

FABRICATION OF A POSITION SURVEYING MICROROBOT IN THE UNDERGROUND PIPE

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1. Introduction

Light-fiber cables for high-speed and large-capacity communication are usually buried under the ground. Once the light-fiber are buried under the ground, it is very difficult to confirm the buried position of the pipe if we use the underground radar, because the light-fiber cables and plastic cover pipes are not the metal. A former way to confirm the buried position of the light-fiber cables is the method, in which a sound source is inserted into the plastic cover pipe and the sound from the source is detected by many in-lined microphones arrayed on the ground. However, the detection is not done at the place where the arrayed microphones can not move along the pipe and the accuracy of the surveying is not good at the place where the position of the plastic cover pipe is so deep in the ground.

We developed a new position surveying microrobot using two rotary encoder sensors. The new position surveying microrobot is structured by a driving microrobot and a position surveying sensor system. The driving microrobot is an inching worm type microrobot using flexible rubber bellows and is driven by the pneumatic and the vacuum pressure [1], [2].

Only two rotary encoders and amplifiers carried on a position surveying microrobot of the position surveying sensor system move in the pipe with the driving microrobot. If the pipe is straight, the two rotary encoders make same pulses. However, the pipe has a curvature, the outside rotary encoder makes larger pulses than pulses made by the inside rotary encoder. The error appears between pulses made by two rotary encoders. The buried position of the pipe is confirmed, because the moving course of the position surveying microrobot is calculated by the error of the pulses.

In this paper, the position surveying sensor system is describes in detail, because the driving microrobot which is an element of the new position surveying microrobot has been reported.

2. The position surveying sensor system

The position surveying sensor system is shown in Fig. 1. The inner diameter of the pipe is 80 mm. The system is consisted by a position surveying microrobot which carries both the left and the right rotary encoders and their amplifiers, a signal processor, interfaces, a position surveying software and a computer.

The position surveying robot is shown in Fig. 2. The position surveying microrobot is consisted by two moving mechanisms. The moving mechanism is held to the inside of the pipe by eight small pulleys. The left and the right rotary encoders are held by arms attached through springs to the front moving mechanism. Each rotary encoder has a pulley 30 mm in diameter. Signal amplifiers are carried on the rear moving mechanism. The signal processor is consisted by a detecting circuit of clockwise or counterclockwise rotation of the rotary encoders, counter circuit and a mechanical chattering checking circuit. The signal from the signal processor is introduced into the computer through interfaces.

The computer calculates the length of the moving path and the angle of the moving path of the position surveying microrobot by the average and the difference pulses of the two rotary encoders. These values are preserved as vector data. The vector data are watched and modified periodically and displayed on the screen.

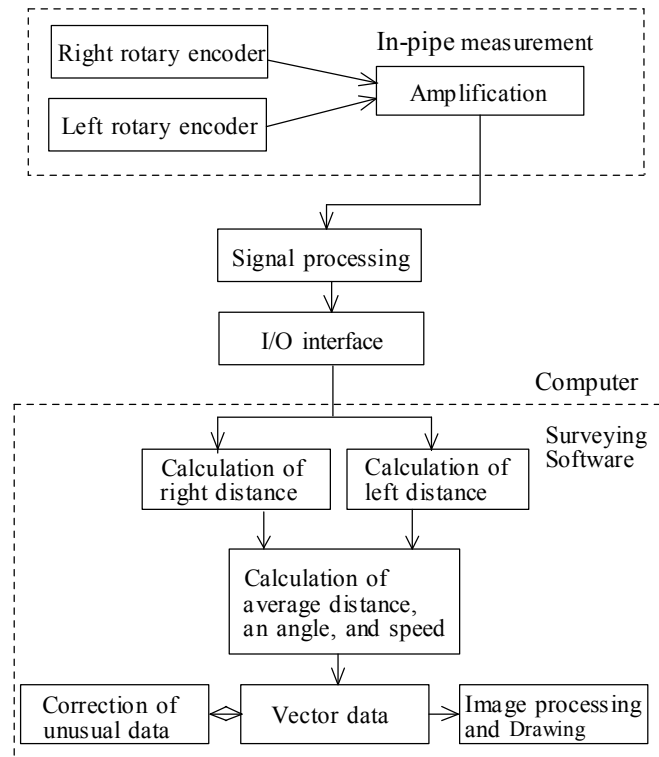


Fig. 1 A position surveying sensor system

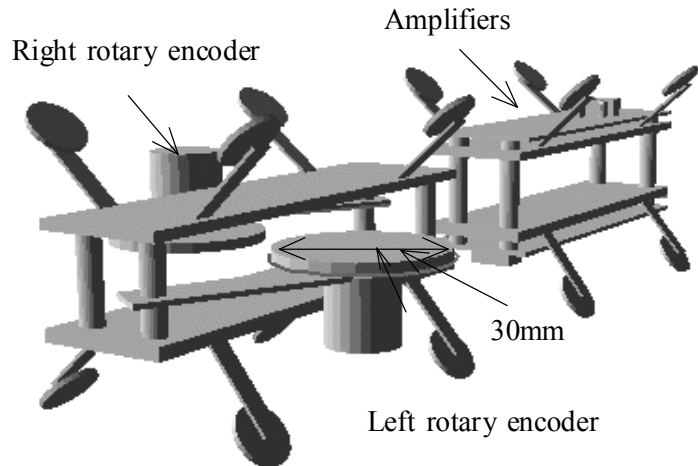


Fig. 2 A position surveying microrobot

3. Principle of position surveying

The principle of position surveying by the position surveying microrobot is shown in Fig. 3. The original point is $P_0(x_0, y_0)$. The angle between the tangential line of the point $P_n(x_n, y_n)$ which is a point of the centerline of the pipe and the y axis is Θ . It is assumed that an error e is made by the two rotary encoders when the surveying microrobot moves a small distance S . This moved point is $P_{n+1}(x_{n+1}, y_{n+1})$. The radius of the curvature is assumed as R . The diameter of the pipe is D . The small angle from the center of the curvature is assumed as q .

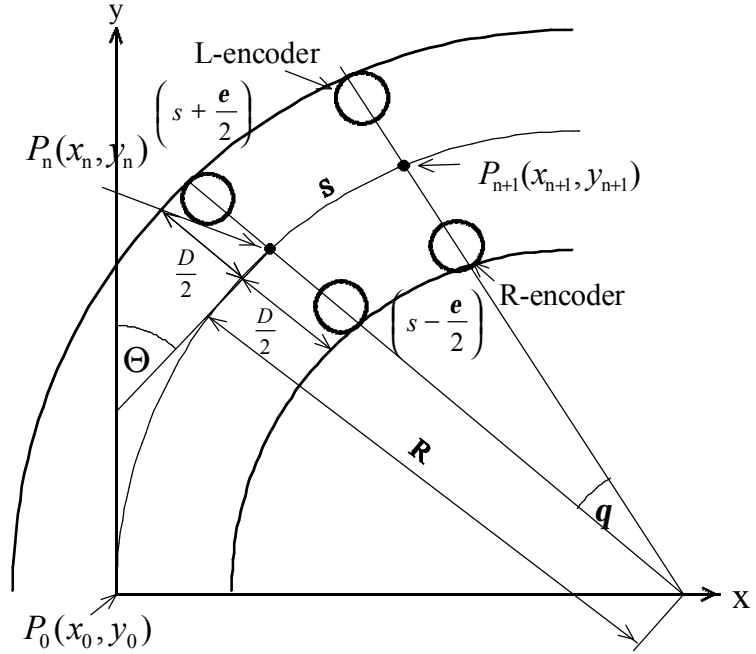


Fig. 3 The principle of the position surveying in the underground pipe by the position surveying microrobot

Then, next equation is obtained.

$$\left(S + \frac{e}{2}\right) - \left(s + \frac{e}{2}\right) = e = \left(R + \frac{D}{2}\right)q - \left(R - \frac{D}{2}\right)q = Dq \quad (1)$$

The small angle q is obtained from the error e as

$$q = \frac{e}{D} \quad (2)$$

Then, the co-ordinates of the point is P_{n+1} calculated from the co-ordinates of (x_n, y_n) as

$$x_{n+1} = x_n + S \cdot \sin(\Theta + q) \quad (3)$$

$$y_{n+1} = y_n + S \cdot \cos(\Theta + q) \quad (4)$$

The tangential angle Θ is the summation of the small angle q and shown as

$$\Theta = \Sigma q \quad (5)$$

The co-ordinates and the tangential angle are preserved by vector data.

4. Result of position surveying

A curved pipe whose diameter is 80 mm, radius of curvature is 100 mm, angle of curvature is 90 degrees and length of the pipe is 1000 mm is laid horizontally and used for the experiment. The position surveying microrobot is moved at the speed of 30 mm/s. The result of 20 experiments is shown in Fig. 4. The result of errors of angle is less than 0.9 degrees and errors of position is less than 10 mm. The reasons of these errors are supposed to become from the roughness of the inner surface of the pipe, the yawing of the position surveying microrobot and the slip of the rotary encoder. These errors may be improved by the reform of the position surveying software.

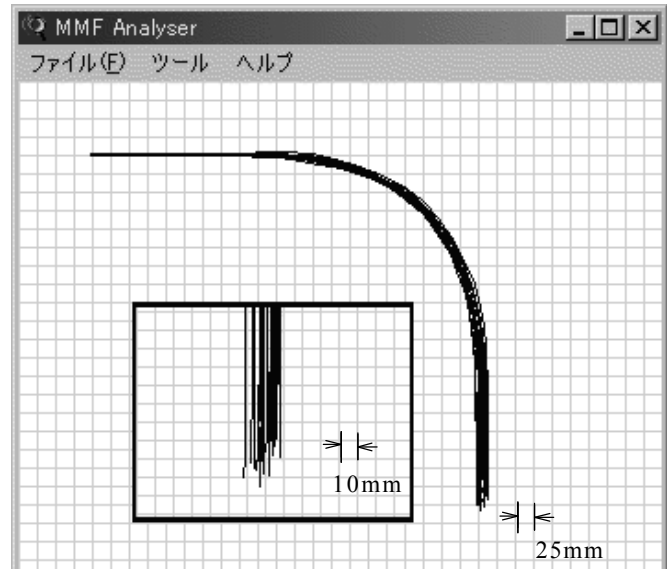


Fig. 4 Computed loci

5. Conclusions

- (1) A new position surveying microrobot which is structured by two rotary encoders and their amplifiers, a signal processor, interfaces, a position surveying software and a computer was developed.
- (2) The position surveying microrobot could measure the position at the accuracy less than 0.9 degrees in the angle and less than 10 mm in the position.

References

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