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Visualization of Real-time Solutions of Routing Problems on Dynamic Networks

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Abstract

There are three elements to route decisions: availability of route network data include real-time updates, scalable approaches to solving capacity-constrained routing, and real-time solutions. A fourth-dimension that runs through these three elements is the visualization of the routes that sufficient fidelity to help the first respondents under the adequacy of the model. This paper proposes tools to validate routing modeling and support emergency evacuation decisions through visualization. We propose a simple route visualization VBA code in ArcGIS, and provide both individual and collective path visualizations.

Keywords
Visualization; Routing; VBA; GIS, Evacuation, Dynamic Network, Network Flow.

1. Introduction
Geographic information systems (GIS) have proven to be an integral tool in addressing the needs of transportation managers. GIS has provided an efficient means for organizing basic transportation related data in order to facilitate the input, analysis, and display of transport networks. While these basic objects are necessary for virtually all transportation applications, they are not sufficient for any comprehensive management or planning process. It has become increasingly obvious that a much wider range of transportation related objects are essential for advanced transportation planning and management tasks.

In the geographic information system (GIS), the basic building blocks of geometric networks are edges (geometric lines) and junctions (geometric points). Edges are constrained to always begin and end at junctions. Edges are undirected but in a directed transportation network, an edge is called an arc. A junction can have many edges attached to it. A path in a graph in a network flow models is composed of nodes and edges or arcs (arcs if it is a directed network), where an arc connects two adjacent nodes. The interrelation between nodes and arcs can, for instance, be described by the node-arc incidence matrix. In the representation of a building and road networks outside the buildings, nodes may represent rooms, or intersection points (on corridors or roads), while arcs can be used to model corridors, stairways, roads or a connection between two intermediate nodes. Hence, this evacuation problem can be modeled as a multi-source multi-destination network flow problem. For pedestrian evacuation, travel time on any edge or arc of the network must consider walking speed.

Data preparation begins with the use of a GIS-software such as ArcGIS to read the building and road network files in their native format, to convert them to shape file format. Shape files are based on geometry type: point, line, multipatch, and polygon. These files contain data in 2D for each floor on a separate file. We only use the point data which represent nodes such as rooms, and line data which represent edges/pathways such as corridors, and stairways in buildings. Another shapefile is extracted for the campus; this file contains data, also in 2D, for the road network outside the building. Data from shape files must be converted to three text files format that the evacuation route planning approaches can use to convert to node-arc-incidence matrix, node files, and edge files. A GIS database is

used for constructing two node-arc-incidence matrices for each floor of the building and the roads around it; these two matrices are used as sources for producing the nodes and edges files that used as input for the developed approaches. All of the input data files are adapted to a format that is compatible with the proposed approaches.

2. Literature Review

Visualization has been used in several areas mainly as educational tools and for analyzing people flow and routes of other moving objects.

Several visualization attempts have been reported in the literature. Hegarty et. al. Hansen et al. (2002) and Schweitzer and Brown (2007) used visualization in computer science education including networking, algorithms and data structures. Yuan et. al. (2010) developed three educational tools for undergraduate-level security classes using Macromedia Flash to demonstrate packet sniffing, Kerberos authentication, and attacks on wireless networks. These tools were developed at the Department of Computer Science at North Carolina A&T State University. Terryet. al. (2011) described a visualization-based simulator to help students gain knowledge of SYN flood attacks. The tool demonstrated normal network traffic and how a SYN flood attack occurs. It also showed how to prevent SYN flood attacks via a firewall. It was developed in the Department of Computer Science at North Carolina A&T State University. Schweitzer et. al. (2006) proposed another visualization tool to be used in an undergraduate information security class. This tool allows users to interact with arbitrary protocols in a user-controlled stepwise manner.

Visualizing routes using graphs is major technique to analyze people and objects flow. Höcker et. al. (2012) proposed an algorithm to search for particular routes and a graph to represent paths of walkers. Çetinkaya et al. (2010) compared 4 types of graph visualization techniques using datasets of locations of states. There have been many existing methods which classify and visualize spatio-temporal people flow data recorded as real values. Andrienko et al. (2014) collected datasets from wide range using GPS, and analyzed properties of various moving objects, using both of drawing specific trajectories and bar charts on maps. Andrienko et al. (2007) visualized popular walking patterns on maps. Guo et al. (2009) developed a composite visualization tool to analyze patterns of various objects such as pedestrians, bicycles, and cars. They adopted not only direct drawing of trajectories on maps, but also other visualization methods including piled polyline charts, scatterplots, and parallel coordinates plots. These techniques do not apply data compression techniques for trajectory datasets. AI-Dohuki et al. (2017) and Wang et al. (2012) visualized moving patterns of taxis in wider regions. Krueger et al. (2013) presented an improved visualization system for chronologically GPS datasets. Wang et al. (2014) presented visualization of automobiles passing at particular positions on roads. Lu et al. (2015) developed a visualization system for routes for taxies. Yabushita et al. (2011) presented a visualization technique that summarizes pedestrians' routes. Fukute et al. (2013) visualized temporal transition of pedestrians by applying a piled polyline chart. Guo et al. (2014) proposed a system to visualize important paths using meaningful colors based on HSV model. Gupta et al. (2016) worked on to visualize relationships among small number of pedestrians using a gantt chart and visualized places where people stayed. Krueger et al. (2016) tried to visualize three types of datasets, for pedestrians, taxies, and air- planes, as graphs and heatmaps. Thack et al. Oates et al. (2013) visualized noisy people flow datasets by adopting SAX or TraSAX. Their visualization results are therefore so complex that it may be dif- ficult to find important routes or places.

3. Visualization of Evacuation Routes in GIS Environments

The emergency evacuation optimization models implemented and visualized in GIS environment could help in performing various spatial-related analyses. The aim of implementing the developed evacuation optimization models in ArcGIS is to provide visualization of the evacuation paths for both the evacuees and the emergency responders for effective routes modeling and evacuation execution. This tool would be most efficiently used where the evacuation data is available, accurate, and consistent.

A desktop GIS software package, ArcGIS, is selected for implementing the evacuation routes. ArcGIS is commonly used in many government settings where GIS is used. The software is available and has Visual Basic for Applications (VBA) as an imbedded software programming package. The implementation of evacuation visualization in GIS environment generally can be seen in Figure 1.

We developed working code in ArcGIS using VBA and ArcObjects. The VBA Code is implemented for: opening GIS shape files, reading evacuation path files obtained as output from the proposed evacuation optimization model and importing the evacuation start time and path edges data input for each individual object, and highlighting edges for visualizing individual evacuation route view and collective route density.

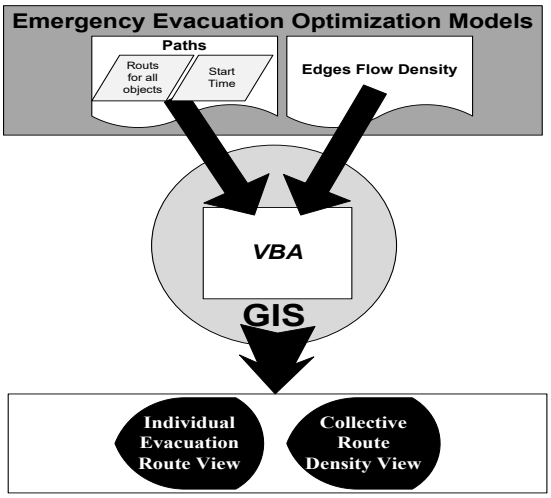

Figure 1. Implementation of visualization in GIS

4. Illustrative Example

Prior to solving and visualizing routes in geographic information system environment, we extracted the input data for the optimization models from a given networks and generated datasets. These datasets consist of pathways and roads from GIS. The number of nodes, gateways, edges on a given road network are given in Table 1 and the GIS maps shown in Figure 2.

Table 1 Road Network Characteristics

No. of Arcs	No. of Source Nodes	No. of Intermediate Nodes	No. of Gateway Nodes
472	111	116	5

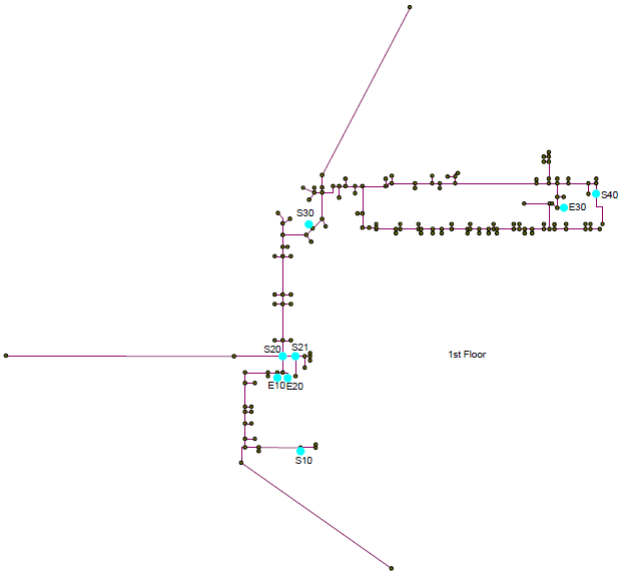

Figure 2. Road network

Then we solved the routing problem on these evacuation networks using optimization models developed by Saeed Osman and Ram (2017). We consider the output of two routes, shortest rout (R28) and longest route (R12), that begin from nodes 103 and 160 respectively end at one of the predetermined gateways G5, which are given in Table 2.

Table 2. Optimization Model Output of two Routes (R28 & R12)

Route No	Sequence of Nodes
R28	160-156-155-153-150-148-147-141-140-168-G5
R12	103-100-98-91-84-34-33-29-27-25-23-22-19-14-12-8-7-108-110-113-14-118-122-123-126-19-131-132-140-168-G5

We provide visualization of the evacuation paths for both the evacuees and for the control room of the responders. A working code was developed in ArcGIS using VBA and ArcObjects. This VBA code opens GIS shape files, and reads evacuation path files obtained as output from solving the evacuation problem using optimization models proposed by Saeed Osman and Ram (2017) and importing the evacuation start time and path edges data input for each individual object, and highlights edges for visualizing individual evacuation route view and collective route density. Figure 3 and Figure 4 show 2D evacuation visualization in GIS environment.

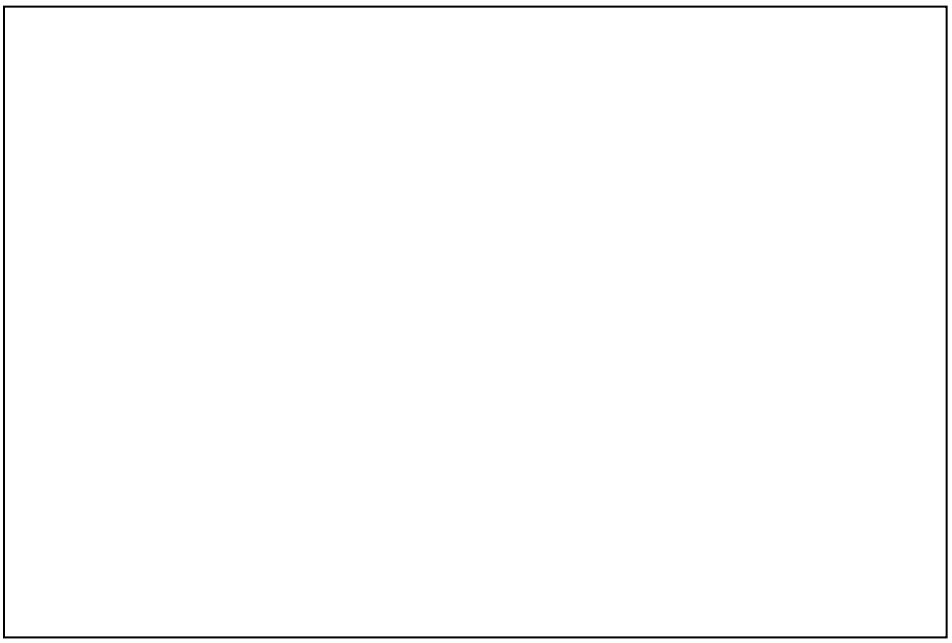

Figure 3. Road network

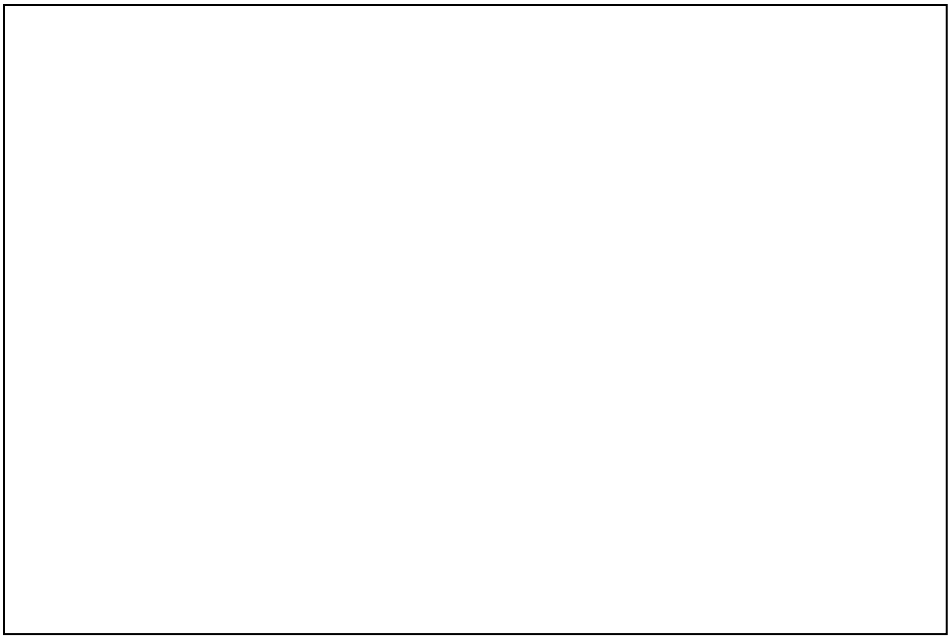

Figure 4. Road network

6. Conclusion

The objective of this research is to define and visualize optimal individual evacuation routes for the evacuation and determine an approximate minimum time required for the evacuation according to capacity constraints. For illustration, the research addressed the problem of finding and visualizing evacuation paths from a small evacuation network on food. The working code developed in ArcGIS using VBA and ArcObjects is limited to 2-dimensional routes visualization that can be implemented only for individual floors. Multiple floors building require 3-dimensional visualization that can be developed in ArcScene environment.

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