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Research on Positioning of High-Density Rail Shunting Locomotive Based on Radar Laser Ranging

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Abstract: The safety of locomotive shunting operations has always been a bottleneck problem that plagues the development of the railway industry. Many marshaling stations use plane wireless shunting systems and incorporate them into the microcomputer interlocking control system, which plays an important role in improving the efficiency of shunting operations and ensuring the safety of shunting operations. However, due to the restriction of the track circuit in the station and the inability of interlocking the ground shunting signal with the locomotive monitoring device to implement safety control, when the locomotive runs to the signal lights, turnouts, derailment devices, and earth blocks, it still depends on the driver and passengers to look for confirmation. In addition, in the case of rainy weather and manual misoperation, it is easy to cause "rush, squeeze, and pull off" and rush into the locomotive. In view of the development and use status of the above shunting operations, combined with the actual production situation of shunting and transportation of heavy-duty trains with 10,000 tons and 20,000 tons in the actual operation of Shuohuang Railway, on the basis of plane shunting equipment, microwave radar ranging monitoring technology is used to realize the monitoring of safety information such as the location of the operator's work site and the location of the parking vehicle. Improve the safety factor in shunting operations, use equipment to more accurately use distance signals, provide effective conditions for the control of the locomotive speed of operators, and reduce the accident rate in shunting operations. The application of the radar ranging system in the shunting operation of the locomotive provides a great safety guarantee for the shunting operation, improves the safety factor in the operation, and uses the equipment to use the distance signal more accurately, and the speed of the locomotive of the operator The control provides effective conditions and reduces the accident rate in shunting operations.

Keywords: Microwave Radar Ranging, Locomotive Positioning, Positioning Matching, Shunting Prevention and Control

1. Introduction

The management and control of locomotive shunting operations have always been a bottleneck problem that plagues the development of the railway industry. At present, many marshaling yards use the plane wireless shunting system and incorporate it into the microcomputer interlocking control system, which plays an important role in shortening the shunting time, improving the efficiency of shunting operations, and ensuring the safety of shunting operations. However, due to the constraints of the track circuit in the station and the inability of interlocking the ground shunting signal with the locomotive monitoring device to implement supervisory control, when the locomotive runs to the signal light, switch, derail or earth block, it still depends on the driver and passenger to look forward to confirming the ground signal. In order to improve the positioning accuracy of the locomotive in traditional track positioning, it is usually necessary to refer to the real-time speed data of the locomotive when calculating the specific position. The speed measurement positioning method is an auxiliary positioning method. In the track circuit positioning algorithm, it is impossible to determine the exact position of the locomotive at the end of the section. Speed data will greatly reduce positioning errors [1]. Before it is determined that the operation of the locomotive in the main line or in the marshaling yard, the location mainly uses traditional methods such as track circuit positioning and odometer positioning [2]. The disadvantage is that this positioning method is prone to accumulative errors. In marshaling yards that require high positioning accuracy, other methods need to be assisted to correct locomotive positioning information to improve its positioning accuracy.

2. Key Technology

The ranging method is composed of a ground system and a vehicle-mounted system. The data is received through a wired or wireless network. The interface sources are the upper level shunting zone supervisor, the shunting locomotive controller, and the leveling hand station of the station shunting personnel.

2.1. Microwave Radar Ranging

The microwave radar uses a frequency-modulated continuous wave (FMCW)-based ranging radar. Compared with the pulse radar, the FMCW radar has a larger bandwidth, so it has a higher range resolution [3]. The microwave radar ranging module has a large time-band product, which is much larger than the pulse radar with the same signal bandwidth and level. Therefore, under the same detection capability, the FMCW radar has low transmit power and is not easy to be intercepted.

2.2. High-Density Map Matching

Map matching is a positioning correction algorithm that combines and compares the track path information in the digital map with the locomotive positioning trajectory to determine the specific location of the target in the digital map. The map matching technology is based on remote sensing technology, and the remote sensing map used is the base map [4]. The difference between the orbit data accuracy of the remote sensing map and the positioning accuracy of the on-board positioning and navigation system is less than 1 meter.

3. Extraction of Locomotive Positioning Information for Rail Shunting

3.1. Mobile Parking Point Recognition

Based on the personal positioning terminal, the differential position is used to provide system-level high-precision positioning for the terminal, and the Beidou satellite ground-based augmentation system's differential data, CELL ID, inertial navigation, map matching and other technologies are integrated. It supports SIM card and can access online through 4G network. Differentiated service function, thereby improves the accuracy of personnel positioning [5].

Characteristic extraction and analysis of personal mobile terminal behavior based on mobile location data. Specifically, it is first necessary to obtain the user's trajectory staying point according to the original location information; then, the single-mode travel chain division is completed according to the staying point information; finally, for the single-mode travel segment, the user's travel location point is matched to the actual travel section, get information about residents' travel roads.

Locomotive initial positioning is the source of locomotive tracking. Fast positioning is required to enter the tracking state and give feedback to the upper-level information management system, so as to continuously track the position of the locomotive and train after obtaining the position of the locomotive and train to ensure fast, accurate and effective locomotive positioning; The ground system will also determine the approximate locomotive range based on the real-time positioning of the target locomotive, combined with the interlocking indication in the current area, lock all occupied sections in the area, and when a new press-in action occurs in the occupied section [6]. Determine whether the locomotive is also in motion and the forward direction is consistent with the section pressing direction [7]. If it is the same, continue to determine whether the next pressing action can match, otherwise, exit the current initial positioning determination process and re-judge the area where the locomotive is located [8]. If the three consecutive pressing in and clearing actions are consistent with the locomotive's traveling direction and running state, and the real-time positioning area of the locomotive also includes the pressed-in section, the current position of the locomotive can be judged, and the protection distance can be calculated and calculated according to the positioning. Automatic remote control calculation, and at the same time feedback the current locomotive location to the upper-level information management system, and update the locomotive position and speed in real-time on the station yard display.

3.2. Cluster Analysis Dwell Point Extraction

According to the density of each area in the data space, clusters are regarded as dense object areas separated by low-density areas. According to the density of each area in the data space, clusters are regarded as dense object areas separated by low-density areas. Input requirements: data sample set; neighborhood radius Eps; minimum number of samples in the core point neighborhood Min Pts; sample distance measurement function distance (x_i, x_j) output requirement: clustering result cluster division data set [9].

Step 1: Initialize the core object set $\Omega = \varphi$, initialize the current cluster number k=0, initialize to the unvisited sample set D, and divide the clustering result into clusters $C = \varphi$;

Step 2: Traverse the samples in sequence, j=1, 2,..., l, and judge whether it is the core object x_j : Get the Eps neighborhood of the sample with the help of the metric function x_j [10]. If the number of other samples in the Eps neighborhood of the sample is satisfied $\left|N_E(x_j)\right| \geq MinPts$, the sample is regarded as the core object x_j and added to the core object set x_j ;

Step 3: Determine whether the core object set Ω is satisfied. If it is, the algorithm ends. Otherwise, go to step 4;

Step 4: In the core object set Ω, randomly select a core object o, initialize the current cluster core object set $\Omega_{cur}=\{o\}$, update the current cluster class number k=k+1, initialize the current cluster sample set $C_k=\{o\}$, and the new unvisited sample set $\Gamma=\Gamma\text{-}\{o\}$ [11];

Step 5: Determine whether the current cluster core object set Ω_{cur} satisfied $\Omega=\varphi$ [12]. If it is, the current cluster C_k is generated and the cluster division $C=C\cup\{C_k\}$ is updated, and the core object set $\Omega=\Omega\text{-}C_k$ is updated, and then go to step 3. Otherwise, update the core object collection $\Omega=\Omega\text{-}C_k$ [13].

Step 6: Iteratively extract a core object o' from the current cluster core object set Ω_{cur}, and obtain the Eps neighborhood $N_E(o')$ of the core object o' with the help of the metric function [14]. Let $\Pi=N_E(o')\cap\Gamma$, update the current cluster sample set $C_k=C_k\cup\Pi$, update the unvisited sample set $\Gamma=\Gamma\text{-}\Pi$, update the current cluster set $\Omega_{cur}=\Omega_{cur}\cup(\Pi\cap\Omega)\text{-}o'$, and go to step 5.

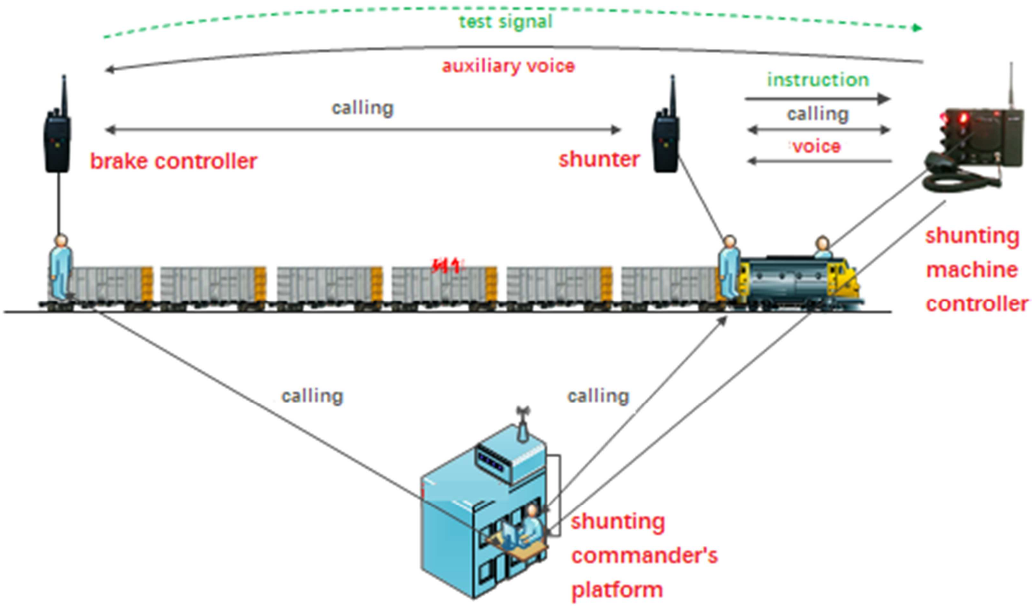

Figure 1. *Schematic diagram of high-density rail shunting with radar laser ranging.*

4. Data Conversion Sends out Distance Signal

The distance measuring equipment adopts the host of data collection and control and transmits the position signal, and then returns to the equipment after encountering obstacles, performs data conversion, converts the measured distance into ten, five, and three vehicle signals, and sends the signal through the wireless module. Go out and inform the shunting staff and locomotive driver. In the case of bad weather or poor lighting conditions at night, correctly judge the position of the parked vehicle, control the speed of the shunting operation, use the driver to operate within the standard speed range of the operation, prevent overspeeding with the trailer train, or push the operation to the end line. When reaching a safe distance, the shunting locomotive can stop in time to prevent the train from hitting the earth block and causing dangerous accidents.

Microwave radar ranging monitoring adopts the host computer for data collection and control and the transmitter position signal, which is returned to the device after encountering obstacles for data conversion, and the measured distance is converted into ten, five, and three vehicle signals, and the wireless module converts. The signal is sent out to inform the shunting personnel and the locomotive driver. The anti-jamming capability of microwave radar is stronger, and it can work normally in severe weather such as rain, snow, haze and sandstorm, and the penetration of microwave radar is more advantageous in bad environment. The working principle of microwave radar speed measurement and ranging is that the microwave transmitter sends out microwave signals. When it encounters the object to be measured, the signal is reflected, and then the signal is received by the receiver [14]. Finally, the distance of the object is calculated by the principle of micro-Doppler translation and speed. The distance from the radar to the object is R, The time difference from transmission to reception of the signal is $K=\frac{BT}{2}$, equal $K=\frac{\Delta f}{\Delta t}$, equal $R=\frac{c*|\Delta t|}{2}=\frac{c*|\Delta f_1+\Delta f_2|}{4K}$, And for stationary objects $\Delta f=\Delta f_n$ [15].

The matching vehicle can remain in motion on the track; after meeting the above two points, the maximum possible position and the most likely trajectory (route) of the locomotive in the track section can be determined through an appropriate matching process. The processing process of a complete map-matching algorithm is shown in the figure. It mainly includes defining the error area, selecting candidate segments that fall within the error area, calculating the matching probability of the candidate segment, and calculating the correction result; the error area value is the current locomotive. The range and area with a high probability of being located, the error area depends on the sensor positioning result and the error situation; the candidate segment is the specific segment that the map matching algorithm thinks contains the true position of the locomotive (usually in the form of a list in the memory) Storage; the selection of matching sections is to select one or several sections from the candidate sections that are most likely to be the locomotive trajectory. The selection principle is usually based on the graphic characteristics of the selected section in the digital map and the locomotive trajectory degree of similarity; after determining the matching section, the most likely position of the computer car in the section is output, and the result is output. Since the locomotive is in the track network all the time in the running state, the conditions for using the map matching technology meet the track. The precise positioning of the shape is required.

5. Conclusion

Using radar laser ranging and map matching technology to monitor the position of railway shunting operators, locomotive position and speed, etc., provide high-tech solutions for locomotive shunting operations, and provide a means of prevention and control for railway shunting operators to achieve Real-time monitoring of the wireless plane shunting operation process, and monitoring of the location of the shunting operator's job site, the precise position of the shunting locomotive, etc., effectively expanding the monitoring field of vision, optimizing the operation of the locomotive, improving the efficiency of railway shunting operations, reducing transportation costs, and avoiding. In the event of a driving incident, it is combined with the flat wireless shunting system to build a new line of defense for railway operation management and control.

High-density track positioning and matching can further control shunting operations. Distance and speed warnings specifically include warnings for more than ten vehicles, warnings for ten vehicles, warnings for five vehicles and warnings for three vehicles. Warning for more than ten vehicles: when the driving distance is more than ten vehicles, and the speed exceeds 25KM, the speeding warning command will be pushed from the background to the personal terminal. Ten-vehicle warning: after the driving distance is ten vehicles, and the speed exceeds 17KM per hour, the speeding warning command will be pushed from the background to the personal terminal. Five-vehicle warning: after the driving distance is five-vehicle distance, and the speed exceeds 12KM per hour, the speeding warning command will be pushed from the background to the personal terminal. Three-vehicle warning: after the driving distance is three-vehicle distance, and the speed exceeds 7KM per hour, the speeding warning command will be pushed from the background to the personal terminal.

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