Research on GPS Remote Precise Positioning of Power Transmission Line Inspection Robot

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Abstract: A method on the remote precise positioning based on the GPS technology for transmission line inspection robot of is proposed. The functional requirement and construction of remote monitoring system, which monitors and controls the inspection robot walking and crossing various obstacles with wireless communication, is discussed based on the review of the development status at home and abroad. This paper puts forward a method for latitude and longitude coordinates calculation of the robot according to GPS data, and derives the formula for robot's location calculation. Good agreement between our results and that from references verified the validity of this method.

Introduction

Traditional and manual inspection methods for power transmission line are gradually replaced by transmission line inspection robot in recent years. With regard to work intensity reduction, inspection accuracy improvement and ensuring the safe operation of power system, it is essential to use inspection robot. Remote monitoring system plays a significant role in precise positioning, operation condition monitoring, control via wireless network technology in real time, and carrying out inspection tasks with obstacle crossing of inspection robot.

At present, some research and development teams both at home and abroad have made a lot of contributions to the study of robot remote monitoring and control. W. Wei[1] studies the location and navigation technology of a substation inspection robot based on differential GPS, solves the problem of difference no difference signal of GPS in power plant within the rest, but it does not solve the issue of obstacle recognition and obstacle avoidance function. X. K. Zhu, F. Ye and B. Li[2] study the control system of inspection robot for substation, the pose and position of robot are determined through magnetic track guidance and RFID positioning, but the applicability is not significant for occasions without magnetic track guidance.

Although most researches carry out the space positioning of inspection robot, the positioning accuracy is low and the calculation methods are more complex[3,4,5]. In this paper, based on the research of key technology of inspection robot in the past decade, a three arm inspection robot with function of automatic obstacle avoidance in both forward and backward directions is developed. Combined with the characteristics of robot operation, a remote and precise location method for inspection robot based on GPS positioning technology is proposed. The remote monitoring system and location method are studied in detail.

Functional Requirements of Remote Monitoring System

The remote monitoring system of the inspection robot integrates various sensor devices. This system helps realizing the control of robot's manual and autonomous obstacle crossing motion, precise positioning and status monitoring, and also real-time detection of obstacle distance, the environment and temperature of transmission line. The monitoring system should meet the following functional requirements:

A. Video Monitoring Function

The robot runs on the overhead transmission lines far away from the ground. It not only needs the infrared thermal imager to inspect the breakage of the line, but also carries the multi-channel video equipment to record its operation state in detail. Remote monitoring system can save and display the image information in real time, and also should be able to remotely control the pan-tilt camera to carry out operations such as focusing, enlarging and steering.

B. Environment Perception Function

The robot carries inspection equipment such as GPS locator and laser range finder, which are mainly used to perceive the external environment of robot. The remote monitoring system can detect the latitude and longitude coordinates of the robot in real time and measure the distance between the robot and obstacles by receiving the environment's perception of the fusion information of sensors.

C. State Display and Information Processing Function

The remote monitoring system can monitor the battery level, the position, speed and other indexes of the robot.

D. Remote Motion Control Function

The remote monitoring system can effectively control all the actuators of the robot. It determines the running speed of robot on the line according to transmission line condition, and also guarantees the precision and sensitivity of various motions in the process of robot's on-line walking and obstacle crossing under remote control.

The Composition of Remote Monitoring System

According to the requirements above, the remote monitoring system is connected with the robot ontology control system through wireless network to realize remote wireless monitoring. Schematic diagram of robot remote monitoring system is shown in Fig.1.

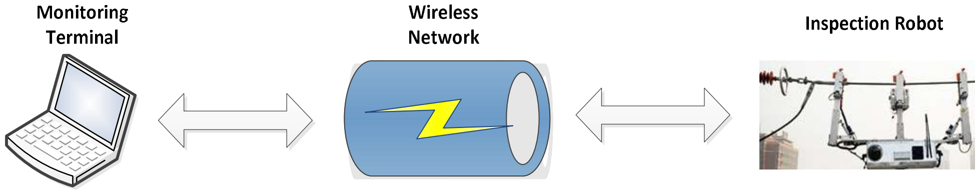


Fig.1 Schematic diagram of robot remote monitoring system.

The remote control system is connected with the wireless network. It collects status information of robot as well as images taken by camera, and sends control instruction to the robot's ontology control module through wireless network after information processing and decision making. After that, instructions generated in remote control system are processed and transferred to the decision layer which controls the lower machine executor, so as to realize automatic walking and inspection function of the robot. The frame structure of remote monitoring system is shown in Fig.2.

The whole ground control terminal is structurally divided into the instruction transmission area and the state feedback area. The command transmission area is responsible for sending the instruction package. The ground operator triggers the command sending module through the control interface, then data is encrypted and compressed according to the data transmission protocol, and finally encapsulated according to the application layer encapsulation protocol of the instruction package. When encapsulation is completed, data and instructions are sent to the remote control terminal, including basic control instruction, autonomous control instruction and video control task instruction.

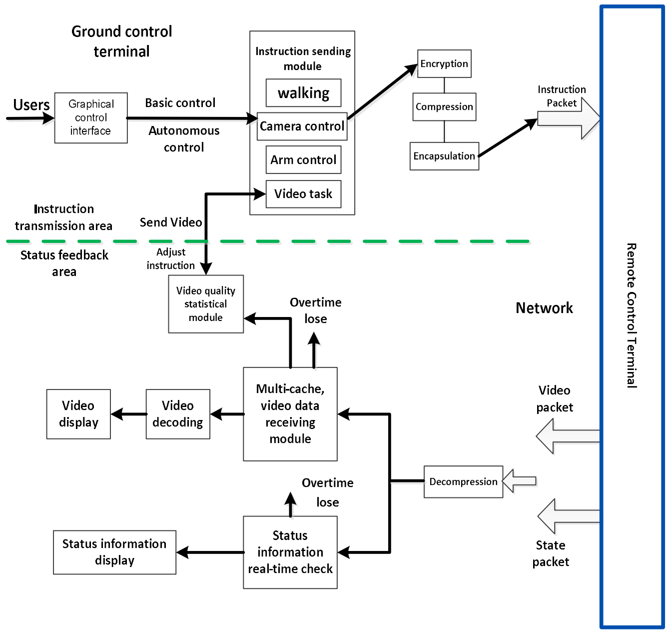


Fig.2 Schematic diagram of frame structure of remote monitoring system.

The state feedback area in the ground control terminal software is responsible for receiving status packets and video packets. It receives the real-time status information of inspection robot and video data sent from the remote control terminal, and checks the real-time data received according to the requirement of program design. The overtime data will be discarded, while the qualified data will be displayed graphically. Real-time status information includes information of robot's position and pose, latitude and longitude, speed and distance from the closest obstacle, which are stored in the SQL2008 database[6]. The video data includes video decoding information, video stream playback, etc.

Accurate Positioning of Inspection Robot

The accurate positioning process of the inspection robot consists of two parts: the determination of the of the latitude and longitude coordinates and the calculation of the distance from the next tower.

A. Determination of the Latitude and Longitude Coordinates

GPS data reception is completed in the remote control terminal, while the running of GPS data extraction program is completed in the ground control terminal under Visual C# compiling environment. The GPS data format is: "$GPRMC, 102040, A, 3600.161831, N, 12011.934041, E, 1.9, 336.9, 151103, 13.6, W*75", where "3601.161831, N" means 36 degrees and 1.161831 minutes in the north latitude, and "12011.934041, E" means 120 degrees east and 11.934041 minutes in the east longitude. Fig.3 shows the flow chart of GPS data collection and extraction.

The Visual C# in the.NET platform of the ground control terminal needs to analysis and process the received GPS data and extract valuable information[7]. The system program firstly detects the data and determines whether it is a $GPRMC statement. If the number of statements beginning with $GPRMC is greater than or equal to 75, it can be determined that these data information are valuable. Received information is stored in form of character string, and extracted by the function "System.Text.Encoding.UTF8.GetString()" in several segments. At last the latitude and longitude coordinates of the inspection robot can be obtained and displayed on the local monitor of ground control terminal, meanwhile data are recorded and stored in the database in SQL2008.

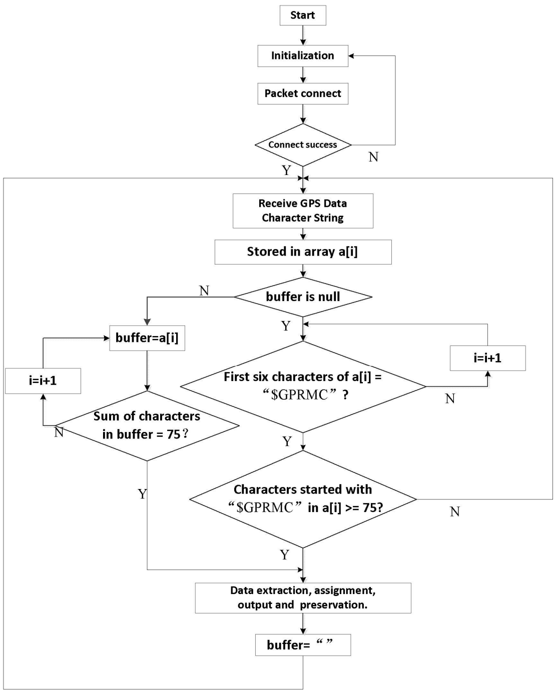


Fig.3 Flow chart of GPS data collection and extraction.

B. Calculation of the Distance from Inspection Robot to a Transmission Tower

The ground control terminal extracts the GPS data to obtain the latitude and longitude coordinates of the robot by using Visual C#. At the same time, Visual C# extracts coordinates of all towers in inspection task list from the SQL Server 2008 database. The distance between the robot and the adjacent tower is obtained through calculation. Fig.4 is a model diagram of coordinate calculation principle.

Suppose that the longitudes of any two points (A and B) are J_a, J_b, and the latitudes are W_a, W_b, and the earth is a standard sphere with radius of R = 6378.137km. Then coordinates of A and B are (R_1, J_a, W_a), (R_2, J_b, W_b). Given relationship between spherical coordinate (γ, ϕ, θ) and rectangular coordinate (x, y, z) is:

$$x = \gamma\cos\theta\cos\varphi,\ \ y = \gamma\cos\theta\sin\varphi,\ \ z = \gamma\sin\theta, \tag{1}$$

where:

$$\gamma \geq 0,\ \ -\pi/2 \leq \theta \leq \pi/2,\ \ -\pi \leq \varphi \leq \pi\ .$$

In this situation, ϕ is longitude and θ is latitude, and γ is the radius of the earth.

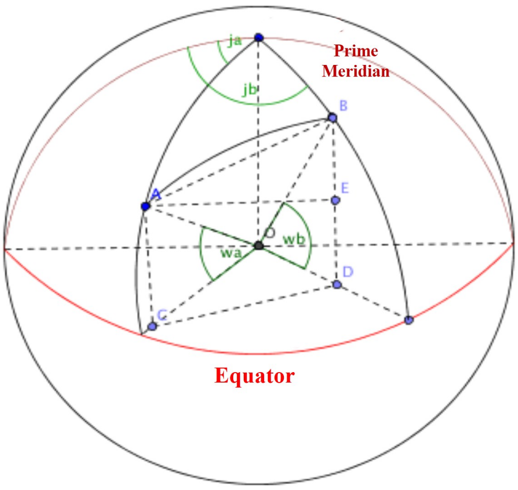


Fig.4 Coordinate calculation model diagram.

Distance L between two different points in the rectangular coordinate system is described by:

$$L=\sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}\ , \tag{2}$$

where the coordinates of two points are M1(x_1, y_1, z_1) and M2(x_2, y_2, z_2).

It can be derived from formula (1) that the rectangular coordinates of A and B are:

$$(R_1\cos(W_a)\cos(J_a), R_1\cos(W_a)\sin(J_a), R_1\sin(W_a)),$$

$$(R_2\cos(W_b)\cos(J_b), R_2\cos(W_b)\sin(J_b), R_2\sin(W_b)).$$

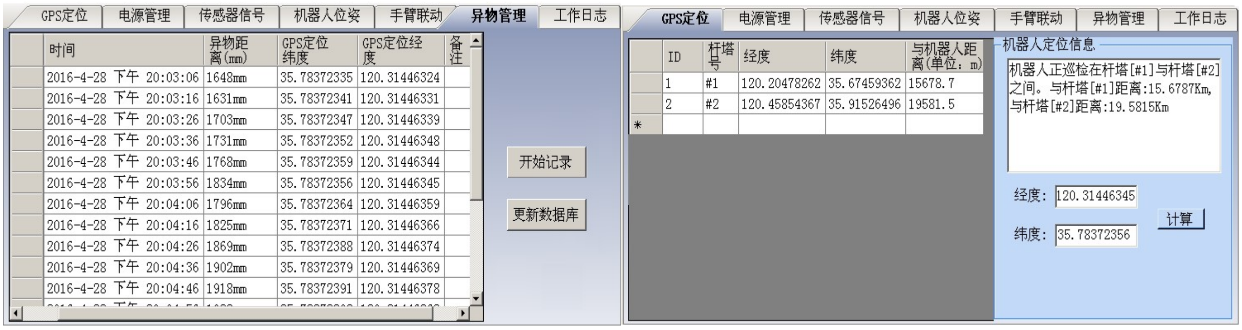
Then combine equation (2) and coordinates of point A and B, the distance L between two points is obtained by:

$$L=\sqrt{R_1^2+R_2^2-2R_1R_2[\cos(W_a)\cos(W_b)\cos(J_b-J_a)+\sin(W_a)\sin(W_b)]}\,. \tag{3}$$

Because of the assumption that the earth is a standard sphere, point A and B are both points on the sphere, their radius are the same, that is, $R_1 = R_2 = R$. Then with equation (3), distance between inspection and tower can be obtained.

Verification through Actual On-line Operation

The comprehensive performance test of the remote monitoring system is carried out under the actual high voltage transmission line environment. The test included video surveillance, obstacle recognition, real-time monitoring, automatic obstacle crossing and motion control, precise positioning and other aspects.



(a) Longitude and latitude cordinates of robot. **(b) Distance between robot and tower**

Fig.5 Screenshot of remote monitoring system software interface.

Fig.5 shows the latitude and longitude of the towers in the remote monitoring system database and the real-time latitude and longitude of the robot. By clicking the “calculation” button, the system calculates the distance between the current position of the robot and two selected tower poles.

Conclusion

Based on the GPS technology, this paper presents a theoretical calculation method and implementation of the accurate positioning of a transmission line inspection robot. The on-line operation verification shows that this method has effectively realized the function of accurate positioning, real-time monitoring and practical application of inspection robot. It meets the requirements of real-time, reliability and stability of remote monitoring system. The system has the advantages of low cost, easy operation, accurate monitoring and high functional extensibility. The research of remote monitoring system has certain theoretical significance and the prospect of application promotion.

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