GOVERNMENT'S CALL FOR PROJECT PROPOSALS: SMART EVACUATION

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PROPOSAL OF THE PROPOSAL

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PURPOSE OF THE PROPOSAL

This concept employs an enhanced Ford Fulkerson algorithm in developing a Smart Evacuation System of the Bunning municipality. The system will assess traffic and fire conditions in real time to determine efficient escape trajectories and further change them to avoid congestion. Since it optimizes the usage of the roads and helps to lead the populace to the most efficient exits, it can safely evacuate them.

BACKGROUND

- ✓ Buninyong is an Australian rural location and the inhabitants of the area are at a high risk of bush fires that are annual occurrences in the region. There are always a high risk of evacuation because the town is surrounded by the woodland and experiences a population change of 4,000 – 10, 000 depending on the tourist seasons. Four main roads interconnect the town with other areas and include north south east and west roads; however, they are single lane, narrow and often clogged during incidents. In addition, in the event of a fire, one or more of these highways may become blocked, leaving the locals marooned in their neighborhood unless they have received specific evacuation warnings which take into account the available road capacity and the fire threat.

- ✓ Current bushfire notice systems are ineffective because, they only convey to the user that they need to avoid the fire and they do not give explicit directions on which roads to follow. This often causes congestion, most especially when many individuals attempt to pass through the same path. This project proposes a smart evacuation app, an application that will provide selected locals with suggestions for evacuation procedures within minutes of a fire incident. Escape routes indicated as safe for evacuation will depend on the app inputting fire conditions, traffic and ability to accommodate a great number of people. The algorithm will achieve optimal traffic circulation and the shortest evacuation time, provided that the greatest number of cars can navigate out without overloading a given lane.

SOLUTION

1. Problem Model

By approaching the issue as a network-flow issue, the Smart Evacuation System's fundamental method is as follows:

- Crossroads and escape routes are represented by nodes.
- The links between these nodes are considered as the edges, and each of them has certain capacity that can be defined as the car throughput within the particular time frame.
- Source is the areas or residential regions or neighborhoods from which residents will begin to evacuate.
- Four highways that are exit the town is represented by four different sinks.

Here, the intended strategy is to ensure that these highways take people through safe and efficient means of evacuation and minimizing the congestion through the spread of the number of persons to be evacuated across the existing highways. In order to compute the maximum number of vehicles possible through this network, the Ford-Fulkerson algorithm will be modified.

2. Ford-Fulkerson Algorithm Overview

This algorithm of Ford-Fulkerson seeks to locate these augmenting paths in a network and transform the traffic in these paths until none of them is possible to be revealed. This technique is designed to be applied in the maximum flow problems. To achieve this, there is an iterative procedure where by the major objective is to ensure that the maximum number of vehicles (flow) can possibly escape through the existing roads.

The algorithm functions by,

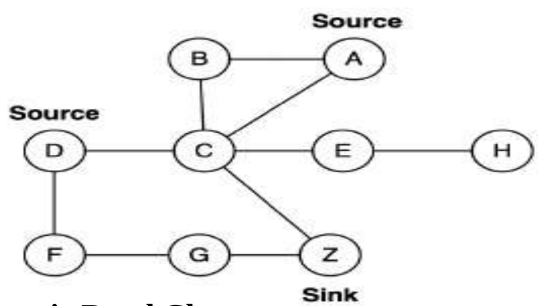
- Finding a path with open space, which means space for more cars, from a given source, a residential area to a washbasin, an exit road.
- Modifying the flow of this route in accordance with the capability of the relevant roads.
- If all cars have not evacuated, continue with the sequence, search for new pathways and change the stream constantly.

Some roads may block or become unreachable during a bushfire evacuation requiring the immediate adjustment of routes. That is why in such dynamics, the standard strategy has to be changed.

3. Significant Algorithm Changes

A number of significant adjustments to the Ford-Fulkerson algorithm will be necessary for the Smart Evacuation System in order to handle the particular difficulties involved in evacuating a community that is in danger of fire:

- **Handling Multiple Sources and Sinks**
  - ✓ Inflow problem involves identification of one source and one sink. The four initial exit highways are one of the unintended reception points and various reasons for this evacuation phenomenon.
  - ✓ All of these sources of traffic flow must be taken into account by the algorithm, which must distribute cars across several viable routes to make the operation overall as good as it possibly could be. As people should be evacuated as soon as possible some roads may turn out to be too popular which the reason every road's capacity is important is.



- **Real-Time Dynamic Road Closures**
  - ✓ His roads are prone to be closed following fires and this special factor makes evacuation from bush fires a tremendous challenge. Consequently, the system must respond in a reactive manner to that contingency, summarized in the next page.
  - ✓ Due to the need to redirect the vehicles to other routes, and to eliminate the blocked roads from the network, the algorithm requires recalculation of the paths that are available once a road is blocked. The recalculation in real time ensures that the Where the evacuees are not led down lethal or impassable routes.

- **Traffic Flow at Intersection**
  - ✓ In some junctions where one road branches into many, there is need for the algorithm to regulate traffic flow. Free flow means that if 100 vehicles approach at a crossroads, while 60 vehicles can fit on one road at a time, but 40 vehicles can fit on the other road, the algorithm must balance it.
  - ✓ This balancing exercise is constructive in directing the lifesaving process by providing orderly access to the highways to avoid congesting important cross roads.

- **Evacuation Completion**
  - ✓ Cars in a particular source (neighborhood) will not be routed by the algorithm if all people living in the area are out of the neighborhood. This helps to avoid unnecessary movements on the road and thus the system can prioritize traffic from the areas which people need to be relocated from.

4. Data Structures and Graph Representation

The road network will be shown as a graph by the Smart Evacuation System, where:

- Nodes are junctions and places to leave.
- Connections between these nodes are referred to as edges; the capacity of the roads in terms of the number of cars that may traverse them in a given time, for instance in five minutes is a weight.

Changes in the road closures and openings in relation to fire conditions will also be depicted from a live graph provided. In order for the evacuees to receive accurate directions from the algorithm in the shortest possible time, it is important that the data is updated dynamically.

5. Flow Calculation Process

The following processes are used to determine the flow of cars from sources to sinks:

- **Finding Augmenting Paths**
  - ✓ The first step of the algorithm is to identify routes with capacity that can connect residential zones as source to exit roads as sinks. To achieve this Breadth-First Search (BFS) is employed. BFS hence generates lanes that can still accommodate the traffic in the PPP planning cycle.

- **Adjusting Flow**
  - ✓ While, the system changes the path of the vehicular traffic by an augmenting path once it has been determined, while trying to avoid overloading of the path with cars most especially to its carrying capacity.

- **Recalculating Paths**
  - ✓ When there is fire on a particular road the algorithm removes the road from the graph and the flow of traffic, re-routing all cars that were initially directed toward the blockage.

- **Evacuation Completion**
  - ✓ The algorithm may then focus on evacuating other areas since each source or residential area is removed from the system once the system has evacuated it.

6. Pseudocode

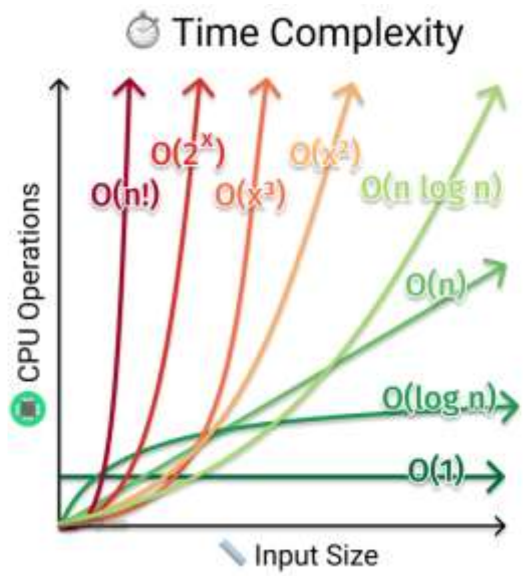
Here is the updated Ford-Fulkerson algorithm's pseudocode:

```
function evacuateTown(graph, sources, sinks):
   maxFlow = 0
   while there exists an augmenting path from sources to sinks in graph:
      pathFlow = findAugmentingPath(graph, sources, sinks)
      adjustFlowAlongPath(graph, pathFlow)
      maxFlow += pathFlow
      if a road becomes blocked by fire:
         recalculateGraph(graph)
   return maxFlow

function findAugmentingPath(graph, sources, sinks):
   # Use BFS to find a path with available capacity
   # Return the path and its capacity

function adjustFlowAlongPath(graph, pathFlow):
   # Adjust the flow along the found augmenting path
   # Update the graph to reflect new capacities

function recalculateGraph(graph):
   # Update the graph when a road becomes blocked
   # Remove blocked edges and recalculate available paths
```

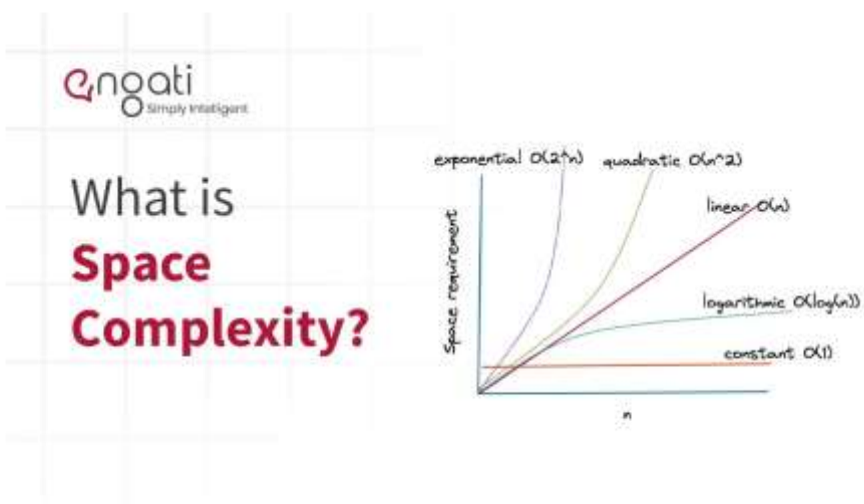
- The basic functions of the algorithm presented in this pseudocode also indicate how it can change traffic in real-time based on changes to the road network.

7. Time and Space Complexity

- **Time Complexity**
  - ✓ By using the Blandford Ford-Fulkerson algorithm above the time complexity of the algorithm is $O(VE^2)$, V being the roadways/edges and E the intersections/nodes. This clearly supports the need to modulate flow and work on the improvement path that is more desirable. Despite the fact that the real-time recalculations are a lot more complicated than the above described, this method is quite efficient given that the road network in Buninyong is, in fact, quite small.



- **Space Complexity**
  - ✓ The space complexity of the system is $O(V + E)$ because at least we have to save the whole graph containing all intersections and roads as well as the latest information you have about blocking and road capacity.



CONCLUSION

The proposal that follows outlines the development of a Smart Evacuation System for Buninyong, that would provide for the safe and efficient evacuation of the local populace in the event of a Bush fire. The system would have principle similar to the Ford-Fulkerson algorithm only that it is modified to fit with the current design of the computer network. The system can eliminate traffic jams for the preliminary graph modeling of roads and for dynamic altering of routs depending on the fire and traffic situations in real time.

The app will also constantly refresh in case the roads are closed or become congested and guide the locals accordingly using the best paths possible. Besides, giving accurate recalculations instantly to respond to changes for optimization, the algorithm assures achievement of the highest off-ramp departure capacity without over-saturating a particular street.

Since this is a scale and flexible system, this can be used as a tool to organize evacuations of people in areas susceptible to fires in a particular town or in rural villages. It provides a practical and efficient solution for the problems referring to the cases when an emergency evacuation is necessary.