PIG FACE DETECTION ALGORITHM AND SUPPLEMENTARY LIGHT SYSTEM DESIGN BASED ON OPEN MV3

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基于 open mv3 猪脸检测算法与补光系统设计

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ABSTRACT

Individual pig recognition is an essential step for accurate breeding and intelligent management of pigs. To realize individual pig identification, applicable dataset of pigs needs to be built. For pigs' behaviour is difficult to control, the data acquisition is of great difficulty and low efficiency. In addition, few reports on pig face detection are there at home and abroad, thus, face data acquisition faces more difficulty. In this study, double open mv3 digital cameras were adopted, and the approach of starting the pig face acquisition program by acquiring pig figure with a vertical camera to calculate the slope of their back before sending a signal to the horizontal camera was adopted. The image brightness was calculated based on RGB function: when the value was less than 90, the supplementary light system would be started by L298 module, and when the value was more than 120, the acquisition system would be restarted. This study provides a reference for solving the key problem of automatic acquisition of pig face data for pig face detection.

摘要

生猪个体识别是生猪的精准养殖与智能管理的必要步骤，为实现生猪个体识别需构建适用的生猪数据集，由于生猪行为难于控制，数据采集难度大、效率低且关于生猪脸部检测的国内外研究鲜有报道，脸部数据的采集难度更大，本研究中采用双 open mv3 数字摄像头，提出由垂直摄像头采集到生猪身影计算背部区域斜率并发送信号给水平摄像头启动猪脸采集程序的方法，并基于 RGB 函数计算图像亮度，当值低于 90 时由 L298 模块启动补光系统，当值大于 120 时重新启动采集系统，为解决猪脸数据自动采集的关键问题猪脸检测提供了参考。

INTRODUCTION

In the field of animal individual identification research, as the image data of animals are difficult to acquire, few animal image datasets are provided for researchers to make classification and identification research under restricted and non-restricted conditions. At present, the animal datasets with research value include KTH-ANIMALS constructed by Afkham et al. *(Afkham et al., 2009)*, in which a total of 1,900 images of 19 kinds of animals were acquired, with about 100 images contained for each kind of animals, and Oxford-iiiT Parkhi animal datasets constructed by Parkhi *(Parkhi et al., 2012)* et al., in which images of two categories, a total of 37 varieties of cats and dogs are included, with 200 images contained for each variety. These kinds of datasets are suitable for species taxonomy, yet datasets for the research of individual species need to be newly constructed. In recent years, researchers have begun to construct datasets suitable for individual identification. The red-bellied monkey dataset constructed by David Crouse *(Crouse et al., 2012)* is small, which is easy to cause overfitting; though the gorilla dataset constructed by Alexander Freytag *(Freytag et al., 2012)* is of a large scale, though the blocking is serious, thus the data availability is poor; the golden monkey face identification database constructed by Fang Nan *(Fang N., 2017; Hu X., 2019; Fan Y. Y., 2018)* includes 80 individual golden monkeys of 4 varieties; datasets of other animals are there, though they are in secrecy, so they are not suitable for study *(Pérezluque et al., 2017; Hughes et al., 2015)*. However, few reports on datasets of individual pig identification are there. *Ma et al., (2016), Nasirahmadi et al. (2016), Chen et al., (2017)* used machine learning method to conduct target extraction and behaviour judgment on pigs, and many

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researchers have studied pig behaviour and health status *(Kim et al., 2017; Haladjian et al., 2017; Ahrendt et al., 2011; Guo et al., 2014; Guo et al., 2015; Li et al., 2017)* from different points of view. In a lot of studies, manually self-constructed datasets are adopted, for which not only the workload is huge but also the generalization performance is poor. With individual pig identification becoming a hot spot, having study of data acquisition methods of pigs is imperative. At present, both at home and abroad, reports on the construction of pig datasets are few, that is why double open mv3 digital cameras were adopted in this paper to design the pig face detection algorithm and supplementary light system, so as to provide reference for pig data acquisition.

MATERIALS AND METHODS

DESIGN OF DATA ACQUISITION SYSTEM FOR PIG FACE DETECTION BASED ON OPEN MV3

In this paper, double open mv3 digital cameras were adopted for pig face detection, which helped realize the pig body detection, acquirable pig face area detection and acquisition, as well as a supplementary light system for solving the problem of uneven light intensity. The core functions included a pig face detection module and a supplementary light module. The overall process and functional modules of the system were as shown in Fig. 1.

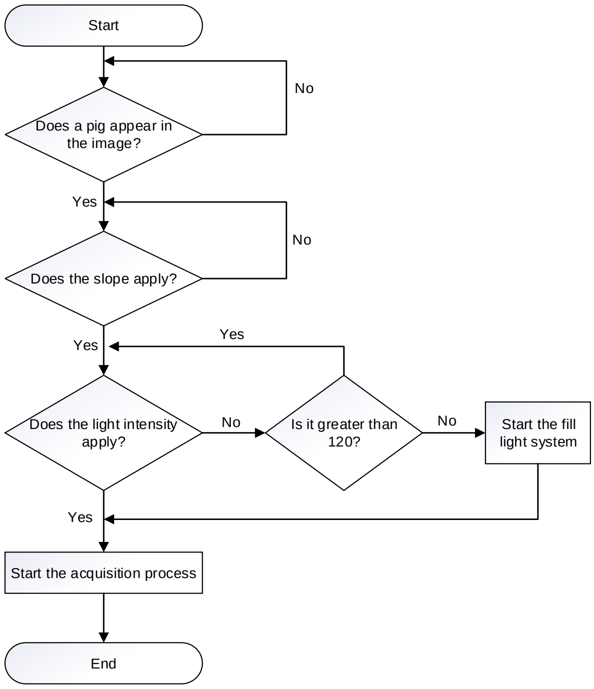

Fig. 1 - Overall Design of Pig Face Acquisition System

The open mv3 digital camera used in the study was as shown in Fig. 2. The main control chip of open mv3 digital camera was STM32F7, with basic frequency of 216 MHZ, 2M flash and 512 KB RAM, colour limp frame rate of 85~90 frames, photosensitive element OV7725, and optional modes of gray (640×480) and RGB565 (320×240), WiFi module of atwinc1500, and transmissibility reaching 48 Mbps. With IP address input in the PC terminal, images could be viewed at real time. With SD card equipped, images and videos could be saved or matching algorithm could be invoked for match identification. With M12 lens base configured, distortion-free viewing angle reached 90 degrees, and standard viewing angle reached 120 degrees. The focal length of lens was 2.8mm and that of a distortion-free lens was 3.6mm.

Fig. 2 - Open mv3 Digital Camera

The acquisition equipment set up in a single piggery management unit was as shown in Fig. 3.

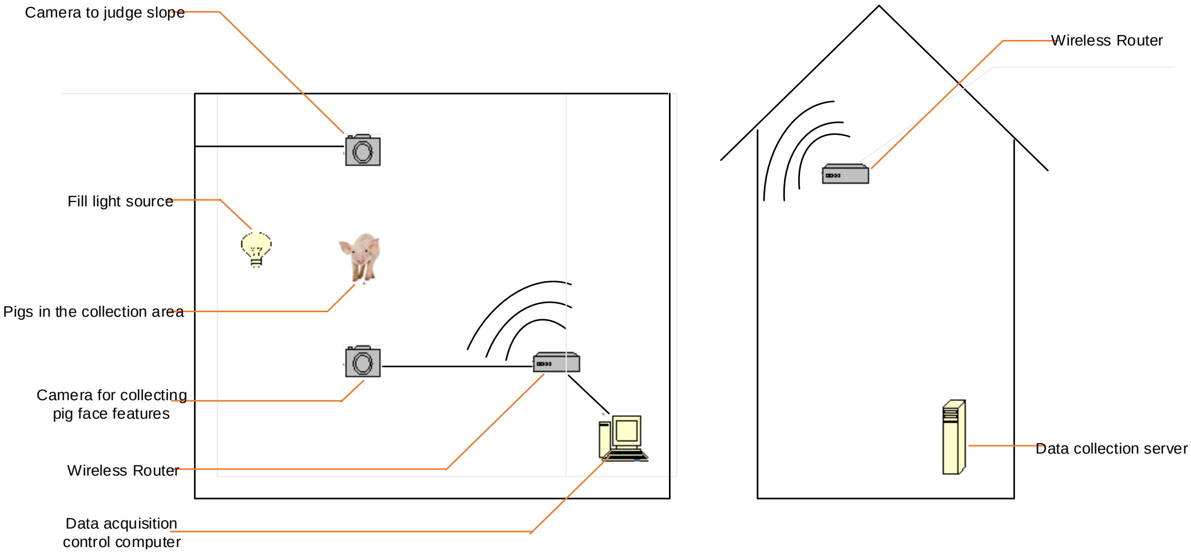

Fig. 3 - Simulated Diagram of Data Acquisition in a Piggery Unit

PIG FACE DETECTION ALGORITHM AND SUPPLEMENTARY LIGHT SYSTEM

Pig face detection module

Principle of pig face detection

The pig face trigger detection system was equipped with two open mv3 cameras, which was able to automatically acquire pig faces when they appeared in the acquisition range. The schematic diagram of the trigger acquisition system was as shown in Fig. 4. The first camera was installed 1.5m directly above the pig body at pigs' activity area. When the pigs entered the camera area, the image of the back of pig body was able to be acquired, and the pixel values of the two centre points selected at back of pigs could be calculated. With the point-point slope k calculated, the pig face samples could be acquired with range of k determined.

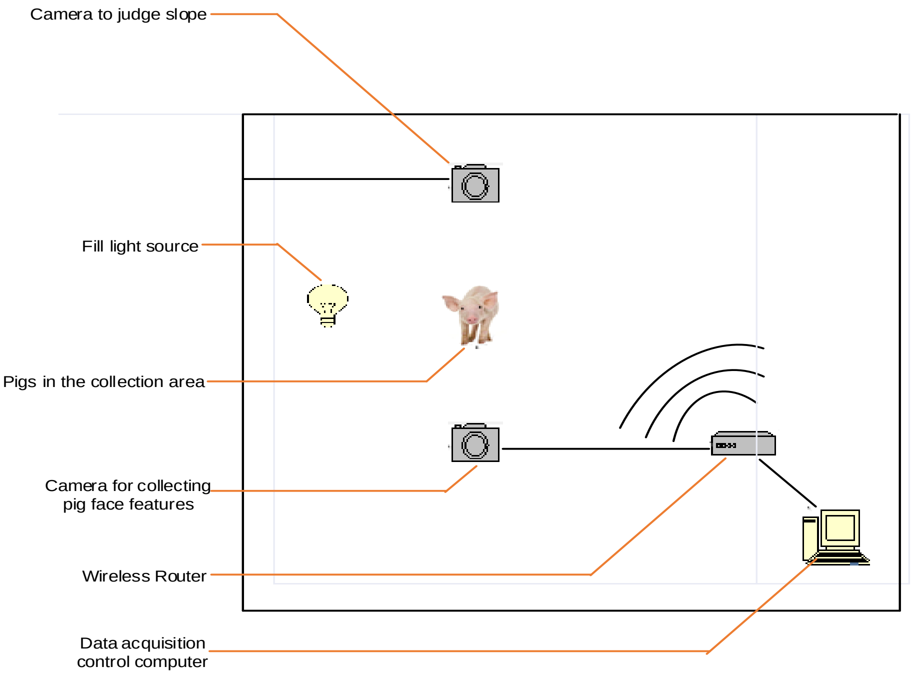

Fig. 4 - Trigger Acquisition Structure Chart

The second camera installed in the front of the pigs' activity area could acquire the image of pig face. When the pig face faced the camera, it was the best time to acquire the image. The timing of pig face acquisition could be determined by judging the value of slope k. There were several representative images of the pigs' back as captured by the vertical camera.

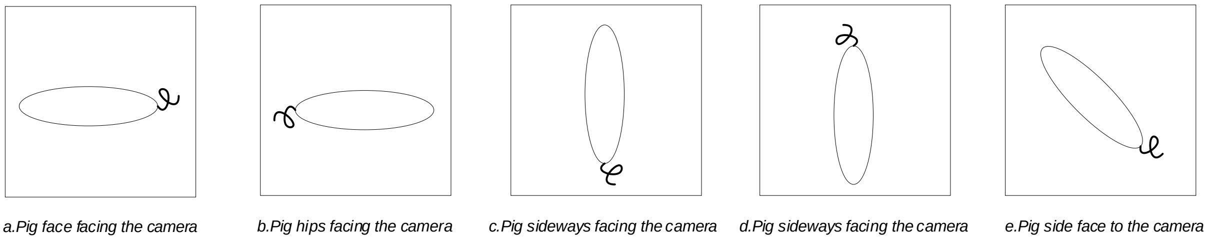

Fig. 5 - Diagram of the Back of Pigs

How to judge whether the image in Fig. 5 was able to acquire pig face? The oval in Fig. 5 that represents the pigs was divided into two areas, as shown in Fig. 6, and the horizontal line in the middle was taken as the boundary to divide the oval into two areas of A and B, then the centre points a and b were found out before their coordinate values were calculated, finally, the slope k of the ligature between a and b was calculated. As can be seen in Fig. 5, when k was of infinity, it meant that pig face or buttock was just facing the camera, while when k was less than infinity and activates within a certain range, the pig face image could be acquired; when k was less than a certain value, the pig face image acquired would be with a slope that was too large, which was not suitable for subsequent identification. In this study, it was set that pig face acquisition procedure could be started when the slope angle was within a range of 30 degrees. In this way, it was OK to have the calculated value of k be larger than $\sqrt{3}$.

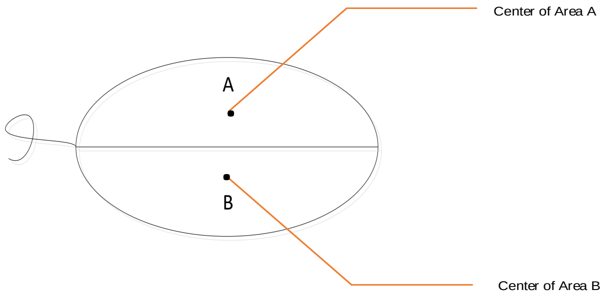

Fig. 6 - Two Areas on the Back Image of Pigs

When k met the requirement, some non-pig face samples could also be acquired. In Fig. 5 (b), (c) and (d), the buttock, left side and right side of the pig body were acquired. At present, such images can be excluded manually. When the slope was of infinity, the pig face samples of the best quality could be acquired, at this time, images of the buttocks and sides of pigs might also be acquired, for which the reason was that when the slope was of infinity, the vertical camera could capture the samples as in the four conditions of Fig. 5 (a)-(d). In Fig. 5 (a) and (b), pig face, pig buttock were directly facing the lens, at this time, images of pig face and buttock were acquired, and in Fig. 5 (c) and (d), sides of pigs were directly facing the lens, at this time, images of sides of pigs were acquired.

Procedures of pig face detection algorithm

The procedures of pig face detection algorithm were as follows.

(1) All the pixel differences of adjacent frames transmitted by the vertical camera were calculated to judge whether pigs had entered the acquisition area;

(2) If the judgment result was true, the adjacent frames were extracted, and then the difference values of all pixel points were calculated, thus the pig body was determined. The theoretical value of pixel points outside the area was 0, with small fluctuations;

(3) The RGB value of each pixel of the pig body was extracted to get the sum, and then it was assigned to the variable r;

(4) The pixels were confirmed to be within the threshold value t of pig body;

(5) Pig body area could be determined when r was larger than the threshold value t;

(6) The pixel points were traversed, and the row and column coordinates (i, j) of the pixels of the pig body area and count s were saved in the array m;

(7) The row coordinates i_1, i_2 and column coordinates j_1, j_2 of the center points a and b of each of the s/2 pixel in the front and at the back were calculated;

(8) The slope k of ligature between a and b was calculated;

(9) Whether the slope k was within the threshold of acquirable slope was judged, and if the result was true, then the pig face was acquired; if the result was false, no operation would be done.

In pig face detection algorithm, the slope k needed to be determined, and its calculation formula was

$$k = \frac{y_2 - y_1}{x_2 - x_1} \tag{1}$$

where: x_1 represents value of row-coordinates of the pixels in the centre point of the s/2 figure in the front of the pig figure, [pixel];

x_2 represents value of row-coordinates of the pixels in the centre point of the s/2 figure at the back of the pig figure, [pixel];

y_1 represents value of column-coordinates of the pixels in the centre point of the s/2 figure in the front of the pig figure, [pixel];

y_2 represents value of column-coordinates of the pixels in the centre point of the s/2 figure at the back of the pig figure, [pixel].

The coordinates of the centre point on the back of the pig body were calculated according to the following formula

$$x = \sum_{i=0}^{s/2} I_i / s/2 \tag{2}$$

$$y = \sum_{i=0}^{s/2} j_i / s/2 \tag{3}$$

where: x represents row-coordinate of the centre point of the pig figure, [pixel];

y represents column-coordinate of the centre point of the pig figure, [pixel];

i represents serial number of pixel points in the front half of the pig figure, [a];

I_i represents row-coordinate of the pixel point i in the pig figure, [pixel];

J_i represents column-coordinate of the pixel point i in the pig figure, [pixel];

s represents total number of pixels in the front half of the pig figure, [a].

As for determination of threshold t in pig body area, the values of the pixels outside the pig figure were 0 in ideal conditions, and when the t value determined in the test was between 90 and 120, signals of pig figures that met the test requirements could be received. The effect of pig face acquired was as shown in Fig. 7. When k was of infinity, the following categories could be obtained: Fig. 7(a), (b) and (c) show the pig face image, the pig buttock image and the pig side image, respectively. When $\sqrt{3} < k < \infty$, the pig face sample acquired was tilted at a certain angle from the camera at the horizontal level, as seen in Fig. 7(d). When $k < \sqrt{3}$, the detection program would not start, and no pig face image would be acquired.

a) Pig front view *b) Pig buttocks photo* *c) Pig side view* *d) Pig side face photo*

Fig. 7 - Right Face, Lateral Face and Non-face Acquisition Conditions of Images for Pig Samples

Supplementary light system module

Structural design for supplementary light mode

Under the influence of weather and other factors, the images acquired were not with even light intensity, but the phenomenon of uneven light intensity could be eliminated by supplementary light. The structure diagram of the supplementary light system was as shown in Fig. 8. The supplementary light bulb was controlled by the output signal of L298 double-bridge module which sent high and low level according to the signals transmitted from the open mv3 digital camera. If the I/O port received a high level, it would control the L298 double-bridge module to turn on the supplementary light bulb; if the low level was received, it would not turn on the supplementary light bulb. The value of the image brightness was calculated according to the pixel information of the pig face image transmitted by the camera, and it was compared with the set threshold value to judge whether the high level or low level would be sent to the L298n double-bridge module.

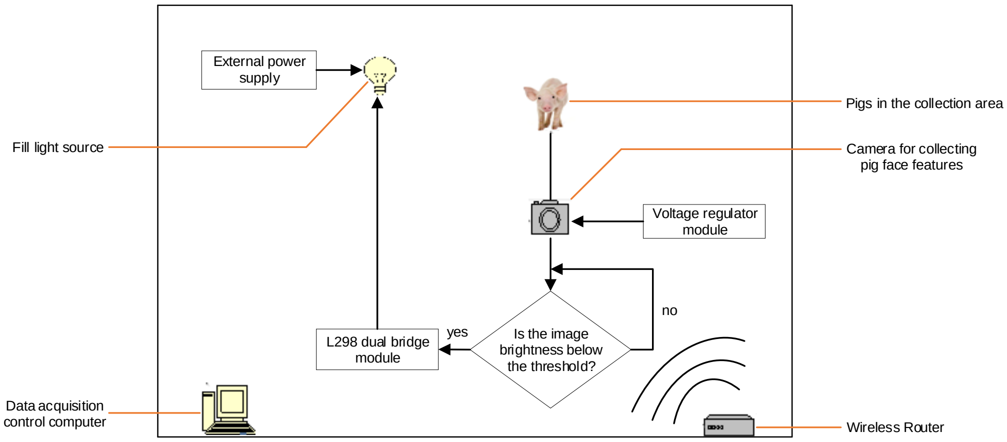

Fig. 8 - Structure Diagram of the Supplementary Light System

Design principle of supplementary light mode and its realization

After samples were acquired by the digital cameras, to obtain uniform brightness values, the values of four thousand pixels evenly distributed in the image of samples were calculated. When the value was less than the threshold value of brightness, high level signals were transmitted. The I/O port received the high level signal to control the switch controller of the supplementary light bulb and start the light source before continuing to acquire images and save them in the frame sequence.

As to the determination principle of the brightness of pig face samples, the pig images were transmitted to the image sensor, and each image point of the image sensor corresponded to a photosensitive element. After receiving the light, the element could generate an electric current. The current intensity was linearly related to the intensity of the light. The induced current converted the digital signal of the output image via the signal amplifier and A/D converter. The RGB value of image points with different light intensity was different, and the value of high intensity was larger than that of ordinary intensity and low intensity. By comparison, it was found that the value of pixels was around 90 under low light intensity, while the value was around 120 under high intensity. Samples acquired in this range was applicable, therefore, the supplementary light threshold was set to be 90. All the digital signals generated by all the photographic units of the camera were all the data of the image. The calculation formula for image brightness was

$$r = \sum_{i=0}^{h} i \sum_{j=0}^{w} j \; RGB(R,0,0) \tag{4}$$

where: r represents brightness value of pixels, [pixel];
h represents height of image, [pixel];
w represents width of image, [pixel];
RGB represents colour function.

Fig. 9 (a), (b) and (c) show pig face samples acquired in conditions of r<90, r>120 and 90<r<120, respectively. After supplementary light treatment, the brightness of pig face samples was uniform and the applicability was strong.

a. Light intensity is less than the threshold b. Light is stronger than the threshold c. Normal light intensity

Fig. 9 - Samples with Different Light Intensity

RESULTS AND DISCUSSION

In order to test the effect of this algorithm and system, the face data of pigs were collected in three breeding places, and the results were as shown in Table 1. The calculation formula for image collection efficiency was:

$$e = \frac{a+b}{a+b+c} \times 100\% \qquad (5)$$

where: a represents the number of frontal pictures of pig faces, [a];
b represents the number of side pictures of the pig's face, [a];
c represents the number of pictures of pig buttocks, [a];
$a+b$ represents the number of pictures of valid picture, [a].

Table 1

Pig face data collection results

Breeding base	a [a]	b [a]	c[a]	a+b [a]	e [%]
The College of Animal Science	968	2903	111	3,871	97.21
Wujiazhuang	377	2061	205	2,438	92.24
Dongsongjiazhuang	1099	2117	199	3,216	94.17

The algorithm and system as used to collect live pig face data with the data collection equipment on three pig farms. A total of 3,982 pieces of live pig face data were collected at the Pig Breeding Experimental Base (112º57′E, 37º42′N) of the College of Animal Science, Shanxi Agricultural University, Shanxi Province, China, among which 3,871 were suitable for follow-up research (live pig face detection, live pig face recognition), with an effective rate reaching 97.21%; a total of 2,643 pieces of live pig face data were collected on the small pig farm in Wujiazhuang (112º53′E, 37º38′N), Taigu District, Jinzhong City, Shanxi Province, China, among which 2,438 were suitable for follow-up research, with an effective rate reaching 92.24%; at the same time, a total of 3,415 pieces of live pig face data were collected in Dongsongjiazhuang (111º95′E, 37º26′N), Jicun Town, Fenyang City, Shanxi Province, China, among which 3,216 were suitable for follow-up research, with an effective rate reaching 94.17%. With the total effective rate of data collected on the three farms reaching 94.54%, it is indicated that the algorithm and system has positive significance for the automatic construction of data sets on live pig face.

CONCLUSIONS

In this study, double open mv3 digital cameras were adopted to conduct pig face detection, which has certain universality and provides certain reference for solving the data acquisition problem in the field of animal individual recognition. Moreover, a supplementary light system was designed to solve the problem of uneven light intensity in the image acquisition process. The conclusions of the study are as follows:

(1) Double open mv3 digital cameras can be adopted to detect pig faces, and the vertical camera can be used to obtain the slope of the back area of the pig body to judge whether the pig faces are in the acquirable range. The test shows that when the slope is more than $\sqrt{3}$, pig faces meeting the requirement can be acquired.

(2) The threshold value of pig body figure can be set between 90 and 120. If it is less than 90, the image acquired will be dim, at this time, the supplementary light system can be started for supplementing the light. If it is more than 120, the image acquired will be bright, and at this time, the images shall be discarded and image acquisition shall be restarted.

(3) Open mv3 and L298 can be adopted to control the supplementary light system. When the brightness value of the pig face sample is less than 90, open mv3 will send high level to the L298 module to start the supplementary light system, which can solve the problem of low brightness of the sample image.

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