An Unconstrained Traffic Flow Paths Solution for Evacuating from Multiple Regions to Safer Regions Using Graph Theory and Dynamic Programming

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Abstract— *During disasters such as natural disasters, fires, wars, industrial accidents or viral outbreaks, it is important to guide the people to safer zones from hazardous zones. Usually the trapped people are guided through safer routes towards safer zones via evacuation paths planned maps. This paper discusses an algorithm based on graph theory and dynamic programming capable of selecting optimum paths (groups of links) solution from multiple zones to safer zones during a disaster for unconstrained traffic flows.*

Keywords— *Dynamic Programming, Dijkstra's Algorithm and Evacuation*

I. INTRODUCTION

An evacuation paths map is represented by nodes and links. The roads are represented by the links and the junctions and the safer zones of the maps are represented by nodes. The evacuation paths solution is setup by usually using stochastic simulation methods[6-11] and taken into account the perception impedance, available paths, mobilizing speeds, traffic flow volume. The path solutions are dynamically changed considering the traffic of the paths their speed and the number of people trapped[8-9]. However if the traffic densities of the paths are not significant to force a perception impedance increment of the movement of the crowd use of stochastic algorithms takes time and in case of short distance paths the solution may not be reached on time. Moreover to simulate the optimum paths from all evacuation nodes to the safer zone nodes would take longer time and in case of a fire of a building this may not be the best approach. The solution of these stochastic methods are mobile entity specific assuming no communication between the mobile entities.

In addition Dijkstra's algorithm[1] is used for estimating optimum path/s between two nodes of a graph. However in case of estimating optimum paths from multiple nodes to selected nodes (safer zones) for a given set of constraints of a graph, this algorithm cannot be applied as it only provides a solution for a selected pair of nodes[4,5]. In addition route planning algorithms[5] estimates the path depending on a weight function of the route which depends on traffic, speed and distance of the paths of the route. In a graph evacuation situation if the distance, speed and the traffic constraints are not significant, then the evacuation paths selection depends on the availability or non availability of paths between nodes of the graph. Each path is assumed to having a path direction indicator capable of indicating path avoid, and two directions (forward and backward) to the people. Thus the indicators act as tri state output variable defining the selected paths. This paper discusses an algorithm based on graph theory[3] and dynamic programming[2] capable of selecting optimum paths solution from multiple nodes to nodes safer zones during a disaster such as floods, earth quick, wars and fires. The safer zones, and the junctions between paths are considered as nodes of a graph and the paths between the junctions and the safer zones are considered to be the links of the graph.

II. FORMULATION OF THE ALGORITHM

Hazardous zones and junctions are taken as multiple start nodes(SN) and safer zones are taken as the destination nodes(DN) of the graph. For unconstrained traffic flows the evacuation paths selection depends on the availability or non-availability of paths between SN and DN.

Each link is assumed to have a tri state direction indicator capable of indicating avoid, and two directions (forward and backward). The tri states are assigned to values as follows, "0" for avoid, "1" for forward direction and "-1" for backward direction. Thus the solution is an output vector of tri state elements, having dimension equals to the number of links of the graph (Figure 1.).

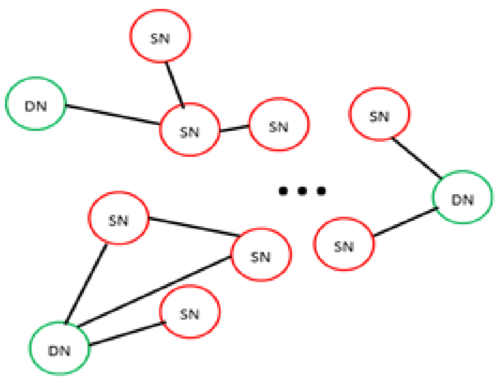


Figure 1. A graph of SNs and DNs

Depending on the disaster situation some links of the junctions and the zones may be not available. The non available links are assigned with "0" state value and opted from the updated graph. If an isolation of a start node occurred an alarm is triggered indicating the location of the trapped zone. This updated graph is used for the algorithm to find the optimum paths (Figure 2.). The directions for the rest of the links are selected by using the Dijkstra's optimum path estimation algorithm and dynamic programming.

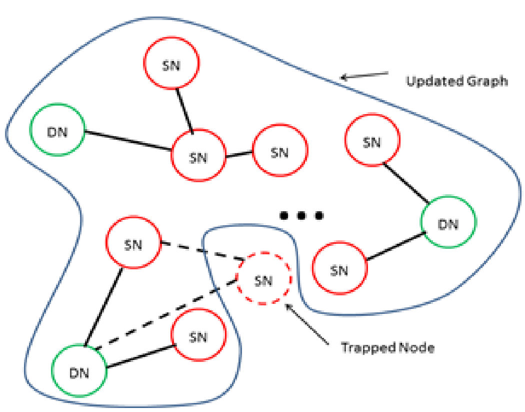


Figure 2. Updated graph and trapped node

All the SNs are numbered and put into an initial source node set (ISNS). All the DNs are numbered put into an initial destination node set (IDNS). The weight of a link is assumed to be 1 between any two pair of nodes. The minimum path length is estimated for each SN node and all the DNs. The Dijkstra's algorithm is used to estimate the optimum path between a pair of (SN,DN). If there is no path between a pair of (SN ,DN) trapped zone/node (TN) is introduced. The SNs are grouped into sets according to their minimum lengths. For example i^{th} group (Gi) consist of SNs of length i . The forward direction is defined from higher order group SNs to a lower order group SNs, and also SN to DN direction is also defined as forward direction(Figure 3.) .

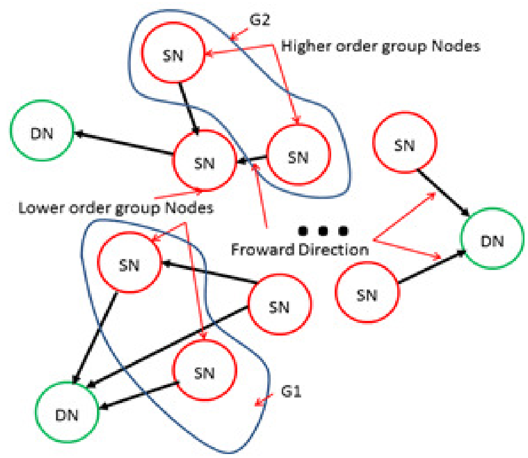


Figure 3. Groups and directions

These SN groups are then passed to the dynamic programming module to estimate the direction of the links as shown in the (Figure 4.).

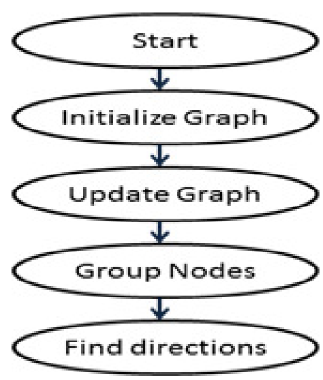


Figure 4. Algorithm flow diagram

Then the most optimum solution defining the directions of the links are estimated by using dynamic programming while minimizing number of TNs.

III. DYNAMIC PROGRAMMING

The number of SN nodes taken as nSN and the number of DNs are taken as nDN. The i^th SN node is noted as SN_i and j^th where $1 \le i \le nSN$, DN node is noted as DN_j where $1 \le j \le nDN$.

Then the minimum length between the SN_i for a given i and all the DNs are found by using Dijkstra's algorithm[1] and then considering the minimum length out of all the lengths. The SNs are then grouped by using a dynamic link list data structure. This data structure consist of stack for holding the SN node information of a particular group. The first entry of the list is the Group 1 (G1) stack. If the minimum length is 1 then the node, the next node and the link information are pushed into the stack. Similarly if a SN node has a length of i then the corresponding data are pushed into the i^th position stack of the dynamic liked list.

The data structure of a group is defined as:

Struct *Node*
    Present_Node integer;
    Lower_Node integer;
    Link integer;
    Next_Node **Node*;
Node end;

Struct *Group_Stack*
    Item *Node*;
    public Pop();
    public Top();
    public Push();
    public Isempty();
Group_Stack end;

The data structure of the group list is defined as:

Struct *Group_Node*

    GrSt *Group_Stack*;
    Size integer;
    Next_Group * *Group_Node*;
Group_Node end;

Struct *Group_List*
    Item *Group_Node;*
    public Insert_Node(SN integer);
    public Get_Nodes();
    public Is empty();
Group_List end;

The minimum length or SN_i (Length_Min[i]) is found by using the following algorithm in pseudocode. Then the SN_i information is pushed into the appropriate stack

For each SN_i in ISNS
    For each DN_j in IDNS
        Length[j]= Dijkstra_algorithm_length(SN_i, DN_j);
    end IDNS
    Length_Min[i]=Minimum(Length[]);
    Group_List.Insert_Node(SN_i);
end ISDN

After all the SN_is are grouped then all the links tri state variables in the links set are updated by using the following algorithm.

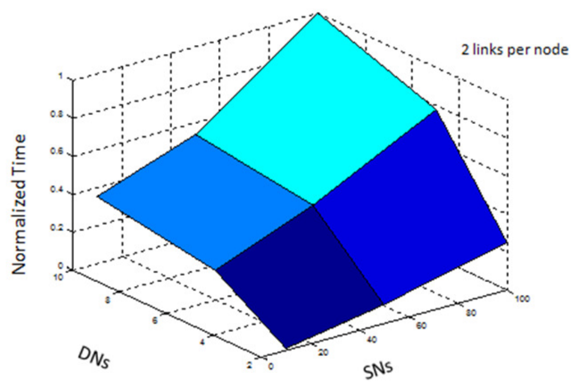
For each SN in a Group
    get the link number and set the corresponding tri state variable to forward direction.
end all the groups;

Set the rest of the Links that are not in the group list to avoid or "0" state. set the indicators according to the tri state variables vector.

IV. SIMULATION RESULTS

Depending on the field data the graph is updated and a new optimum path is estimated. The MatLab(TM) simulation of this algorithm is carried out for graphs with 10,50,100 SNs, and 2,3,4 links per node, and 2,5,10 DNs. It was observed that the speed of the algorithm is reduced as the number of SNs, DNs and the Links increased. The execution time is a function of SNs, DNs, Number of Links per node.

$$excicution\ time = f(SNs, DNs, Links\ Per\ Node)$$



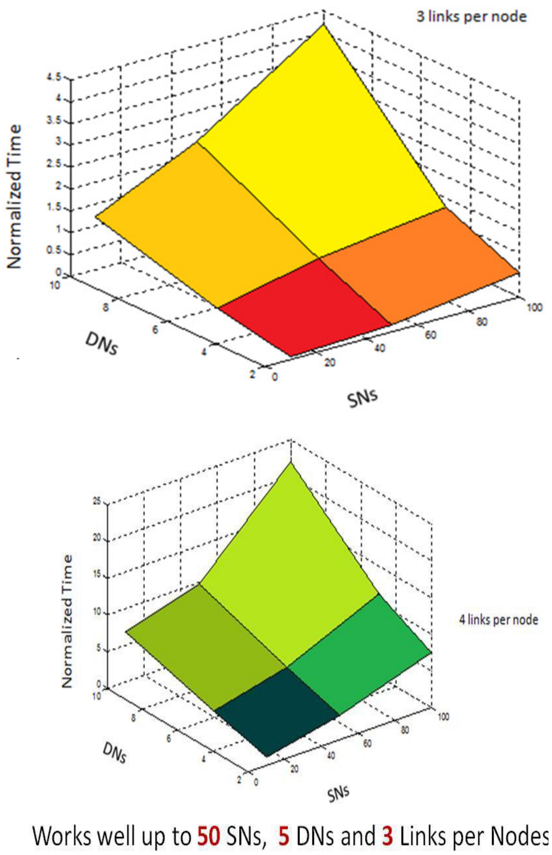


Figure 3. Groups and directions

V. CONCLUSION

This algorithm only provides a simple way of selecting the directions without taken into the account the traffic flow and the path impedance. Therefore ideal for situations where a fast solution is required such as disaster of a building or a ship. The algorithm can be modified by considering the time variations of the graph as the disaster spreads. In such situations the graph can be updated and this algorithm can be used on the updated graph with a predetermined time interval of scanning the variations of the graph.Possible applications include buildings, cruise ships, manufacturing plants, power plants, underground mining facilities and unconstrained traffic regions.

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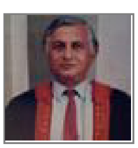

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