بیستمین کنفرانس اپتیک و فوتونیک ایران
و ششمین کنفرانس مهندسی و فناوری فوتونیک ایران
۸ تا ۱۰ بهمن ماه۱۳۹۲ - دانشگاه صنعتی شیراز

طراحی و ساخت ماشین هوشمند ردیاب لیزری بر اساس الگوریتم تطابق الگو در پردازش تصویر و سیستم میکروپردازنده

الناز افشاری پور[۱]، پرویز پروین[۲] و رامین خویی[۳]
[۱]گروه مهندسی فتونیک، دانشگاه صنعتی امیرکبیر، تهران، ایران
[۲]دانشکده مهندسی انرژی و فیزیک، دانشگاه صنعتی امیرکبیر، تهران، ایران
[۳]گروه فیزیک، دانشگاه آزاد اسلامی واحد شهرری، تهران، ایران

چکیده- هدف از این پروژه دستیابی به یک سیستم جدید برای ردیابی هدف با دقت بالا، با استفاده از الگوریتم های پردازش تصویر و نشانگذاری لیزری میباشد. در سیستم پیاده سازی شده، یک دوربین CCD بر روی یک بازوی دوّار، که روی یک شاسی چهار چرخ قرار گرفته است نصب شده، و در حال تصویر برداری از محیط است و دائماً محدودهٔ مد نظر را اسکن میکند. از طرفی یک پرتو لیزر نیز آمادهٔ اصابت به هدف و نشان گذاری آن است. هنگامی که یک شی ء متحرک با شکل ویژه ای که در سیستم تعریف شده است در محدوده تصویر برداری قرار میگیرد، پرتو لیزر به آن برخورد کرده و بازتاب میشود. این پرتو بازتاب شده توسط CCD دریافت شده و از طریق پرت USB به کامپیوتر ارسال میشود. اطلاعات دریافت شده توسط کامپیوتر، با استفاده از الگوریتم های پردازش تصویر در نرم افزار Matlab پردازش شده و مختصات لکهٔ لیزر به دست می آید. سپس مختصات حاصله، به مدار الکترونیکی واسط ارسال شده و توسط میکروکنترلر این مختصات تحلیل میشود. پس از انجام محاسبات، فیدبک به گونه ای به موتورهای شاسی اعمال میشود که با چرخش مناسب دوربین، شی ء در مرکز تصویر قرار بگیرد.

کلید واژه- استخراج لکه لیزر، تشخیص لکه لیزر، سیستم ردیاب لیزری، کاربردهای نشانگذاری لیزری

Intelligent machine equipped to laser spot tracker system based on template matching and microprocessor system

Elnaz Afsharipour[1]*,Parviz Parvin[2], and Ramin khoei[3]
[1]Department of Photonics Engineering, AmirKabir University of Technology, Tehran, Iran
[2]Department of Energy Engineering and Physics, AmirKabir University of Technology, Tehran, Iran
[3]Department of Physics, Islamic Azad University,Shahr-e-reyBranch,Tehran,Iran

* Email: [1]e.afsharipour@aut.ac.ir, [2]parvin@aut.ac.ir, [3]r.khuee@iausr.ac.ir

Abstract- *Targeting far movable objects is the biggest challenge in most of the tracking systems. In this project, an accurate far tracking system is proposed based on laser marking and image processing simultaneously. Basically, there is a motorized camera which is scanning its surrounding area. Recurring regularly, the camera locks on the object pointed by the laser beam. Moreover, the captured images are transmitted to PC via a USB port and processed by an M-file developed in MATLAB. By this way, the coordination of the addressed object is determined by color image processing and proportional command is sent to a driver which is based on microcontroller. Designing during the project, this driver analyzes the data, runs the motor, and rotates the camera to follow the spot which is adjusted to the center of image.*

Key words: *Laser marking applications, Laser spot Detection, Laser Spot extraction, Laser tracking system*

1. Introduction

Automatic guiding Vehicles have several applications in military, firefighting, civil and rescue purposes. The way, how they find their object is different due to their applications. This paper presents a method using a laser to target the object, then the labeled object will be captured by machine's CCD and the image will be processed by a laptop to extract the coordinate of laser spot. Then the appropriate command is sent to machine in order to follow the object.

In section 2, a description of system including how to produce a laser spot is presented.
Also the analyzer algorithm for extracting laser spot is explained in section 2.2. The hardware and control circuit is introduced in section 2.3. Section 3 is dedicated to results and the conclusions are drawn in section 4.

2. Experimental

Our system is divided in 2 sections, PC algorithm analyzer, and hardware navigator. Figure 1 shows the system sections. Different parts of system will be explored in the following subsections.

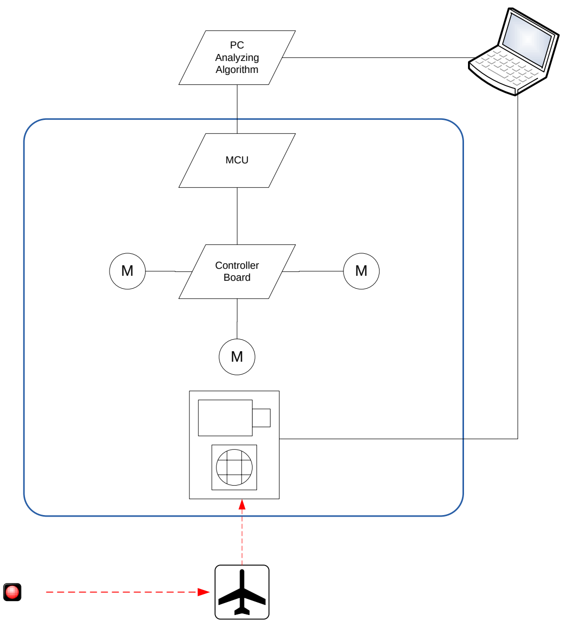

Figure1. Process of tracking the object

2.1. Laser Spot Production

Regarding to system, several ways for producing Laser spot is being used by researchers. In papers [1] and [2] authors have used laser pointer for marking their object.
This way is an appropriate way for systems in which object is not so far from the camera and for our purpose, they don't need high power. In our system, as the object could be far away from the tracker system, we need a laser with high range of power. In this case for laboratory sample, our source of light is a green diode laser pointer with 50mw power and 532±10 nm wavelength.

2.2. PC Algorithm Analyzer

Above described laser is the beginner of our cycle. Its duty is to indicate where the object is located. The reflected laser beam from the object is captured by camera. Meanwhile the images sent by the camera is being analyzed in a PC and the algorithm is searching to find the laser spot and its coordinate.
A brief review of the previous researches is presented in this section. A hybrid technique based on template matching [1] separates the zone which is more likely to have a laser spot in it, and then a fuzzy rule technique is used to compare the related zone with a set of predefined data to find the right location of laser spot.
This work could be developed by adding genetic algorithm for adjusting the Fuzzy rule based system [2] and have effectively reduced the false offs. Also, by adjusting the camera and using dynamic value threshold [3] it would be possible to extract the laser spot in HSV mode.
In a research done by Byung M et al. [4] Homography transform and some software algorithms are used in parallel with a hardware architecture based on FPGA that result in finding laser point in several lighting conditions.
This paper presents a new system that not only finds the laser spot by using algorithm based on color filtering and template matching, but also uses this data for guiding a machine which follows the target.
The video camera used by this system is a JVC CCD camera with 480 x 540 pixels. As described above, the laser pointer used, is a green color one. The analyzing algorithm is developed in Matlab.
In order to extract laser spot in the received image, there are two levels of processing. The first step is to detect pixels, in which level of green is more than red and blue. Then the main image is converted from RGB domain to gray scale and subtracted from the green detected image. So we have a gray scale picture with parts which just have green information in them.
The image enhancement algorithm starts with two dimension median filter, a technique based on nonlinear operation that can remove salt and paper noise while saving the edges.

After removing noises, image will be converted from gray scale to binary. Threshold between black and white pixels is obtained by Otsu algorithm such that internal variance between black and white pixels is minimum. Next step, the pixels are labeled and total number of pixels with the same label is counted for each label, so the connected components with few pixels are ignored. It's another approach for omitting unwanted pixels.

For a more precise laser spot detection, final and most important step of our algorithm is template matching. First, we have to find a template for laser spot which can appropriately describes its shape.

In previous section we achieved some small objects which are laser spot candidates. But the reflections of laser beam from any other surfaces may also be categorized as a laser spot. In order to avoid such mistakes, we compared the laser spot candidates with a template laser spot and calculated the correlation coefficient. The template used by our algorithm, was chosen among more than 100 images of ideal laser spots. The selected one contains most the features of an ideal laser spot so it's an appropriate reference for comparison. Here we correlate the template image with the obtained image in previous section. As images are in two dimensions we used two dimensional correlation as bellow. Where V is the image resulted from previous section and *tem* is the template image.

$$r = \frac{\sum_m \sum_n (V_{mn} - \bar{V})(tem_{mn} - tem)}{\sqrt{(\sum_m \sum_n (V_{mn} - \bar{V})^2)(\sum_m \sum_n (tem_{mn} - \overline{tem})^2)}}$$

Where $\bar{V}: mean2\ (V)\ and\ \overline{tem}: mean2\ (tem)$

The result is an array of numbers which its length represents the number of objects that are assumed to be laser spots, and the numbers are the correlation coefficients calculated for each object.

Where the result array reaches its maximum, means that the most correlation is occurred there. Whatever the number is closer to one, the correlation is stronger. High correlation is a symptom of most similar shape to template. So by finding the corresponding coordinate to maximum value of the result array, the location of laser spot is found. So after eliminating errors of previous process, Figure 2 shows the right location of laser spot detected by template matching algorithm.

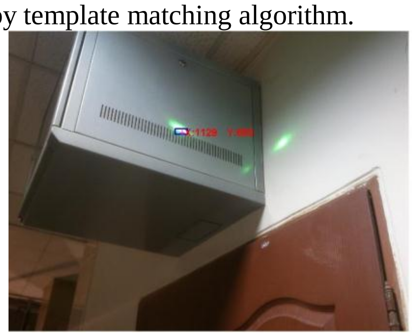

Figure2. Identifying the correct location of laser spot by Template Matching algorithm

Once the laser spot has been found, next step is to mark the location of it. For this purpose, center of the spot is found by using Centroid algorithm. This algorithm will specifies center of mass of the spot by calculating weighted average of the pixel coordinates and their intensity levels:

$$x_c = \frac{x_1 I_1 + x_2 I_2 + x_3 I_3 + \cdots}{I_1 + I_2 + I_3 + \cdots} \quad (2)$$

$$y_c = \frac{y_1 I_1 + y_2 I_2 + y_3 I_3 + \cdots}{I_1 + I_2 + I_3 + \cdots} \quad (3)$$

Where x and y are pixels coordinates and I is the related intensity level of each pixel.

This coordinate is our criterion for guiding the vehicle. The coordinate of laser spot center is then converted to string and sent to our processor.

2.3. System control hardware

The second section of the system deals with the system control. As shown in figure 3, the system hardware consists of a 4 wheel chassis with a rolling arm. The camera will be mounted on the arm on the head of the machine. The controller circuit is also mounted on the device.

Figure3. The hardware system contains of a four wheel chassis with a rolling arm on the head

The processor is continuously scanning serial port. The coordinate which was calculated from the previous step, is now received by the processor and another analyzing algorithm is here trying to control the machine. The method is comparing the numbers with the coordinate of center pixel of the image. Due to location of the laser spot, four cases may occur:

Table1. Possible positions for the coordinate

Location of the spot	Movement	
	Machine	Arm
First quarter	Right	Up
Second quarter	Left	Up
Third quarter	Right	Down
Fourth quarter	Left	Down

Regarding to above table, the algorithm will make the appropriate decision for moving the camera.

ie. if the spot is located in the first quarter of the image, in order to tracking the spot, the camera should be moved toward up-right such that the spot matches the center pixel of the image.

PWM method is used for controlling motors. Pulse Width Modulation is a method in which the pulse frequency is fixed but the duty cycle of the pulse varies with a parameter. Here, the coordinate of spot's center is our reference. It means that the percentages of 1 and 0 levels are determined by the location of spot.

So the appropriate pulse width is calculated and related contour is set. Motors will rotate in the high mode and stop in the low mode. As a result the amount of motor rotation is limited by the pulse width, while the pulse width is a function of laser spot coordinate. In this case, we need tree PWM outputs for controlling tree motors. So we have to set the related timer parameters (OCR0, OCR1A and OCR1B) such that the motors get signals with appropriate pulse width. For this purpose we converted the distance of coordinate from center (which was calculated before) to a number between 0 and 255 (considering 8bit timer) and the pulse duration is divided into 256 levels. Actually it's the system feedback that is used for making decision. Finally by rotating the motors, machine will track the target.

3. Results and discussion

This system was tested in several environments with various brightness levels. Our main setup was tested in Laser laboratory of Amirkabir University of technology, by changing light conditions. We measured the speed of reaction to moving the laser point and accuracy of response to change of coordinate. The analyzer algorithm is implemented on every 3 frame. In order to catch up the real time video we have set this limitation. Meanwhile depending on the PC processor, the algorithm takes some time to be completed on a single frame. These two delays will cause about 300 ms delay in analyzing algorithm.

The controller board is receiving a chain of coordinates. An external oscillator is used to make the processor clock in 16 MHz. Considering the whole delay times used in processor program, it will take about 400ms to send appropriate signal to motors. Altogether, in the worst case, we have a maximum total delay of 700ms to make the first reaction to laser location change. By measuring the reaction times with a stopwatch, we achieved an average of 400ms delay in 100 experiments. It means that this system can easily follow the objects with rather high speeds. Obviously, several laser spots in one capture will be illusive for the algorithm. It is a rare error that may be solved by manipulating the environment.

Meanwhile, in order to improve efficiency and accuracy, we are designing an appropriate optical system for this project.

4. Conclusions

In this paper we presented a system for tracking objects marked by a laser pointer. The process was introduced in two phases: PC analyzer algorithm, hardware and control system. The presented analyzer algorithm is based on template matching. Also color isolation and intensity threshold is deployed to help the detection of laser spot coordinate. The laser spot coordinate is then sent to a microprocessor that determines the amount and direction of moving. The related signal is sent to motors by an interface circuit that can provide required current for rounding motors. This interface circuit is mounted on a 4-wheel chassis with an arm on which the camera is installed.

Comparing to similar researches, the most important approach of this project is three degrees of freedom and its high precision and efficiency in tracking laser marked objects.In addition, we plan to extend our work in two separate research ways: first of all by testing different lasers with different wavelengths and at the same time, expanding the operation range range by optimizing search algorithms, designing appropriate optical system as beam expander and receiver and at last, optimizing electromechanical platform of the system.

References

[1]. F. Chávez , F. Fernández,R. Alcalá,J. Alcalá-Fdez, G. Olague, F. Herrera (2010):*Hybrid laser pointer detection algorithm based on template matching and fuzzy rule-based systems for domotic control in real home environments*, © Springer Science+Business Media, LLC 2010

[2]. F. Chávez , F. Fernández, M.J Gacto, R. Alcala, (2012): *Automatic Laser Pointer Detection Algorithm for Environment Control Device Systems Based on Template Matching and Genetic Tuning of Fuzzy Rule-Based Systems*, International Journal of Computational Intelligence Systems, Vol. 5, No. 2, 368-38

[3]. Matej MEŠKO, Štefan TOTH, (2013): *Laser spot detection, Journal of Information, Control and Management Systems*, Vol.11, No.1. pp 35-41

[4]. Byung, M.J., Ngyuen, D.D., Sang J. L., Jung D. J., Jae W. J. (2012): *Hardware architecture for detecting laser point using FPGA*, 12th International Conference on Control, Automation and Systems (ICCAS)