph, one of them is path. A path is a route that connects two vertices, Vo and Vn, inside a graph. Another terminology is circuit. A circuit or a cycle is a path that starts and ends in the same vertex.

There is also terminology called connected graph. A graph is called a connected graph if for every pair of vertices Vi and Vj in that graph, there is a path that links Vi to Vj. Below is the example of a connected graph:

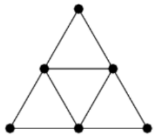


Image 2.3 Connected graph (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Graf-2020-Bagian1.pdf)

B. Tree

Tree is defined as a connected undirected graph that does not contain a circuit. Examples of trees can be seen below:

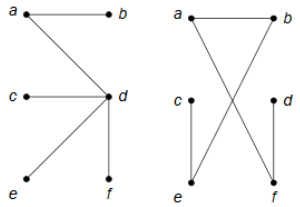


Image 2.4 Tree (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Pohon-2020-Bag1.pdf)

There are several types of trees, one of them is rooted tree. A rooted tree is a tree in which a node is singled out. This node behaves as a "root" for all the other nodes. In rooted tree, each of the edges are given direction pointing away from the root, making it a directed graph. Examples of rooted tree:

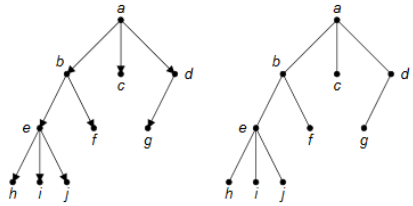


Image 2.5 Left: Rooted Tree, Right: As convention, the arrow signs on the edges can be removed (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Pohon-2020-Bag2.pdf)

There are several terminologies for rooted tree:

1. Child/children and parent

Nodes acting as successors of another node is called the child of that node, while the nodes preceding the child is called parent of the child node.

2. Path

A path is a unique route that connects the root to a certain node.

3. Sibling

Siblings are the children of the same parent.

4. Subtree

A subtree consists of a node, acting as the new root, and all of its successors.

5. Degree

The degree of a node is the amount of subtree or children of that node.

6. Leaf

A leaf is a node with zero degree, meaning the node does not have any child.

7. Internal nodessa

Nodes with atleast one child.

8. Level

How many nodes does it takes to reach the root from a certain node (including the node itself).

9. Height or depth

The maximum posible level of the tree.

One of the applications of the rooted tree is a decision tree. It is designed make decision-making processes easier. A decision tree modifies the basic rooted tree with the following:

1. The nodes with children represent conditionals to be graded and evaluated.
2. All edges represent the outcome of the evaluation of the conditionals. The edges will lead to more conditionals or the final decision.
3. The leaves represent the final decision or action that will be taken.

Here is an example of a decision tree:

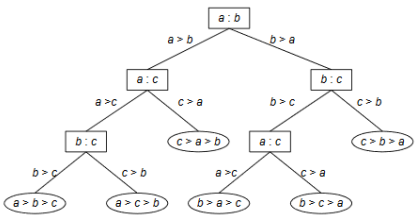


Image 2.6 Decision Tree (Source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2020-2021/Pohon-2020-Bag2.pdf)

C. Plague Inc. Evolved

Plague Inc. Evolved (will be refered to as Plague Inc. onwards) is a strategy and simulation game developed by Ndemic Creations. It is the PC version of the mobile game *Plague Inc.*, a game made by the same developer. In Plague Inc., the player controls a type of plague and must evolve to infect and kill the entire human population. Humans will try their best to cure the disease and it is up to the player to kill the world population before that happens.

1. World View

The game simulates the world quite realistically, with each countries having different climate, population density, humidity, and demographics. The disease will behave differently as expected when faced with these diverse conditions. For example, easy access to medicine in wealthy countries will slow down the spread of the disease, and the disease will have an easier time spreading in a dense, urban environment as opposed to sparse, rural environment. Extreme temperatures can also hamper the spread of the disease.

Image 2.7 World View

The world map will slowly turn red as your disease spreads, and eventually it will turn dark red as people began dying because of your disease. It will also be filled with red trails left by planes or ships carrying your disease. On the bottom screen, the red/blue/black bar shows how much of the world is infected, dead, and uninfected compared to the total human population. On the bottom right corner is the cure progress while on the bottom left corner is your DNA points. You can access the disease tab by clicking the red button there. On the upper right corner is the game speed control and on the upper left is an assortment events/news. In the early game, the events/news won't be affecting the disease much. However, as the game progresses, the events/news will slowly detail on how the world is putting an effort to combat the disease, such as starting cure development, putting the disease on CDC watchlist, governments burning dead bodies, banning livestocks, or exterminating pigeons, etc. Sometimes, there are also events/news that provides a boost of infectivity to the disease, such as Rio olympics, a rise in urban population, and festival of love. These events however, are not very common and should not be depended on when spreading the disease.

2. Country Overview

Each country information can be accessed by clicking said country. The world info normally shown on the bottom will be replaced by a quick detail about said country, as shown by the image bellow.

Image 2.8 Country Overview

As visible above, there are several symbols shown, each denoting a piece of information. The plane, anchor, and line symbols denote that this country has open airport, seaport, and land border connection, while the leaf, water drops, and heat symbols denote that this country is considered to be mostly rural, having humid atmosphere, and having hot climate.

While this provides a more general overview, if more detailed information is deemed necessary, the player can click on the button with three dots. It will open a page as shown bellow. The page will provide more information regarding said country, such as percentage of infected people, cure research contribution, and government policies regarding the disease.

Image 2.9 Country Screen

3. DNA Points and DNA Bubble

In order to evolve the disease, the player must gather enough DNA points. There are several ways to gather DNA points and the amount gained differs depending on the how far the game have progressed.

In the early game, day-to-day infections will generate some DNA. However, as the game progress, day-to-day infections will give smaller and smaller amount of DNA. This can be counteracted by having increased severity, more on this when we discuss about the disease itself.

DNA points can also be gained by killing humans. However, the player must be careful when controlling the lethality of the disease, more on this when we discuss about the disease itself.

A more consistent way of getting DNA is through clicking DNA bubbles. There are two DNA bubbles, orange DNA bubbles and red DNA bubbles. Orang DNA bubbles randomly pop up in infected countries, while red DNA bubbles pop up whenever the disease first entered a country. The DNA gained from both bubbles can be increased by increasing the severity of the disease, more of that when we discuss about the disease itself.

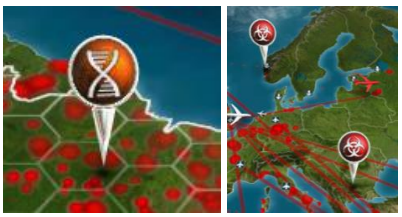


Image 2.10 and 2.11 Left: Orange DNA Bubble, Right: Red DNA Bubbles

4. The Cure

Once the disease has been noticed or discovered, humans will start working on the cure. At first it will start slow, with only one country contributing to the research. However, it will quickly increase in speed as more and more countries are infected. Eventually, to speed up the cure even more, the humans will start sending teams to do field research. On the map, this is represented by the blue cure bubble and the blue plane. If these blue bubbles aren't clicked by the player it will boost the speed of the cure research.

Image 2.12 Blue Cure Bubble and Blue Plane

Once the cure research has reached 100%, the number of infected will start decreasing until there's no more infected. When that happens, it is game over.

There are several ways to combat this, the first one is simply to kill every human before the cure reaches 100%. This is done by evolving many lethal and severe symptoms. However, more often than not, this is not a viable solution due to various circumstances. So another way to combat the cure progress is to evolve "cure resistance" abilites such as genetic hardening and genetic reshuffle to delay the cure progress.

5. The Disease

If the player clicks the red button shown before in image 2.7, it will open the disease screen as shown by the image bellow.

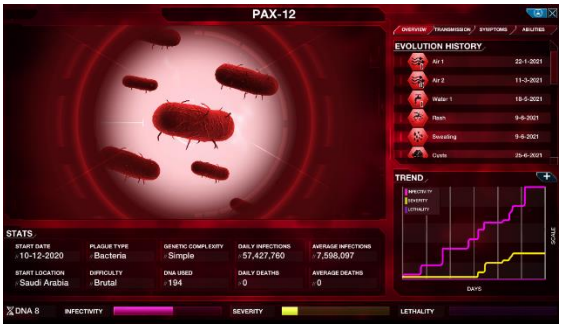


Image 2.13 Disease Screen

The disease has three stats, infectivity, severity, and lethality. Infectivity denotes how quickly the disease spreads. Severity denotes how noticeable the disease is, it also increases DNA points gain and slows down cure research. Lethality denotes how deadly the disease is. The player must be careful in balancing these stats. Too much severity early on will lead to countries closing their connections, too little severity and you'll quickly ran out of DNA points. Too much lethality and you'll kill all infected before they have a chance to spread the disease, leaving the uninfected unharmed (normally dead bodies cannot transmit the disease), too little lethality on the late game and the cure will be finished before you kill every infected.

There are three tabs in the disease screen, the transmission tab, the symptoms tab, and the abilites tab. The transmission tab allows the player to evolve ways to transmit the disease, such as through insects, livestock, blood, water, air, etc. The symptoms tab allows the player to evolve various symptoms with differing levels of infectivity, severity, and lethality. The abilities tab allows the player to evolve resistances and abilities, such as cold resistance, heat resistance, drug resistance, cure resistance, and unique plague ability depending on the type of plague chosen.

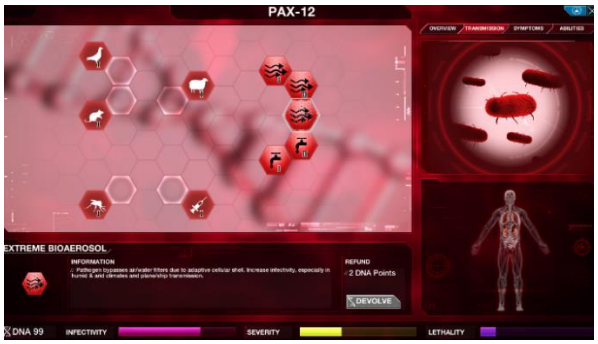


Image 2.14 Transmission Tab

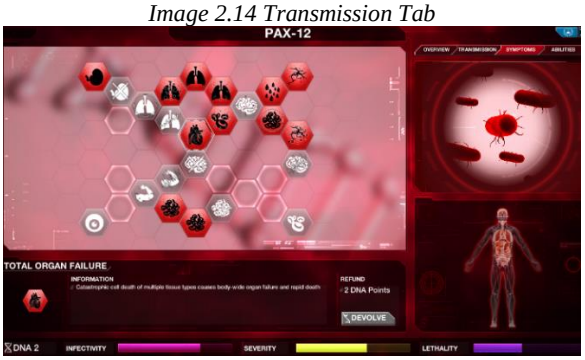


Image 2.15 Symptoms Tab

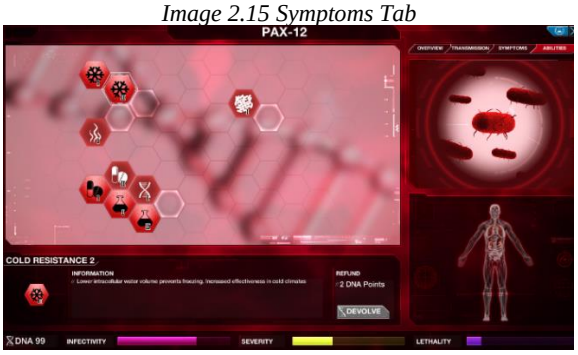


Image 2.16 Abilities Tab

While it is tempting to evolve every single transmission, symptom, or ability to make a more rounded disease, it is generally not a very viable strategy. This is because for every evolution the disease have, the complexity of the disease will increase, and with that, so does the DNA cost of other evolutions. This mechanic is called genetic drift. When left unchecked, genetic drift can go out of hand and make every evolution unaffordable, thus condemning the player to a game over most of the time. So with this reason, it is generally more viable to specialize and go deeper with evolution in transmission, symptom, and ability.

In Plague Inc., there are several plague types that the player can unlock and choose. Each plague types have their own traits and gimmicks. The plague types that this research paper covers are :

a. Bacteria: Basic, robust, and versatile
b. Virus: Very high mutation chance
c. Fungus: Lower cross country infectivity
d. Parasite: Lower DNA gain from day-to-day infections
e. Prion: Evolutions are slower to take effect

f. Nano-virus: Higher infectivity, cure research starts immediately
g. Bio-weapon: Slowly gains lethality overtime

This paper does not discuss the more "exotic" plague types such as necroa virus, simian flu, neurax worm, and shadow plague. This is because those plague types alter the game mechanics greatly, thus requiring more specialized and complex strategies to tackle compared to the rest of the plague types.

The player can also modify the starting genetic code of each plague with the genetic codes they have unlocked while playing the game. However, in this guide, the genetic codes will be left as default or empty as it will provide more consistent results.

6. Mutation

Sometimes the disease will mutate a symptom on its own without the use of DNA point. This is called mutation. Each plague type has different mutation chances, with the virus plague type having the most mutation chance. mutation chance can also be increased by evolving zoonotic (animal) transmission or by evolving immune suppression symptom. The symptoms mutated will be randomized from all the available symptoms ready to evolve.

Image 2.17 The disease mutating a random symptom

While at first glance, mutation seems only beneficial, as the player does not have to spend DNA points to evolve, mutation can easily go out of hand. Firstly, the symptoms mutated still counts towards genetic drift, making every other evolution more costly. Secondly, mutation can evolve symptoms with too much severity or lethality for the stage of the game. If the disease is too severe early on, governments will be quick to react and close all connections to a country before the disease has a chance to spread. If the disease is too lethal too early, it will kill all infected before they have a chance to spread the disease to the uninfected, leaving them unharmed.

III. FORMULIZING THE WINNING STRATEGY

As written before, this paper will only discuss the six main plague types, bacteria, virus, parasite, prion, nano-virus, and bio-weapon.

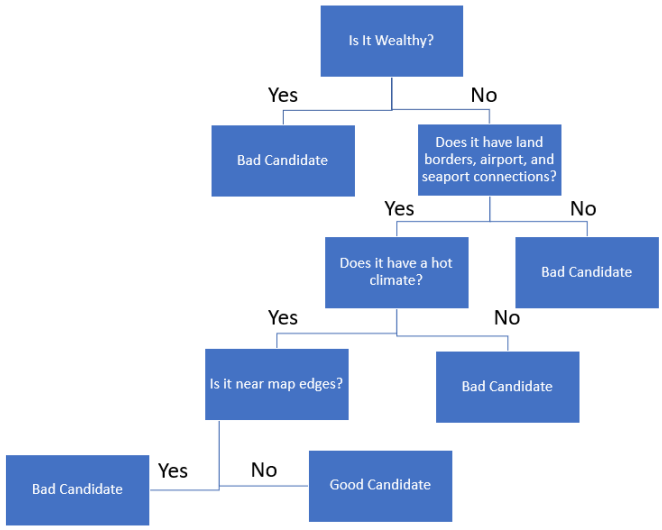
A. Picking The Starting Country

At the start of the game, the player is told to choose one of the many countries of the world to be the origin of the plague. No matter the plague type, a good starting country location will quickly snowball the game into an easy win, but a bad starting country can make the game significantly harder, or even unwinnable. Unfortunately, not all countries are equally good as a starting country.

There are several points to consider when choosing where to start the disease. Those points are :

1. Demography (wealthy or poor):
   Wealthy countries have easier access to medicine, slowing the spread of the disease.
2. Connections (airports, seaports, and land borders):
   More opportunities to spread to neighboring countries.
3. Climate (hot or cold):
   The disease will be slightly adapted to the climate of the starting country.
4. Traffic going in and out of the country:
   Higher traffic means more opportunities to spread.

From these points and through testing, it can be determined that the decision tree for choosing the starting country will look something like the tree bellow:



Tree 1.1 Starting country

The reasoning behind chosing hot climate as opposed to cold climate is that the DNA cost for cold resistance ability is cheaper than heat resistance, thus proving to be the better choice.

Countries near map edges tend to get fewer air and sea traffic, while countries closer to the center of the map get more air and sea traffic, thus making them a better choice.

While population density is also another valid point to consider when chosing a starting country, through testing, it is found that the win condition is still very achievable even when starting in a rural country. This makes population density is not as important to consider when chosing a starting country.

Several countries that fulfil the tree conditions above are Saudi Arabia, Egypt, and India.

B. Early Game

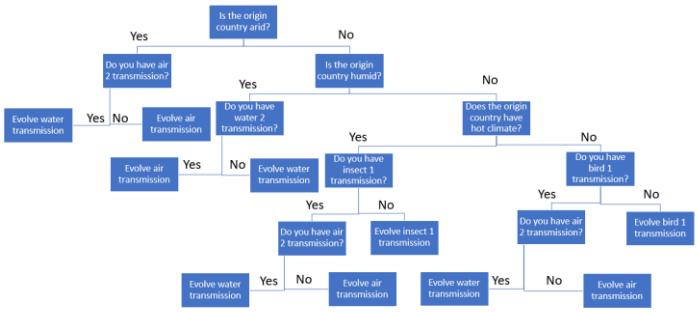
In the very early game, the goal is to "escape" from the starting country and start spreading into neighboring countries. To achieve this, the disease needs to evolve a transmission method. There are many transmission available to evolve at this point of the game, each of them better in a certain condition than others. Those transmissions and their specialty are the following:

1. Air transmission: better in arid conditions and plane transit
2. Water transmission: better in humid conditions and ship transit
3. Birds transmission: better for crossing land borders
4. Livestock transmission: better for rural regions
5. Insect transmission: better for hot climates and capable of crossing land borders
6. Blood transmission: better for poor countries

As explained before, it is also better to specialize in a type of transmission or two rather than generalize in all of them due to

genetic drift.

From those transmission and their specialty, and also through testing, it can be determined that the decision tree for choosing transmission will look something like the tree bellow:



Tree 2.1 Early game transmission

It is clear that air and water transmission have higher priorities than other transmission types. This is because air and water transmission improves the disease's ability to spread through plane and ship transits. Plane and ship transits will be the primary way of cross-country infections (infection from one country to another) for most of the game. This is because there are many island countries in the world without land borders, thus making airport and seaport (or sometimes even just a seaport) their only connection to other countries. As to why air is prioritized above water, it is because planes spread the disease faster, farther, and more commonly when compared to ships.

Another point to discuss is the reason why livestock and blood transmission are not considered. This is because those transmissions lack cross-country infectivity, while other transmission types provide both cross-country infectivity and general infectivity for spread within countries.

When playing parasite, the player can find himself frequently running low on DNA in this stage due to reduced DNA gain from day-to-day infections. To counteract this, it is adviced to evolve a symptom to increase severity slightly, thus increasing DNA gain. As to what symptom to evolve, this will be discussed in the next part.

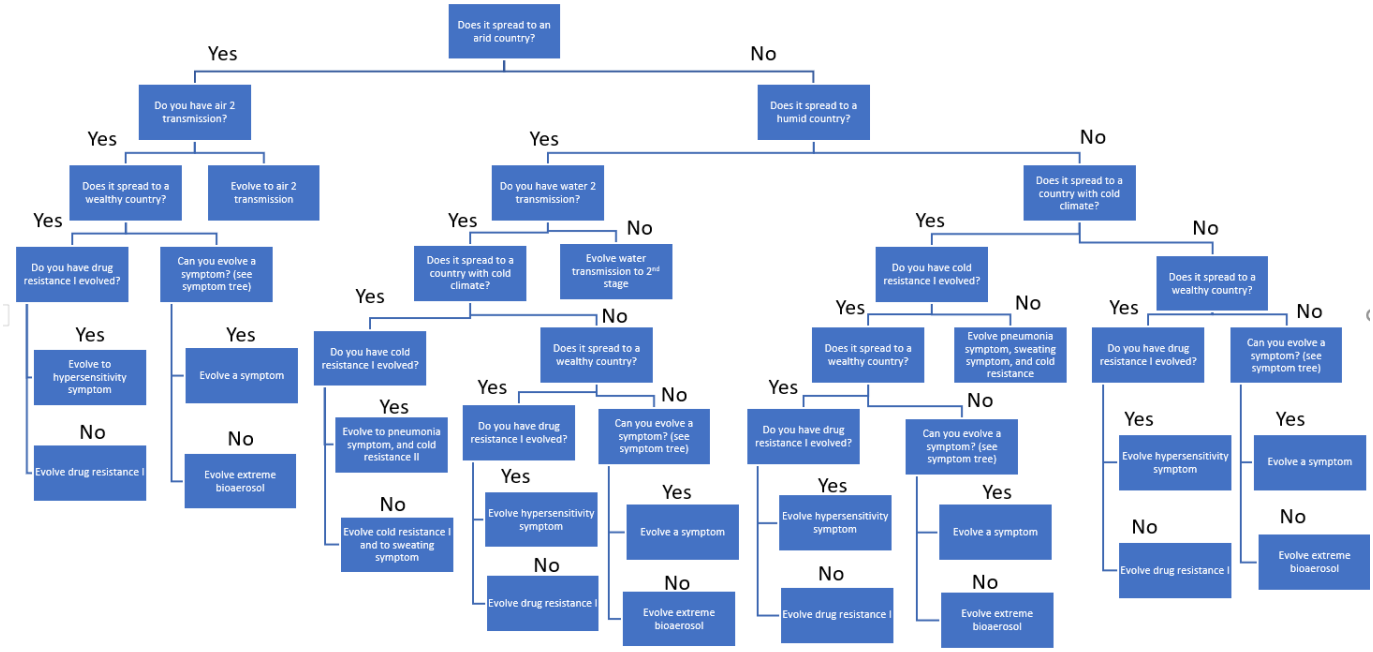
C. Mid Game

Mid game starts when the disease has "escaped" its starting country and has spread into other countries. There are many

things that can, and will, happen in this stage of the game (such as the start of cure research and governments starting to close connections). The player must stay on his feet to anticipate, react, and take advantage of the situation by evolving relevant evolutions. To facilitate this, the game provides the player with extra DNA points in the form of red DNA bubbles that will frequently pop up in this stage of the game.

Unfortunately, many players, especially newer ones, quckly got overwhelmed by the things that happened in this stage. They then went into a state of panic and evolve traits that does not provide much benefit for the current situation. This will quickly lead into a game over when the player ran out of DNA points but haven't evolved the necessary evolutions, or when governments close all their connections before the disease has a chance to spread because of severity or lethality being too high.

It is important to stay calm and analyze the situation properly in this stage. Do not get overconfident with the surplus of DNA as every single DNA counts and there's also the dangers of genetic drift. This is especially important with prion plague type as any changes or evolutions on the disease will need some time to take effect and the player needs to be strategic about any evolutions.



Tree 3.1 Mid game main decision tree

There are several things that the player can do to anticipate, react, and take advantage of the situation. Those things are :

1. Evolving transmission to further spread the disease.

It is necessary to evolve a transmission fitting in the new country's environment to quickly spread there. It is also important to keep evolving air and water transmission to spread better through plane and ship transits as explained before.

2. Evolving drug resistance to spread better in wealthy countries.

This will counteract the effects of easily accessable medicine in wealthier countries, allowing the disease to spread as effectively there as other, poorer countries.

3. Evolving cold resistance to spread better in cold climates.

Since we're starting in a hot region, adaptation to cold climates is necessary to spread and infect the colder regions such as Russia, Canada, Sweden, Iceland, and Greenland.

4. Evolving symptoms to increase severity, thus increasing DNA gain from red DNA bubbles.

The player should take advantage of the high number of red DNA bubbles popping up by increasing the DNA gains from each and every single one of them.

5. Evolving "cure resistance" abilites such as genetic hardening and genetic reshuffle to slow down the cure.

If not handled properly, the cure can quickly pick up pace and progress under the player's nose. It is important to anticipate the cure and react when it has reached a certain threshold.

Due to the complexity of this stage of the game, a single decision tree is not enough to map all the possible actions. So three decision trees have been made. The first tree is the main decision tree. It helps the player decide on when to evolve certain transmissions, when to evolve drug and cold resistances, and (partially) when to evolve symptoms. The second tree is the symptom tree. It helps the player decide on when to evolve symptoms and when to hold back on the symptoms. It also helps to decide what to do with mutations. This is especially important for the virus plague type with the high mutation chance. The third tree is the cure checking tree. It helps the player decide what to do when the cure has reached a certain degree of completion. This tree however, requires the player to constantly check on the cure progress from time to time.

The player should consult the main decision tree every time the disease has infected a new country. This is because whenever the disease entered a new country, the player is given DNA points in the form of red DNA bubbles. These points must be spent as effectively and as soon as posible to ensure the disease maintains its momentum of infections.

The first focus of the main decision tree is transmission, both air and water transmission. This is because, as explained before, cross-country infections through planes and ships will be the primary way to spread to most countries, and the only way to spread to island countries, making it a vital evolution to have.

Another focus of the main decision tree is dealing with wealthy and cold countries. Some of the evolutions are quite straightforward, drug resistance for wealthy countries and cold resistance for cold countries. However, the symptoms might not be as straightforward. Let uss discuss hyper sensitivity symptom first.

Image 3.1 Hyper Sensitivity Symptom

Hyper sensitivity is a symptom accessable by evolving cysts symptom. Other than providing severity and slight infectivity, it also increases the effectiveness of the disease in rich or wealthy countries. This makes hyper sensitivity one of the better symptoms to pick as it deals with the need for increased severity and dealing with wealthy countries.

Another symptoms that need discussing are the sweating symptom and pneumonia symptom. Sweating symptom can be accessed by evolving rash symptom, while pneumonia symptom can be accessed by evolving coughing symptom. Both have good infectivity from their preceding symptom and both provide some severity. However, the most important part is that both symptoms increases the effectiveness of the disease in cold regions, something that is needed by our disease since it is only adapted to hot climates because of its starting country.

Image 3.2 Pneumonia Symptom

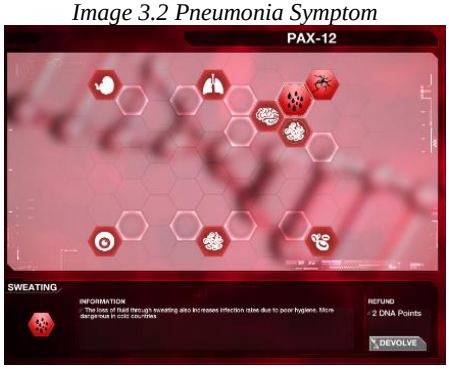
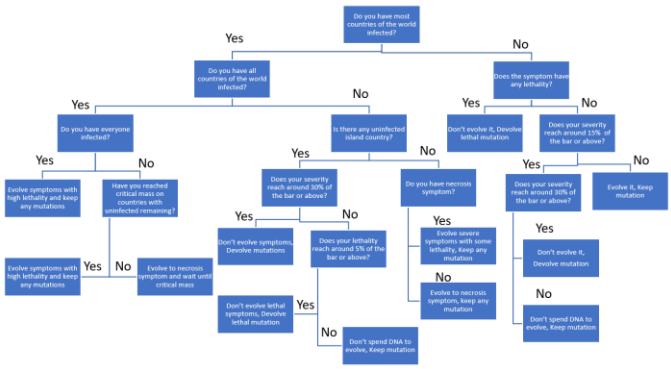


Image 3.3 Sweating Symptom

You might notice from the main decision tree that it requires the user to see the symptoms tree, the second tree. The last thing you might notice is the evolution extreme bioaerosol, since it is not available from the beginning. Extreme bioaerosol is accessed by evolving both air and water transmission to the second level as shown in the image bellow, something that should already be done when the player reached this branch. It is the best transmission available for plane and ship transits, and it is necessary most of the time to get to the most isolated island countries.

Image 3.4 Extreme Bioaerosol

As for the symptoms tree, the reason it is required is because the player needs to control how much severity and lethality his disease has, as explained before. Through testing, the following tree has been resulted for evolving symptoms:



Tree 3.2 Symptom and Mutation Tree

This tree aims to help player know when to evolve symptoms, when to save DNA points, and when to devolve mutations. In early-mid game, when most of the world is still not infected, it is best to hold the severity to around 15% as shown by the image bellow, any higher and the player risks agitating governments to close down all connections.

Image 3.5 15% Severity

When the player has reached mid-late game, almost, if not all countries in the world should be infected. When that happens, the player can ramp up the severity higher, but the player still needs to be careful about lethality, as under normal circumstances, dead bodies cannot transmit disease. Thus it is best to hold the lethality up to 5% so that the disease has a chance to spread before killing its host. One thing you might notice on the tree is the necrosis symptom. This is a special symptom that will soon be discussed.

As to what symptoms are good choices to evolve, through testing, it has been found that these following paths are the better symptoms to evolve when compared to the rest:

1. Cysts > Hyper Sensitivity (explained before)
2. Rash > Sweating > Skin Lessions > Necrosis > Hemorrhagic Shock

Both rash and sweating have been explained before. Skin lessions provide a great amount of infectivity with good amount of severity. However, necrosis is the crown jewel here, this symptom has a special property where it allows for corpse transmission, meaning dead bodies now transmit disease. This allows the player to build up more lethality without worrying too much about infectivity. Another point is hemorrhagic shock, it has the second highest lethality next to total organ failure.

3. Coughing > Pneumonia > Pulmonary Fibrosis > Total Organ Failure

Coughing and pneumonia have been explained before. Pulmonary fibrosis provides some severity with small amount of lethality that is close to hitting the 5% mark. The best thing about this path is total organ failure, it has the highest lethality of all symptoms, enabling quick death to all infected. However, it must be used carefully, as even with necrosis, evolving this too early will kill all infected and still leave some uninfected remaining.

The last interesting bit in the tree is the “critical mass.” This part will be discussed in the next part, when it plays an even more important role.

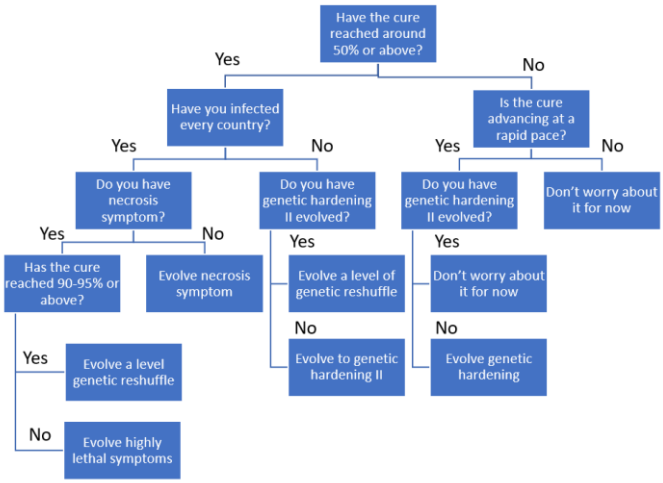
The last tree in this part is the cure checking tree. It is best to discuss about the countermeasures the player has against the cure before going over the tree.

The first countermeasure is severity. The game tells you that to combat the cure, the player needs high severity. However, after testing, the effects of high severity on the cure progress is very minimal, thus making this method of countering the cure to be not very effective.

The second countermeasure is one of the “cure resistance” ability, genetic hardening. This ability slows down all future cure research speed. Making it more useful the earlier it is evolved. However, it is important not to evolve this too early, as transmissions and symptoms still require a higher attention especially early on.

The third countermeasure is another “cure resistance” ability, genetic reshuffle. This ability increases the work needed for cure. When the player evolve this ability, the cure progress percentage will be shown to have decreased. This is a very potent countermeasure with limited use (up to three levels). As such it is better to be used when it is only necessary.

Timing is key when countering the cure, so. This tree aims to help the player anticipate and react accordingly to the cure progress. Through testing, the following tree has been made:

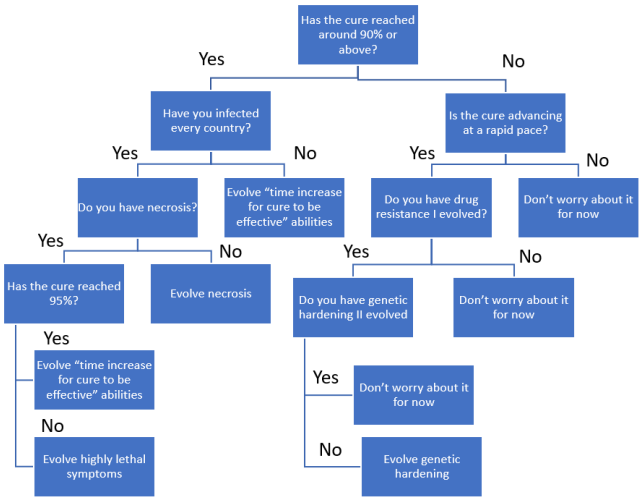


Tree 3.3 Cure Checking Tree

The cure usually starts picking up pace when it has reached 25%-30% progression. When that happens, it is adviced to evolve both levels of genetic hardening first, before going to genetic reshuffle.

One thing that might be interesting is that on the far left branch, it tells the player to evolve highly lethal symptoms, as opposed to delay the cure. This is because, if there are high enough deaths in a country, that country will enter a state of anarchy and all cure contribution from that country will stop, slowing down the cure progress.

For nano-virus plague type, since the cure starts when the game begins, it becomes very important to check on the cure progress. Since nano-virus have special countermeasures against cure progress, this following tree is much better suited for that plague type:

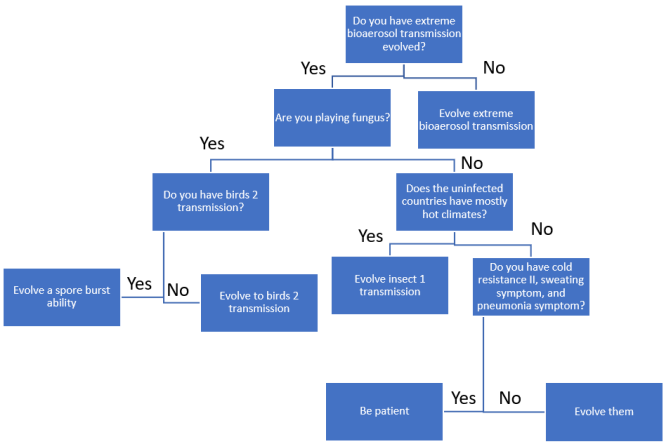


Tree 3.4 Nano-virus cure checking

Another thing to note about nano-virus, is that the cure will progress at a very rapid pace very early on. So it is highly adviced to evolve both Code Fragment Interception and Code Segment Interception (nano-virus special abilities that slows down cure research) first before going down the transmission tree.

D. Late Game

If everyting went accordingly, almost, if not every country in the world now has infected people inside them. If not all countries are infected yet, then "sniping" these countries is required. "Sniping" means evolving traits that are especially effective in the target country and its surounding regions. Sometimes however, the traits needed are already evolved and all the player have to do is be patient. The following decision tree can help suggest what action the player have to take:



Tree 4.1 Infecting the last remaining countries

Most of these transmissions have been explained before. However, one thing that might be interesting is the spore burst ability. It is an ability unique to the fungus plague type. The fungus plague type has a special modifier that reduces the cross-country infectivity the disease has. To counter this, the fungus has the spore burst ability that sends infected spores to a random uninfected country.

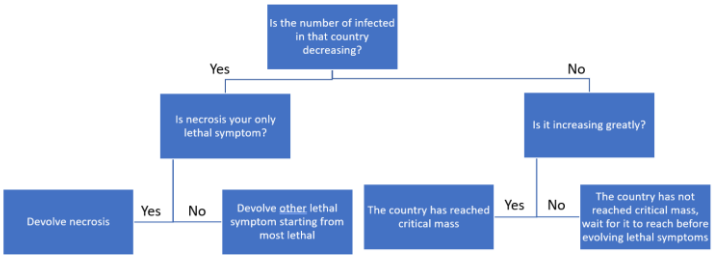
The last thing that needs attention in the late game is the "critical mass" of a country. In this game, critical mass can be defined as the minimum number of infected to sustain continuous infections within a certain country. It is usually signaled by the sudden jump in the number of infected in a country. A country that has entered critical mass will soon become fully infected.

The last remaining countries that have not reached critical mass are usually wealthy countries. So it is adviced to evolve drug resistance II if there are DNA points left to spare.

It is important to wait for the last remaining countries to reach critical mass before evolving highly lethal symptoms, such as total organ failure and hemorrhagic shock. If not, then the disease will kill all infected before they have a chance to spread the disease to the uninfected.

When the disease has too much lethality while the remaining countries have nott reached critical mass, the number of infected in those countries will noticeably start decreasing. The clear solution to this is to reduce lethality by devolving lethal symptoms. However, be careful not to devolve too much lethality as it might give just enough time for the cure to be effective.

Below is the decision tree for deciding whether or not a country has reached critical mass and what to do when it has not reached it:



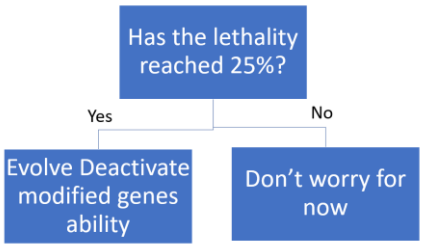
Tree 4.2 Critical mass

E. The Lethality on Bio-Weapon

On bio-weapon plague type, the disease will slowly increase lethality overtime. While this might sound bad, the additional DNA points from lethality in the early game is a great boon for quickly evolving the disease. If the lethality is controlled properly, it can even save DNA points from evolving strictly lethal symptoms such as total organ failure.

Through testing, it is found that to control the lethal build up, simply evolving Deactivate Modified Genes ability all the way to level 3 at once in the correct moment.

Further testing pinpoints the timing to around when the lethality has reached 25% of the bar. Below is the decision tree that can help pinpoint that timing:



Tree 5.1 Bio-weapon lethality reset

IV. Conclusion

The decision trees and strategy guidance on this paper has been tested on the game itself up to mega-brutal difficulty and have yielded a quite consistent result up to these difficulties for these plague types:

1. Bacteria: brutal
2. Virus: brutal
3. Fungus: normal
4. Parasite: brutal
5. Prion: brutal
6. Nano-virus: brutal
7. Bio-weapon: normal

While it is still possible to win on mega-brutal with the strategies listed on this paper, it does not yield a consistent enough result. This is because winning on the hardest difficulty requires not only knowledge of the winning strategy, but also understanding of the game mechanics and the decision-making flexibility of an experienced player.

With all said and done, graph, tree, and their derivations are amazing mathematical models that can be used for a very wide variety of purpose. The purpose does not even have to be a mathematical or computational one in nature as shown by this paper and many other papers that my friends have made.

Although the decision trees and strategies provided here are still not perfect, since it has not reached a consistent enough win in brutal and mega-brutal difficulty in some plague types, I believe with enough time and resource to test and develop these strategies, a better, more thorough decision tree and strategies can be made.

V Acknowledgment

In this section I would like to express my gratitude towards God, my friends, and my family for supporting me all the way up to this point of my life where I finish this paper. I would also like to express my gratitude to Ms. Fariska Zakhralativa Ruskanda, S.T.,M.T. as my Discrete Mathematics lecturer. It is thanks to her guidance and teaching that I am able to finish this paper and understand the wonders of graphs, trees, and other mathematical models taught in Discrete Mathematics. Lastly I would like to apologize for any mistakes that occured in the process of making this paper. I hope this paper can help and inspire other people to learn, think rationally, and perhaps spark an interest in the game I like so much.

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Pernyataan

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

Bandung, 11 Desember 2020

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