An Improved Line Following Optimization Algorithm for Mobile Robot

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***Abstract*— Although machine vision based robot navigation technology has become the mainstream nowadays, the traditional line following navigation still plays an important role because of its simple design and low cost. We have designed and tested a line follower robot and attended line follower robots competition. In order to address the common issues in the traditional robot line following navigation technology, such as weak environmental adaptability and vulnerability to the external ambient light, an improved line following navigation optimization algorithm have been proposed. The experiment results show that it improves the robustness and stability of the line following navigation robot control.**

***Keywords:* mobile robot, line following navigation, the adaptive threshold, phototransistor**

I. INTRODUCTION

Since the autonomous mobile robots can independently complete the scheduled tasks without extra intervention from human beings, it has become a growing field of research. The navigation of autonomous mobile robot is still the focus. Although machine vision based robot navigation technology has become the mainstream nowadays, traditional line following navigation is still used in a wide range of applications because of simple circuit design and low cost.

A line following robot is a robot designed to follow a line or path predetermined by the user [1, 2, 3]. This line or path normally is a physical mark on the floor. Line tracer will trace dark line on a white surface or vice versa. The sensors works with analog signals from the microcontroller and the digital input is used to drive the motors [4]. The motor works according to the sensing output and driver.

These kinds of robot can function as material carrier to deliver products from one manufacturing point to another where rail or conveyor solutions are not possible [5]. Most of the lines following robots were designed with different ideas for entertainment or education purpose [3], robot races and other purpose.

We have designed and tested a line follower robot and attended line follower robots competition shown in Figure 1. The proposed and presented in this paper is an improved line following navigation optimization algorithm. The hardware design of the navigation is based on the photoelectric sensor. The core detecting element is the phototransistor array which is lined up by the 32 phototransistors and used to detect the white guide lines on the dark blue ground. The robot position deviated from the white guide lines can be calculated from the sensing output. Based on that, the robot system produces the appropriate control to make sure the robot can walk along the white line.

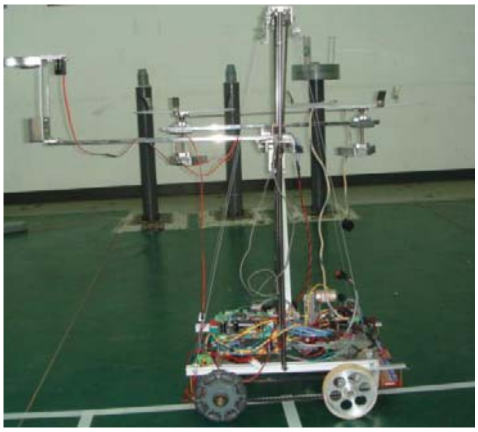

Fig 1. The designed robot for contest

The line following navigation optimization algorithm proposed in this paper enables the robot to study and adapt to its specific surroundings the first time the robot is launched in order to record a number of environmental parameters to guide its movement. The procedure is that the photoelectric sensor perceives the intensity both on the ground and on the white guide line and convert it to electrical signals. The analog electrical signal is then converted to digital signal by the AD sampler which is used as the input of the optimization algorithm. Finally, the best threshold calculated by the algorithm can be set to distinguish between the ground and guide lines. This threshold is related to the current environment and can change as the surrounding changes. In addition, the optimization algorithm provides a filtering function for robot to filter out wrong sampled signals. The robot then analyzes comprehensively the previous position information to get the actual current position so that wrong navigation judgment can be effectively avoided. Therefore, this algorithm greatly improves the stability and precision of the robot.

II. LINE FOLLOWING NAVIGATION SYSTEM OPTIMIZATION ALGORITHM

As mentioned above, to walk stably in an unknown environment, the line following robot needs to be able to gradually adapt to the environment. The most critical point to decide whether the robot can walk stably in an unknown environment is to find a threshold value which distinguishes between the dark blue ground and white guide line. Therefore, this paper presents an adaptive threshold algorithm to meet this requirement.

2.1 Adaptive threshold algorithm

Once the robot launches, let the light board sample the light intensity on both the ground and the white line, and convert it to digital signal with which the adaptive threshold algorithm is applied. The output is the threshold which is closely related to the current environment.

Figure 2 shows the flow chart. Each phototransistor samples 1000 times, which guarantees that at least one sampling is on the white line while most of the time is on the dark colored ground. Take the minimum value as the sample value on the white line from the 1000 sampling values, and calculate the average of the 1000 sampling values as the sample value on the ground. Finally calculate the mean value of sample values on both the white line and the dark colored ground as the threshold. In this way, whenever the robot is in a new environment, the robot will re-sample to get an adaptive threshold in current environment. Therefore, the robot can accurately identify the white line on the ground to adapt various kind of environment.

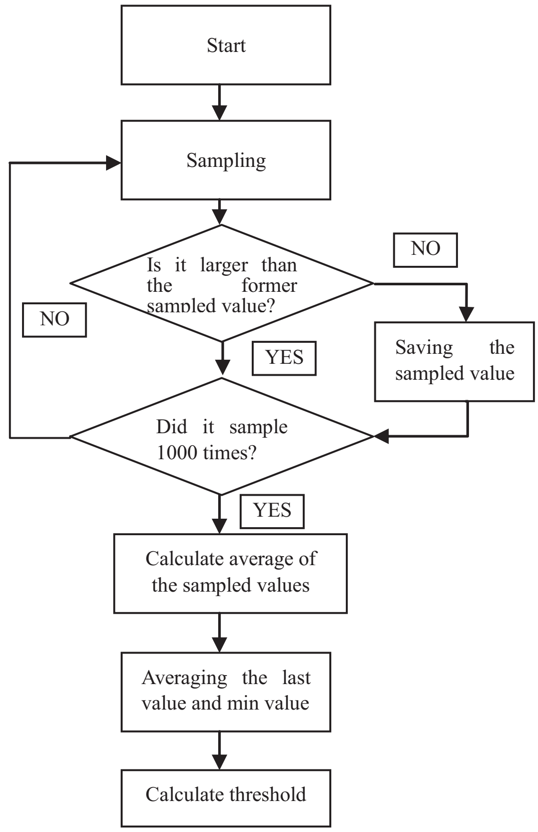

Fig. 2. The flow chart of adaptive threshold algorithm

2.2 Software filtering algorithm

Although hardware adjustment has been done to minimize the inconsistencies among the phototransistors, erroneous judgment on distinguishing white guide line and background can be hardly avoided in the actual experiment. To address this issue, software filter algorithm is designed for data processing.

Considering the distribution of the sensor locations on a white guide line, we know that the phototransistors on the white line must be adjacent while interference points must be discontinuous, thus, we can take advantage of this feature to filter out interference.

The procedure is as follows:

1) Binarize the sampling values. Compare the gray value of the current sampling value and the threshold. If the sensing value of the current sampling is less than the threshold, we conclude that the sensor is on the white line and set the sensing value as one, otherwise, the sensor is on the dark ground and set its value as zero.

2) Record the serial number of the sensors on the white line as $D_i(1 \leq i \leq 32)$. If the $D_i - D_{i-1} \leq 2$ and $D_{i+1} - D_i \leq 2$, then three sensors must be adjacent and they are all located on the white line; if four sensors are adjacent; if more than five sensors are on the white line or less than tow sensors are adjacent, then discard the current sampled results and use previous sampled results instead. The flow chart of the software filtering algorithm is shown in Figure 3.

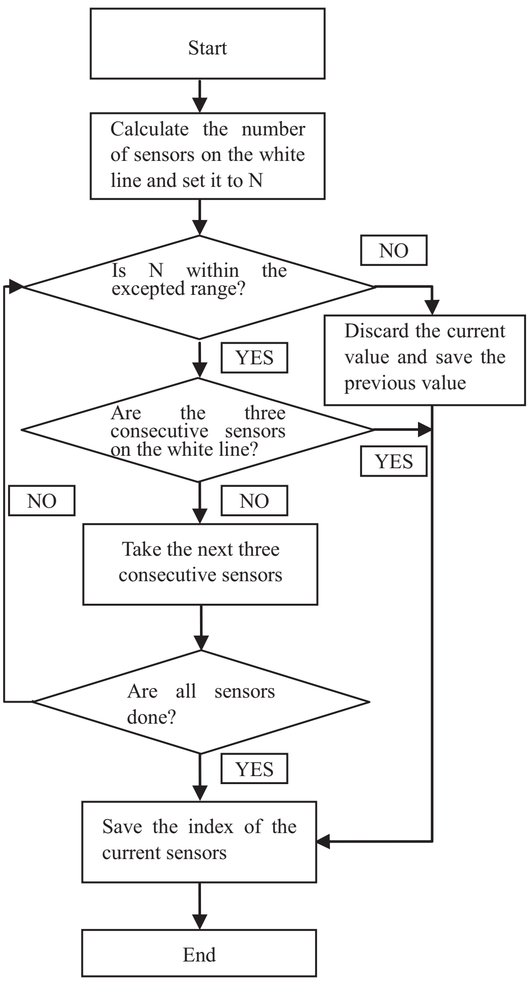

Fig 3. The flow chart of Software filtering algorithm

III. EXPERIMENT RESULTS

In this paper, the experimental platform consists of upper computer and lower computer. The CPU of the lower computer is an Atmag8 single chip, whose on-chip resources is used as AD sampler and the accuracy of the AD sampler is 8-bit. The lower computer collects and processes the information of the line. The upper computer (PC) receive the real-time data from the lower computer via the UART serial communication.

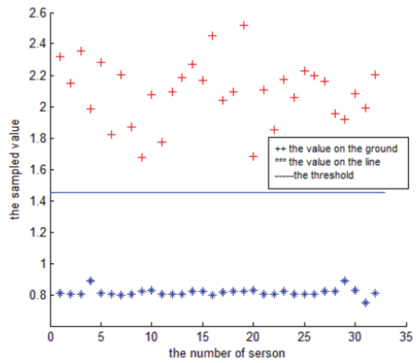

Fig. 4. The sampled value in a certain site

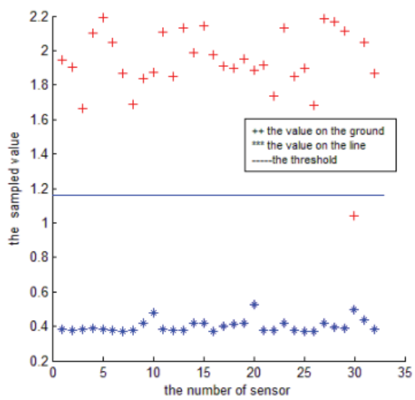

Fig. 5. The sampled value in another site

In two venues under different environment, with proposed adaptive threshold algorithm, the calculated threshold and related data are shown in Fig 4 and Fig 5.

As shown in the above two figures, the sampled values in the same environment from the white line or dark colored ground show little fluctuation, but in different environment, the sampled values on the white guide line (or dark colored ground) vary significantly. It means in the same environment the threshold set by the light board makes it easy to distinct the white lines and dark colored ground. Once the environment changes, the former threshold cannot be used to distinguish the white line and the dark colored ground. However, the adaptive threshold algorithm can adaptively set thresholds depending on different environment. The misjudgment by using fixed threshold can be avoided and accuracy is increased.

About the filtering algorithm, the experiment has proved that as long as the interference of the sampling data is within a certain range, the light board is basically able to accurately identify the location of the white line. The data shown in Figure 6 are recorded by the upper computer, in which the zone of the zero value represents the location of the white line. The experiment shows that the variation trend of the white line presented in the data fits the real situation very well. Therefore, the proposed filtering algorithm is proved to be effective.

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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Fig. 6. The variation trend of the white line

IV. Conclusion

Mobile robot navigation in an unknown environment is always the research focus in the mobile robot intelligent control domain. The flexibility is an important criterion to evaluate the robot intelligence. In this paper, an improved line following navigation optimization algorithm have been proposed and the experiment results show its effectiveness in the robot contest. The proposed method is also a general method which can be applied in different robotics research fields.

V. Reference

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