CCD-Camera Guiding of a Vehicle Robot

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ABSTRACT

There are so many types of sensors which have been developed in order to construct intelligence robots. This paper presents the study of the movement of a vehicle robot using a CCD-Camera. The CCD-Camera is used as a sensor to control a vehicle robot in a stable movement. This vehicle robot is called CVR. The system is the combination of the CCD-Camera, the vehicle robot and a dedicated software controller. The stability of CVR is proven by studying the movement methodology. The performance of the movement is experimented.

1. INTRODUCTION

In the development of an Automated Guided Vehicle systems (AGV) based on inexpensive systems and fast moving[1], we developed a guided vehicle robot. This paper presents the usage of CCD-Camera systems in controlling the stability movement of the vehicle. The vehicle moves along a provided line. In other words, this line acts as a guider as shown in Figure 1.

In this system, the image of the guide line is transformed to a camera processor by the CCD-Camera. Then, the dedicated software controller will formulate the digital signals of the image in order to move CVR.

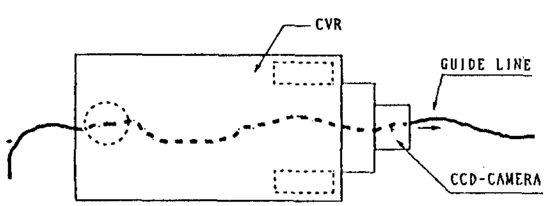

Figure 1 The CCD-Camera guiding of CVR.

2. THE VEHICLE ROBOT WITH A CCD-CAMERA (CVR)

The specification for CVR as shown in Table 1, is choosen under the consideration of the AGV which is generally used in factories.

Table 1 The specification for CVR.

VEHICLE:	CVR(Vehicle Robot with CCD-Camera
APPLICATIONS:	It can be used as a moving machine or robot for any locations or distances with guide lines.
SPEED:	Adjustable.
CONFIGURATION:	Two-degree of freedoms.
RANGE OF MOTIONS:	Any locations of distances.
TYPE OF ACTUATORS:	Stepping Motor.

2.1 Mechanical Design

CVR is a front wheel drive vehicle. It has two driven wheels and one free wheel as shown in Figure 2. Each front wheel is driven by a stepping motor. The rear wheel moves freely in two-dimensional movement. If CVR wants to make straight movement, the both stepping motors turn at the same speed and direction. And, if CVR wants to turn left or right, the both stepping motors turn at the same speed in different direction. Only one CCD-Camera is used which is fixed vertically. The image of the guide line can be detected easily by using a bright light. The lamp is fixed parallely to the camera.

2.2 The Architecture of the CCD-Camera

In this research, the CCD-Camera is used in combination with a dedicated software controller in order to control the CVR. The CCD-Camera is used as a reflector to create an image of the line. In this case, we use a black line for the reflector. The camera takes an image of the line in two-dimension, then transforms to the camera processor. The camera processor will transform the image into digital signals. From the digital signals, the dedicated software processor formulates the signals for positioning informations in two-degree of freedoms.

The CCD-Camera itself is attached with a lamp. Figure 3 shows the overall control system.

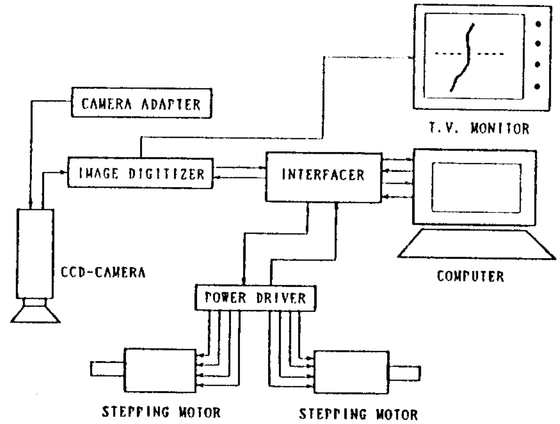

Figure 3 The control system for CVR.

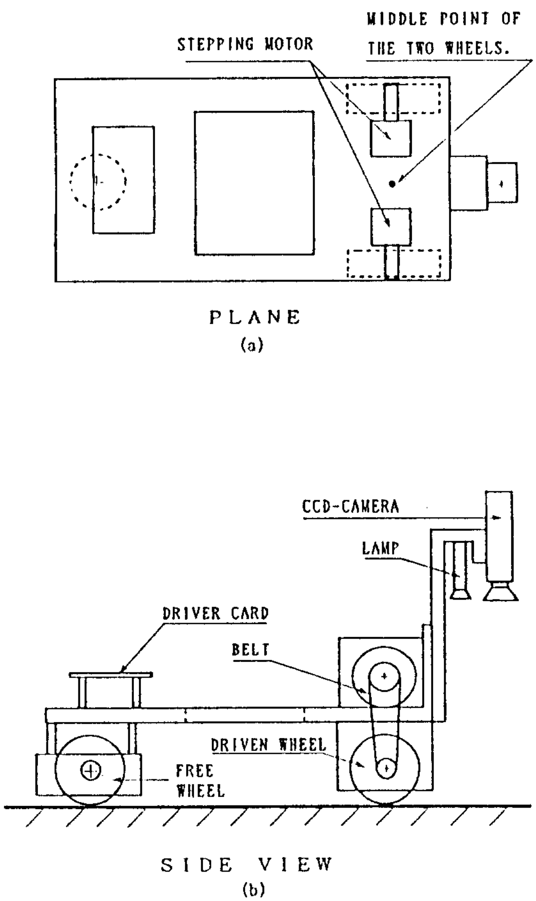

Figure 2 CVR with a CCD-Camera.

3. THE MOVEMENT METHODOLOGY

The developed CVR is driven and steered by the two wheels which are driven independently by stepping motors. The movement methodology of CVR is explained as follows:

Step 1

CVR is at the beginning position as shown in Figure 4(a). The middle point of the two wheels(M0) is at distance x(0) and the center line(from M0 to c0) is at angle $\theta(0)$ to the guide line. At this position, the CCD-Camera detects the guide line on point c0" at distance $\beta(0)$.

Step 2

During computing the values of $\beta(0)$ and $\phi(0)$, CVR moves at distance α and then turns at angle $\phi(0)$. Now, as shown in Figure 4(b), the CCD-Camera is at the position c1'. At this position, the CCD-Camera detects the guide line on point c1" at distance $\beta(1)$. The middle point of the two wheels is at distance x(1) and the center line is at angle $\theta(1)$ to the guide line.

Step 3

During computing the values of $\beta(1)$ and $\phi(1)$, the CVR moves at distance α and then turns at angle $\phi(1)$. Now, as shown in Figure 4(c), the CCD-Camera is at the position c2'. The middle point of the two wheels is at distance x(2) and the center line is at angle $\theta(2)$ to the guide line. At this position, the CCD-Camera detects the guide line at point c2" at distance $\beta(2)$.

These steps will continue until the values of $\beta(k)$ and $\theta(k)$ become zero.
Where k=0, 1, 2, . . . , n.

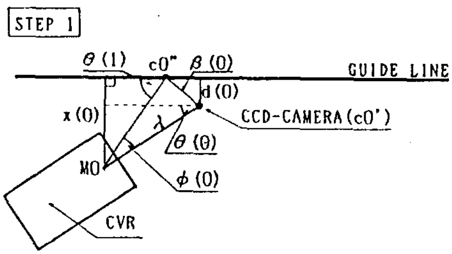

Figure 4(a) CVR is at the beginning position at angle $\theta(0)$ to the guide line.

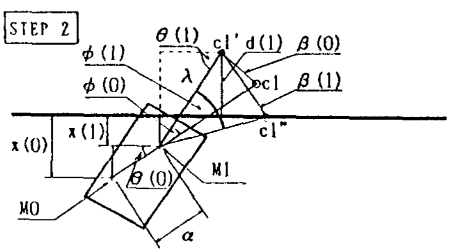

Figure 4(b) CVR moves by distance α and then turns at angle $\phi(0)$.

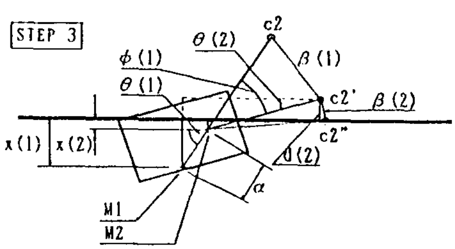

Figure 4(c) CVR moves by distance α and then turns at angle $\phi(1)$.

Figure 4 The movement methodology.

4. STABILITY ANALYSIS

The movement methodology which is introduced in chapter 3, can be explained by using the difference equations as follows. By using Figures 4(a) and 4(b), the relation between x(0) and x(1) can be written as follows,

$$x(1) = x(0) - \alpha \sin\theta(0) \tag{3.1}$$

and,

$$\sin\theta(1) = \frac{x(0)}{\lambda} \tag{3.2}$$

where,

$x(0), x(1)$ = the distance between the middle point of the two wheels and the guide line.
λ = distance between the CCD-Camera and the middle point of the two wheels.
α = forward movement distance in one step.

By using Figures 4(b) and 4(c), the relation between x(1) and x(2) can be written,

$$x(2) = x(1) - \alpha \sin\theta(1) \tag{3.3}$$

where,

$x(2)$ = the distance between the middle point of the two wheels and the guide line in Figure 4(c).

Substitute equation (3.2) into equation (3.3).

$$x(2) = x(1) - \frac{\alpha x(0)}{\lambda}$$

or

$$x(2) - x(1) + \frac{\alpha}{\lambda} x(0) = 0 \tag{3.4}$$

From the equation (3.4), the following difference equation is obtained,

$$x(k+2) - x(k+1) + \frac{\alpha}{\lambda} x(k) = 0 \tag{3.5}$$

The stability of the equation (3.5) is analyzed as follows. Suppose that the second order algebra equation is

$$z^2 + b_1 z + b_2 = 0 \tag{3.6}$$

then the two roots of this equation are existed inside the unit circle of the complex plane of z, if and only if, the following Schur-Cohn matrix is positive definite[2].

$$\begin{bmatrix} 1-b_2^2 & b_1-b_1 b_2 \\ b_1-b_1 b_2 & 1-b_2^2 \end{bmatrix} \qquad (3.7)$$

So, in order to be stable, it is required,

$$1-b_2^2>0$$
$$b_2^2<1$$

where, $b_2=\frac{\alpha}{\lambda}$

so, $$\left|\frac{\alpha}{\lambda}\right|<1$$
$$|\alpha|<|\lambda|$$

This means, the forward movement distance α must be less than λ

Furthermore, it is also required,

$$(1-b_2^2)^2-(b_1-b_1 b_2)^2>0$$
$$(1-b_2)^2(1+b_2)^2-b_1^2(1-b_2)^2>0$$
$$(1-b_2)^2[(1+b_2)^2-b_1^2]>0$$

so, $$(1+b_2)^2-b_1^2>0$$
$$(1+b_2-b_1)(1+b_2+b_1)>0$$

from equations (3.5) and (3.6),

$$b_1=-1$$

so, $$(2+b_2)b_2>0$$

therefore, $$b_2>0$$
$$\frac{\alpha}{\lambda}>0$$

This means, α and λ must have the same sign. If CVR wants to move backward, the CCD-Camera has to be put at the back of the two wheels.

5. COMPUTER SYSTEM

The flow chart for the computer system is shown in Figure 5. Basically, the computer system formulates the signals of the image and values of $\beta(k)$ and $\phi(k)$. During the fomulating, the computer will send signals to the stepping motors to move CVR in a straight movement at distance α, and then turn at angle $\phi(k)$.

The computer system receives signals from the values of $\beta(k)$ and $\phi(k)$ until the both values are zero. If the values of $\beta(k)$ and $\phi(k)$ are zero, the computer sends signals to the stepping motors, in order to move CVR along on the straight line. If the both values are not zero, the computer will formulate these values, in order to move CVR at distance α and then turn at angle $\phi(k)$....and so on.

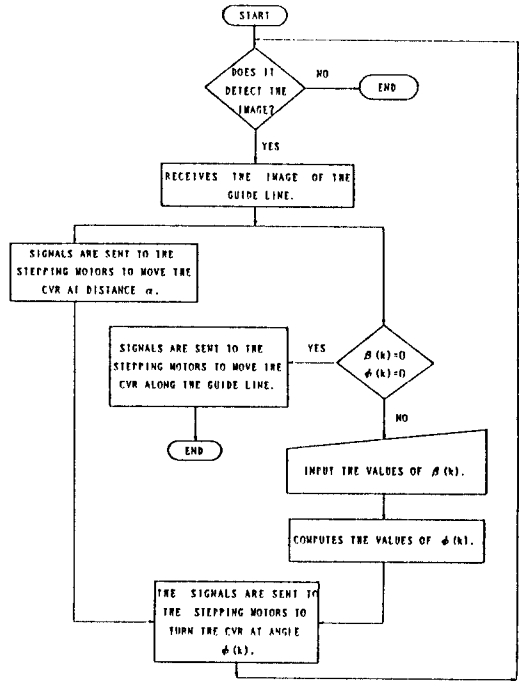

Figure 5 The flow chart for the computer system.

6. EXPERIMENTS

The experiments have been done to CVR based on the various dimensions of α and λ in order to study the stability.

Figure 6 shows the real movement of CVR on the 45° turning. In this experiment, the value of α = 24 mm and λ = 169 mm. Figure 7 is the movement with α = 24 mm and λ = 108 mm. By these experiments, the study on the stability conditions in section 4 has been confirmed.

7. CONCLUSIONS

The CVR is the new type of vehicle robot design. It is easy to control and drive using computer control interfacing. The stepping motors drive the front wheels for forward movement and circular movement.

The stability of CVR is proven by using the movement methodology in section 3. The ratio between the forward movement (α) and the distance of the camera from the middle point of the two wheels (λ) are important for the stability of CVR. Figures 8 and 9 show how CVR does the job.

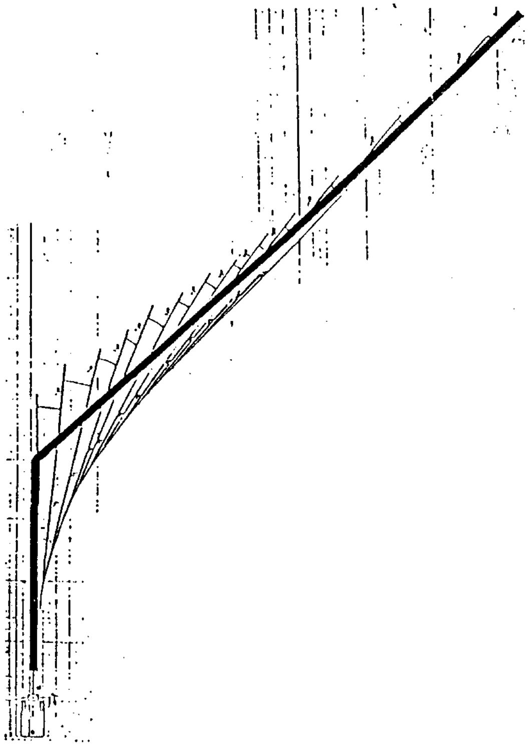

Figure 6 The real movement of the CVR in 45° turning, where λ = 169 mm and α = 24 mm.

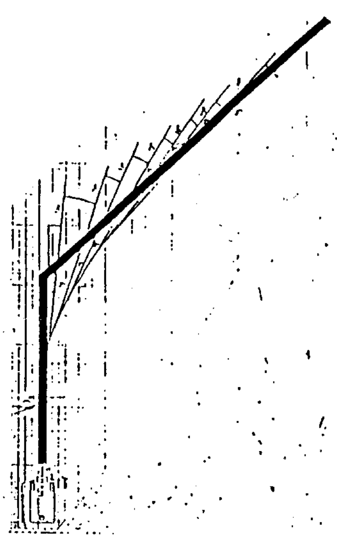

Figure 7 The real movement of the CVR in 45° turning, where λ = 108 mm and α = 24 mm.

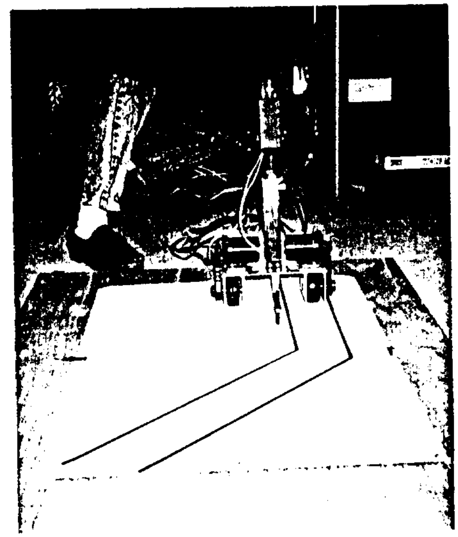

Figure 8 CVR is at the beginning position.

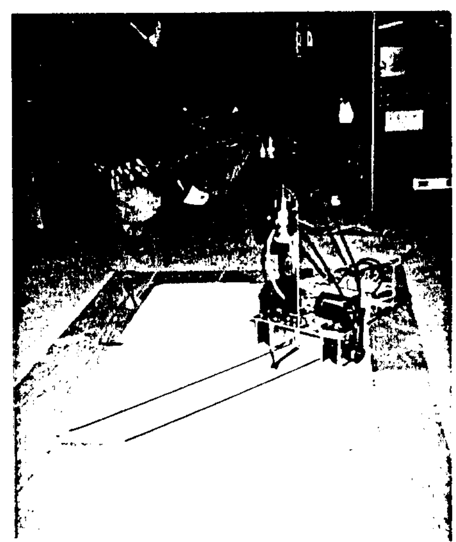

Figure 9 CVR is already on the 45° turning guide line.

REFERENCES

[1] R.H. HOLLIER AND L.F. GELDERS,"Automated Guided Vehicle Systems", Proceedings of the 6th International Conference, Brussels Belgium, 25-26 October 1988.

[2] M.HAYASE," Introduction to System & Control Engineering ", (in Japanese) , Ohm Publication, 1980.