IE 48F

FINAL PROJECT

GROUP 5

SUBMITTED TO GÖNENÇ YÜCEL

ON THE DATE OF 05.06.2017

THE WALKING DEAD

BY

ALPEREN İNAL 2012402144

MUHAMMED BÜYÜKKINACI 2012402030

1)PROBLEM DESCRIPTION

According to some researches, the humanity will suffer from contagious diseases in the next decades. Some of these diseases may cause zombies to come out . Owing to these predictions , zombie and zombie related broadcasts became so popular in popular culture in the last decade. The most outstanding of them is The Walking Dead. In The Walking Dead, Humans are trying to survive against the danger of zombies . We inspired from The Walking Dead for our model . In our model, there will be humans and zombies fighting against each other in line with The Walking Dead . Our model will consist of 3 types of agents : Food-collectors , Hunters and Zombies. Hunters will fight against zombies. Food-collectors will provide food for Hunters in order to assist them in tackling zombies . When food-collectors find a food, they are taking that food to the nearest hunter . Zombies will try to kill Hunters & Food-collectors by reducing the stamina of food-collectors/hunters . If the stamina of hunter/food-collector becomes below 0 , Hunter/Food-collector gets killed and gets out of the model. At this point, a critical value parameter becomes important. Critical value parameter is a parameter which hunters have. If the stamina of any hunters becomes below the critical value parameter, that hunter will leave looking for a zombie and start to act like a food-collector. Hereby , There appears out a tradeoff : If critical value is high, hunters won’t be eager to fight zombies . If their critical value is low, it is more possible for hunters to die. Therefore, the critical value parameter is important.

In addition, zombies will have stamina ,which will be decreased by attack of hunters. In addition to this, food-collectors and hunters have also stamina, which will decrease over time due to consuming stamina. When a hunter/food-collector eats a food, the stamina will get high. The stamina values for a hunter and a food-collector are different than each other for all scenarios &

policies . The hunters need more food because they are consuming more energy than food-collectors. At this point, the sharing percentage of a food-collector becomes important. If the stamina value of a hunter/food-collector becomes 0, that agent will die and disappear.

Thirdly, there will be a ratio of hunter to food-collectors. If all agents were chosen as food-collectors, food-collectors would become vulnerable to danger from zombies. If all agents were chosen as hunters, hunters would suffer from starving. Therefore, it is clear to say that hunters and food-collectors have to collaborate.

The main outcome-of-interest is the number of remaining humans at the end . If number of remaining food-collector/ hunter is high, it could be evaluated as better. If the number of remaining hunter/food-collector is low or 0 at the end , it could be assessed as worse. We also evaluated the effect of zombie for each policies. Firstly, we obtained runs from policies having zombies. Secondly, we obtained runs from policies not having zombies. Then, we compared both in order to comprehend which policy is better to fight against zombies . Hereby, we took the influence of zombies into consideration .

2) METHOD JUSTIFICATION

The scientists has to make some researches in order to learn which policy is better for humans. As stated above, zombies aren’t real creatures. They are fictitious creatures . Therefore, it is impossible for scientists to have zombies in laboratories. If they were real, it would be so costly to conduct an experiment over zombies (catching them, bringing them to laboratories etc.). In addition to this, this would require consuming so much energy. Furthermore, conducting such an experiment would spend so much energy and each run would require new humans, foods and zombies. Therefore, we can say that having such an research in a laboratory is consuming lots of time & energy & money, which is inefficient . As it can be remembered, "*the goal of ABM is to search for explanatory insight into the collective behavior of agents obeying simple rules, typically in natural systems, rather than in designing agents or solving specific practical or engineering problems*"[1] . Furthermore, agent based simulation is providing opportunities to analyze statistics of a micro scale model and facilitating interactions of many agents. Hence, we found it logical to work on Agent Based Models.

1: https://en.wikipedia.org/wiki/Agent-based_model#Simulation_models

3) MODELLING QUESTIONS

1) How does the critical value of hunter affect the ultimate survival ?

2) How is food sharing percentage of food-collectors influencing the ultimate survival ?

3) What is the best level of the ratio of hunter to food-collector ?

4) MAIN ASSUMPTIONS

a) Finite Food : In our model, the amount of food will be finite, which means that it will decrease over time. We made this assumption because we wanted to have a more-realistic model. In The Walking Dead , the humans are searching for canned foods to eat. They aren't producing any food .

b) Perishable Food: As described above, when a food is taken from the ground, it has to be taken to nearest hunter. For instance, when a food-collector takes a food and converts the patch from red to yellow, food-collector starts searching for hunters. If there is any hunter in the range of food-collector , food-collector delivers the food to the hunter and increases the stamina of the hunter. In our model , the food has to be delivered to hunter in the same tick when the food is taken. Hence, our food becomes perishable.

c) No Fertility of Agents: We assumed that the number of agents aren't increasing over time. We made this assumption because this model is a survival scenario . Positive fertility isn't a logical assumption, people firstly try to survive under survival circumstances. Hence, we accepted no regeneration of agents in order to make our model more realistic.

d) Starvation : We assumed that humans (hunters & food-collectors) suffer from starvation. Hunters suffer more than food-collectors because it is logical to say that hunting is more energy-consuming than collecting food. In every tick, the stamina value of food-collectors and hunters decrease by 2 and 3 respectively. We also assumed that zombies don't suffer from starvation ; therefore zombies don't eat food to increase their stamina

5) STATIC DESCRIPTION OF AGENTS AND ENTITIES

ZOMBIES (TURTLES)	FOOD-COLLECTORS (TURTLES)	HUNTERS (TURTLES)
Stamina	Stamina	Stamina
Types	Types	Types
Species	Species	Species
Attacking-Power	Food-Search-Range	Hunting-Power
Searching-Range	Food-Deliver-Range	Hunting-Range
Attacking-Range	Oriented-Hunter	Survival-Range
Oriented-Human		Targeting-Range
		Oriented-Zombie
Try-To-Kill-Human	Food-Collector-Search	Hunter-Search
Zombie-Search	Search-A-Hunter	Try-To-Kill-Zombie
		Survival-Search

Key Parameters :

Percentage-Of-Hunters: In our model, there will be 100 humans. This key parameter is giving us the number of total hunters in humans

Critical-Value : A Key Parameter about the *stamina* of hunters. If *stamina* of hunter is lower than *Critical-Value* , Hunters start behaving like Food-Collectors .

Share-Percentage : How percent of food taken by Food-Collectors will be delivered to Hunters

Common Attributes:

Stamina: Showing the energy level of turtles. If it is below 0, turtle dies

Types : Defined in order to differentiate zombies and humans

Species: Defined in order to determine whether a turtle is zombie/food-collector/hunter

A) ZOMBIES

Specific Attributes of Zombies:

Attacking-Power : meaning that how much damage is given to humans

Searching-Range : the range in which zombies orient to a human

Attacking-Range : the range in which zombies attack humans

Oriented-Human : when there are plural humans in *Attacking-Range*, zombies spot the nearest human and attack that human .

Functions of Zombies:

Try-To-Kill-Human : When a human is in *Attacking-Range* , its *Stamina* is decreased by the amount of *Attacking-Power* .

Zombie-Search : Checking whether any human is existent in *Searching-Range*. If there is any human in Searching-Range , zombie orients to that human. If not , moves randomly .

B) FOOD-COLLECTORS

Specific Attributes of Food-Collectors:

Food-Search-Range: To find whether a food is existent in the range. If food is existent, food-collector orients to nearest food in *Food-Search-Range* .

Food-Deliver-Range : the range in which a food-collector which has food gives the food to *Oriented-Hunter*

Oriented-Hunter : a hunter chosen to provide food by Food-Collectors in *Food-Deliver-Range*

Functions of Food-Collectors:

Food-Collector-Search : If a food-collector is on a food, it takes the food and *Search-A-Hunter* . If not, a food-collector starts to search food. If any food in *Food-Search-Range* , orients to the nearest food.

Search-A-Hunter : When a food is taken, food-collector tries to find a *Oriented-Hunter.* If any hunter in *Food-Deliver-Range ,* the *stamina* of *Oriented-Hunter* increases by 100 * *Share-Percentage* .

C) HUNTERS

Specific Attributes of Hunters:

Hunting-Power : The amount of damage given to zombies

Hunting-Range : The range in which a hunter can attack *Oriented-Zombie*

Survival-Range : When a hunter converts to food collector due to its stamina lower than *Critical-Value* , the range in which food is searched .

Targeting-Range : The range in which a zombie is searched. If any zombie in *Targeting-Range* , hunters orient to *Oriented-Zombie* . If not , moves randomly

Oriented-Zombie : The zombie which a hunter orients to in *Targeting-Range*

Functions of Hunters :

Hunter-Search : Hunters are looking for zombies in *Targeting-Range*

Try-To-Kill-Zombie : If any zombie in *Hunting-Range* , Hunters attack *Oriented-Zombie*

Survival-Search : When the *stamina of* a hunter is lower than *critical value* , hunters stop acting like Hunters and starts acting like Food-Collectors

6)PSEUDO CODE OF GENERAL PROCESS AND IMPORTANT PROCEDURES

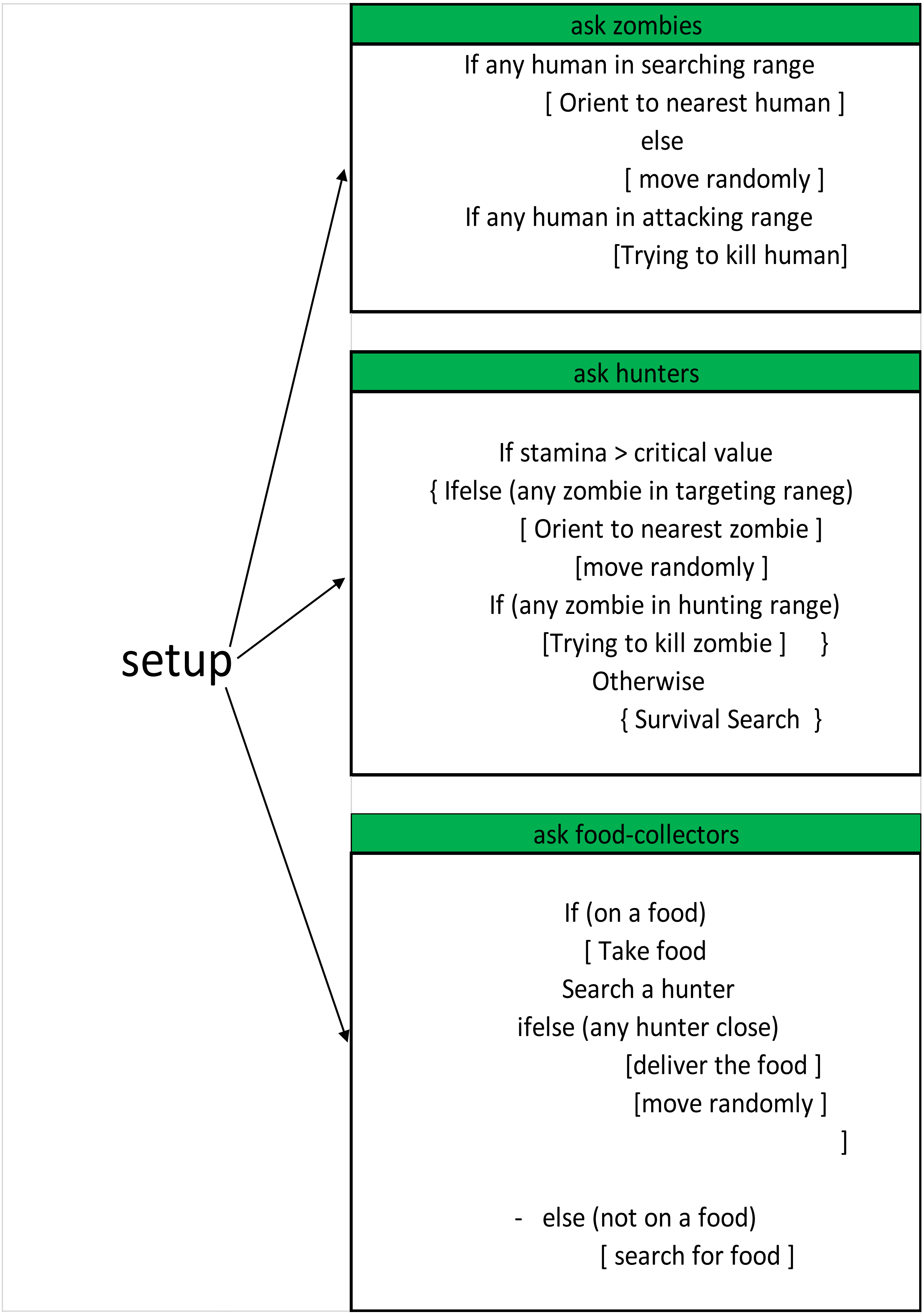
setup

create-hunters percentage-of-hunters
set stamina 1000
set types 1
set species 1
set targeting-range 4
set survival-range 5
set hunting-power 70 + random 11
set hunting-range 2

create-foodcollectors 100 - percentage-of-hunters
set stamina 600
set types 1
set species 2
set food-search-range 4
set food-deliver-range 3

create-zombies 500
set stamina 300
set types 2
set species 3
set attacking-power 5 + random 6
set attacking-range 1
set searching range 2

global variables
set no-of-clusters 60
set percentage-of-hunters 50/60/70
set critical-value 100/200/300
set share-percentage 0.3/0.5/0.7


setup
ask zombies
If any human in searching range
[Orient to nearest human]
else
[move randomly]
If any human in attacking range
[Trying to kill human]
ask hunters
If stamina > critical value
{ Ifelse (any zombie in targeting raneg)
[Orient to nearest zombie]
[move randomly]
If (any zombie in hunting range)
[Trying to kill zombie] }
Otherwise
{ Survival Search }
ask food-collectors
If (on a food)
[Take food
Search a hunter
ifelse (any hunter close)
[deliver the food]
[move randomly]
]
- else (not on a food)
[search for food]

7) VERIFICATION AND VALIDATION

As we know from the IE 48F course, no model can claim absolute objectivity, for every model carries in it the modeler's worldview. It cannot be said models are true or false, the important thing about them is that how well do they describe or explain the problem.

Verification is checking of whether code is correct translation of conceptual modeling or not. A conceptual model is built firstly and then, we started to code the model. In the meantime , we pay attention the consistency of the code with the conceptual model.

Validation is that the model is an adequate, close, good enough representation of the real dynamic problem. Our model is imaginary so we cannot test that it is a good representation of a real problem. However, we can test it by thinking logically. In other words, we can do extreme condition test. For instance, suppose there is no hunter, only food collectors and zombies are in the model. If we run the model, it is expected that zombies would kill all food collectors over time. Our model gives the same result as expected. Such extreme condition simulations are made and the result is always as expected.

8) EXPERIMENTS AND RESULTS

In the model, there are 3 different key parameters which have 3 different levels, so we have 27 different experiment settings. These key parameters are ratio of hunters over food collectors, critical value and share percentage. All scenarios are tested with each policy to analyze which policy is better for ultimate human survival.

There are 4 policies which are designed to test and understand what might occur in totally different settings.

Policy 1 : is the policy explained so far.

Policy 2 : Hunters start to group and hunt together. In every tick, hunters seek for the closest stronger hunter in a specified range than themselves. Strongness can be evaluated in terms of stamina level. In other words, hunters look for the closest hunter whose stamina level is higher than their stamina level is within the specific range. If someone is found in this range, hunter moves towards to founded strongest hunter.

Policy 3: This time zombies seek for the closest stronger zombie in a specified range and if such a zombie is found, the zombie is followed by fellows.

Policy 4 : Adding 5 shelters to the base model. Rather than food collectors search for hunters after collecting food, food transfer centers between hunters and food collectors are created. These shelters are the meeting points for humans.

To sum up, we have 27 different scenarios with 4 four policies. Each scenario and policy combination is run with 30 times (30 replications) to obtain a confidential conclusion. In total, 3240 simulation runs are needed to come up with a conclusion. All results from these 3240 simulation runs can be found in additional excel files. The ultimate survival for humans are investigated and main concern of the project. However, the main outcome is analyzed in different angles. That is to say, not only the average number of survivals at the end of each run is examined but also the average length of simulation runs is the main interest. As it was mentioned before, in the model resources (food) are scarce and humans are vulnerable to zombie attacks. Humans are threatened 2 different factors. To separate these two distinctive effects, the average length of simulation runs is viewed as an output from the model. Thus, it can be analyzed the effect of zombie behavior on humans in different setups. Besides, in order to answer modeling questions, we get number of runs where humans beat zombies (surviving until all zombies are dead.) in 30 replications for each scenarios and policies.

Comparison of the extent of the effect of zombies on human life for each policy

In order to come up with a conclusion about the effect of zombies on humans, models are ran both with and without zombies for each scenario and policy. When there is no human left in the run, simulation stops and the number of ticks passed is gathered at the end of the simulation. In every policy model, the average number of steps with and without zombies are calculated from 27 different scenarios. The following table is obtained from this evaluation :

Policy Number	Average Step with Zombies	Average Step without Zombies	Difference
1	293,4248148	396,1985185	102,7737
2	342,9337037	384,2637037	41,33
3	393,032963	410,8474074	17,814444
4	551,9711111	778,6688889	226,69778

The result is clear : policy 4 is the best policy for each case (with & without zombies) with respect to the number of steps passed until all humans are gone, therefore there is no need for further calculations such as standard deviations. This probably happens thanks to the shelters' properties which prevent the stored food from getting spoiled. As it was mentioned in assumptions part, food can be perishable after food collectors gather food and try to reach and supply food to hunters. However, in policy 4 once food is brought into shelters, it never spoils and goes waste.

As comparing policy 2 and 3 with policy 1 in with zombie case, it can be observed that hunter grouping help humans to live longer but in policy 3 humans live even more longer. It is quite interesting that zombie grouping works for the benefit of humans. The possible reason behind this interesting result is that zombies search for humans in smaller areas when they form group. Therefore, some food collectors that are not spotted in searching range of zombies for long times may survive by searching food and eating them. In terms of the average number of steps humans live, it can be said that the grouping strategy of zombies fail. On the contrary, it seems like hunter grouping works well for humans.

Now, let's focus on the difference value between average steps with and without zombies. It can be observed that there is no clear difference in policy 2 & 3. Since grouping for hunters seems beneficial for humans' life and zombies grouping fails, zombies have little impact on human life compared to other policies. In reference case, the significant detrimental impact of zombies is expected. In other words; the model is created to show this negative effect in normal conditions. Finally, zombies play crucial role on policy 4 because it might be the case that adding food transfer center means meeting and gathering together which also means there is less probability that zombies lounge around instead of attacking humans, therefore humans may be even more vulnerable to zombie attacks.

Comparison of the policies with respect to number of wins in 30 replications

In this part, we investigate that who comes out victorious after the war between humans and zombies. The simulation ends if all humans or all zombies are dead. The following table shows the average number of wins gained by humans for all scenarios in 30 replication runs.

Policy Number	Avg # of wins gained by Humans
1	7,148148148
2	0
3	15,81481481
4	15,2962963

These results are similar to the results that are came up from the previous comparison. Zombie grouping does not work well for zombies and adding shelters to the reference model can be considered an improvement for humans. On the other hand, it is surprising that humans do not win a single round (simulation run - replication) in policy 2. It have been found that humans live longer in hunters grouping case compared to base model. However, it can be clearly observed that in policy 1 humans are more successful on killing all zombies in comparison to policy 2. The reason behind this is grouping of hunters causes that food collectors are more vulnerable to zombie attacks since hunters control smaller territory. Hence, it can be concluded that grouping of hunters is not a good way to win the game.

Investigation of effects of key parameters

In order to answer modeling questions, the effect of key parameters on the life time of the human race is analyzed in the model setting with zombies. Recall that when all humans are dead, the simulation stops and last tick of the simulation is main output for this type of study.

Policy 1

Key Parameter	Value	Average Step
Share Percentage	0,3	267,0733
	0,5	294,9822
	0,7	318,2188
Critical Value	100	331,4133
	200	300,2966
	300	248,5644
Percentage of Hunters	50	194,9477
	60	309,13
	70	376,1966

Policy 2

Key Parameter	Value	Average Step
Share Percentage	0,3	301,3667
	0,5	335,2667
	0,7	392,1678
Critical Value	100	371,3144
	200	348,5311
	300	308,9556
Percentage of Hunters	50	303,9822
	60	337,7544
	70	387,0644

Policy 3

Key Parameter	Value	Average Step
Share Percentage	0,3	301,3667
	0,5	335,2667
	0,7	392,1678
Critical Value	100	371,3144
	200	348,5311
	300	308,9556
Percentage of Hunters	50	303,9822
	60	337,7544
	70	387,0644

Policy 4

Key Parameter	Value	Average Step
Share Percentage	0,3	517,4967
	0,5	545,5522
	0,7	592,8644
Critical Value	100	615,8767
	200	551,1322
	300	488,9044
Percentage of Hunters	50	398,0411
	60	601,1311
	70	656,7411

In all policies, the result is similar. For share percentage = 0,7 & critical value = 100 & percentage of hunters = 70, the average last step before simulation ends is higher. Therefore it can be concluded that most people of the population should be hunter and food collectors should be more generous to share food with hunters for the sake of humans. Additionally, hunters should not give up hunting easily, they should fight as far as possible to the end.

9) CONCLUSION

The model is a reflection of an imaginary world which we are inspired of " The Walking Dead" series. First conceptual model is built and it is translated into NetLogo codes. After that, key parameters and their different levels for experimentation are determined. To be able to explain the effects of these key parameters on human life, several simulations are done. As a result, humans should be composed of mostly hunters that are fearless against zombies to cope with both zombie threat and scarce food. Since number of hunters are greater than number of food collectors, food collectors share a big portion of food collected with hunters for the sake of human race.

Apart from testing of key parameters, different model settings (policies) are designed to do further research. All policies are analyzed in different aspects, and consequently policy 4 which is adding shelters to the model is found to be the best environment for humans.