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Bicycle Safety Map System Based on Smartphone Aided Sensor Network

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Abstract. This paper presents a self-updating bicycle safety map system which is based on the sensor data collected from node bicycles on the road. By using the smartphones, the GPS and accelerometer of the node bicycles on the road were recorded and transmitted to the safety map system server. The proposed system constructs and updates the safety map by analyzing the road surface, node bicycle trajectories, and crash spot information. Based on updated bicycle map, the system provides the safety level of the corresponding road section to the bicycle user. Our system was tested on the segregated bicycle track and showed usefulness of the safety map.

Keywords: Sensor network, GPS, Bicycles, Crash risk

1 Introduction

As the technology of the handheld device improved and came into wide use, the smartphone is becoming one of the most useful devices for the data collections. Various studies were performed to utilize the smartphone with other vehicles as a data sensing prove node [1]. Moreover, investigating the road or street environment with sensor embedded vehicle is one of the popular for both in area of the sensor network and intelligent transportation system [3-6]. In this study, we propose a bicycle safety map system which utilizes the bicycle and smartphone as a sensor prove. The bicycle nodes collect data during riding, and send them to the server to construct the safety map.

Compared to other previous studies, the proposed system can cope with the environmental or geometric changes of the roadway rather easily without any additional information from a map or field investigation, and it also can support low-cost and periodic safety map information.

The components and procedures of the proposed system will be shown in section 2 and its experimental results will be shown in section 3. Finally we conclude this paper at section 4.

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2 System

The proposed system consists of two main parts: the safety map server and node bicycles, and three procedures: collecting real time sensor data, updating the safety map, and distributing the safety information to the bicycle nodes. The node bicycles collect their sensor data and send them to the safety map server with their riding states. Then the server updates its safety map with received data and transfer updated safety information to the node bicycles. Fig. 1 shows the procedures of the proposed system.

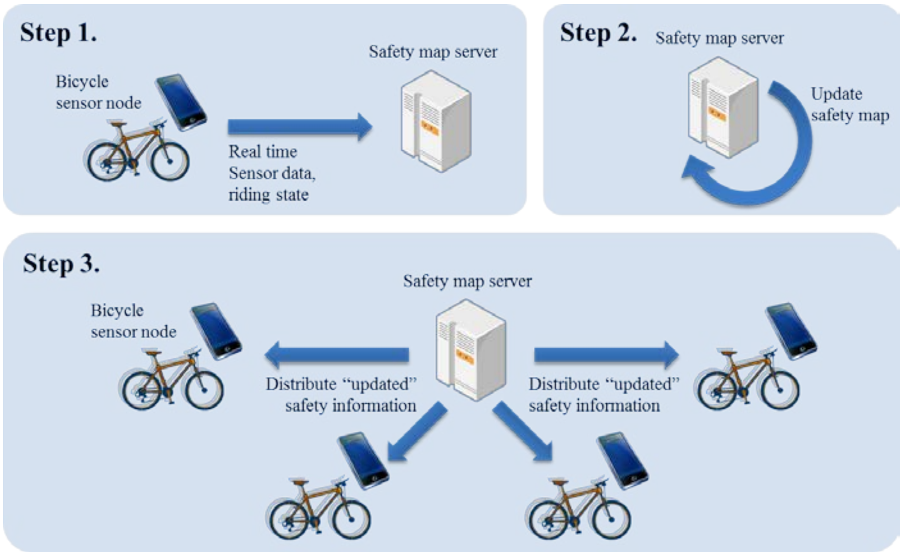

Fig. 1. Procedures and structure of self-updating bicycle safety map system

In order to communicate with the safety map server, each node bicycles carries a smartphone which can collect sensor data and access to the internet. The sensor data gathered by using the smartphone are the acceleration, latitude, and longitude. Based on the sensor data sent from the node bicycles, the safety map server can calculate road surface status and riding trajectory and consequently assume the bicycle safety information of the specific road section.

2.1 Node bicycles

The communication between the node bicycles and the safety map server was established by using TCP/IP. The node bicycles send the sensor data to the safety map server every 60 second or when an abnormal riding state detected. The state of riding was decided based on the collected sensor data and geometry of the bicycle user's position.

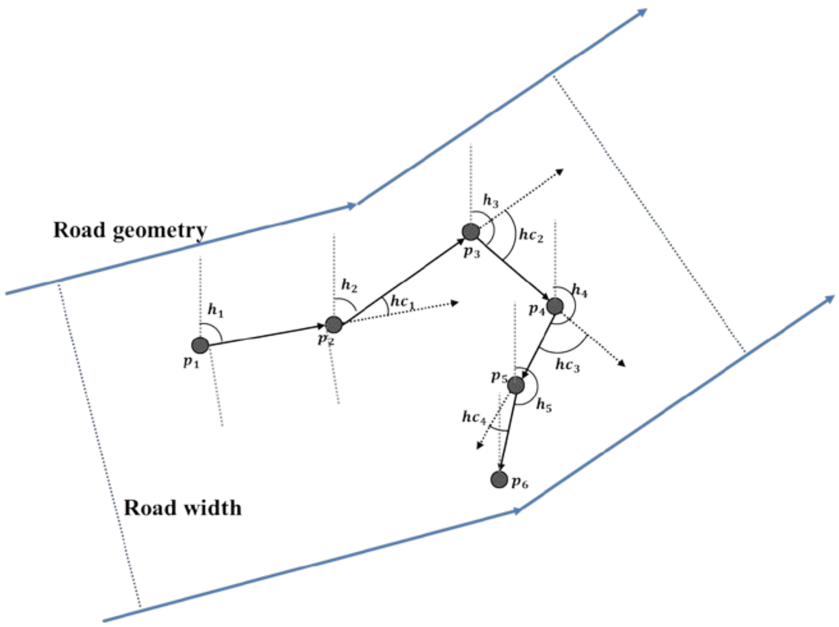

Fig. 2. Example of node bicycle in abnormal state

If sudden direction or speed changes occur, the bicycle node checks its current position, and compares the changes with the road geometry. The accelerometer of the bicycle node was also utilized to find the abnormal state. Fig. 2 shows an example of the abnormal state. $p_{1\text{-}6}$ indicate the positions of the node bicycles and $h_{1\text{-}6}$ show the heading directions at each positions. The differences between two adjusting heading directions are $hc_{1\text{-}4}$. The heading directions in the figure are showing sudden changes compared to the road geometry, and if these changes over certain threshold (i.e. 90 degree), then the node bicycle decides the current state as the abnormal. In order to minimize the data sent from the node bicycles, the sensor data were compressed with lossless compression. The safety map server sends the safety information when the node bicycles are moved into different road sections or their corresponding road segment is being changed.

2.2 Bicycle safety map

The bicycle safety map provides the bicycle crash risk of the road section. In order to rate the crash risk of the road section, we have to divide it into a number of segments. The road segmentation was performed based on the length and homogeneity of the segment. Namely, the geometry of the road was sequentially analyzed and was divided into segments at the sudden elevations or curvature changes occurred. The maximum length of segment was 3 km and the minimum was 0.02 km.

The bicycle crash risk was calculated based on the sensor data, riding state, and crash spot information. From the sensor data, two variables were calculated: vibration and summary trajectory. The vibration indicates the smoothness of the road surface and calculated with the z-axis accelerometer data from node bicycles. The z-axis accelerometer shows sudden magnitude changes when the road surface was bumpy. However the accelerometer also shows similar data when the node bicycle shows decline or incline in speed. In order to rid the effect of the speed, the z-axis accelerometer was compared with the speed and acceleration of the node bicycle, and was counted only when there were no sudden changes in the speed and acceleration.

The summary trajectory was constructed to find out the major center line among the trajectories of the node bicycles. The summary trajectory was constructed by utilizing the latitude and longitude data with principal curve method. The principal curve is the self-consistent smooth curve which shows a nonlinear summary of a given data points [2] and it was applied to calculate the road geometry [5, 6]. Next figure shows an example of the principal curve.

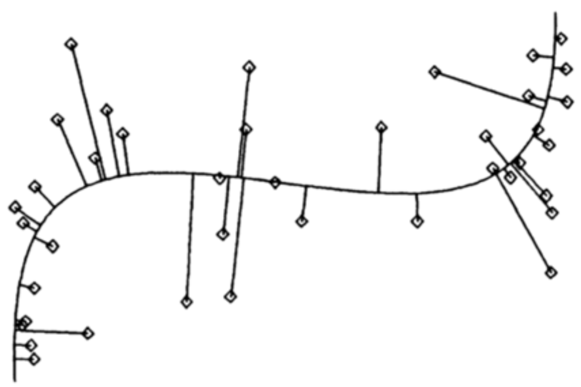

Fig. 3. Example of principal curve with given data [2]

Constructed summary trajectory was compared to the road geometry of the segment with Fréchet distance. The Fréchet distance measures the shape difference and distance between two polygonal lines [7]. If the Fréchet distance between the summary trajectory and the road geometry over certain threshold, the risk ratio of the segment was increased.

Lastly, the crash spot information was examined. The bicycle crash information for recent five years was provided from Seoul metropolitan government. If the segment contains the crash spots, its crash risk ratio was increased. Based on information, the crash risk C was calculated as,

$$C = w_v (t_v/t_s)v + w_f d + w_c n \quad (1)$$

w_v, w_f, and w_c are the weight value for the vibration, Fréchet distance, and crash spot, respectively. t_s is average passing time of the segment and t_v is vibration time. v, d, and n are average value of the segment for vibration, Fréchet distance, and crash spot number. v and d were normalized between maximum and minimum values.

3 Experiments

In order to evaluate the proposed system and to collect the sensor data from the node bicycles, we tested our safety map system at the segregated bicycle track near the Han River. 45 Korean bicycle riders participated to the experiments for two weeks. Fig. 4 shows the bicycle track used for the experiments and constructed safety map.

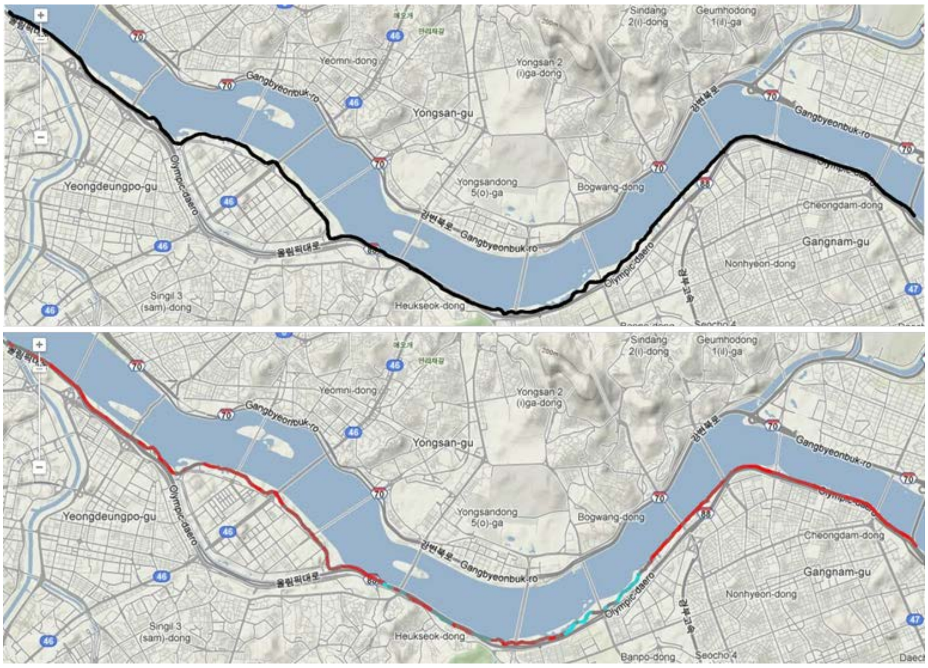

Fig. 4. Bicycle track for experiments and safety map

While blue color shows less crash risk, dark red color indicates higher crash risk. By observing the collected sensor data, we can find several errors from the vibration data. The vibration data showed jittering without any reasons, and we assumed that it might cause by noises produced from the node bicycles. The Fréchet distance and the crash spot information showed minor similarities.

4 Conclusion

In this study, we proposed self-updating bicycle safety map system by using the bicycles as sensor nodes. The proposed system consists of the node bicycles which collect the sensor data with smartphone and the safety map server which manages and updates the sensor data and safety map. We tested our system at the segregated bicycle track, and find out its usefulness.

For future work, we will find and apply methods that can reduce the effect of noise and purify the sensor data.

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