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Classification of Roadway Type and Estimation of a Road Curvature Using a Road Characteristic Conversion Coefficient

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Abstract. We define a road characteristic conversion coefficient (RCCC) based on an intersection point to classify roadway type and estimate a road curvature. The intersection point must be distinguished. The beginning and the finishing of curved sections are included within a representative range of variable positioning because a road with large curvature is highly prone to cause accidents. A gradient of a straight line between two points of a consecutive lane segment is computed and normalized to calculate a RCCC. The RCCC classifies the intersection point with the difference of crossing angle using the previously established criteria value. The RCCC is a criterion for classifying roadway type, and it is able to determine a large curved section based on construction criteria. Standard deviation of a large curved section from simulation is 2–807 times bigger than that of a straight section.

Keywords: Road curvature, characteristic conversion coefficient, roadway type, classification of roadway

1 Introduction

Roadway is composed of various data, such as lanes, lane boundaries, and road signposts. Such data help motorists to locate visible markings when driving. A lane is an area of a roadway wherein a vehicle is expected to stay if the driver has no intention of changing his path. Visible lane markings are delineators that are intentionally placed on the borderline of the lane. These markings are directly visible to the driver while driving. Line data should be abstracted from the visible lane markings for vehicle measurement and control. One section of a road is usually determined as curved or straight based on the feature of the lane boundary. Thus, a lane boundary can be classified as straight or curved. Nowadays, most vehicle provides intelligent function to give help to a driver during fast driving. But drivers are easy to be at risk of losing concentration at the instant of the shift from a straight section to a curved section due to such intelligent function. Moreover, the vehicle

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requires complicated control when its speed is reduced during steering. PIARC (2013) showed that the accident rate within a horizontal curved section is 1.5 to 4 times higher than that within a straight section. Thus, drivers need to keep their attention on a roadway when a curved section begins.

Identifying horizontal curve from roadways using geographic information system (GIS) has recently gained increasing research attention. Findley et al. (2012) attempted to find a way to identify all curves of roadway segments that depart from straight segments with a change in heading. Andrasik et al. (2013) presented a method to automatically identify curves based on available geographic data. They focused on finding curve features accurately with an angle from GIS points. However, their result of the curve features is generally considered related to processing speed and performance which can use the intelligent function. Frequent segmentation of curve and straight sections mainly results in loss of performance due to safety requirement.

In this paper, we define a road characteristic conversion coefficient (RCCC) based on a coefficient of gradient, which provides a criterion for estimation of a road curvature. To identify each section, we present an algorithm for an intersection point using the coefficient of gradient. The intersection point is the most suitable criteria to make distinction between a large curved section and a straight section.

2 Extraction algorithm for an intersection point

The lane data, including the error from the lane type of a distinguishable point in a curved section, can be extracted through the gradient of a straight line and continuous length, such as the lane boundary line in Fig. 1. Gradient β_p^k is the value of global coordinate standard of the *k*-th and the (*k*+1)-th in the straight line, i.e., the lane position information in extraction flow chart of Fig. 1 that can be obtained by Eq. (1). To compare the gradient of the lane in the series of sections, we obtain the standardization for error range by multiples of about 2 times of sine function, which we show as gradient of coefficient, as follows:

$$\beta_p^k = \left[2 \cdot \arctan \frac{\Delta y_p^k}{\sqrt{(\Delta x_p^k)^2 + (\Delta y_p^k)^2} + (\Delta x_p^k)} \right], (-\pi, \pi] \quad (1)$$

$$Z_p^k = \sin(\beta_p^k) \times \cos(\beta_p^k) = \sin(2\beta_p^k)/2 \quad (2)$$

The coefficient of a lane gradient is used to obtain a RCCC from the different values between the continuous lanes, thereby creating groups of lane types. A RCCC can be obtained from the *k*-th lane information to the (*k*-4)-th lane information, i.e., the cumulative difference among from the (*k*-1)-th to the (*k*-4)-th value. The RCCC shows the status value 1 toward negative and positive values from Eq. (3) and the fourth RCCC, such as in Eq. (4). This coefficient distinguishes the *k*-th position information P_G that K_p^k, K'^{k}_{p} = 1. The lane position information of distinguished

P_G creates groups by using the criterion of 100 m, which is the minimum required road length and determines the distinguishing point extraction algorithm, as follows:

$$\begin{cases} Z_p^k - Z_p^{k-n} > 0, K_n^k = 1, K_n'^k = 0 \\ Z_p^k - Z_p^{k-n} = 0, \quad K_n^k, K_n'^k = 0 \quad [n = 1,2,3,4, k = n+1, (k > 4)] \\ Z_p^k - Z_p^{k-n} < 0, K_n^k = 0, K_n'^k = 1 \end{cases} \tag{3}$$

$$\begin{aligned} P_G &= K_p^k = K_1^k \cdot K_2^k \cdot K_3^k \cdot K_4^k = 1 \\ P_G' &= K_p'^k = K_1'^k \cdot K_2'^k \cdot K_3'^k \cdot K_4'^k = 1 \end{aligned} \tag{4}$$

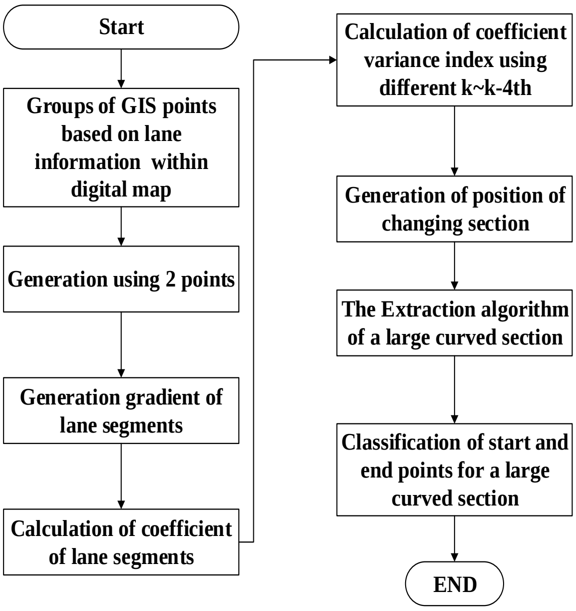

Fig. 1. Diagram for extraction (intersection point)

The algorithm distinguishes a curved section with a large curvature radius, chases the section that is larger than the variance value Z_G as a distinguished group, and extracts the entry and the exit points. The entry and the exit points are extracted from the curved section with a large curvature radius if the gradient coefficient differs by more than 0.1. If the difference of the gradient coefficient is lower than 0.1, then the section is a straight or easy curved one that doesn't limit the designing velocity due to the driving environment.

3 Simulation for extraction curved section

The GIS lane information used in this research is a 3 km section in the Yeoju test-road and is given as a database for the position value of lane information. The property table containing the points extracted from the lane information as curved section candidates and computed characteristic coefficient index of each section is shown in Fig. 2.

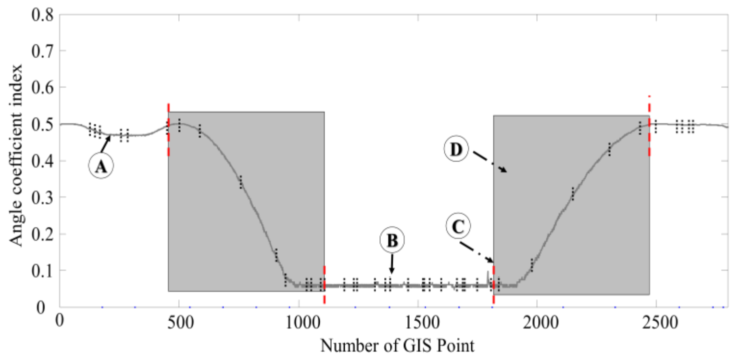

Fig. 2. A graph of the characteristic index of lane segmentation

Position ‘A’ in Fig. 2 is the characteristic coefficient index of lane gradient. Position ‘B’ is one candidate of a curved section with a large curvature radius. ‘C’ is the extracted curved group. ‘D’ shows the section having a large curvature radius. Group index values are chosen where the filed numbers are 452, 1100, 1849, and 2495, in which the change of gradient is recognized. The candidates between the beginning and finishing areas of curved sections are included in the representative range of variable positioning. The curvature range increases with increasing value difference of the coefficient in the ‘D’ section.

As shown in Fig. 2, the section can be a candidate curved section when the difference of the crossing angle with the previous criteria point is more than 5° in the area classified as the curved section. The lane area of index numbers 1–373 can be included in the curved section. However, the difference value of the characteristic coefficient index is 0.007, which is smaller than the criteria coefficient 0.05, the crossing angle with the next extracted point 452 is 1.2°, and the difference of characteristic coefficient index is 0.026. Thus, the section is not extracted as a dangerous section that has a large curvature radius.

Index number 452, which is extracted from the beginning point of curved road, has a cross angle of about 8.2° with previous section points. The characteristic coefficient index 0.002 shows a different gradient of the linear group’s shape. However, a 10.4° angle and a characteristic coefficient index value of 0.079 were found in the index number 682 lane section point. Thus, this point is classified as the beginning of the curved section.

As shown above, the lane type can be checked by linking the extracted points by continuously using the criteria of crossing angle and length of section extracting point. Fig. 3(a) shows the range of section 1 that is extracted as curve index. Fig. 3(b) shows the range of section 2 that is extracted as the curve index. The section extracted point, which is classified from the road type, indicated the beginning and finishing points of entry to the large curvature radius section. Thus, the driver can prepare for the dangerous situation earlier with the help of humanoid engineering alarm and warning system.

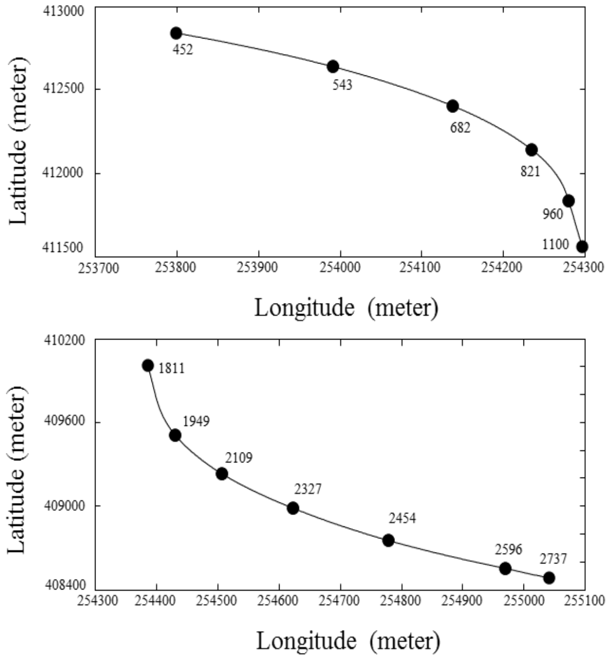

Fig. 3 The result of extracted curved section

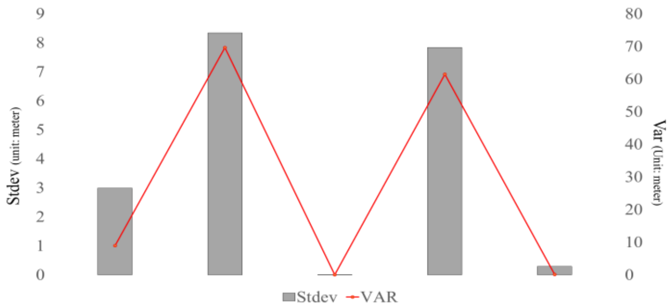

Fig. 4. Standard deviation and variance of gradient of divided lane section

The standard deviation and variance of gradient of divided lane section are shown in Fig. 4. The large curvature radius section shows a standard deviation that is larger than 8 and a variance that is larger than 61. Straight road has standard deviation that is smaller than 1 and also has variance that is smaller than 5. In the case of small curvature radius section, the standard deviation is approximately 3, which is similar to the first sign, and the variance is 10. Thus, this section can be classified as a small curvature radius section because of the gradient difference and combined interpretation.

4 Conclusion

A method for classifying roadway types using the gradient of a line segment based on GIS point information is presented. To identify a criterion, we define a characteristic coefficient index of consecutive line segments. Verification is done by implementing it to a system for detecting a curved section that has larger value than the criteria. This method can easily extract the intersection points between a straight and a large curvature roadway with a long range which cannot be obtained with previous researches. Also, the roadway type can reliably be classified with the RCCC. However, the proposed method needs be verified with various driving positioning tests.

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