Algorithmic disaster preparedness for Roadways and Railways.

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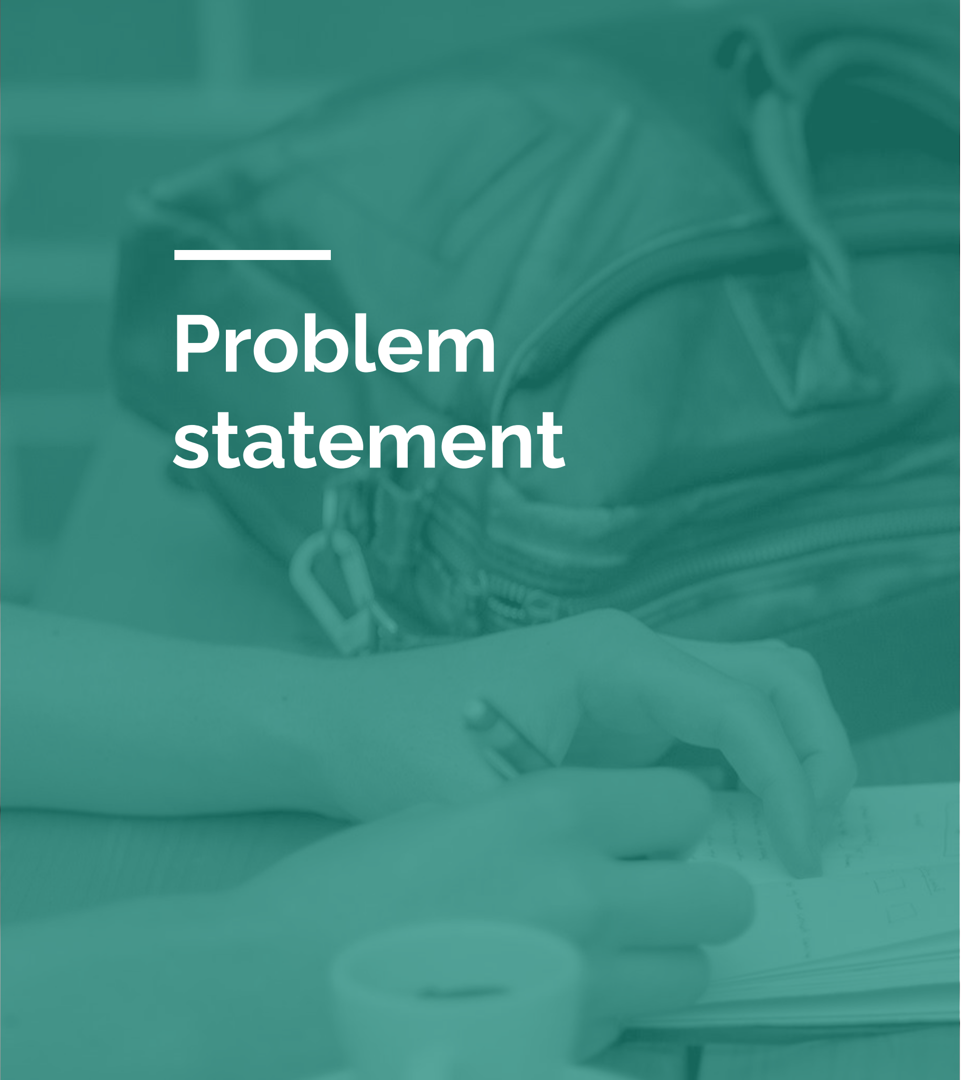
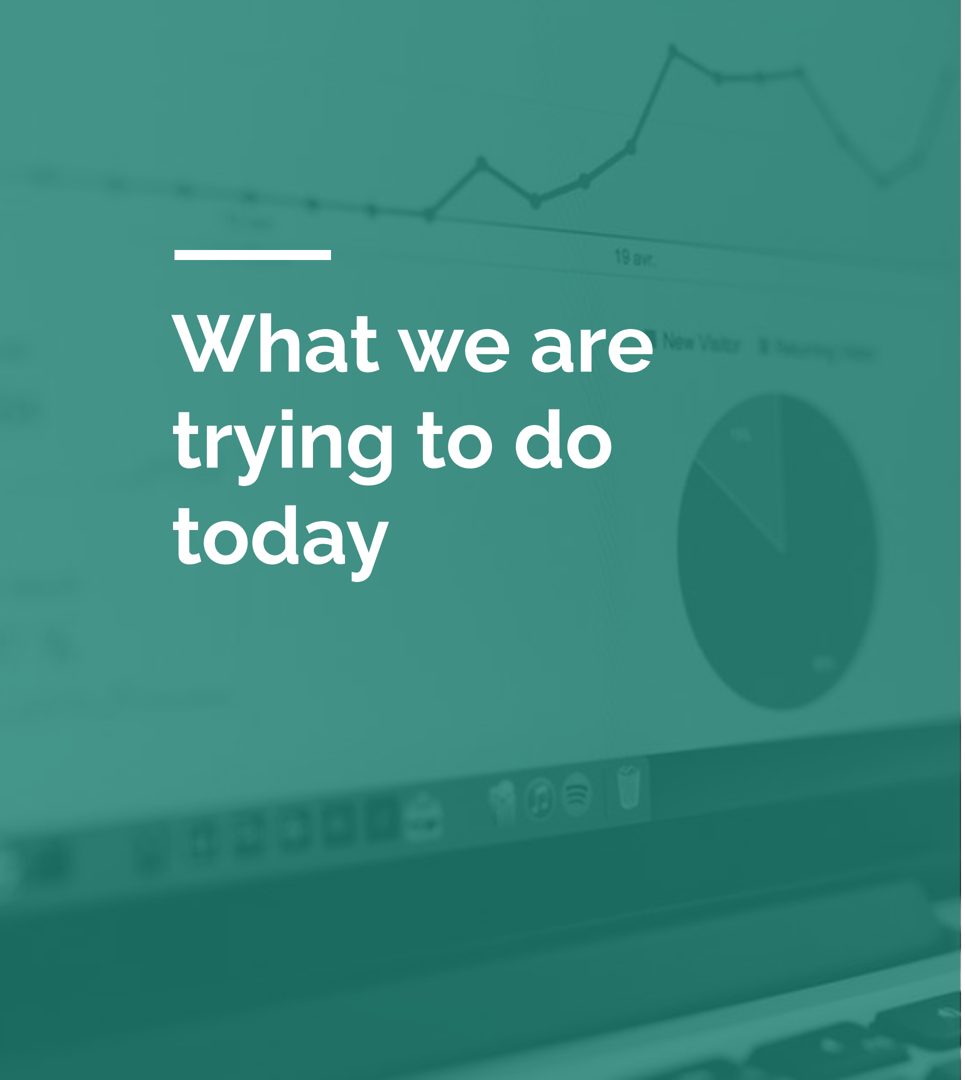


Problem statement

Optimising railways and roadways preparedness for accidents using geographical approach.

More than 13,000 train accidents across the country have killed nearly 12,000 railway passengers last year, according to a recent report by the National Crime Records Bureau (NCRB). The latest statistics mean that on average, 32 people lost their lives every day in these accidents in 2020.

India ranks first in the number of road accident deaths across the 199 countries and accounts for almost 11% of the accident related deaths in the World. A total number of 449,002 accidents took place in the country during the calendar year 2019 leading to 151,113 deaths and 451,361 injuries.



What we are trying to do today

Use genetic algorithm and ML based algorithm to solve the issue of approachability during disasters and accidents.

Propose locations to place accident and disaster relief infrastructure at an optimal place to cover the maximum area in the GOLDEN HOUR period.

The golden hour is the first '60 minutes' following any injury or trauma. Prompt medical attention during this period can save one's life. This period is very critical as the chances of survival depend on this window period.

Motivation

Why work in this field?

How to approach the problem?

What is the need of the hour?

Algorithmic disaster preparedness for Railways

Solution

- Deployment of Accident Relief Medical Vans (ARMV) used for accident relief and rescue operations is generally done heuristically.
- ARMV is an ambulance-train equipped with various tools like jacks, heavy cutting tools, generators, operation theatre, artificial breathing equipment etc. to ease the rescue process.
- The present study will examine the current ARMV asset management of North Eastern Railway (one of the Zone of IR) which is the share of 3032 route-kms of the Indian Railways network.
- We have used Girvan-Newman (GN) algorithm, a weight-based graph for clustering of NER network where nodes are taken as depots with ARMV parking facilities & crew availability and distance between these nodes is taken as edge weight of the graph.

Literature Review

- There is no direct reference similar to the proposed study of is available but there has been quite some research on optimal location of emergency vehicles (ambulance, fire fighting vehicle etc.) in metropolitan cities.
- Goldberg (2004) noted in his research that different models are needed to describe the different types of emergency services.
- Girvan and Newman (2004) did their work on community detection based on edge betweenness calculation to find out communities in the network. Newman and Girvan used weights as the measure to find betweenness of the edges.
- Khan et al. (2017) say that the Newman-Girvan algorithm was the first and efficient algorithm for network optimization

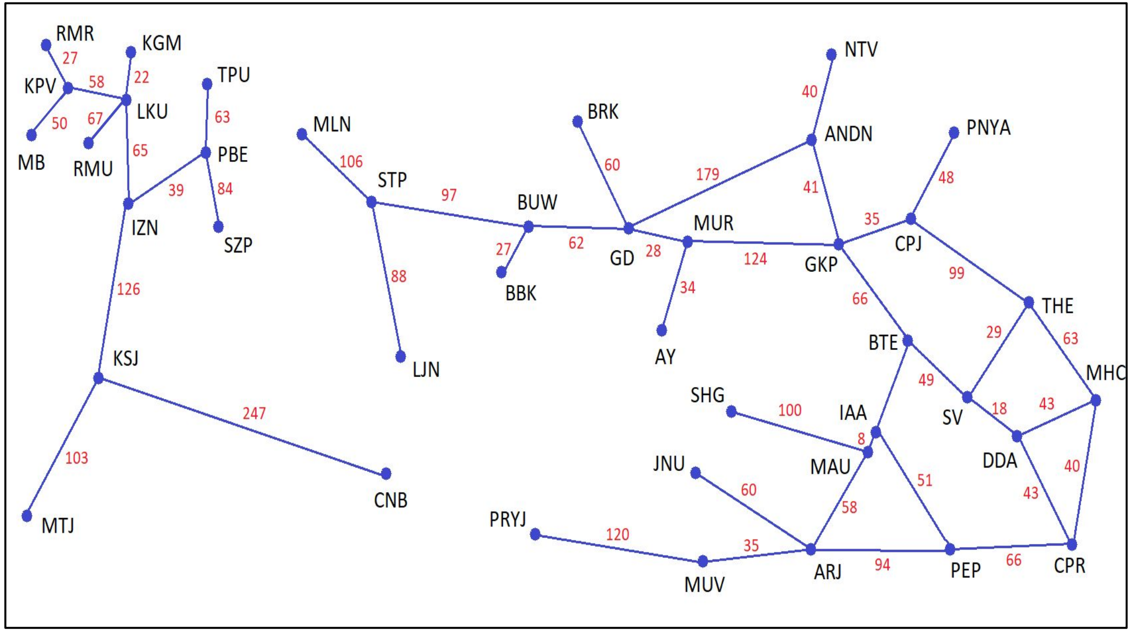
Methodology

- In the present study the NER network (3032 Broad Gauge (BG) Route-KM) of Indian Railways has been taken for a case study, where presently 08 BG ARMVs were deployed for accident care.
- In the present study, we have proposed a new Cluster Coverage Model (CCM) using Python3 and Newman-Girvan algorithm from NetworkX library for python3 for the clustering of nodes where the relocation of ARMV is to be proposed.
- Using of the GN algorithm for relocation of existing ARMVs on NER network to achieve maximum possible coverage within one hour @100 kmph and compare the results obtained.

Methodology

- In graph theory, a network is depicted with a graph, where the nodes are the vertices and the links are the edges of that graph.
- Graph is an ordered pair $G = (V, E)$, where $V = V(G) \neq \Phi$ is the set of vertices and $E = E(G)$ is the set of edges such that for any two vertices $u, v \in V$ there exists $e \in E$ which connects the two endpoints u, v.
- Two connected vertices are adjacent vertices and we say that the edge and its endpoint are incident. The number of edges incident to a given vertex is the degree of that vertex.
- In the graph N E Railway having 41 nodes and 44 edges the edges are weighted as distances.
- Edge can be weighed by many other factors besides distance.

Network



RMR
KGM
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RMU
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124
179
40
41
35
48
99
66
29
63
49
18
43
100
8
58
51
40
43
60
35
120
94
66

Methodology

- Since clustering algorithms work on determining the communities by taking edge weight into account, it is necessary to choose significant factors that might influence edge weight.
- Other factors include age of tracks, maintenance schedules, accident history, traffic density, average age of locomotives, wagons and coaches running on track, single/double tracks, diesel/electric traction and maximum permissible speed among others.
- If the weight of tracks is w and factors affecting them are x, then, (where a, are constants for unit and range adjustments).

$$w = \sum_{i=0}^{n} a_i x_i$$

Girvan Newman Algorithm

- The Girvan-Newman algorithm is run for one less time than the number of ARMVs available. This creates clusters equal to the number of ARMVs.
- The algorithm removes the least important edge from the graph and hence converts the fully connected graph to a disjoint graph. This disjoint graph consists of 2 connected graphs and on subsequent application of the algorithm this graph gets further disjoint. For N-1 iterations, the graph yields N disjoint graphs which we call clusters.
- The algorithm works by first making the clusters using Girvan-Newman method and finding the suitable location in the clusters by finding the node with maximum strength. In a weighted network, the strength of nodes is calculated by summing the weights of its adjacent edges.

Pseudo Code

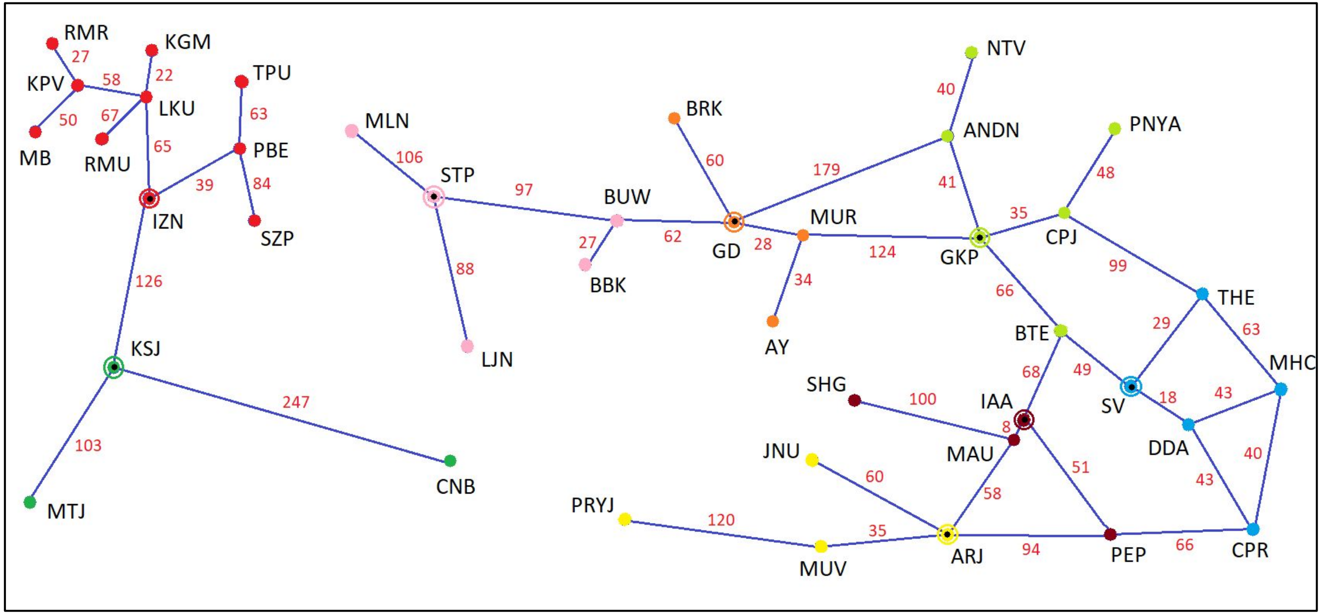
Algorithm: Determining locations for stationing Relief Trains

Input: Stations as nodes, tracks as edges, weight of edges and number of Relief Trains(N)

Output: Nodes suitable for Relief Trains as relief_train_location

```
graph G ⟵ node
graph G ⟵ edge
    edge ⟵ edge_weight
    for i ⟵ 1 to i ⟵ N-1 do
        procedure girvan_newman
            clusters ⟵ girvan_newman(G)
    for j ⟵ 1 to j ⟵ N-1 do
        procedure finding_stations
            if nodes_in_cluster > 1 then
                procedure find_maximum_weight_node
                    relief_train_location ⟵ maximum_weight_node
                if maximum_weight_node > 1 then
                    procedure find_highest_degree_node
                        relief_train_location ⟵ highest_degree_node
            else if nodes_in_cluster = 1 then
                relief_train_location ⟵ node
print relief_train_location
```

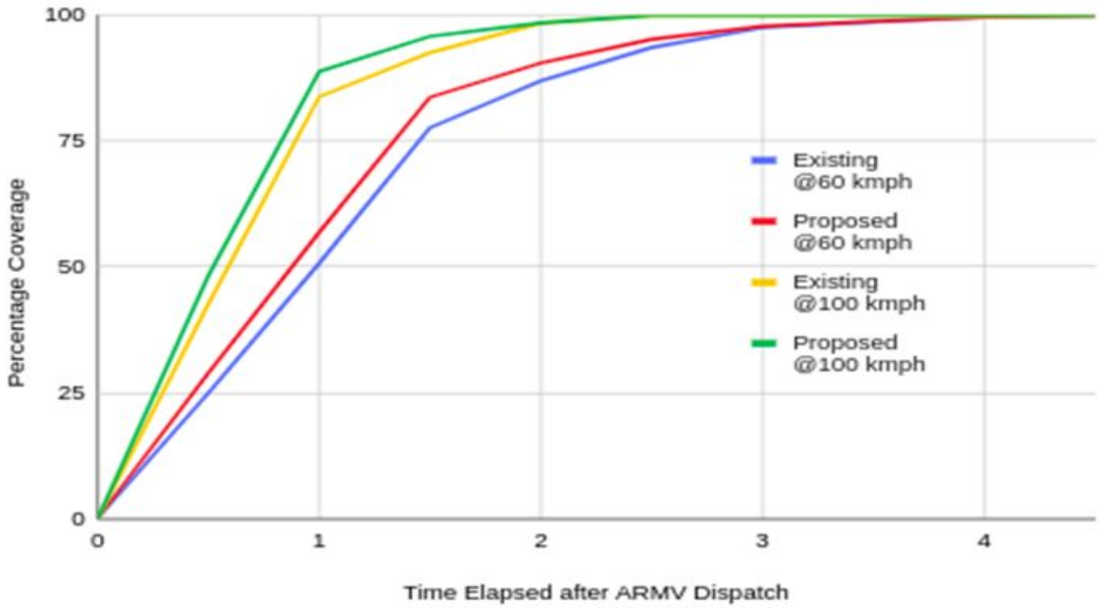
Network after clustering



Results

Clusters	Existing Locations	Proposed Locations
MLN, STP, LJN, BUW, BBK	LJN	STP
BRK, GD, MUR, AY	GD	GD
GKP, ANDN, NTV, CPJ, PNYA, BTE	GKP	GKP
SV, THE, DDA, MHC, CPR	CPR	SV
IAA, MAU, SHG, PEP	MAU	IAA
JNU, ARJ, MUV, PRYJ	MUV	ARJ
CNB, KSJ, MTZ	KSJ	KSJ
KPV, MB, RMR, RMU, LKU, PBE, IZN, KGM, TPU, SZP	LKU	IZN

Results



100
75
50
25
0
0
1
2
3
4
Percentage Coverage
Time Elapsed after ARMV Dispatch
Existing @60 kmph
Proposed @60 kmph
Existing @100 kmph
Proposed @100 kmph

Conclusions

- Result shows by redeployment and relocation of existing 08 ARMVs to the locations proposed in Cluster Coverage Model, for one hour stipulated time, 12% and 6% more coverage can be enhance by the ARMVs travelling with speed of 60 kmph and 100 kmph respectively.
- Solutions of the model shows that total 10 ARMVs (@100 kmph speed) are capable for the coverage of 98% of the given network whereas the results of the proposed new cluster coverage model shows that after the proposed relocation, deployment of only 08 number of ARMV will give coverage of 88.84% on the given network with the same speed.
- We have made some simplifications by assuming that accidents occur randomly and probabilistically over a network, but in most real-life problems the assumption of traffic and train density becomes significant factors to be considered as edge weights because the numbers of train services are not homogenous over the network.

Algorithmic disaster preparedness for Roadways

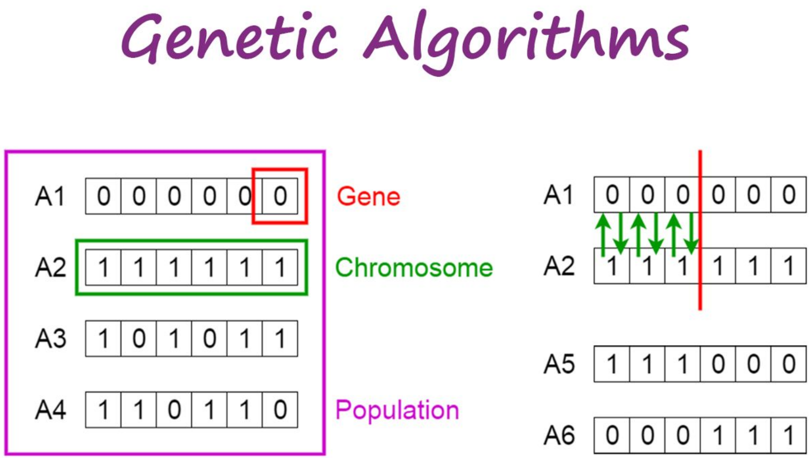
Solution

- Road accidents are unplanned and sudden mishaps that result in major casualties, damage or even death. Hyderabad is a bustling city and on every day basis hundreds of people lose their lives in car, bike, bus and other forms of road accidents. Accidents can’t be prevented but immediate response can most certainly be provided to the affected people.
- Let’s take the example of Delhi, Delhi’s total road length is about 28,504 Km’s creating a network of emergency response vans is not an easy task. Managing that network is also not an easy task to execute. In such a case figuring out an effective disaster response point is the first step towards solving the problem. The disaster response point can be either a headquarter or even a hospital for that case to help in immediate response in case of a road accident or even a fire hazard that has broken loose.

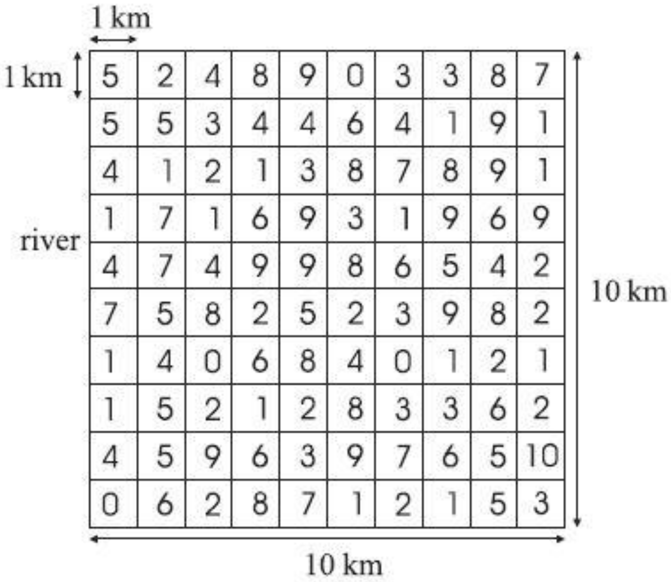
Methodology

- A genetic algorithm is a search heuristic that is inspired by Charles Darwin's theory of natural evolution. This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation.
- The process of natural selection starts with the selection of fittest individuals from a population. They produce offspring which inherit the characteristics of the parents and will be added to the next generation.
- If parents have better fitness, their offspring will be better than parents and have a better chance at surviving. This process keeps on iterating and at the end, a generation with the fittest individuals will be found.

Genetic Algorithm



Methodology



Cost Function

- Consider this grid as a system of roads with the grid representing the city as a whole; each square in the grid has a specific value assigned to it. This specific value represents the accident/disaster frequencies which are associated with that particular region of the grid.
- For this simulation we assign the squares random accident frequencies and we calculate the cost of each square.
- Using this cost function we calculate an aggregate sum of all the possible paths of a square. This aggregate sum represents the cost of the square. This cost is what we are trying to minimize using genetic algorithm.

Cost Function

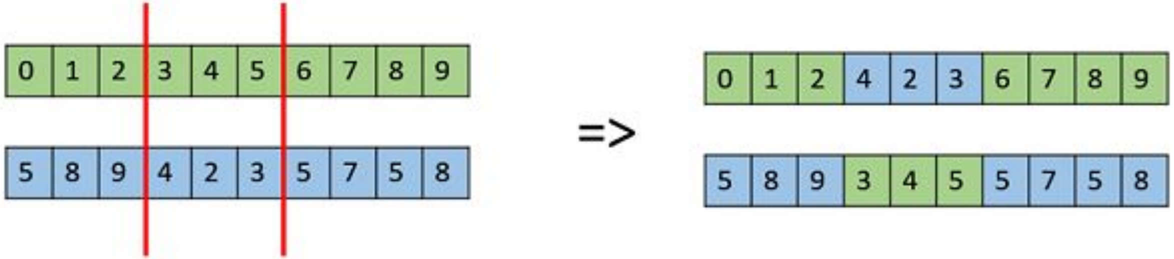
$$cost = \sum_{n=1}^{100} w_n \sqrt{(x_n - x_{fs})^2 + (y_n - y_{fs})^2}$$

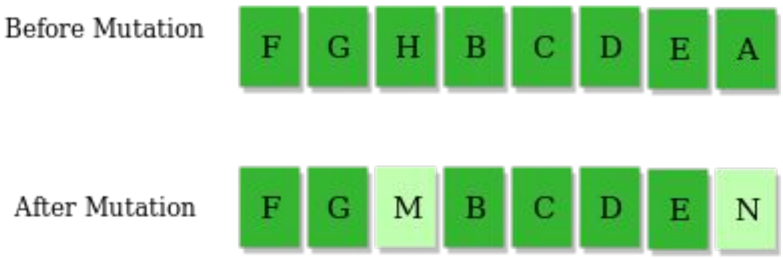
where

(x_n, y_n) = coordinates of the center of square n

(x_{fs}, y_{fs}) = coordinates of the proposed emergency response unit

Crossover and Mutation





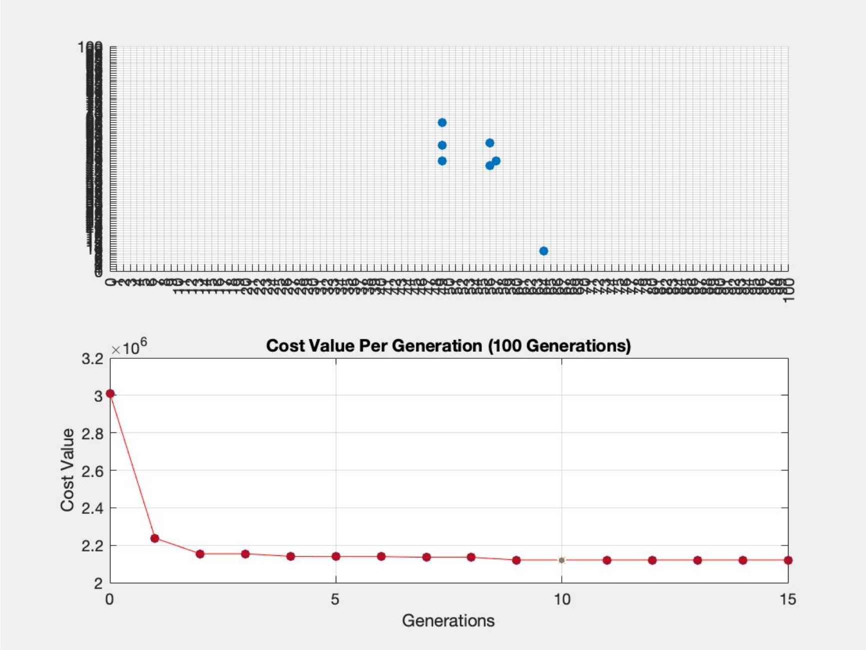
Crossover and Mutation

- In the first pass we will determine the costs of N different squares this N can be controlled by the code. After the first pass we sort out the costs in ascending manner, in this way we get our best seed vectors on the top. Now we perform crossover along with mutation.
- Point (x,y) on crossovers with point (x1,y1) will yield in point (x,y1) and (x1,y) these are the 2 new children seeds. We can also perform mutation on them by playing around with the x,y values. For eg in our case we've played around like (x1*3%49,y*3%49) and (x*3%49,y1*3%49).
- Now using the newly formed children, we again calculate their costs using the cost function. These costs will now again be arranged in an ascending manner along with the parents and then again the top M vectors will be chosen. This process is called generation. In our simulation we generate 15 generations worth of seeds and determine the lowest cost node in the city.

Output

- Using Truncation Selection, the most efficient location will be found right at generation 1. A simpler approach in solving this problem is to evaluate all the locations, then sort them by efficiency. Since Truncation Selection uses sorting, it makes sense that it will get the best location right at generation 1.
- After we have received 15 generations our final output will be indicative of the cell which has the least value of cost. Due to computational costs right now we are only running a grid of 50*50.
- But the real advantage of this algorithm is when the number of cells are very high in number and computation time is something that we can’t afford because of a disaster impending.

Result



Cost Value Per Generation (100 Generations)
Cost Value
Generations

Results

Generations	ProposedCoordinates		CostValue
0	64	9	3.0118e+06
1	49	66	2.2377e+06
2	56	57	2.1543e+06
3	56	57	2.1543e+06
4	57	49	2.1403e+06
5	56	47	2.1393e+06
6	56	47	2.1393e+06
7	49	56	2.1351e+06
8	49	56	2.1351e+06
9	49	49	2.1212e+06
10	49	49	2.1212e+06
11	49	49	2.1212e+06
12	49	49	2.1212e+06
13	49	49	2.1212e+06
14	49	49	2.1212e+06
15	49	49	2.1212e+06

Conclusion

- Here is the result from our simulation with 2500 points on the top with the specific points highlighted in each of the generations.
- The graph below indicates the decrease in the cost value with each iteration. Cost comes to a saturation after a few generations as we converge to the least cost vector.
- Using this cost function we calculate an aggregate sum of all the possible paths of a square. This aggregate sum represents the cost of the square. This cost is what we are trying to minimize using genetic algorithm.

Questions?

References

Goldberg, J.B. (2004). Operations Research Models for the Deployment of Emergency Services Vehicles. EMS Management Journal, 1(1):20–39, January-March 2004.

Khan, B.S., and Niazi, M.A. (2017). Network Community Detection: A Review and Visual Survey. CoRR. Vol. abs/1708.00977, http://arxiv.org/abs/1708.00977.

Newman, M. E. J. (2006). Fast algorithm for detecting community structure in networks. Phys. Rev. E .Vol 69,66-133 doi = {10.1103/PhysRevE.69.066133}

Newman, M. E. J., and Girvan, M. (2004). Finding and evaluating community structure in networks. Physical Review E - Statistical, Nonlinear and Soft Matter Physics 69, 2 Pt 2, 16.

Report No.13 of 2016 (Railways) https://cag.gov.in/uploads/download_audit_report/2016/Chapter_6_Disaster_Management.pdf