CHALLENGE #3
SURVIVING THE ZOMBIE APOCALYPSE

IMT Atlantique
Bretagne-Pays de la Loire
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It is no longer a speculation. As predicted by TV series ,the Zombies are at the **Turkish town of Rize** and they are here for you and me in **Brest.** Where will you be on the 18th of August, 2019?

Based on a population density and elevation map of some part of Europe made available, we want to find out if we will make it.

How long will it take the zombies to end our lives?
Let's rack our brains

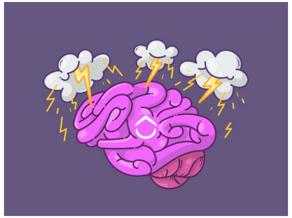


Fig 1. Zombie Cartoon & BrainStorming [6] [7]

CHAPTER 2 : CRISP METHODOLOGY

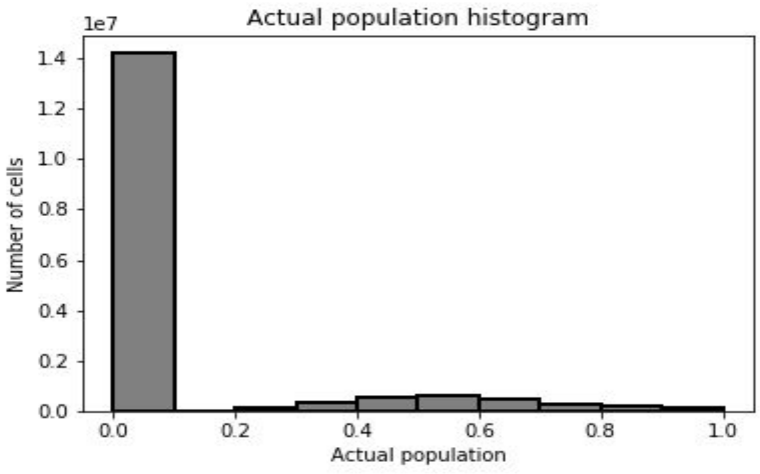
2.1 Business Understanding

The **aim** of this project is to answer the following questions:

- Will zombies in Turkey make it to Brest?
- How long will it take for them to reach Brest?
- Which 20 cells should European Union secure two months after the Zombie epidemic to protect the maximum number of people?
- Will Zombies still get to Brest if the European Union secured these 20 cells?
- How many nuclear bombs should European Union launch, and to which cells should they be launched in order to get the best possible ratio of (humans killed by bombs) / (humans saved by total destruction of zombies)
- Will Zombies still get to Brest if the European Union launched the nuclear bombs?

Fig 2.Brittany Flag,Turkey Flag, Zombie, Clock [3] [4] [5]

Image	Dimension
Population Density	3510 x 4830 (height x width)
Elevation	4251 x 4901 (height x width)



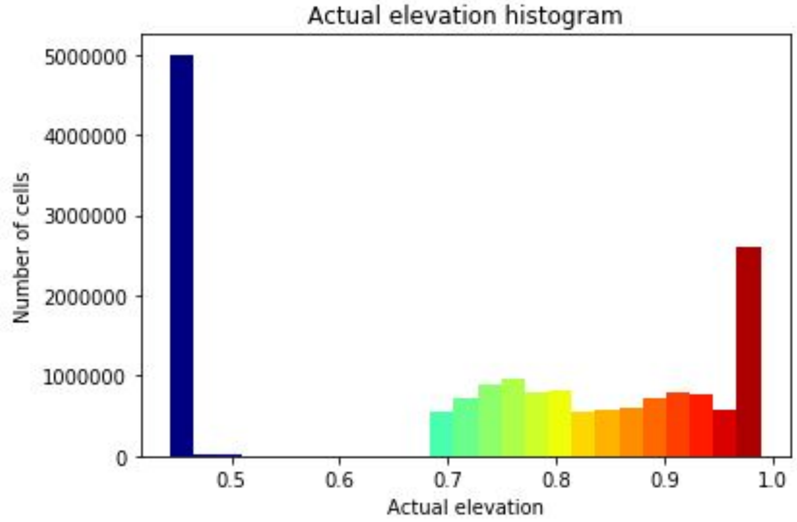


Fig.3 Actual Population and Elevation Histogram

- In the population density image, the **red pixel** indicates the location of **Brest** which is the destination and the **green pixel** indicates the location of **Turkey** which is the starting point.

Location	Coordinates
Brest	669,1306 (x,y)
Turkey	4426,2108 (x,y)

- 1 pixel in both population density and elevation images is 1 km^2 .
- Zombies can move in **8 directions** from one cell to another cell.
- Zombies cannot move to a cell with altitude greater than 10 degrees.
- Λ_d is 0 for a slope higher than 10°,1 for a slope of 0° and linear between these two values for slopes between 0 and 10°.
- The life cycle of a zombie is 15 days.
- The highest altitude in the elevation image is Mont Blanc (4810m).
- An absolute white color is 3000 inhabitants per km^2 .

- A cell is composed of 15 x 15 pixels.
- $H_j(c_i)$ is the human population at cell c_i.
- $Z_j(c_i)$ is the zombie population at cell c_i on day j.
- N zombies kill 10 × N humans in the cell they enter.
- M humans that survive the zombie attack destroy 10 x M zombies in that cell.
- Daily, zombies spread from day j to day $j + 1$. The contribution $C_{j+1}(c_0, c_i)$ of cell c_0 to cell c_i is define by :

$$C_{j+1}(c_0, c_i) = \frac{H_j(c_i)}{\sum_{k=1}^{8} H_j(c_k)} Z_j(c_0)\lambda_0,$$

$$C_{j+1}(c_0, c_i) = 0$$

$$C_{j+1}(c_0, c_0) = Z_j(c_0)$$

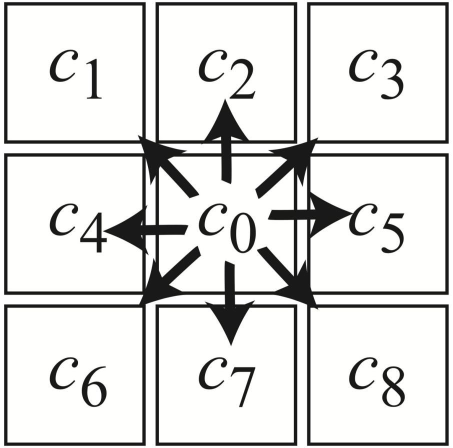


Fig 4. Zombie Movement

- Elevation image was superimposed on the population image with the help of MATLAB [1] to get an image of the same size, with pixel coordinates representing the same position.
- Elevation image was converted from RGB to HSL.
- Population image was converted into Grayscale image.
- A **15 x 15 filter** was applied to the image in order to create a cell.
- The **Mean value** of 15 x 15 pixels captured by the filter became a pixel in the **output image.**
- The **pixel** in the output image is considered as a **cell.**
- The image was then **cropped** to capture Brest and Turkey.

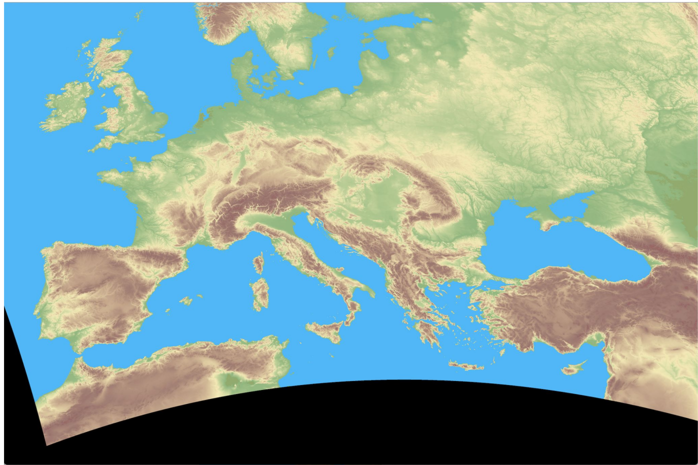
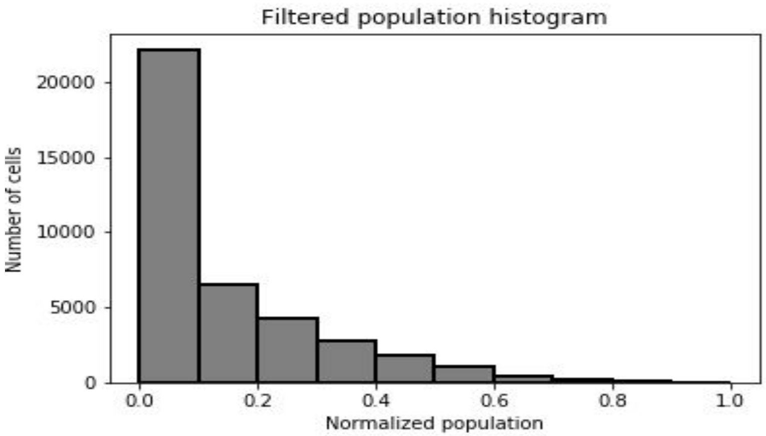


Fig 5. Result of Superimposed Image

2.3 Data Preparation

	Before filter(pixels)	After 15 x 15 filter	After Cropping
Population Density	(3510, 4830)	234 x 322	140 x 282
Elevation	(4251, 4901)	234 x 322	140 x 282



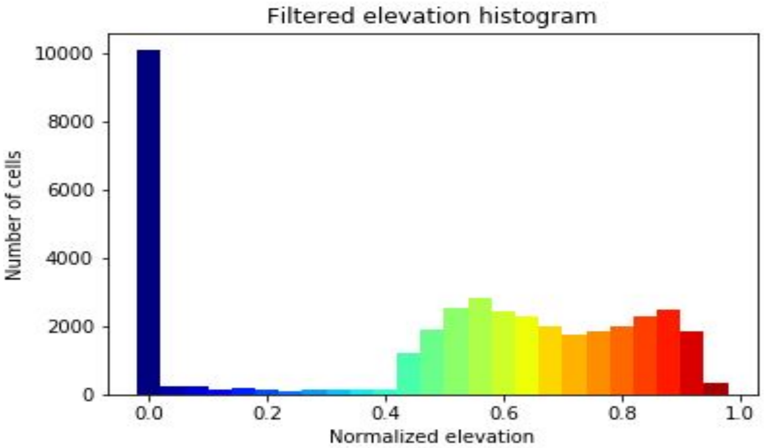


Fig 6. Filtered Population and Elevation Histogram

- Pixels below the value of 0.15 in the **population density image** were set to 0.0 to indicate that there are no humans there.
- Pixels below the value of 0.1 in **elevation image** were set to 0.0 to indicate sea level.
- To calculate the **human population**, every cell in the filtered population image is multiplied by **3000*15*15**

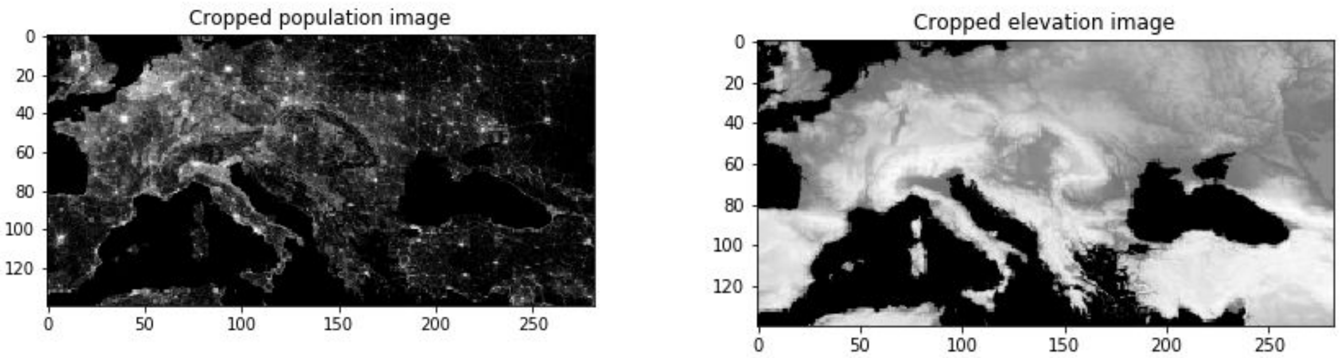


Fig 7. Cropped Population and Elevation Image

This project was modelled using 2 methodologies

- Custom method to propagate dictionaries where the zombies moved.
- The concept of graph theory using the adjacency matrix .

In order to solve this problem, we modelised our data as a graph data structure

- A **graph** is a set of **nodes** .
- A **node** is a pixel in the density image.
- **Neighbours** of a pixel can be defined as 8-neighbours
- Zombies are attracted to nodes which consist of humans
- A node is infected once zombies reach their.

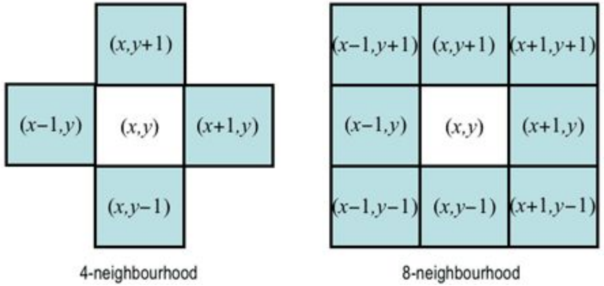


Fig 8 . Pixel Neighbourhood [2]

For the **population density** map:

- A pixel of color “bright white” indicates high population.
- A pixel of color “dark black” indicates no population.

For the **elevation** map:

- A pixel of color “bright red” indicates high altitude.
- A pixel of color green indicates ground level.
- A pixel of color blue indicates sea level.

Concerning Zombies movement :

- They cannot go beyond a certain altitude, neither can they be at sea since no humans are located there.
- Zombies can move to their neighbouring cells only.
- If the elevation angle between two nodes is less than 10° and the human population in the next node(the node where zombies will be moving to) is greater than zero and total population in surrounding neighbours is greater than zero, zombies can move to that cell.
- Else they will stay in the same node.
- Zombies propagate as per defined in the formula in the data understanding section.

How did we store the zombies information?

- We created a 3D array of height and width the same as that of the size of the image and a depth of 15 representing the life cycle of the zombies (starting from 0 to 14)
- This is to easily locate the number of zombies of different ages in a subcell of each cell in the image.
- As the days went by, we shifted the zombies to make them a day older(with the help of shift function).
- Zombies shifted for 15 days were moved out of the cells and considered as dead.

Day	0	1	2	3	4	5	……..	14
No of Zombies	10	50	0	70	50	30	……	80

Fig 8 . Zombie Movement [8]

We used the two methodologies to find the shortest path between the two cities.

Model 1 :- Custom based model

Prerequisite :-

- We created an empty nested dictionary and updated the node with the starting point and set a variable to track the count of number of days .
- We also created a list source cell consisting of the source cell.
- We set the zombies population as the human population of Riken city (at the node (100,255)) on day zero.

Algorithm:

Start-

Step_1 : - **Zombie movement function** (its task is to update the zombies movement every day)

1. Shift the array of zombies to one position ahead.
2. Create an empty List to store the cells the zombies moved to.
3. Check if the current cells have the zombies count greater than zero.
4. If yes , take the neighbouring cells around it and calculate their total population.
5. Update the zombies according to their movement logic (as indicated in slide 12).
6. Create a dynamic dictionary to consist of information about cells and where they moved to.
7. Update the list with the new position the zombies moved to.
8. Update the main dictionary once the zombies information has been updated.
9. Return list from the function

Step_2 :- **Zombies killing human function** (its task is to kill the human)

1. Take the updated list of zombies position (in Step_1).
2. Iterate through the list and kill the humans (human to be killed = 10 * zombies present in the cell).
3. Update zombies array at current cell on day zero with the number of human killed.

Step_3 :- **Human killing zombies** (its task is to kill the zombies)

1. Take the updated list of zombies position (in Step_1).
2. Iterate through the list and kill the zombies (zombies to be killed = 10 * Human present in the cell)
3. Update human and zombies array of the cell.

This process is repeated until our list contains the cell location of the Brest.

Model 2 :-The concept of graph theory (shortest path algorithm-Dijkstra's Algorithm)
The goal of this model is to find the shortest path using the dijkstra algorithm.

Prerequisite : -

- Create an boolean empty adjacency matrix of the size of the image

Steps:-

1. Follow the same methodology in the model 1.
2. Updated the adjacency matrix with the boolean **True** for the cells where the zombies reached.
3. Compute the shortest path between the source cell to all other points in the image using the dijkstra algorithm.
4. Construct the path between source and destination (Brest) by creating a list of the cells between the source and destination.
5. Return the length of List which indicates the number of days it took the zombies to reach Brest.

The result as per the implemented models are:-

	Model 1(Dictionary)	Model 2(Adjacency Matrix)
Reached Brest	yes	yes
Number of Days	251 days	251 days

The number of days obtained in both the models are same.

:-

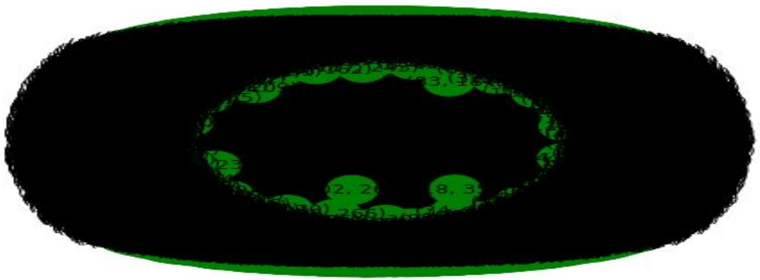


Fig 9 .Densed network DiGraph

Fig below shows the path followed by the zombies to reach brest from the riken:-

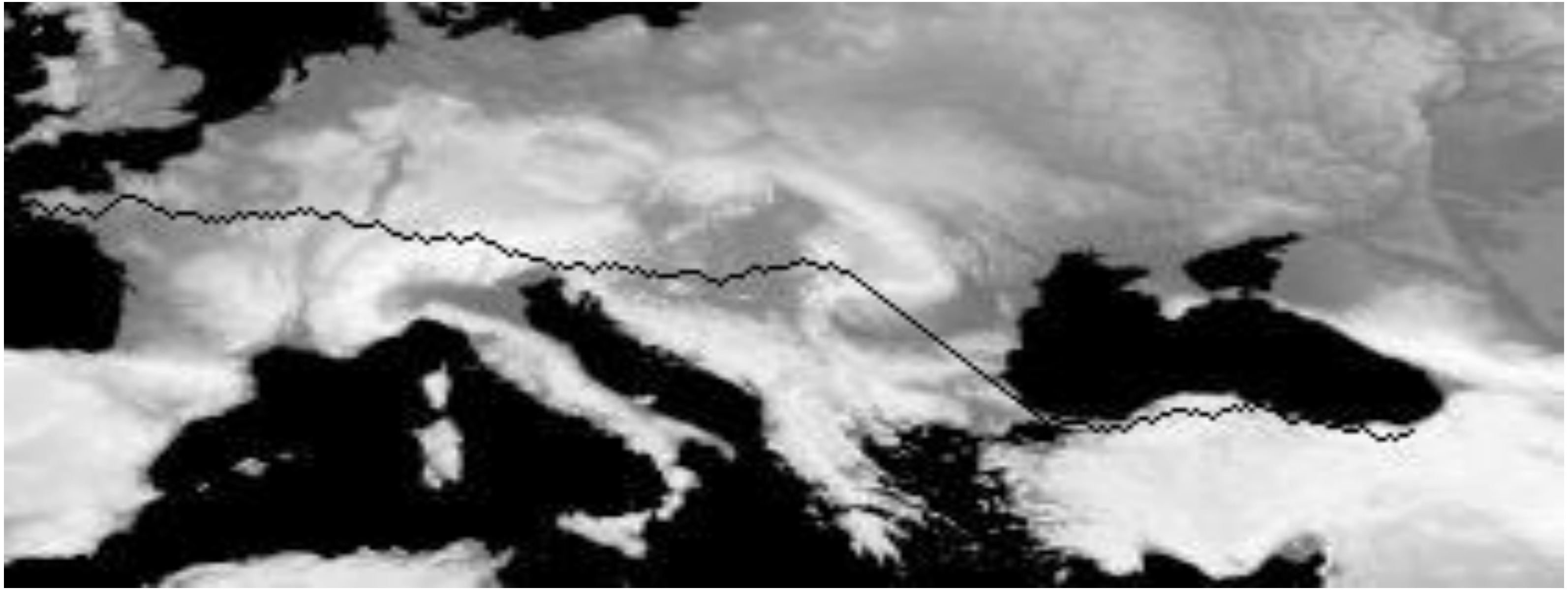


Fig 10 .Path followed by zombies

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Fig below shows the the zombies movement from beginning till they reached to brest

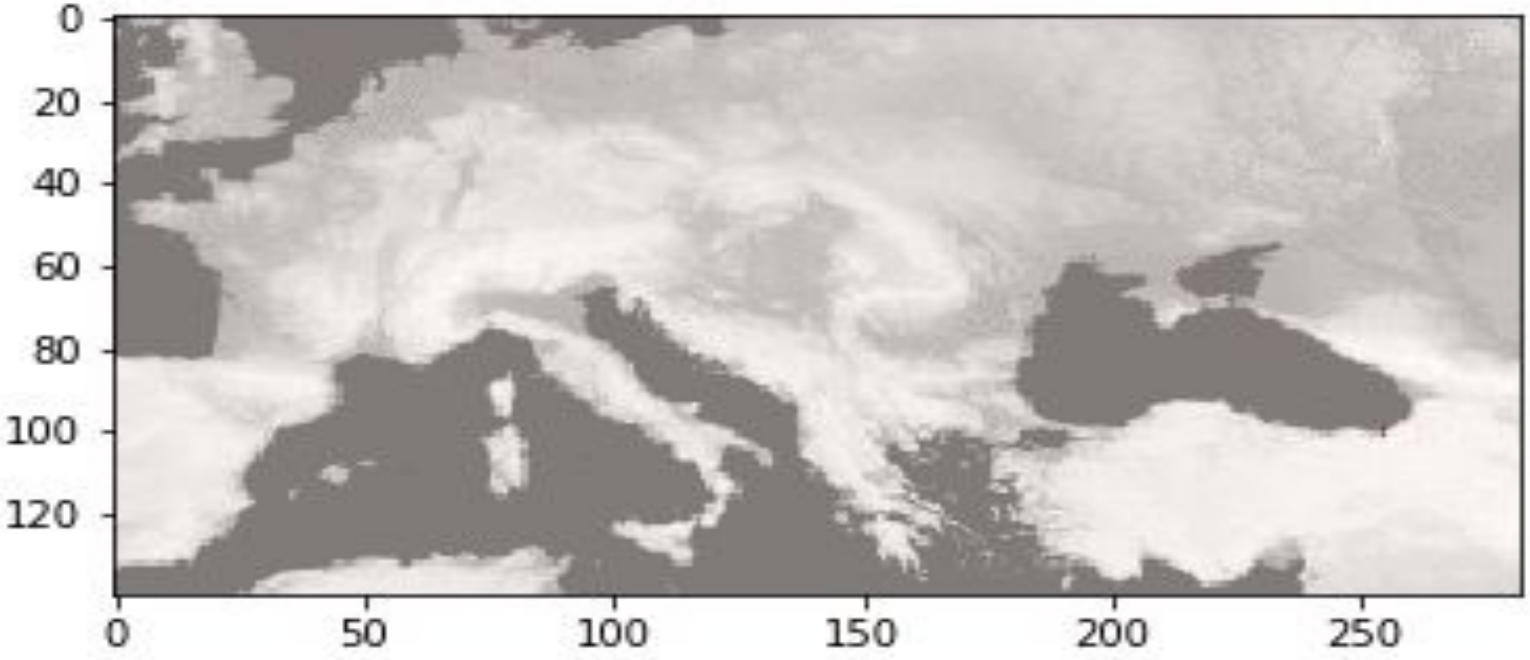

Fig 11 .Zombie movement from Turkey to Brest

Zombies are here after the 60 days

Zombies after the 120 days

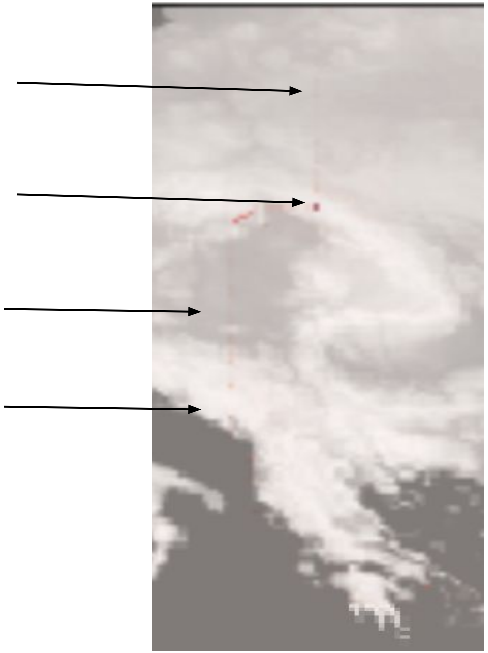

Fig 12 .Zombie movement after 60 and 120 days

2. Military Deployment

In order to obtain the most influential cells to deploy the military troops :-

- One of factor which can play vital role in saving the human population is the betweenness centrality. Based on graph theory, the higher the betweenness centrality, the more control a cell has over the network ,which indicates that a lot of zombies cells pass pass through it.
- Among the cells obtained, we tried to secure the cells with the following characteristics:-
    - With high betweenness centrality .(7 cells)
    - Cells with the highest number of zombie population .(1 cell)
    - Highest human population surrounding the current zombies location. (12 cells)

The 20 obtained cells are - (102, 175), (40,218),(101, 174), (101, 192), (106, 192), (103, 192), (38, 219), (46, 216), (39, 216), (64, 207), (69, 207), (50, 216), (49, 216), (38, 217), (47, 216), (100, 190), (99, 190),(100, 193)(101, 193)(102, 193)
Due to the large propagation of zombies, the Brest city won’t be safe with the above effort .

3. **Nuclear deployment**

- The best regions to deploy the nuclear bomb are the places where the zombies are located at the end of three months and are forming a bridge with the cells where humans are alive.

- The cells located in this area should act as a border line in order to prevent zombies from having any further contact with the human in future.

- The number of cells obtained in our case were 121 cells.

Yes the Brest is safe now :D

CHAPTER 3 : CONCLUSION

Based on the result , we have following conclusion.

- With the current condition , brest can not be saved unless nuclear weapons are deployed.
- With in the two method which we used , the method with the adjacency matrix gave us a quick result.(it has less turnaround time)
- Securing the cells with highest betweenness centrality degree and killing the zombies coming to that cell could change the result, due to time constraint we couldn't implement it

This challenge has helped us to deal with the application of graph theory concept in the real life situations.

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