PLANAR SLIDING WINDOW TECHNIQUE FOR
SEARCHING ACCIDENT HOT SPOTS

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ABSTRACT
Hot spots (also called black spots) are locations in the national public road network, where the accident density is higher than expected. There are several methods to find these places, but most of them are outdated. There have been several technical improvements in the last decade (for example, the spreading of GPS technology). Therefore, it is necessary to adapt the already existing procedures. This paper presents a new version of the well-known sliding window technique working with planar coordinates.

Keywords: GPS, accidents, hot spots, sliding window, planar

INTRODUCTION
One of the most important road safety procedures is the identification and elimination of road accident hotspots. There are places in the national public road network, where the accident density is higher than the average (Fig. 1). There are several procedures [1,2,3] to find the hot spot locations, but none of them are uniquely correct. There are several theorems [4,5,6] and methods based on these to locate the problematic areas [7].

Figure 1. Accident black spot in Esztergom, Hungary. Red signs are accidents identified by GPS coordinates.
The government recommendations vary depending on countries. The main reason for this is that the definitions of hot spots are also varied in different countries. For example, in Hungary, a public road junction or a section that is at least 100 meters long, can be identified as a black spot, if there were at least four accidents there during a three-year period. According to this, the directive recommends the traditional and well usable "sliding windows technique" to find these places.

**RELATED WORK**

There are several studies concerning this method. For example, a study in Wisconsin was conducted using a sliding window based approach to identify the roadway crash locations. They have developed an algorithm named PRECIS to aid the analysis. There are several GIS tools that use sliding window variants to analyse accident data. These tools usually include different methods in the case of intersections and road segments.

Basically, a sliding window technique calculates the accident density on a dynamic scale of predetermined segment lengths. There are several subversions of the basic algorithm: we can use fixed or variable segment lengths and continuous or discrete window movement. The inputs of the algorithm usually include the data of accidents occurred in one road (or road section), a section length (or an interval of valid section lengths) and a density limit. The output of the algorithm is a list of sections, where the accident density is higher than the given limit.

This raw result can be fine-tuned using some additional techniques, like future prediction (in some cases, it is not enough to analyse the accidents of the past, it would be better to make predictions about the future and analyse these results), additional filtering (it is worth analysing the results of the sliding window method one-by-one to decide that the results are real black spots or not). There are many books [8] and papers about this technique, and several years of experience proves that it is well usable in practice.

**PLANAR SLIDING WINDOW**

The sliding window technique basically executes a one-dimensional search. The main input of the algorithm is the accidents of a given a road, where the road number is always the same and only the road sections (kilometre section of the accident) identify the exact positions of the accidents. This approach was satisfactory for several years, but in the last decade, there are several additional location identification methods. The spreading of GPS (Global Positioning System) technology has led to the extensive use of planar coordinates. For example, in the case of road accidents, the scene investigators use GPS coordinates to record the exact location of the accident.

Nowadays, it is common to use duplicated positioning systems to handle this issue. Investigators locate the GPS coordinates in the scene, and based on maps or GIS applications, they convert these values to the traditional road number + road section pairs. Road safety analysts can use both data, but in several cases, for example in the case of the sliding window technique, they have to use the latter, converted values.

The biggest deficiency of this traditional method occurs in the case of processing accidents that have occurred on multiple roads. There are several situations, when we would like to find hot spots consisting of sections of multiple roads. For example, in the
case of public road junctions, the accidents are spread over different roads. In these cases, the traditional sliding window methods cannot locate these places, because the accident density of both roads can be lower than the given limit. This situation is rarer in the case of built-up areas, where most of the accidents occur near junctions. Another issue in built-up areas is that there are several smaller cities, where the positions are identified by street names and house numbers instead of road numbers and sections.

IMPLEMENTATION OF THE NEW METHOD

Our new method, the planar sliding window method, is based on the already presented idea. The advance of the new procedure is that we use a two-dimensional window instead of the traditional one-dimensional one. Based on this, the input of the algorithm is the following:

- Set of accident locations (identified by GPS coordinates).
- Window width and height (these are usually the same).
- Minimal density.

There are several differences between these parameters and the parameters of the original method. The accident location is identified by GPS coordinates and not by road name and section pairs. Dual identification is possible, but the algorithm will only use the planar coordinates. The definition of the window is similar, but in this case, it is not enough to define the window length, we have to give two parameters: window width and window height. It is hard to suggest the correct values: it mainly depends on the goal of the search.

The interpretation of the minimal density is quite different in this case. In case of the original method, the dimension of the accident density is accident/metre. There are several recommendations for this value, for example the above-mentioned 5 accidents/100 metres. The new algorithm uses the area of the planar window to divide the accident number; therefore, the dimension of the minimal density value is accident/metre$^2$. This new approach needs some further investigations to find the best parameter values [9].

As it is visible in Algorithm 1, the method consists of two main parts. The first part collects the windows in which the accident density (number of accidents divided by the window size) is larger than the given limit. These are the possible black spot areas, but it is worth noting that these windows are not mutually exclusive. The second part removes all previously selected windows, where there is another window containing any shared accident with larger density value.
Algorithm 1 Planar Sliding Window

function PSW(ACC : set of accidents, W_{height}, W_{width}, minDENS : float)
1: result ← \emptyset
2: for x ← \min_{a \in acc} a.Lon to \max_{a \in acc} a.Lon − W_{width} do
3:     for y ← \min_{a \in acc} a.Lat to \max_{a \in acc} a.Lat − W_{height} do
4:         wacc ← \emptyset
5:         for all a ∈ acc do
6:             if x \leq a.Lon \leq x + W_{width} ∧ y \leq a.Lat \leq y + W_{height} then
7:                 wacc ← wacc ∪ \{a\}
8:         end if
9:     end for
10:     if |wacc|/(W_{width} * W_{height}) ≥ minDENS then
11:         result ← result ∪ \{wacc\}
12:     end if
13: end for
14: for all wacc ∈ result do
15:     for all wcheck ∈ result do
16:         if wacc ∩ wcheck = \emptyset ∧ |wacc| < |wcheck| then
17:             result ← result \{wacc\}
18:         end if
19: end for
20: end for
21: return result
22: end function

Algorithm 1. Planar Sliding Window technique

EVALUATION OF THE NEW METHOD

It is very hard to evaluate a new black spot searching method. First, there is no adequate definition of hot spots. Therefore, it is hard to check that the candidates given by the algorithm are valid results or not. However, there are some methods to check the usability of a new method, presented by Chang and Washington [10]. These usually test the consistency of the methods.

Chang and Washington suggest checking the following in order to test the consistency of a method:

- Site consistency: we assume that a site considered as a hot spot in time period A, should contain a lot of accidents in another time period B too.

\[
SC = \frac{\sum \text{Accidents in } i^{th} \text{ window of period A during period B}}{\sum \sqrt{\text{window height} \times \text{window width}}} 
\]
Method consistency: we assume that a site considered as a hot spot in time period A, should also be a hot spot in time period B.

\[
MC = \frac{\text{Number of black spots identified both in A and B period}}{\text{Number of black spots identified only in A or B period}}
\]

Rank difference: if we run the black spot searching method in time period A and B, we assume that we will have similar black spot locations. Furthermore, we can assume that the order of the black spots candidates (based on the accident density) will be similar too.

\[
RD = \frac{\sum \text{Rank difference between hot spots in A and B period}}{\text{Number of hot spots}}
\]

We ran these tests using the accident data of Budapest. The input parameters were:

- Window size: 100m x 100m.
- Minimum accident density: 0.0003 accidents/metre\(^2\).

Due to length limitations, this paper will not present all details of the test implementations. We show the final results for the tests (we can compare these values to the results of another paper like [10]):

- Site consistency test result: 0.0054 (accident/m).
- Method consistency test result: 0.4983
- Rank difference: 0.1626

CONCLUSIONS

Our objective was to adopt a new accident black spot search method using GPS coordinates. We have developed a new algorithm for this purpose and implemented it as a web service.

The practical use and our tests show that it performs very well. The calculated consistency values are very promising compared to other methods. It is usable outside built-up areas, but the main strength of the algorithm is its usage inside built-up areas.

REFERENCES


