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The Optimization Layout Method of Intelligent Roadside Sensor System in Traffic Management and Control

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Abstract. The vehicle sensor information and road side sensor information will be collaborative used in traffic management and control. In order to improve the comprehensiveness and economy of the traffic and road conditions' information collection, we focus on the intelligent roadside system in this paper. Firstly, we analyse the functions of the intelligent roadside system. Through the analysis of the detection range, detection accuracy, price and applicable conditions of similar sensor, we delineate the selection range of the intelligent roadside sensor. Then we determine the layout scheme of the testing equipment sensors for different functions according to different types of network structure. Finally, we apply similarity analysis to optimize the configuration density to reduce system cost by selecting the sensor layout-intensive sections.

Introduction

With the development of the Internet of Things technology and intelligent vehicle technologies, intelligent transportation industry will be undergoing major changes. Cooperative vehicle and infrastructure is the new hot spot of international research in the field of intelligent transportation, and also it will lead the future development of intelligent transportation[1]. While intelligent roadside system plays a vital role in Cooperative vehicle and infrastructure, it not only need to provide real-time, accurate traffic and road conditions of basic information, but also need to complete the rapid identification and location of unexpected traffic and road events. The reasonable selected type and the optimization layout of the sensor are the foundations to achieve the above functions[2]. Currently, the major developed countries and regions are aimed to achieve more efficient, safe, environmentally friendly transport environment, and to build a collaborative system based on cooperative vehicle and infrastructure's communication in the R & D and application of the cooperative vehicle and infrastructure areas. Such as IVI(Intelligent Vehicle Initiative) program, the Smart way project, the EU's Speed Alert project, Denmark INFATI plan and the French STOPPING projects[3], these studies are all at an experimental stage. Among them, the roadside sensor appears not enough coverage and high cost of layout in the process of demonstration to verify of IVI plan[4]. This paper is starting from this issue, through the research on the optimization layout method of roadside sensors, we try to reduce the system cost on the basis of comprehensive transportation and traffic information collection

Functional Analysis of the Intelligent of Roadside System

The intelligent roadside system provides basic information such as transportation, traffic, sudden road traffic events, weather, environment, vehicle location and so on. The information provides data to support the formulation of the macroscopic traffic flow control strategies and the micro-vehicle

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warning decision-making. The multi-sensor is the source of information of the intelligent roadside system, its layout scheme is reasonable or not directly determines the comprehensiveness of information collection and utilization of information and the system's cost-effective.

Function-based Multi-sensor Selection

The cost is the key quantitative indicators to measure the testing equipment. On the basis of extensive market research, we delineate the scope of the multi-sensor selection based on the established function of the intelligent roadside system, a comprehensive analysis of similar sensor detection range, detection accuracy, price and applicable conditions. The details are shown in Figure 1.

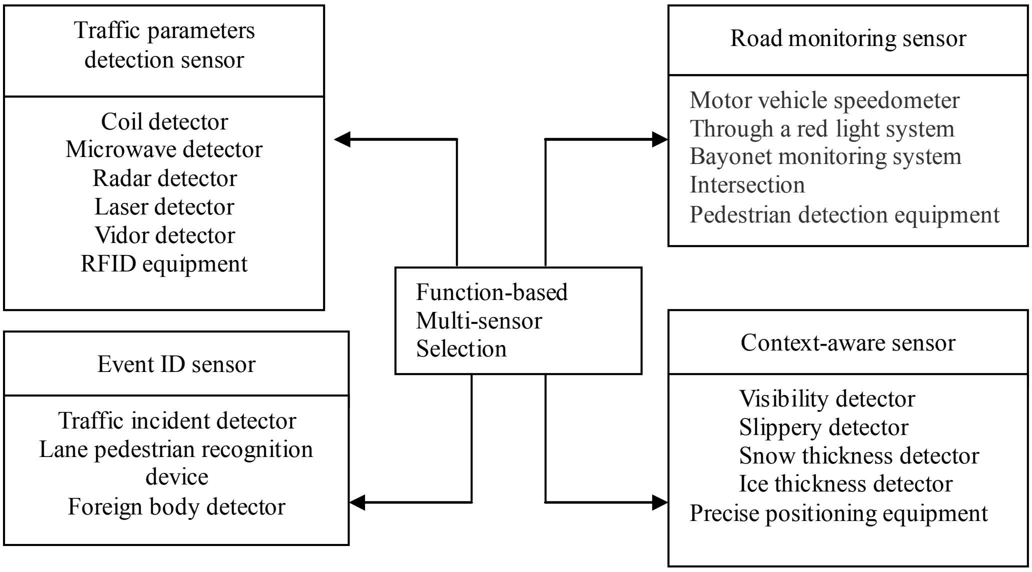

Fig. 1 Function-based Multi-sensor Selection

Layout Scheme of Multi-sensor

We determine the layout scheme of sensors of different functions according to different types of road network structure and multi-sensor selection, from a comprehensive collection of information view.

Layout Scheme of Context-aware Sensor. The method of context-aware sensor layout is in accordance with the applicable conditions and detection capabilities, through the combination of the visibility, slippery, snow depth, ice thickness sensor to form an automatic weather station. For example, if the visibility range of sensor detection is about 10,000 meters, it is better to lay in urban centers to monitor the entire city road network, while an additional sensor laid in peri-urban highway network within the special monitoring points (such as water net area, easy to produce windshear and local climate Valley) can also be considered, but notes to avoid tall obstacles, and the location where the local smoke often appears[5].

Layout Scheme of Road Monitoring and Event Detection Sensor. Road monitoring sensor has its own specific layout position (such as motor vehicle speedometer propose to lay in the upstream sections of the site-specific need speed limits, red light system is laid at the intersection, etc.); Event ID sensors need to target monitoring area to determine the layout position, the layout number should be determined by the camera's performance.

Layout Scheme of Traffic Parameter Detection Sensor. To ensure that the sensor data can reflect the road traffic conditions quickly, accurately and truly, and monitor queuing of vehicles at the intersection, the sensor should be set at 15 to 30 meters away from the intersection of the upstream exit of the sensor, beyond the length of expected maximum queue, and the motor vehicle can pass through the sensor by average velocity. If the upstream intersection export is signal controlling pedestrian crossing, the sensor should be set from 25 to 30 meters of street crosswalk, as shown in Figure 2.

In addition, because the differences of the road traffic conditions in the complexity, diversity, and urban road network and geographical conditions, the layout of sensor should be considered in the specific application, and be based on the specific situation of the urban traffic and intersection location specific analysis, as shown in Figure 3.

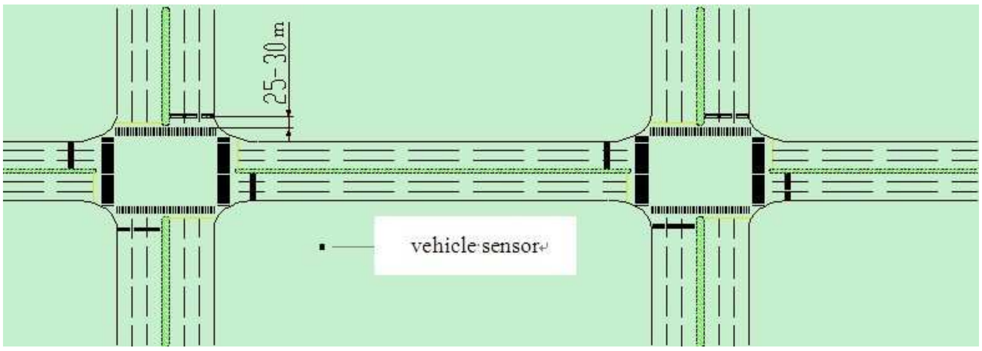

Fig. 2 Traffic parameter sensor layout scheme in signal control intersection

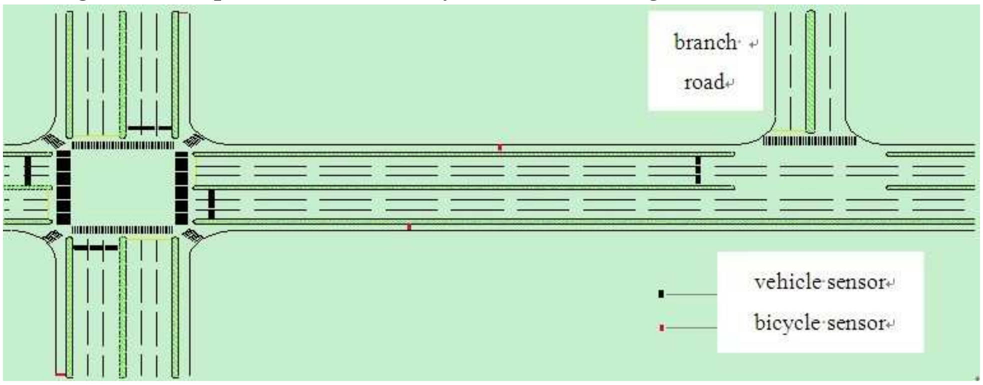

Fig. 3 Traffic parameter sensor layout scheme in slip import

Configuration Density Optimization Method of Multi-sensor

In practical engineering applications, after determining the layout scheme of traffic parameter detection sensors, we need to select the sensor layout-intensive sections, to reduce system cost by the method of similarity analysis to conduct configuration density optimization.

Step1: delineate the range of the road network which needs similarity analysis, including the more dense basic layout sections of traffic parameters detection sensor and flow similarity network area with their experience.

Step 2: Basic Traffic Counts survey. To survey the traffic for 5min in typical period, for each link, to ensure that traffic number investigated in the 5min, $n \geq 50$.

Step 3: Calculate of the degree of similarity between the two basic sections of the traffic flow.

$$\rho(X,Y) = \frac{\operatorname{cov}(X,Y)}{\sigma_X \times \sigma_Y} \quad (1)$$

$$\sigma_X^2 = \frac{1}{n}\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2 \tag{2}$$

$$\sigma_Y^2 = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2 \tag{3}$$

In which: X represents the section of X traffic array; Y represents an array of traffic sections of Y; $\rho(X,Y)$ on behalf of the correlation coefficient between X ,Y traffic flow. It should be noted that the traffic data of sections X, Y must be from same time period.

Step4: determine similarity index α and sections of similar matrix.

$$\alpha_{ij} = \begin{cases} 1 & i,j \quad similar \\ 0 & i,j \quad not \quad similar \end{cases}$$

Step5: model sensor optimized distribution and solve.

$$\min Z = \sum_{i=1}^{n} C_i X_i \qquad i = 1,2,\cdots,n$$

$$s.t. \quad \sum_{j=1}^{n} \alpha_{ij} X_j \geq 1 \tag{4}$$

Which $X_j = \begin{cases} 1 & road \quad j \quad distribution \\ 0 & road \quad j \quad no \quad distribution \end{cases}$

Step6: If the layout of the sensor arranged in a pre-set detection point scale, then stop, otherwise choose another section of the regional to do similarity analysis, return to Step1.

Case study

In order to verify the effectiveness of the method, we take coil detector for example, relying on the road network of Changchun City, South Gate area, delineate the needed range of the similarity analysis, and uses VISSIM (a microscopic traffic simulation software) tool to create a simulation network, shown in Figure 4 The road network includes trunk roads, sub-distributors, signal controlled intersections and no signal controlled intersections. The box is the intersection number, next to a straight line is the sections of number, the thick solid line represents a one-way 3-lane urban arterial road, the thin solid line represents a lane of a one-way trunk road, No. 6, 9, 10 intersection represents no signal control intersection, all the rest of the intersections are signal control sections, section13, 16, 17 has a bus station

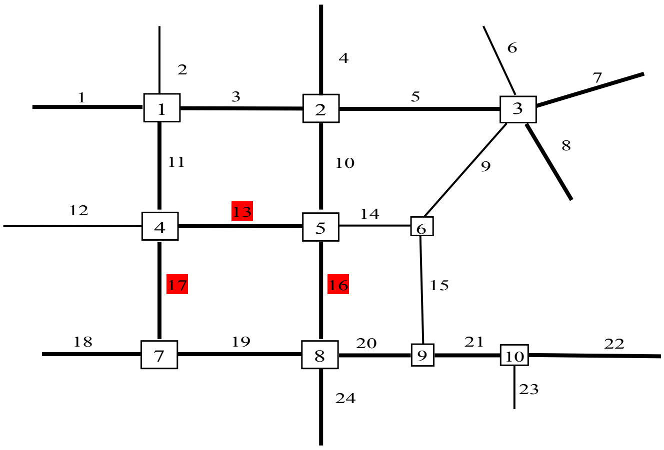

Fig. 4 Simulation road network

The layout of coil detector in simulation network is according to the coil detector layout standard of the traffic control system TD250 Changchun City, (laid on at each intersection of the exit of each lane, each with a set of coils), with a total of 100 induction coil. The initial flow data of each section uses the actual traffic survey results, the simulation time is 15600s, we begin collecting the data after 600s, get 5min flow data of the various sections, with a total of 50 groups.

Through the similarity calculation of traffic flow in the degree, the sections of similarity matrix are as follows:

Table 1 Similarity matrix

α	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
2	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
3	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
4	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
5	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
6	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0
10	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
12	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0
16	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
18	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
19	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
20	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
21	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

Solving to the above data, we get the results: the induction coil should be reduced after the optimization of the configuration density of 59 groups, and the total cost reduces 41%. Set the optimized sensor layout scheme in the simulation network, for example, sections 16 compared with the original scheme, average flow relative error in 5min of the 15600s is1.46%, which meets the demand of accuracy of traffic data collection in traffic management and control.

Summary

The method shows in this paper will not only acquire accurate information but also reduce the sensors' emplaced cost.

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