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High accuracy crash mapping using fuzzy logic

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ABSTRACT

Accurate crash location data in crash databases can be shown to be essential for crash modelling, crash mapping, hazardous road segment identification and other studies that aim to decrease the number of crashes within a network area. In this paper a generic and high-accuracy automatic crash mapping method is developed and presented. The methodology is based on a transformed map-matching method for candidate road segment identification and on a fuzzy logic inference system for the final road segment selection. The method is implemented by employing all injury and fatal crashes that occurred during 2012 in the UK Strategic Road Network but can be transferred to other network/crash data. The accuracy of the developed method is estimated to be 98.9% (±1.1%) correct matches. The results of this method are compared to other less advanced crash mapping methods.

1. Introduction

In order to mitigate the impact of road traffic crashes, it is important that reported crashes contain key variables that include crash time and location, road, driver and vehicle characteristics and contributory factors related to drivers' errors, defects in the vehicle(s) and the problems with the road environment. Crash data can therefore be considered as the primary safety performance data because an in-depth analysis of such databases may assist in designing effective countermeasures and formulating efficient crash prevention policies (Koike et al., 2000). Since road traffic crashes are predominantly spatial events, all the relevant information that describe the crashes may not be very useful if the locations where crashes took place on the network are not correctly specified. The identification of the crash location is very important as it contributes significantly to detailed crash analyses aiming to identify the contributory and causal factors including the reconstruction of the crash.

The accuracy of crash analyses in terms of modelling the severity and frequency of traffic crashes primarily depends on the availability of high quality and reliable safety performance data (Austin, 1995; Loo, 2006; Tarko et al., 2009). Crash data are often not reliable and therefore it is essential for it to be refined so as to enhance the overall quality. Spatial data are likely to be erroneous as space is multidimensional and that complicates the identification of a precise crash location, especially in complex road configurations such as junctions, roundabouts and flyovers (see Fig. 1). It is not known to what extent these errors are acceptable because the differences of road characteristics and the traffic conditions between two network points that are physically very close to each other can be important (e.g. the difference between a main motorway and its slip road) but there are indications that the estimated coefficients of a safety model differ significantly when the corrected crash

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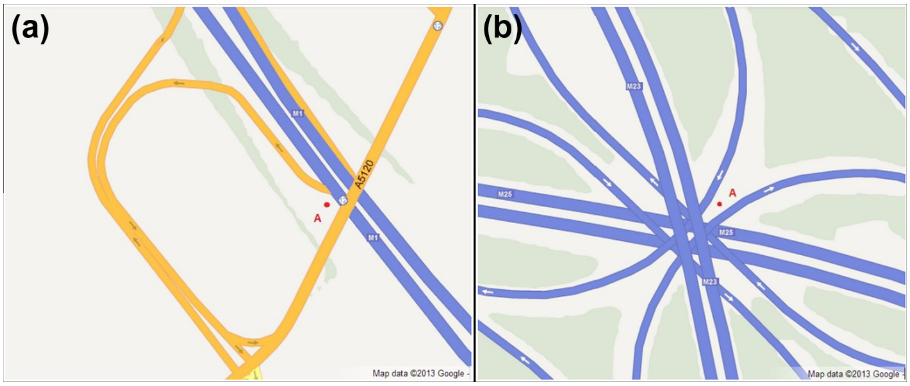

Fig. 1. Examples of complex crash mapping cases: (a) junction and (b) complex fly-over.

locations are used (Tegge and Ouyang, 2009). As a result, spatial crash data need to be enhanced through some special treatments in order to be confident about their quality.

Road traffic crash data are usually recorded by police officers who visit the crash scene just after a crash occurrence. Crash location is reported in several different ways: (1) by recoding spatial variables such as the road name and type, the proximity to junctions, (2) by assigning a crash at a point on a segment through the relative distances from some defined markers placed on the road and other physical facilities (i.e. a linear referencing system) and (3) by recording a single set of coordinates using a GPS or the national grid coordinate system. As crash databases usually do not include very precise geographic information though, it is reasonable to apply geocoding methods in order to estimate the exact crash location (Kam, 2003). Based on the fact that "each accident is a geographic event in the sense that is tied to a unique location defined in a given referencing framework" (Thill, 2000), a very common practice followed by many authorities around the world is recording the grid reference of the collision spot obtained by grid maps or Geographic Information Systems (GIS) so as to achieve a higher level of accuracy.

However, even when the crash location coordinates are recorded, it is still not guaranteed that the location of the crash can correctly be identified on a road network map. This is due to the error that these measurements may include and the inconsistency between the network databases that are used for crash mapping and the actual road network. For example, there are many simplified digital road maps in which roads are represented only by their centrelines and in some cases omitting features of the actual road geometry. As the majority of crash locations do not fall exactly on these centrelines, they have to be transferred and matched to the correct road segments. This is a quite challenging process, especially when they occur at areas with complex road networks where many road segments intersect, such as at junctions. Another important reason for the errors in recording crash location is that these crash data are primarily collected for administrative purposes rather than for scientific analyses (Loo, 2006). All the above, lead to the conclusion that when the identification of crash locations plays an important role in a traffic crash analysis study, a matching process of the crashes with the correct road segment would benefit the quality of the data and possibly the results.

In summary, it can be concluded that although precise crash locations are usually missing from the majority of crash analyses, assigning crashes onto the correct segments where they occurred is crucial if the purposes are:

- Locating hazardous segments within a network so as to design effective engineering countermeasures (e.g. altering road geometry) (Bíl et al., 2013; Karlaftis and Golias, 2002).
- Modelling segment-based traffic crashes with the aim of identifying the factors affecting crash frequency (e.g. curvature, gradient, traffic density and flow) and crash prediction (Wang et al., 2009).
- Spatial distribution of safety risk across the network. This can be employed for risk mapping that may lead to the introduction of targeted and specialised crash prevention measures (Steenberghen et al., 2004; Loo, 2009).

The primary objectives of this paper are therefore to highlight the importance and the challenges of crash mapping on road segments, especially in complex road networks and to develop a new generic and transferable crash mapping algorithm so as to map accurately traffic crashes onto road segments aiming to enhance the quality of crash data.

This paper is organised as follows: firstly, a brief literature review of prior research on crash mapping and an introduction to some map-matching techniques that can be applied to crash mapping are presented followed by the aim of this paper. Next, detailed descriptions of the data and the crash mapping method and the performance evaluation process are provided. Finally, the evaluation method and the results of the implementation of the crash mapping method are presented along with the main conclusions drawn from this study.