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Implementation of a Mobile Robot Using Landmarks

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Abstract – In this paper, we suggest the method for a service robot to move safely from an initial position to a goal position in the wide environment like a building.

There is a problem using odometry encoder sensor to estimate the position of a mobile robot in the wide environment like a building. Because of the phenomenon of wheel's slipping, a encoder sensor has the accumulated error of a sensor measurement as time. Therefore the error must be compensated with using other sensor. A vision sensor is used to compensate the position of a mobile robot as using the regularly attached light's panel on a building's ceiling. The method to create global path planning for a mobile robot model a building's map as a graph data type. Consequently, we can apply floyd's shortest path algorithm to find the path planning. The effectiveness of the method is verified through simulations and experiments.

1. INTRODUCTION

The Service-Robot commented on this paper is a robot so-called autonomous mobile robot which does human labours where by transferring an object to the place at which it targets. This robot is highly likely to cause errors in location by external factors when it comes to operating.

As a consequence, Service-Robot would not be able to reach the aimed place from the initial spot because accumulated errors results from measuring faults of encoder sensors are proportional to the distance covered[1][2].

Therefore, an algorism of ceiling light panel is put forward in order to cover up location errors while Service-Robot is running.

This method is to trace moving robots, using the light panel which gives information of where they are in building[3], that is, faults are to be covered up in a way of tracing moving robots from light panel of ceiling by using vision sensor which tells the degree of accumulated errors resulted from measuring faults of encoder sensors.

2. UNCERTAINTY OF TRACING LOCATIONS

Assume that the information from measured sensor data could be driven from nonlinear vector function of sensor data - look at the Eq. (1).

$$\text{Where} \quad x \in R^n \quad x \in R^m$$
$$x = f(\theta) \tag{1}$$

It is supposed that sensor data measured include Gaussian noise. $\underline{\theta}$ is an actual sensor value.

$$\theta = \underline{\theta} + \delta\theta \tag{2}$$
$$E[\delta\theta] = 0$$
$$E[\delta\theta\delta\theta^T] = Q = diag(\sigma_1^2, \ldots, \sigma_m^2)$$

Therefore, supposing that the value could be deduced from only sensor date with noise and $\delta\theta$ is small enough, it is possible to approximate it as like Eq. (3), using the Expansion of Taylor polynomials.

$$x = f(\underline{\theta} + \delta\theta) = f(\underline{\theta}) + \frac{\partial f}{\partial \theta}\delta\theta \tag{3}$$

At this point, the average of deduced value x and covariance matrix determinant are same as Eq. (4).

$$E[x] = \underline{x} = f(\underline{\theta}) \tag{4}$$
$$E[(x-\underline{x})(x-\underline{x})^T] = \frac{\partial f}{\partial \theta} Q \frac{\partial f}{\partial \theta}^T$$

Having covariance matrix determinant done with singular value decomposition, Eq. (5) is came up.[6]

$$\frac{\partial f}{\partial \theta} Q \frac{\partial f}{\partial \theta}^T = UDU^T \tag{5}$$

At this point,
$U = [e_1 \ldots e_n] \in R^{n*n}, D = ding(\sigma_1, \ldots, \sigma_n)$ and σ_i is singular value.

Eq. (6) is given for Dispersion of direction of unit vector (e_i)

$$E[e_i^T x(e_i^T x)^T] = e_i^T \frac{\partial f}{\partial \theta} Q \frac{\partial f}{\partial \theta}^T e^i$$
$$= e_i^T UDU^T e_i = \sigma_i \tag{6}$$

Therefore, $\sqrt{\sigma_i}$ stands for the degree of uncertainty in e_i direction of x.

Ellipsoid is being formed once calculating all of a direction with unit vector.

This ellipsoid is named as Uncertainty Ellipsoid of which figure gives information on which direction of uncertainty is severe.[4]

Fig. 1 is indicating the increase of uncertainty ellipsoid through trial experiments on tracing moving robot.

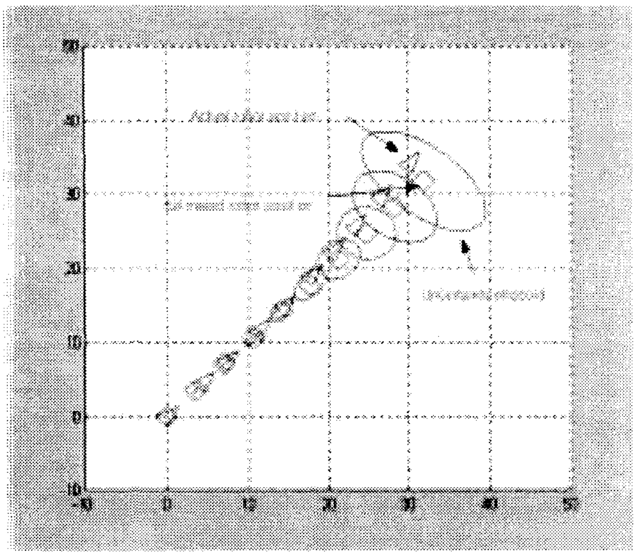


Fig. 1. The uncertain propagation of a position estimation.

3. Algorism of recognition of Landmarks image

3.1. Tracing moving robot, using image information

Pin-hall Camera Model has been used for the calculation of tracing actual objects in image information.

In this essay, ceiling light panels are being used in a way of image information and cameras are set in Service-robot at right angles to ceiling.

Fig 2 shows the way that it can presume the center point of camera by using image information of lights panel in ceiling.[6]

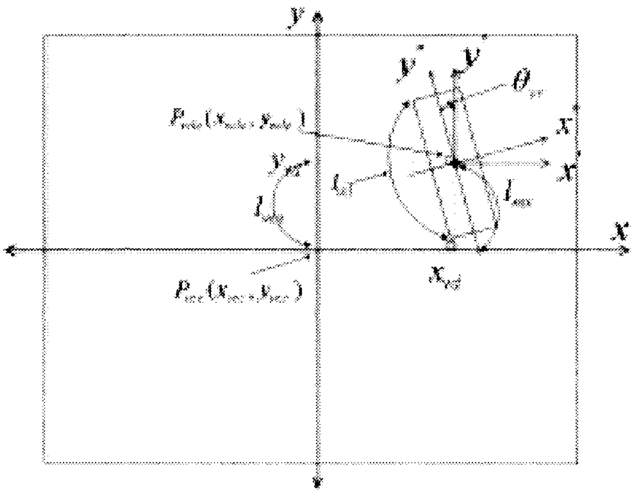


Fig. 2. Camera position's estimation using vision information from the light's panel of ceiling.

When the center point P_{vcc} of vision is standardize by the view of a coordinate axis x', y' whose central point is the one of ceiling light panel, that is, lying $x_{vclc} = 0, y_{vclc} = 0$ it can define that P_{vcc} is Eq. (7)

$$x'_{vcc} = x_{vcc} - x_{vclc}$$
$$y'_{vcc} = y_{vcc} - y_{vclc} \qquad (7)$$

The change of the axis "y" results from the fact that the axis Y, the actual one in math, increases upward, whereas the one in computer screen does downward.

Ceiling Light panels from Fig 5 turn by θ_{vr} on the screen, that is, Rotation matrix R for the axis x'', y'' having turned is given as Eq. (8).

$$R = \begin{pmatrix} \cos\theta_{vr} & -\sin\theta_{vr} \\ \sin\theta_{vr} & \cos\theta_{vr} \end{pmatrix} \qquad (8)$$

As a consequence, P''_{vcc} could turn out to be Eq. (9)

$$\begin{pmatrix} x''_{vcc} \\ y''_{vcc} \end{pmatrix} = \begin{pmatrix} \cos\theta_{vr} & -\sin\theta_{vr} \\ \sin\theta_{vr} & \cos\theta_{vr} \end{pmatrix} \begin{pmatrix} x'_{vcc} \\ y'_{vcc} \end{pmatrix} \qquad (9)$$

Also, θ_{vr} can be like Eq. (10), only, sign of θ_{vr} being right-turned is "+" and "-" being left-turned.

$$l_{mx} = \sqrt{(x_{vclc} - x_{vx})^2 + (y_{vclc} - y_{vcc})^2}$$

$$l_{vcx} = |y_{vclc} - y_{vcc}| \qquad (10)$$

$$\theta_{vr} = \cos^{-1}\frac{l_{vcx}}{l_{mx}} \qquad (11)$$

Let's assume that we all know the size of all light panels inside of building and $P_{clc}(x_{clc}, y_{clc})$, the central point of them.

Eq. (12) is given by Pin-hall Model which the relation to l_{vcl} and l_{rcl}, the length of ceiling light panel.

$$l_{vcl} = k \cdot l_{rcl} \qquad (12)$$

Eq. (13) is to tell the relation of the central point between of actual camera from the image axis and of ceiling light panel.

$$x_{rcc} = x_{rclc} + \frac{1}{k} \cdot x''_{vcc}$$
$$y_{rcc} = y_{rclc} + \frac{1}{k} \cdot y''_{vcc} \qquad (13)$$

$P_{clc}''(x_{clc}'', y_{clc}'')$ is the central point of all light panels set in ceilings of building in the coordinate system and 'n' indicating index of light panels.

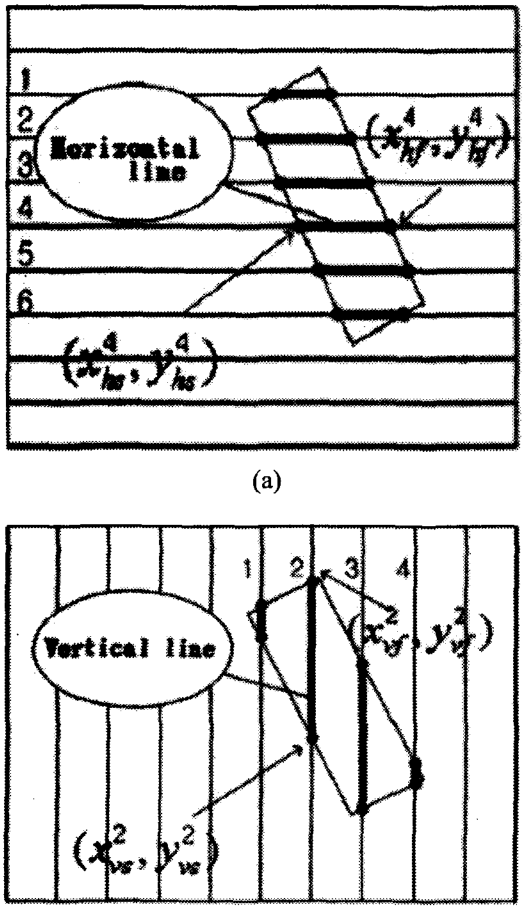
3.2. Suggested algorism for recognition of light panel ceiling

It needs to calculate the length and the central point of light panels in order to presume traveling direction as well as place of Service-robot from image information of light panels of ceiling[7].

In Suggest algorism, it has to come first to distinguish whether or not it is one of ceiling light panels, and then presume necessary information from the central point and the length of panels.

3.3. Recognition of light panel of ceiling

Fig 3 is illustrates image information excluding any other of them apart from edge substitute of trial light panels of ceiling.



(a)

(b)

Fig. 3. The simulated edge's vision information of ceiling light's panel.
(a) Two points of intersection with a horizontal line.
(b) Two points of intersection with a vertical line.

As like Fig 3(a), it finds out two dots where ten even lines meet one segment of a line and vertical lines meet one segment like Fig 3 (b).

Where l_h^n, l_v^n is the length of two each dots, l_h^n, l_v^n ' s Form is Eq. (14) and its value is equal to Eq. (15).

$$\{l_h^n\} = \{l_h^1, l_h^2, \ldots, l_h^n\}$$
$$\{l_v^n\} = \{l_v^1, l_v^2, \ldots, l_v^n\} \quad (14)$$

$$l_h^n = \sqrt{(x_{hf}^n - x_{hs}^n)^2}$$
$$l_v^n = \sqrt{(x_{vf}^n - x_{vs}^n)^2} \quad (15)$$

Eq. (16) is the value of Recognition, which is the one of ceiling light panels from trial image information.

$$\mathrm{Re}cognition = \begin{pmatrix} if\ l_{hx}^n n \geq n_{th} or l_{vx}^n n \geq n_{th}, \mathrm{Re}cognition = 1 \\ if\ l_{hx}^n n \prec n_{th} or l_{vx}^n n \prec n_{th}, \mathrm{Re}cognition = 0 \end{pmatrix} \quad (16)$$

3.4. Sampling of center point and length of ceiling panels

it has to sample the central point and length of ceiling panels from edge image information of them so as to trace main position of Service-robot in the coordinate system

Fig 4 shows the way to extract them from image information.

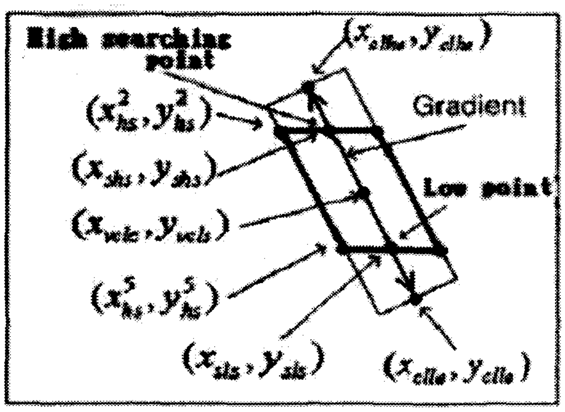


Fig. 4. The method finding center point and length of ceiling light's panel.

The following is how to get the length and central point of ceiling light panel; on setting up an equation that goes through two dots-one is high searching starting point (x_{shs}, y_{shs}) by Gradient $= \frac{y_{hf}^5 - y_{hf}^2}{x_{hf}^5 - x_{hf}^2}$ from ($x_{shs}^2, y^2{}_{shs}$) and (x_{shs}^5, y_{hs}^5), find out upper point (x_{clhe}, y_{clhe}) and lower point (x_{clle}, y_{clle}) of ceiling light panel.

4. Experiment and Conclusion

Fig 5 is illustrates the degree of accumulated errors of encoders for the traveling of moving robots, and that also shows accumulated errors are out of range-over 200cm axis of x bound and over -300cm axis of y bound from the target point.

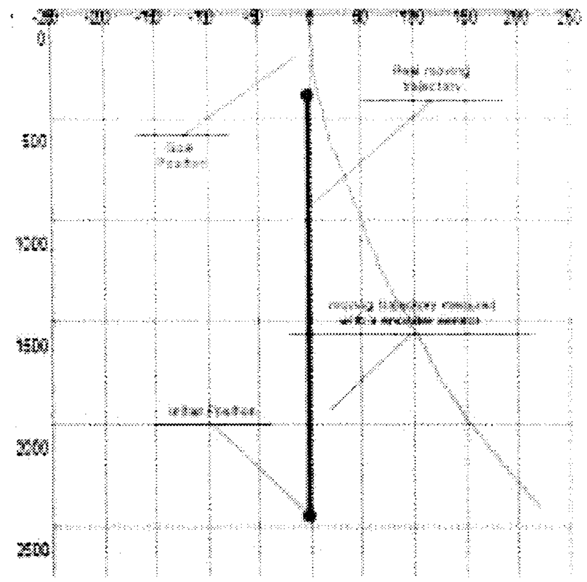


Fig. 5. the accumulated error of a encoder.

Through this experiment, robots can nearly reach the target point whereby covering up accumulated errors of encoding sensor in the help of geometric relation between ceiling light panel and moving robots regarding operations in corridor.

From Fig 6, we can see that self-controlled moving capability has been improved in the success of cover-up of accumulated errors in running.

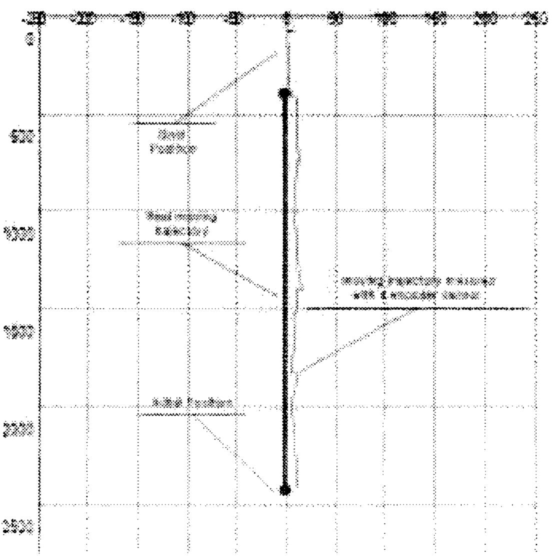


Fig. 6. the compensation of the accumulated error using a vision sensor.

5. CONCLUSIONS

In this paper, the way to recognize ceiling light panel in building is suggested in order to set up route project which moving robots carry out from initial point to target, whereby revising the degree of tracing service robots by using the cover-up method for accumulated errors of encoding sensor which are led by wheel slide that is known as problems regarding tracing service robots operating under long-run environment such as building.

In order to prove this method suggested, satisfying results have been achieved throughout simulations and experiments.

All in all, having improved the degree of accumulated errors of encode sensor designed for tracing position of service robots by using vision sensor, it is proved to be possible that intellectual Service-robot conveys objects to target point.

6. REFERENCES

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