

## Integration of GIS and Orthophoto to Enhance Road-Network Screening – A 3GR Approach

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### Abstract

This paper presents a new road safety analysis technique for verifying and enhancing road-network screening database. The technique is based on the integration of data obtained from a Geographic Information System (GIS), orthophotos and a road-networks database. The integration of the GIS with different road-network database was used to identify illuminated road segments. A cross correlation technique was used to extract the streetlight location and position. The integration of GIS and orthophotos was used to check and update the road-network database. A semi-automatic method was developed to recognize illuminated and un-illuminated road segments by using a specific group of filters and the cross correlation technique. Validation of the procedure showed that the new technique improved the light database, and the semi-automatic method successfully identified street segment types and extracted the streets poles' positions. Rural and semi-urban areas were targeted in this study. The limitations of the new technique are discussed and future research into the integration of geomatics tools with road safety is highlighted.

### Introduction

Fatal collisions are more likely to occur on rural highways than on any other road types. Traffic crashes are a major cause of death and injury in the United States. In 2002, there were 42,815 fatalities and over 2.9 million injuries on the nation's highways. Crashes on rural roads (roads in areas with populations of less than 5,000) account for over 60 percent of the deaths nationwide, or about 70 deaths each day and the rural fatality rate per vehicle mile traveled on rural roads was over twice the urban fatality rate (General Accounting Office, 2004). Good visibility is essential to the safe operation of motor vehicles. Driving at night can be more challenging than daytime driving, as the distance that a driver can see clearly is reduced at night.

Collisions and lighting conditions are generally classified into eight categories: (1) collisions in daylight, (2) collisions in daylight with artificial light, (3) collisions at dawn, (4) collisions at dawn with artificial light, (5) collisions at dusk, (6) collisions at dusk with artificial light, (7) collisions in darkness, and (8) collisions in darkness with artificial light. There is a clear need to improve the analysis for nighttime collisions and to identify the lighting conditions accurately, but little effort has been done in this area because the collection process is costly and time consuming.

#### 1.1 Scope

The focus of this paper is identifying illuminated and un-illuminated rural highways segments to check the existing data; complete missing records and solves data conflict. This will improve the quality of the data, road safety analysis, and network screening. Since collecting detailed information on street poles is costly and time-consuming, fast and inexpensive methods must be explored.

#### 1.2 Objectives

The purpose of this thesis is to develop a semi-automatic method to identify illuminated and un-illuminated road segments by integrating geomatics tools and road network databases. The specific objectives of this research are:

1. To integrate Geographic Information System (GIS) and collisions data.
2. To integrate GIS and road network data other than collisions data.
3. To integrate GIS and orthophoto images to identify illuminated road segments and to extract the

location of street light pole locations and positions from the images.

4. To validate the proposed method by using actual data.
5. To examine the implication of the proposal methodology for the safety performance function.

## 2 Dataset

Three different sources of data were used in this study: (1) digital orthophoto images for target area, (2) roads database records (e.g. collisions records, traffic volume, etc.) and (3) single line road network (SLRN) in GIS, ArcView, format. The data and images used in this study were obtained from the Regional Municipality of Durham.

## 3 Methodology

### 3.1 Challenge

The main challenge in this research is to recognize and extract the streetlight poles, which are narrow, vertical objects that have very limited width in orthophoto images. The poles appear as only a few pixels in the orthophoto. They are very difficult to locate or recognize using direct extracting methods. An indirect method is developed to extract the streetlight poles. The method is based on a unique idea that uses the image's filters in an unusual way. As streetlight poles cannot be easily recognized on the image, a semi-automatic method has been developed to help users to recognize the streetlight poles types and location. The method is based on observing the streetlight poles and their shadow as the shadow makes the streetlight pole easier to recognize. To make the streetlight poles' shadow more clear, filters were used.

The technique is designed to be user-friendly for road agencies and safety analysts and achieves accurate results without the need for a strong background in photogrammetry and orthophoto images.

### 3.2 Semi-Automatic Methodology

The semi-automatic method consists of two main steps: (1) extracting streetlight pole locations (2) identifying the illuminated rural highway road segments and update the GIS database.

#### 3.2.1 Identifying Pole's Types and Locations

The Semi-automatic method for extracting streetlight poles locations and types can be summarized as follows (Fig.1):

- The orthophotos are linked with SLRN by using ArcView.
- Template windows for streetlight poles are chosen as signatures. These templates are chosen from the segments where no conflicts are recorded.
- To enhance the shadow of the streetlight poles, a custom filter called the "Minimum Filter" is applied. The "Minimum Filter" changes the brightness value of the pixels. In this study, the brightness value of each pixel is changed in the image according to a predefined mathematical operation. Each pixel is reassigned a value based on the values of the surrounding pixels. The "Minimum Filter" assesses individual pixels in a selection. Within a specified radius, the "Minimum Filter" replaces the current pixel's brightness value with the least brightness value of the surrounding pixels. The "Minimum Filter" has the effect of spreading out black areas and shrinking white areas.
- To enhance the objects in the image, the "Find Edges" filter is applied. The "Find Edge" filter is not applied to find the object edge as normal, but to make the object image more recognizable visually and mathematically when cross correlation is applied.
- The cross correlation technique is applied to identify streetlight pole types and locations. Template windows for each pole type are chosen and used as a signature. To achieve accurate results, the template windows are chosen from the nearest road segments having similar bearing. The area chosen to extract the streetlight poles is limited to a specific distance from the street centerline. In this study, this distance equals the road width plus the road's 17 meters buffer. Any results obtained form beyond the buffer are discarded. The width of the buffer can be changed depending on the angle of the sun and the length of the pole's shadow. The buffer is recommended to minimize computation time and to improve the results of the cross correlation operation.
- To improve the result of the cross correlation operation, the cross correlation parameters are pre-determined as follows: First, the clearest target is chosen from the nearest recognised road segment; this target is used as a template. Second, the cross correlation is applied for this

segment. The results are evaluated, and the best minimum value of the cross correlation parameter is chosen. This is called supervised selection.

- The results are merged with the GIS system.

### 3.2.2 Identifying Road Segment Types

In this study, the data were classified into three different types: digital orthophotos, road network database records and SLNR. Each one had its own format and structure. Microsoft Access was used to link the different database files. The ArcView GIS system was used to link the digital images, network screening database, collision database, and SLRN (Fig.2).

The linking procedure was used to identify which road segments are illuminated (Type 1) and un-illuminated (Type 2). Three tasks are required to make this distinction:

- In the first task, the collisions database, accident locations records, and SLRN are linked together using ArcView. Collisions are classified into two main categories: (1) nighttimes collisions in low visibility on roads without illumination, and (2) nighttimes collisions on the roads with illumination. From this classification, "Type 1" and "Type 2" are identified.
- In the second task, road database records other than the collision database and SLRN are linked together. From this new task, the road-segments (Type1/Type2) are also identified.
- The results from the first and second tasks are compared. If there are no conflicts, the results are stored. Parts of these results are used to choose the best comparison template windows for the cross correlation operation. If conflicts are found, the segments are marked for further investigation and checking. The conflicts can be classified into the following groups: (1) the illumination records are missing from the database, (2) the illumination data recodes as unknown, and (3) there are different records for the same segment (e.g. the segment is recorded as un-illuminated and as unknown or illuminated in other database).
- If conflicts are found, the segments are marked for further investigation and checking. The conflicts can be classified into the following groups: (1) the illumination records are missing from the database, (2) the illumination data recodes as unknown, and (3) there are different records for the same segment (e.g. the segment is recorded as un-illuminated and as unknown or illuminated in other database).
- The semi-automatic method, which described in section 3.2.1, is used to identify the streetlight poles and to verify the road segments. To achieve accurate results, comparison windows are chosen from the nearest road segments having a similar bearing. The semi-automatic method is used to clarify the conflicts in the existing database; this can be used to create GIS data for street poles as well.

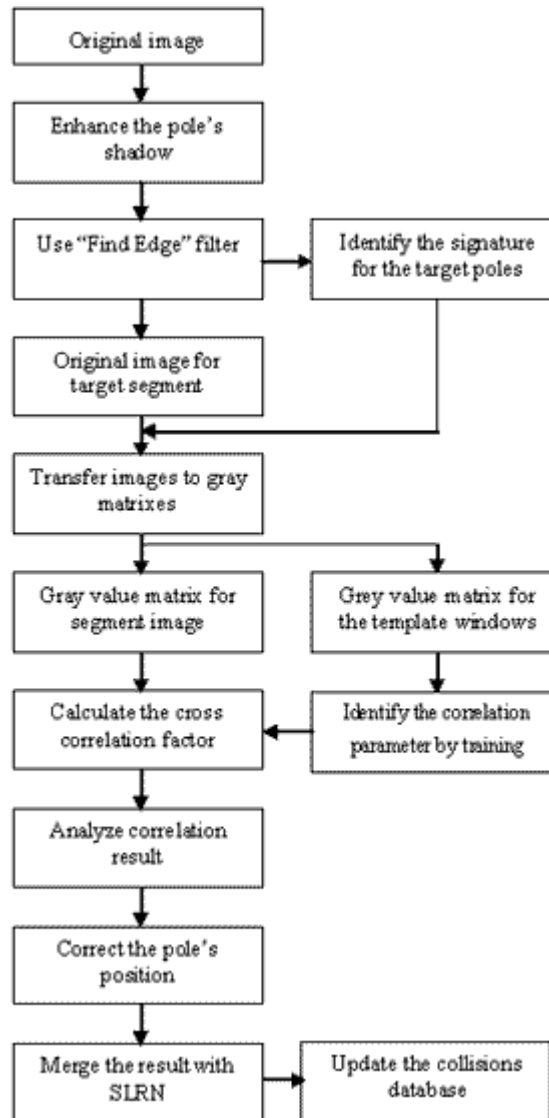
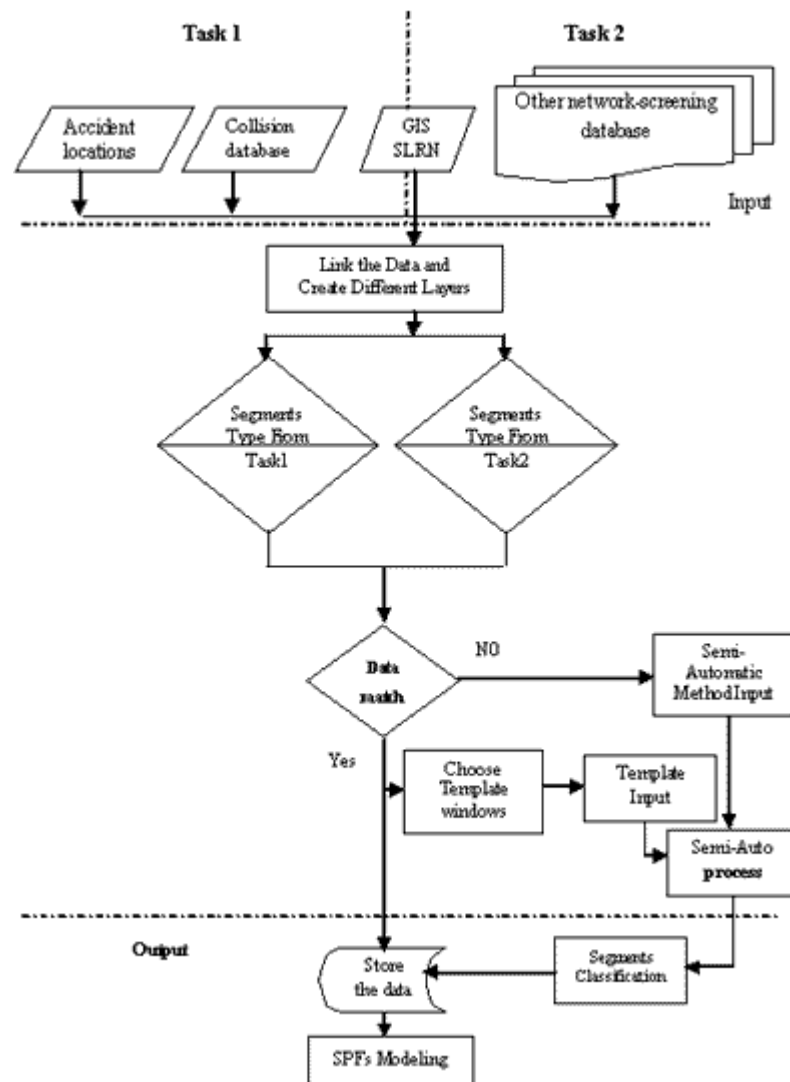


Fig. 1. General procedure for identifying pole type and location



**Fig. 2 Scheme for the proposed methodology to enhance the illumination database and extract the poles location**

#### 4 Validation of The Methodology

To evaluate the semi- automatic technique performance, the technique was applied to the route, which consists of 62 different road segments with a total length of 39,886 meters. The site images were explored by using the semi-automatic technique.

The results were recorded in the GIS system. The results were checked on a site trip for the target route, which found that:

- Fifty-seven out of sixty two segments (91 %) had matching results.
- Five segments cannot be identified clearly. Three of the five segments were located in the core of downtown of the target city (Uxbridge city, Greater Toronto Area, Canada) where the view of the street poles was obstructed by the shadows of high buildings. The remaining two segments had illuminated and un-illuminated components. These segments should be subdivided to match the difference in illumination. Road agencies should note changes in road illumination as well carefully as they note physical changes in the road design

#### 5 Implementation on Safety performance Function

The technique developed in this paper to enhance the street lighting database record is applied to the development of safety performance functions (SPFs). the SPFs, calibrated for two-lane rural highways

under different lighting conditions. The SPFs calibrated for the raw data without any enhancement and for the data after enhancement. The results shows that the integration of GIS, orthophotos, and the road network database (e.g. collisions database, AADT, and intersection data) enhance the SPFs analysis.

The study how the method might affect road safety analysis, SPFs for two-lane rural highways (300 road segments with a total length 140 km) were calibrated before and after enhancing the data using the thesis technique. The thesis technique was also used to discover and resolve hidden problems in the data record.

The results were as follows:

- 7 % of the raw data was subject to conflicts. The new technique was able to identify and correct 90% of the conflicting records.
- 8 % of the raw data were unknown segments. The technique was able to identify 92 % of the unknown segments.

## **6 Summery, Conclusions and Recommendations**

### **6.1 Summery**

The integration of GIS, orthophotos and road network-screening database was implemented in this paper. Few researchers have worked in this field. The semi -automatic technique, which developed in this research, provides a tool that enables road safety agencies to verify illumination data in their databases and to fill in any gaps. The integration procedure improved the network-screening database.

The semi-automatic method successfully extracted the position of streetlight poles and identified whether road segment types were illuminated or not An important advantage of the semi-automatic method is that its application does not require users to have a strong remote sensing background or image processing skills.

The procedure resolved 90% of the data conflicts found in the data for illumination; and identified 92 % of the unknown segments (illuminated or not) for the targeted highways. The semi-automatic method is ideal for rural and semi-urban areas. The proposed technique is considered to be unique because it improves the data for illumination in the road database (enhancement illumination database is not covered adequately in the field of road safety).

However, the semi-automatic method may not work if high buildings or other obstructions cover the pole's shadow. For this reason, the method is not recommended in downtown areas or close to high-rise buildings. Nevertheless, if the street poles are unobstructed, it may be possible to determine the segment type even if some poles cannot be located.

### **6.2 Conclusions**

Many researches in road safety field wish to maximize their use of existing databases. Efficient and inexpensive solutions need to be found to check data and to fill gaps in the data. Data improvements and validation will have a direct effect on the quality of any analysis of the data.

The integration of GIS, orthophotos and databases can play a key role in improving the road network-screening database. The integration approach presented and discussed in this thesis offers a new tool to check and improve illumination data in the databases of road safety agencies. The technique can also help road safety agencies to extract additional features from road network data.

In this study, orthophoto images with 0.2m spatial resolutions were used to extract the pole type/positions and to identify the segment types and locations. High-resolution remote sensing images can be used to accomplish the same task, but it is recommended that remote sensing images with 1.0-metre resolution should be used to identify road segment types.

### **6.3 Recommendations**

Orthophoto images can play a key role in extracting illumination data from the street network. Road agencies should give more attention to orthophotos images because the mages have considerable potential for supplying additional data about the road network.

High-resolution remote sensing images can be used to identify the segment type and to improve the street network database. Remote sensing images are widely available at a low cost, which will encourage road agencies to acquire them.

It is recommended that the technique proposed in this thesis should be used to check and examine intersections to identify which intersections are controlled by traffic signals. In addition, this technique can be used to improve collision data records for accidents involving fixed objects.

Illumination can improve road safety especially in rural areas. While it is not practical to illuminate all rural roads, hazardous segments should be identified and illuminated.

Road jurisdiction databases should also benefit from the integration of GIS and network-screening databases.

The integration of GIS, GSM, GPS and remote sensing (3GR) can help road safety analysts to improve the quality and accuracy of their analysis. It can help the road safety analyst to predict annual average daily Traffics (AADT), and vehicles miles travel (VMT). It can improve crashing data analysis and classification.

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