A Detour Route Model Considering Flooded Regions Using Network Analysis

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Abstract

Heavy rains have caused an amount of damage from flooding and landslides nationwide. Specially, because of flooded road when disasters occurred, traffic congestion and isolation have caused many losses to drivers during rush hour. In this study, we propose a detour route model considering the damage area and compare optimal route and detour route. Also, we construct our network dataset to analyze the routes with categorized hierarchy level. The model can provide some information to reduce traffic congestion and can present effective traffic routes when disasters occur.

1. Introduction

Abnormal climate phenomena have occurred as a result of global warming and have frequently caused heavy rainfall. The damage from natural disasters such as flooding and landslide caused by a localized torrential downpour has increased, so we have experienced many casualties, damaged property, and traffic congestion.

To reduce the damage caused by the natural disasters, the research and the development of its prevention and response system have actively been conducted. However, most current researches focused on the prevention for disaster victims and the damage to property, disaster support and management. There is a lack of research to prevent traffic congestion and isolation caused by the flooding in roads. The damage occurred on the roads usually starts at an initial place, then will spread throughout the entire transportation network when the processing of accidents was delayed or made an inappropriate response [8]. To prevent this situation, we need to identify damaged disaster regions and to guide evacuation routes or detour routes within the radius of disaster influence. The portal sites such as the Google and the Naver and car navigations provide the shortest path and optimal path, but these services do not provide detour routes considering disaster areas because they do not know information of occurred disasters. Therefore, the aim of this study is to propose a detour guidance model with the ArcGIS(Software suite developed by ESRI™) network analysis for providing optimal routes to arrive in the workplace as fast as possible.

2. Related Work

2.1. ArcGIS Network Analysis

Network Analyst is one of the ArcGIS Desktop Extensions for spatial analysis and includes five

functions including Route, Closet facility, Service Area, Origin Destination Cost Matrix, and Vehicle routing problem. The roads are constructed on the network with nodes and paths. We can find the best route or the shortest route using Network Analyst functions [1][4].

2.2. Disaster and Transportation Management

On the ubiquitous transportation environment, the researchers proposed effective ways to control traffic flow in the flooding event when natural disasters occurred [9]. Y.T.Son developed a traffic disaster prevention system for Cheongju City and identified the effect of the traffic light control system [11]. T.G. Jeon developed a system based on Urban Information System(UIS) to express damage history information. They suggested a framework for managing disaster history.

2.3. Route Algorithm

Junru Cao et al. developed optimal path analysis based on Dijkstra algorithm in Zibo fire Emergency Process Information System using ArcEngine and Geodatabase [6]. Yang et al. developed algorithm for detour route based on n-path. They evaluate detour route algorithm which is applicable to handle terror scenarios. But scenarios don't involve Geographic Information System(GIS) and natural disaster information [3].

3. Detour Route Analysis Model

3.1. Data Construction

In this study, we use the UIS map in Busan Metro City, Korea. The layers of the map include the administrative districts, buildings, roads, and roads centerline. Before performing network analysis, we need to generate a network dataset. There are three types of sources to generate the network dataset: geodatabases, streetmaps, and shapefiles provided by ESRI^{TM}. In this study, we constructed the network dataset using the shapefiles. The network dataset consists of Junctions, Edges, and Turns. Before creating the network dataset, we modified the attribute data of road line shapefile which has hierarchical classification according to road types. The road hierarchy is categorized into five types of levels as shown in Table 1. The hierarchy level was specified for each road, and the Gwangan Bridge was assigned as hierarchy level of 2 such as Urban Expressway.

The hierarchy level is in the range of from first level to third level, so we assigned the primary roads as first level through third level 3, secondary roads as fourth level, and local roads as fifth level.

Table 1. Classification of Roads

Classification	Function	Hierarchy Level
Primary Roads	Expressway	1
	Urban Expressway	2
	Circumferential Expressway	3
Secondary Roads	Major Arterial	4
Local Roads	Minor Arterial	5

The network dataset were created with modified shapefiles as following steps.

1) Edge connectivity policy is assigned to any vertex.
2) Cost variable is assigned to distance value.
3) Hierarchy variable is assigned to hierarchy level value.

Our network dataset were generated in 191,320 junctions and 174,788 edges as shown in Figure 1.

Figure 1. Junctions and Edges

3.2. Sample District

We selected the sections for analyzing routes based on the traffic volume surveyed in 2009.
The Busan metropolitan city investigated and surveyed up to 84 points of research including city's traffic condition, traffic congestion so identified and analyzed primary metropolitan area, 2nd urban areas, major intersection, total traffic, and other research points. In this study, we selected sample target regions in the area of Nam-gu and Sooyoung-gu assigned for each first Urban area and second Urban area for traffic congestion sections.

3.3. Disaster History Data

To analyze the detour routes, we used disaster history data in the Busan Metropolitan City. This data consists of disaster history data which are composed of four natural disaster types of data including flooding, damage from wind, wave, and landslide. In this study, the historical flood data occurred in July of 2009 was used.

3.4. Analysis Model

We propose a model for Network analysis using model builder tool in ArcGIS. The basic model is used to find a best route with hierarchy to minimize impedance of distance or time.
Figure. 2 shows a detour route model considering disaster area generated with the model builder tool.
The procedure of the detour route model is as follows in order.

1) Clipping road line with disaster area data
2) Finding any vertex in road line within disaster area
3) Extracting disaster area boundary
4) Vertex intersect action at disaster boundary
5) Creating a route layer using network dataset
6) Add origin
7) Add destination
8) Add barriers from results in step 4 and step 7.
9) Executing the solve function

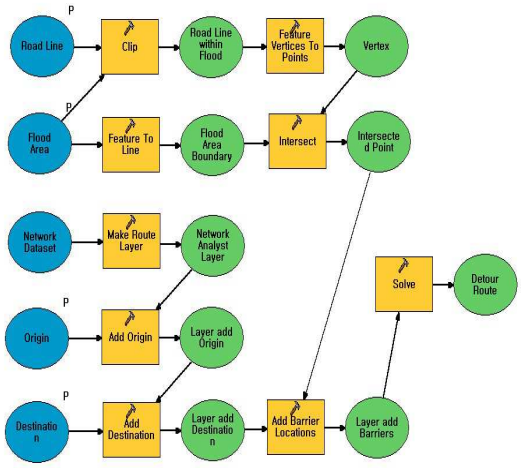

Figure 2. Detour Model

4. Analysis Results

We analyze the detour routes with our proposed model in previous section 3. For each section, we analyzed optimal routes and applied with and without hierarchy. Also we discovered some detour routes considering occurred damage regions. The analysis results for with and without hierarchy were different. When we compared resulted detour routes with the shortest detour route with and without hierarchy, the results generated different routes.

Figure. 3 shows analysis results in range from Yeonsandong to Haeundae.

The length of the shortest detour route was calculated as 10.13 km from Yeonsandong to Heaundae, while the optimal detour route with hierarchy was about 11.29 km in length. Although there is one km in difference between the routes, the actual driving time to the destination can be reduced.

However, sections on Guan-An-village through Heaundae, Guan-An-village through Yeonsandong, and Sooyoung through Heaundae were calculated as same in length of the shortest route and the optimal route. Accordingly, the length between particular sections can be similar to the shortest route and the optimal route. Originally, there are many different detour routes from start to destination point. Therefore, the goal of this study is to calculate the shortest detour route and the optimal detour route according with and without hierarchy. However, the route analysis has some limitations not considering time and speed. If we use speed information for each section, optimal routes could be analyzed in different results.

Table 2. Characteristics of Sections

Classification	Directions	Bus	Car	Taxi	Van	Truck	Shortest Route (in km)
Traffic Congestion Sections	Guan-An-village ~ Heaundae	919	11,598	9,251	1,227	1,121	5.11
	Guan-An-village ~ Yeonsandong	719	12,307	8,750	640	1,024	5.06
	Yeonsandong ~ Heaundae	829	11,626	10,509	526	859	8.90
1st Urban Area	Guan-An-village ~ Yongdang	18,307	2,339	808	19,841	24,675	4.42
2nd Urban Area	Sooyoung ~ Heaundae	1,294	16,464	14,351	3,651	2,188	5.05

Table 3. Results of Route Analysis

No	Directions	Shortest Route (in km)	Detour Route (in km)	
			Without hierarchy	With hierarchy
1	Guan-An-village ~ Heaundae	5.11	7.22	7.22
2	Guan-An-village ~ Yeonsandong	5.06	8.92	10.59
3	Yeonsandong ~ Heaundae	8.96	10.13	11.29
4	Guan-An-village ~ Yongdang	4.58	9.29	9.29
5	Sooyoung ~ Heaundae	5.08	6.98	6.98

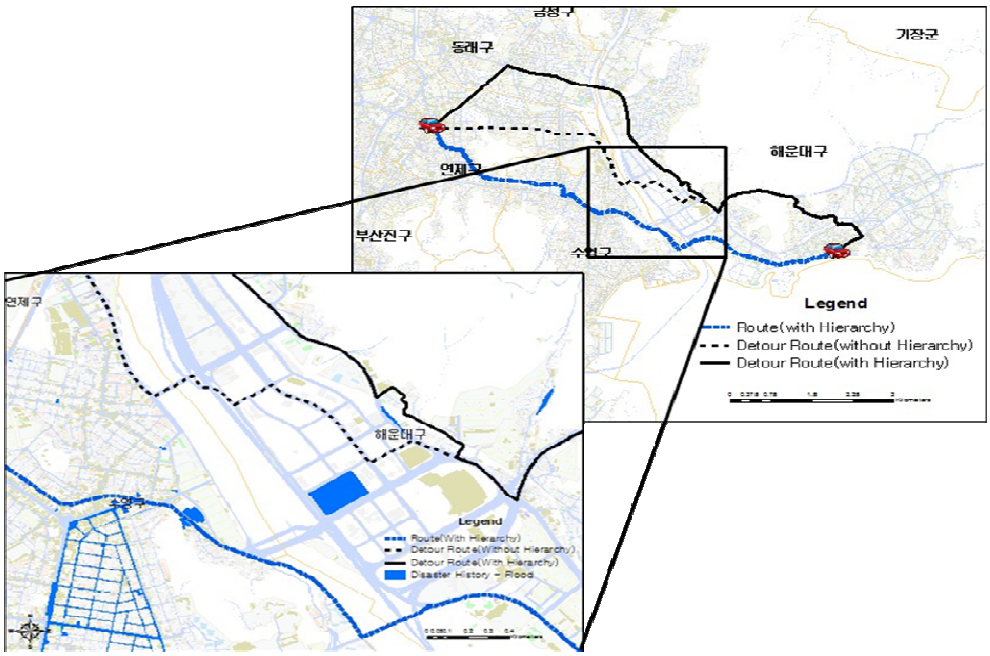

Figure 1. Route from Yeonsandong to Heaundae (3rd row in Table.3)

5. Conclusion

In this study, we made a detour route finding model considering flood damage area occurred in the defined regions and compared the optimal route and the detour route.

The Detour route information can be used to prevent additional traffic congestion and to provide optimal path information to drivers when disaster occurs. If the information of detour routes could be provided on VMS(Variable Message Sign), Web GIS Services, and smart phones, additional traffic congestion may be reduced. In future, we will conduct the route analysis with speed and time data extracted from traffic centers.

Acknowledgements

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