Research on intelligent express sorting equipment based on image recognition

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Abstract. In this paper, an intelligent express sorting device based on image recognition technology is designed to meet the need of sorting under the background of the rapid increase in express business volume. The device uses Raspberry PI master control, combined with high-resolution camera, computer vision and image processing algorithm to realize the automatic identification of express tracking number, sorting location determination and logistics information input. The equipment has the characteristics of high efficiency, accuracy and stability, and can be widely used in small and medium-sized logistics centers to improve sorting efficiency and reduce labor costs. In this paper, the design idea, working principle, system analysis and technical scheme of the equipment are introduced in detail, and the application prospect of the product in the express industry and other fields is prospected.

Keywords: Image recognition, Intelligent, Express sorting, Computer vision.

1. Introduction

In recent years, with the rapid improvement of market demand and the rapid development of express delivery industry, the total volume of express delivery business in China has grown rapidly. In 2021, the total business volume of express delivery service enterprises in China has completed 108.30 billion pieces. From 2016 to 2020, the revenue of express delivery business in China has increased from 300 billion yuan to 4.6 trillion yuan in 2020. The total number of express deliveries increased from 31 billion to 83 billion. Coupled with the rapid development of e-commerce industry in China, the demand for express delivery market will continue to grow, and the scale of China's express delivery industry will expand.

While the scale of express delivery continues to rise, the amount of express sorting has also increased sharply. For large logistics centers and warehousing departments, large automated sorting equipment such as cross-belt sorters and roller sorters are often used to complete a large number of sorting needs, but for small and medium-sized sorting centers, airport cargo centers, and small express stations, the traditional sorting method of manual sorting is often used, and the proportion of automated sorting equipment is low. In recent years, with the rising labor costs and the problem of Courier loss and delay, as well as the threat of dangerous items contained in Courier packages to personnel safety, it is very important to develop an intelligent sorting equipment for small and medium-sized sorting centers.

In response to market demand, intelligent sorting equipment for small and medium-sized sorting should meet the following requirements:

(1) Stability and reliability: the equipment should have stable performance and reliable work efficiency, can run stably for a long time, and is not prone to failure.

(2) Efficiency and accuracy: the equipment should be able to quickly sort express packages, and the sorting accuracy should be high to meet the sorting needs of express companies.

(3) Diversity and flexibility: the equipment should be able to adapt to different shapes, sizes and weights of express packages, and can be flexibly sorted.

(4) Simple operation and easy maintenance: the equipment should be easy to operate and maintain, and the operator does not need too high a technical level to operate and maintain.

(5) Safety: The equipment should have safety and environmental protection, to ensure the safety of the operator.

(6) Cost effectiveness: The equipment should have lower input costs and higher cost performance, which can meet the economic strength of small express companies.

2. System Design

2.1. Overall Design

Use high-resolution cameras to capture images of express packages to be sorted. Then, the image is preprocessed, including denoising, image enhancement and edge detection, to improve the recognition accuracy. Next, computer vision and image processing algorithm are applied to identify and extract the tracking number in the image. By querying relevant information, the corresponding sorting position is determined and the express package is placed in the corresponding position. Finally, the identified express tracking number and related information are entered into the system to achieve real-time logistics tracking and management. The image recognition flow chart is shown in Figure 1.

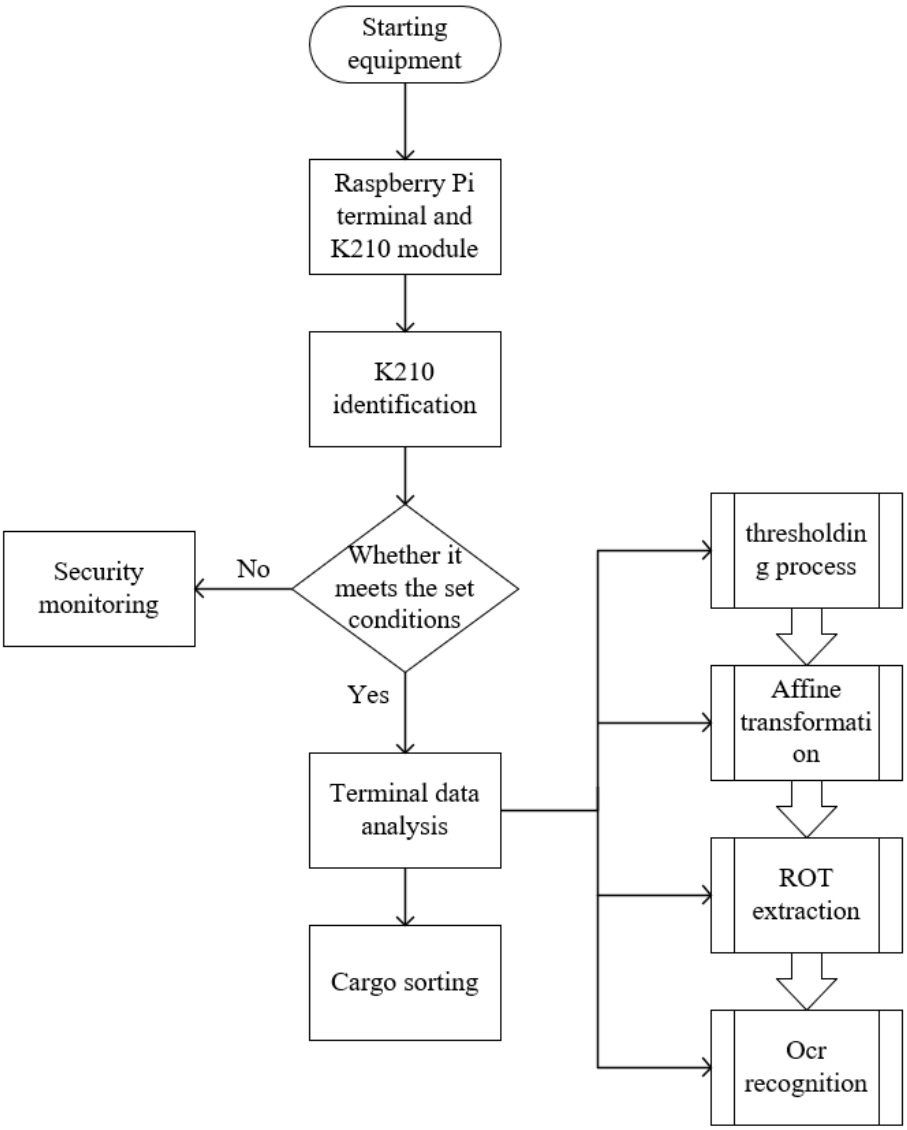


Figure 1. Image recognition flow chart

The product needs to process a large amount of data quickly, so the master needs to have a strong processing capacity and be able to process and analyze the data quickly. The main control boards on the market include Arduino, Raspberry Pi, STM32, ESP32 and BeagleBone. The Raspberry PI main control board is selected as the main control board from the aspects of rapid response, high cost performance, adaptability and expansibility.

Table 1 lists the specific parameters of the Raspberry Pi. The Raspberry PI and camera images are shown in Figure 2.

Table 1. Detailed parameters of the Raspberry Pi

Network card	BroadcomBCM2835(CPU, GPU, DSP和SDRAM, USB)
CPU	ARM1176JZF-S Core (ARM11 series) 700MHz
GPU	Broadcom VideoCrore IV, OpenGL ES 2.0,1080p 30 h.264/MPEG-4 AVC Hd decoder
Internal memory	512MByte
Number of USB 2.0 ports	2 (Support USB hub expansion)
Image output	Composite RCA(PAL & NTSC), HDMI(rev 1.3 & 1.4), raw LCD Panels via DSI 14 HDMI resolution from 640x350 to 1920x1200 plus various PAL andNTSC standards
Audio output	3.5mm jack, HDMI
Onboard storage	SD/MMC/SDIO Card slot
Network card	BroadcomBCM2835(CPU, GPU, DSP和SDRAM, USB)



Figure 2. Raspberry PI (left) and camera (right)

2.2. Working Principle

1) Combine key technologies such as camera capture, image processing, machine vision and database query, and realize real-time tracking and management of logistics information through automatic identification and entry process.

Principle of machine vision: Image processing is carried out through convolutional neural network[1-3]. The difference between convolutional neural network and neural network is that several convolutional layers are added, and the convolutional layer can be subdivided into CONV and POOL operations (these two important concepts will be briefly introduced later[4,5]. Then there is the fully connected layer (FC), which corresponds to the hidden layer of the neural network. Finally, the softmax layer predicts the output value y_hat. Figure 3 below shows the structure of CNN.

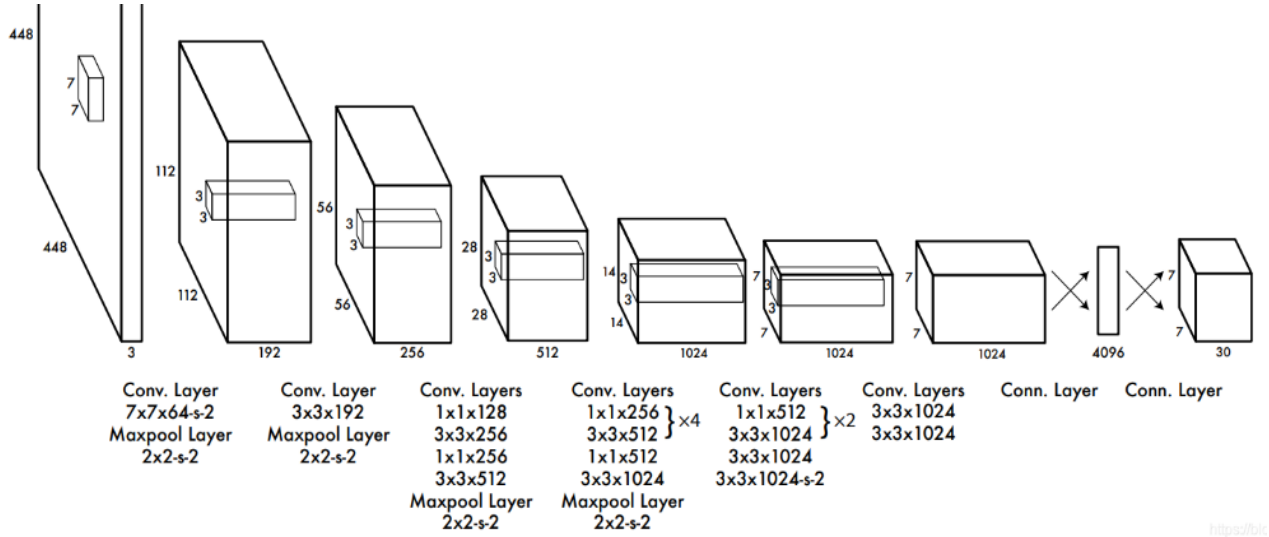


Figure 3. CNN structure diagram

Because the pixels in the corners or edges are used relatively infrequently. This will weaken edge information in image recognition. padding can be used to fill P-layer data around the original image data, as shown below. When the filled data is 0, we call it Zero-padding. In addition to preserving more valid information, padding ensures that the volume's height and width do not change before and after using convolution.

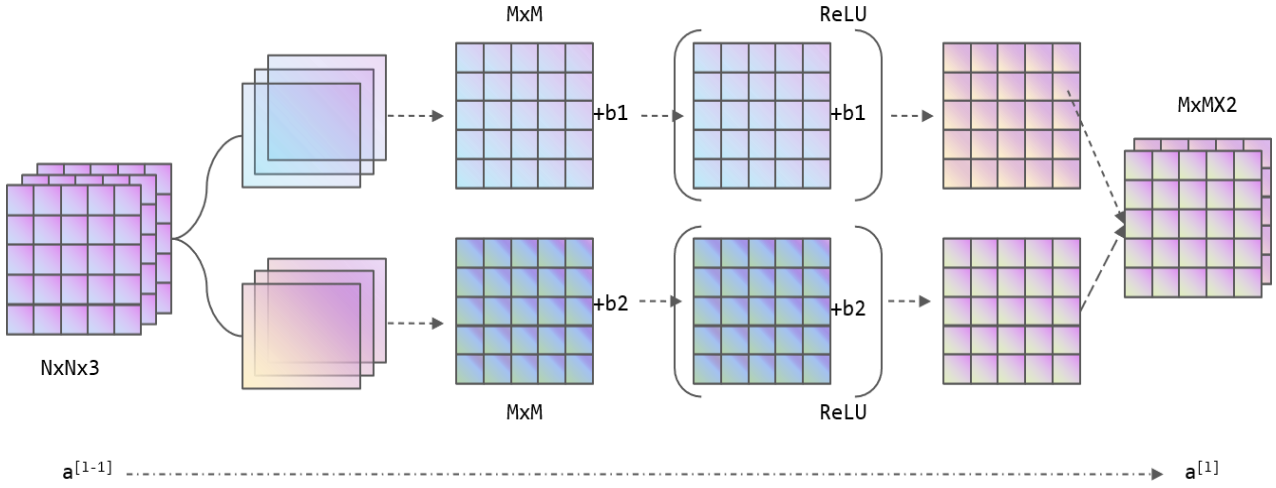


Figure 4. Process of convolutional algorithm

After grouping and labeling a large number of images in convolution, the GPU training model will be conducted, and tests will be carried out after the training to prevent overfitting or underfitting of the training results (Figure 4).

To this end, the product uses the K210 camera to transmit the data after the image (RGB565) processing to the Raspberry PI through its serial port, and then runs the linux system on the Raspberry PI. And through the open source machine vision library OPENCV image processing, when the identification of photos, to get the interested image. When the image enters the detection area, the image is preprocessed, including denoising, image enhancement and edge detection, to improve the recognition accuracy. Next, computer vision and image processing algorithms are applied to screen the interesting content through regular expression, and the express tracking number in the image is identified and extracted. Finally, the identified data will be uploaded to the web side for corresponding real-time data update to ensure the accuracy of its information.

2) The use of shading and filling processing can make the control camera of the device in a good light source environment to ensure accurate recognition rate.

How the camera works: The cargo is focused through the lens of the camera to form an optical image, which is then projected onto the image sensor surface. The image sensor converts the optical signal into an electrical signal, which is converted into A digital image signal by an analog-to-digital converter (A/D converter). These digital image signals are transmitted to a digital signal processing chip (DSP) for various image processing and enhancement operations, such as denoising, color correction, contrast adjustment, etc. The processed image signal can be transmitted to the computer through the USB interface for further processing. Finally, through the display, you can see the image captured by the camera.

The product adopts the key components such as RISC-V K210 camera, voice module and LCD display. Here's how it works: First, the camera is responsible for capturing the image to be processed. After the image data is collected by the sensor, it is transmitted to the RISC-V K210 chip. The chip has powerful image Processing capabilities, and is equipped with a special accelerated computing KPU (K210 Processing Unit), which can perform efficient convolution operations. The camera workflow is shown in Figure 5.

By using KPU for convolution calculations, the product is able to process image data quickly and accurately. Convolution operation is an important image processing technique, which can extract features and patterns from images. After the convolution operation, the identified results are extracted and stored inside the chip. Next, through the serial port, the identification results are exported to the Raspberry PI for further processing and application.

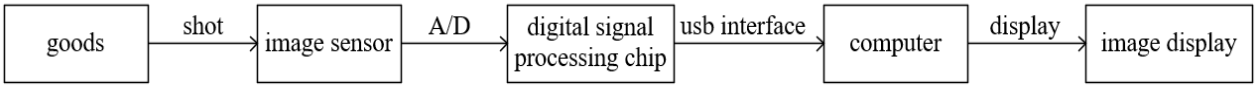


Figure 5. Camera working flow chart

3. System Analysis

3.1. Nine-screen analysis

The nine-screen method is a method to consider problems, which means that when analyzing and solving problems, not only the current system should be considered, but also its supersystems and subsystems. Consider not only the past and future of the current system, but also the past and future of the supersystem.

In this study, the current system is the express sorting equipment, the super system is the logistics center, and the subsystem is artificial intelligence technology. The nine-screen analysis diagram is shown in Figure 6:

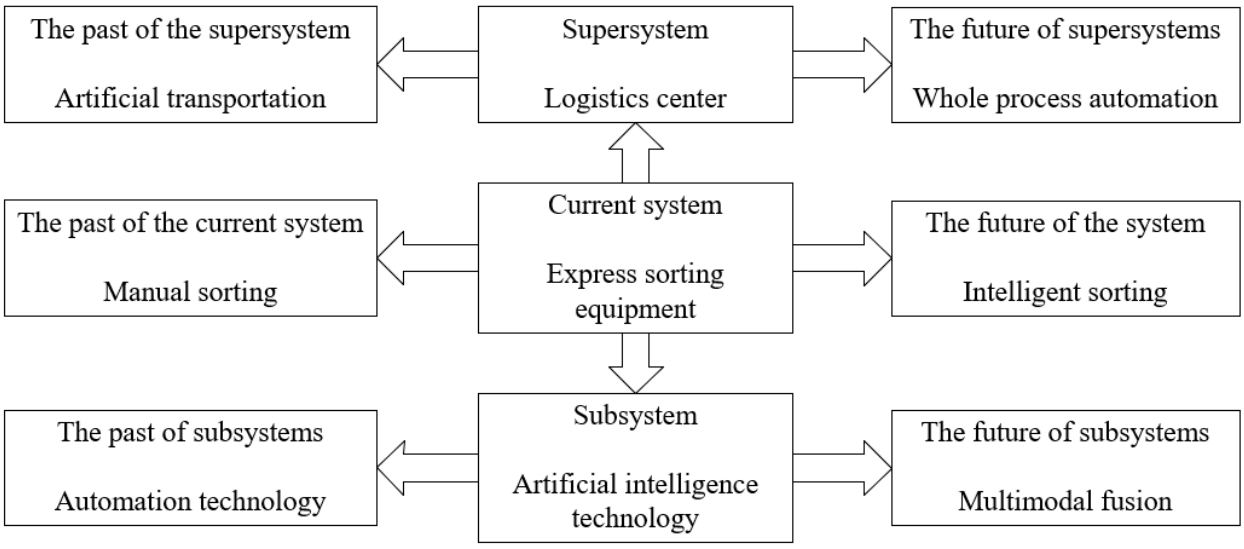


Figure 6. Nine-screen analysis diagram

Thus, one of the ways to solve the express sorting of small and medium-sized logistics centers can be obtained: the use of artificial intelligence technology to improve the automation equipment, integrate various modes, improve the accuracy and practicality of sorting, and reduce the labor burden and error rate.

3.2. Resource Analysis

In the TRIZ theory, resources refer to various elements in the system and its environment, which can reflect many system functions, functions, components, connection structures between components, information, energy flow, matter, form, spatial distribution, time parameters of functions, efficiency and other individual parameters related to functional quality[6,7]. It can be said that the essence of solving technical problems is the reasonable application of resources, the use of technical system resources is one of the most important means to improve the ideal degree, only with reasonable use of resources can solve all technical problems[8]. The essence of resource analysis is to study and analyze resources from the height of the system, dig the derived resources of the system, pay attention to the organic relationship between the system resources, rationally combine, allocate and optimize the resource structure, and enhance the application value or ideal degree of the system resources[9,10]. The sequence for selecting resources is shown in Table 2. A comparison of available resources is shown in table 3.

Table 2. The order in which resources are selected

Resource attribute	Selection sequence
value	Free → Cheap → expensive
quantity	Infinite → enough → insufficient
Quality	Beneficial → neutral → harmful
availability	Finished product → Available after change → Need to be built

Table 3. Comparison of available resources

Resource type	value	quantity	Quality	availability
Circuit board	At a low price	sufficient	beneficial	Finished product
K210 chip	At a low price	sufficient	beneficial	Need to build
shell	At a low price	sufficient	beneficial	Need to build
External contact switch	At a low price	sufficient	beneficial	Finished product
lead	At a low price	sufficient	beneficial	Finished product
support	At a low price	sufficient	beneficial	Finished product
display	costly	sufficient	beneficial	Finished product
Camera module	costly	sufficient	beneficial	Finished product
LED panel	At a low price	sufficient	beneficial	Need to build
Raspberry PI control	costly	sufficient	beneficial	Finished product
Voltage regulator circuit	At a low price	sufficient	beneficial	Need to build

3.3. Function Analysis

When improving the existing technical system, it is to clarify the main functions of the technical system and its auxiliary functions in order to understand the system and find out the problems of the system (Table 4).

Table 4. Functional analysis

Technical system	Intelligent sorting equipment
use	Quick sorting of deliveries in the express workshop
Technical function	Identify the express code, and display the express information on the display, including the place of origin, the place of transfer, and the destination, and sort the express according to these three locations. Maintain low power consumption when there is no express trigger to ensure the suitability of the system environment.
Main function	The equipment scheme has the characteristics of convenient use, adaptability, universality and strong security. The function of the device is to effectively identify and sort the express code based on Raspberry PI technology to ensure the normal operation and measurement accuracy of the device.

Combined with the resource analysis table, the following points can be identified:

1) Component analysis: camera, main control system, display, LED panel, voltage regulator circuit, goods, lighting environment.

2) Interaction analysis (Table 5).

Table 5. Interaction analysis table

module	camera	Main control system	display	Electric field	Voltage regulator circuit	cargo	Light environment
camera		+	+	+	+	+	+
Main control system	+		+	+	+	-	-
display	+	+		+	+	-	-
Electric field	+	+	+		+	-	-
Voltage regulator circuit	+	+	-	+		-	-
cargo	+	-	-	-	-		+
Light environment	+	-	-	-	-	+	

1) Build a functional model (Figure 7).

The problem that can be found is that the lighting environment has insufficient effect on the working performance of the camera, and the electric field has large energy supply and much consumption. It can be solved by adding light filling/shading equipment and improving energy saving methods.

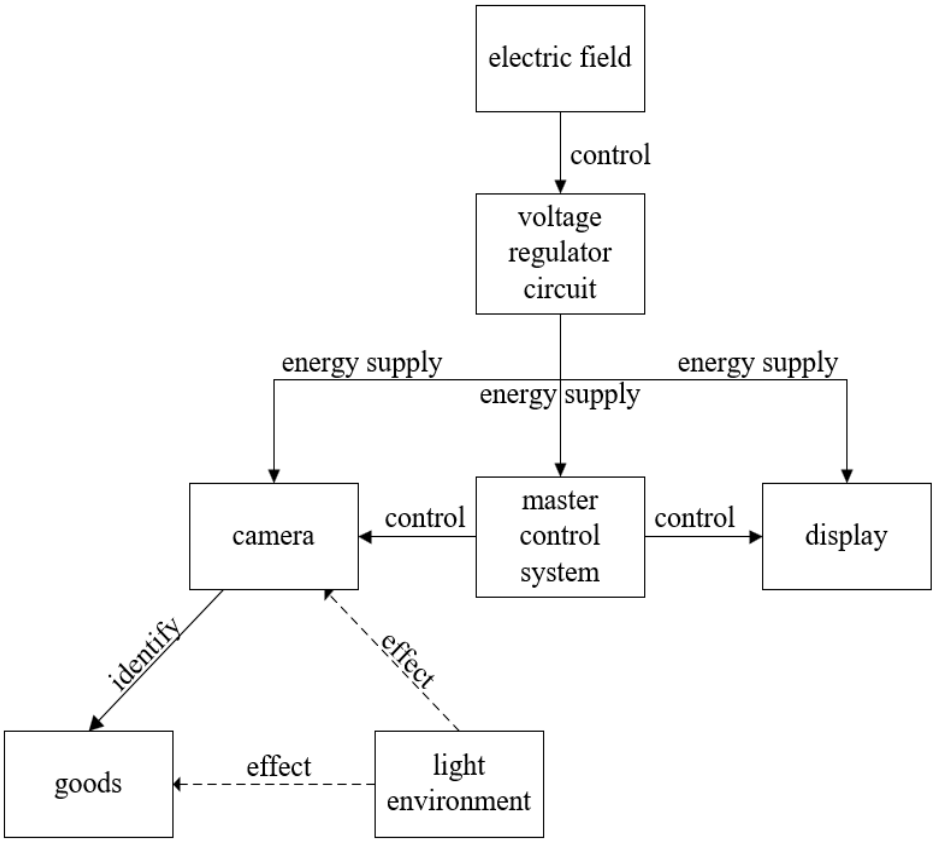


Figure 7. Functional model diagram

4. TRIZ tool to solve the problem

4.1. Technology contradiction matrix

According to the 39 general engineering parameters summarized by Archie Schuler, the theoretical founder of TRIZ, the visual epidemic risk detection system based on TRIZ theory is considered as the standard TRIZ problem. In three steps:

(1) The problem is that the detection system developed based on machine vision is inaccurate in the detection of the express code under certain lighting environments.

(2) The existing solution is to use it in a suitable lighting environment indoors, or to replace a clearer camera module to ensure the accuracy of the Courier code recognition system.

(3) The disadvantage of the existing solution is that the lighting environment is more complex, and the CPU operation rate should be considered after using a clearer camera module. This problem defines the technical contradiction.

The technical decomposition table is shown in Table 6, and the simplified technical matrix is shown in Table 7.

Table 6. Technical decomposition table

Primary classification	Secondary classification	Three-level classification	Four-level classification
Express code recognition	The camera recognizes the delivery code	Noise cancellation	Avoid light environment

Table 7. Simplified technical matrix

Improved parameter	Deteriorating parameter		
	25 time lost	36 Device complexity	26 The number of substances or things
28 Test accuracy	24、34、28、32	27、35、10、34	2、6、32
35 Adaptability and versatility	35、28	15、29、37、28	3、35、15
27 reliability	10、30、4	13、35、1	21、28、40、3
18 illumination	19、1、2、6、17	6、32、13	1、19

According to the contradiction matrix, principle 28 and principle 35 appear 4 times, and principle 1 and principle 6 appear 3 times. By looking up 40 invention principles in Table A-2 through contradiction matrix, it can be seen that principle 28 is the replacement principle of mechanical system, principle 35 is the parameter change principle, principle 1 is the segmentation principle, and principle 6 is the multi-function principle.

The replacement principle of mechanical systems: Replacing traditional mechanical systems by using other technologies or systems to improve efficiency, reduce costs and reduce waste of resources. For example, replace the mechanical system with hydraulic or pneumatic system, replace the mechanical system with electronic system, replace the mechanical system with software system, replace the mechanical system with biological system, replace the mechanical system with magnetic system, etc. This product uses an electronic system and a software system to replace the mechanical system of the traditional sorting machine. Electronic systems such as infrared sensors are used to detect and control mechanical motion, and software systems use computer vision and database queries to improve efficiency, reduce costs and reduce waste of resources.

Parameter change principle: A method to improve performance or solve problems by changing the parameters of a system or product. The parameters can be divided, combined, reversed, equivalent replacement and other operations to improve the performance. This product combines the original mechanical system with intelligent equipment through system combination to achieve accurate sorting and effectively improve product reliability.

4.2. Matter-field analysis

Object-field analysis is an important problem description and analysis tool in TRIZ theory, which is used to establish functional models related to existing system or new technology system problems, and find general and standard solutions corresponding to TRIZ theory according to the problems described by object-field models. Matter-field analysis treats all functions as being composed of two substances and one field.

The problem system is that the current system is too affected by the external lighting environment, so the following object-field analysis is made based on the description of the problem:

Step 1: Identify the Courier code; Step 2: Establish the matter-field model of the dynamic system (FIG. 8); The third step: Select the general solution of the matter-field analysis model. As can be seen from FIG. 8, this system belongs to the complete model with insufficient effect of the third type of object-field model. The functional elements exist that camera module S1 has insufficient effect on express code S2, which has three general solutions, namely 4, 5 and 6. General solution 4 is chosen for this problem.

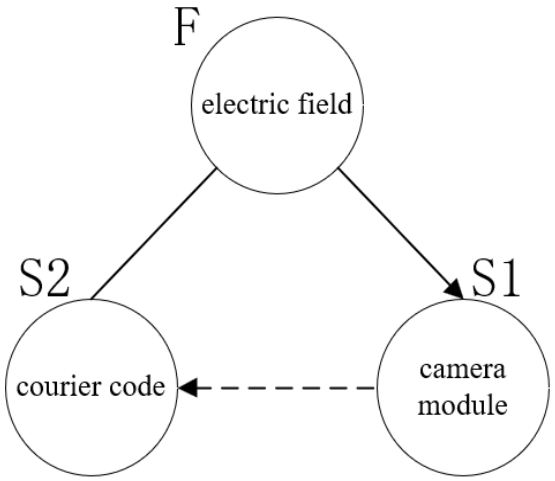


Figure 8. Matter-field model of dynamic system. Note: S1 - camera mode, S2 - express, F - electric field

Step 4: Develop the concept further (Figure 9)

General solution 4 is applied to introduce a third intermediate substance S3, which is used to improve the insufficient action. Insert additional material model as shown in figure. Through the systematic study of various substances, the external complementary optical circuit is finally selected as the material S3.

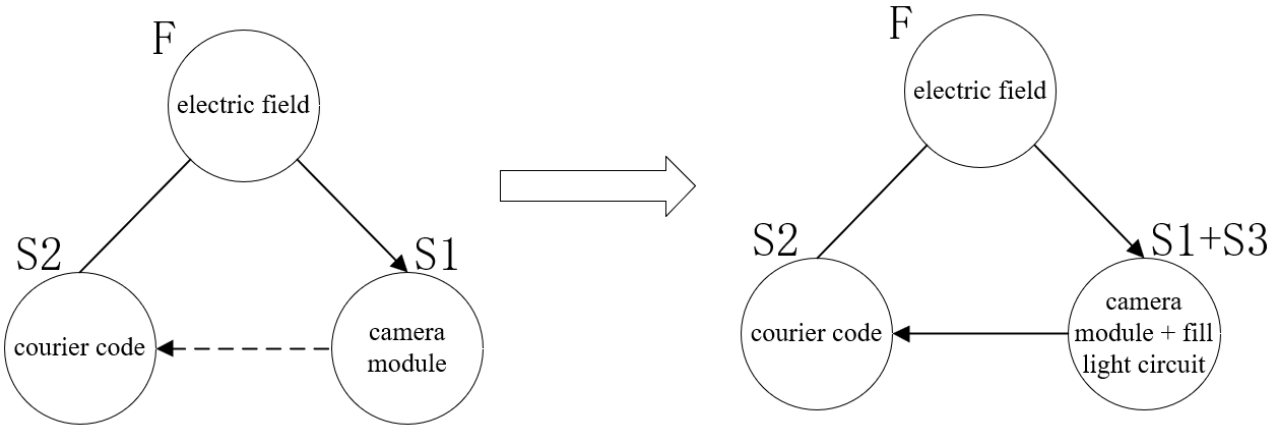


Figure 9. Substitute model

4.3. Final ideal solution model

IFR qualitative description: The system can achieve the maximum degree of self-service with the minimum degree of change.

IFR quantitative description:

$$\text{Ideal degree} = \frac{\sum \text{Useful function}}{\sum \text{Harmful features} + \text{cost}} \quad (1)$$

IFR Description Form: The system/component performs the required function without additional consumption.

IFR description form: X element, can not complicate the system, can not cause harmful effects, complete the specified function, and X element is preferably an internal system resource.

An important index of express sorting is the express code, but the detection of the express code under inappropriate light environment will cause misjudgment. To ensure the normal operation of the sorting work, it is necessary to ensure the normal operation of the identification system. Therefore, for the accuracy of camera recognition, the following analysis of the final ideal solution is obtained (Table 8).

Table 8. Analysis of the final ideal solution

procedure	Analytical specification
Step 1: What is the ultimate goal of design	To provide accurate and reliable intelligent sorting equipment for small and medium-sized logistics centers
Step 2: What is the ideal solution?	100% accurate identification of the destination, transit, origin of the Courier code, and sorting
Step 3: What are the obstacles to an ideal solution?	The camera cannot accurately identify the delivery code because of the lighting environment
Step 4: What is the result of this disorder?	The influence of complex lighting environment
Step 5: What are the conditions for not having this disorder?	Use the device in a suitable light environment
Step 6: What are the resources available to create these conditions?	Set up blackout tarps and use LED fill light

According to the technical contradiction matrix and the final ideal solution model, it can be seen that the available resources to solve this situation are the construction of shading tarpaulin and the use of LED fill light.

Among them, the use of blackout cloth can effectively avoid the external strong light environment to reduce the camera exposure, the image is too dark problem; The use of LED fill light can avoid the problem of low camera exposure and wrong recognition effect caused by low light environment. Through the control of the camera module, remote control, program control and computer control are realized, and then an automatic control system is formed (Figure 10).

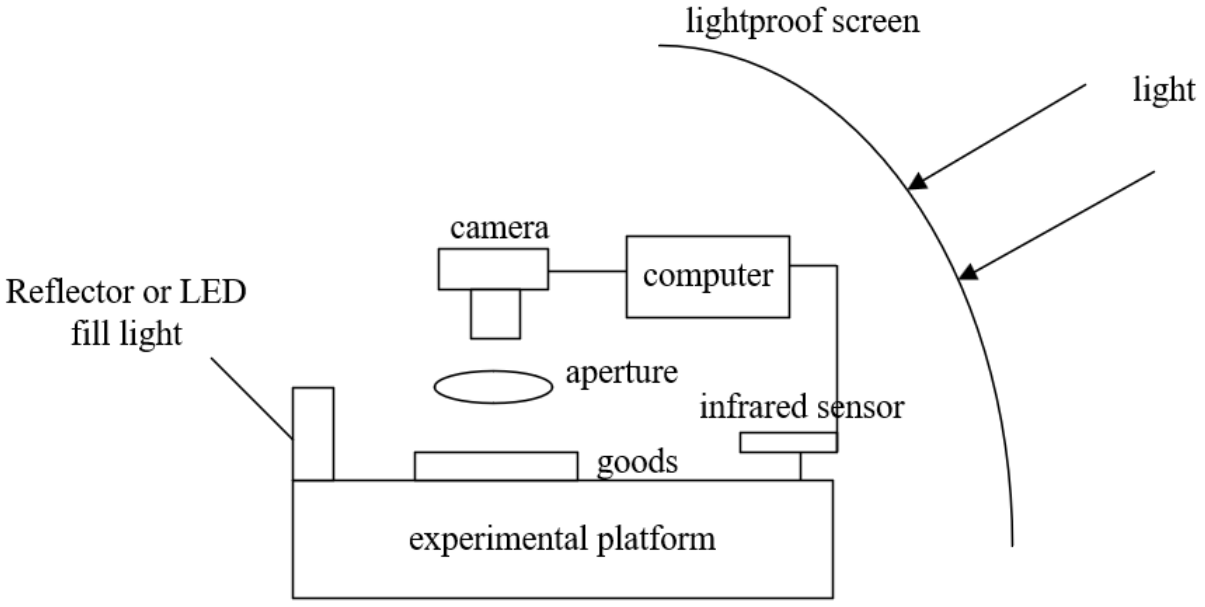


Figure 10. Schematic diagram of shading/filling scheme

Based on the analysis of TRIZ innovative method theory, the basic idea of "using shading and using LED fill light solution" is proposed as follows:

(1) For the complexity of the lighting environment, create a suitable light environment to avoid health detection and identification system detection errors.

(2) For the low light environment using LED fill light, strong light environment using shading measures to improve the accuracy of camera recognition.

5. All technical solutions and evaluation

Scheme 1: Dynamic extraction of tracking number data

Use high-resolution cameras to capture images of express packages to be sorted. Then, the image is preprocessed, including denoising, image enhancement and edge detection, to improve the recognition accuracy. Next, computer vision and image processing algorithm are applied to identify and extract the tracking number in the image. By querying relevant information, the corresponding sorting position is determined and the express package is placed in the corresponding position. Finally, the identified express tracking number and related information are entered into the system to achieve real-time logistics tracking and management.

Evaluation: For the gentle light source, the recognition accuracy is basically stable at 95%, but when the work is carried out without light source, the external physical light source is required to compensate or attenuate to ensure the accuracy of recognition.

Scheme 2: Face identification

For the correct collection of the recorded face information, Raspberry PI with a domestic self-developed chip RISC-V K210 camera (computational power 0.8Tops) with a computational power higher than 0.1Tops is used, and its single-chip computer (K210) is operated by yolo2 network. For the correct collection of the recorded face information, the team uses the domestic self-developed chip RISC-V K210 camera (computational power 0.8Tops) and the single-chip microcomputer (K210) with high computational power (0.1Tops) to ensure the correct collection of the recorded face information. The system uses yolo2 network to operate.

Evaluation: The recognition accuracy is stable at about 35 frames per second, and the performance is smooth. Using advanced neural networks to ensure accuracy, face recognition accuracy in the 1-2m range near the camera exceeds 99%.

Scheme 3: Use multi-layer and multi-channel infrared sensors for delivery quantity measurement

Using infrared sensors to detect and collect the number of express deliveries, Raspberry PI is responsible for collecting sensor data, and processing the digital signal of multi-layer and multi-channel infrared sensors, and finally obtain the accurate number of express deliveries.

Evaluation: The multi-layer and multi-channel infrared sensor is used for algorithm compensation technology, which effectively reduces the measurement error of single infrared sensor count.

Scheme 4: Transformation of infrared sensor window structure

For the transformation of the infrared sensor window structure, the main purpose is to shield the external light of the environment to prevent the infrared sensor data measurement error, so as to reduce the error of the delivery quantity measurement.

Evaluation: This scheme is low in cost and easy to implement, and can effectively ensure accurate measurement in accordance with the principle of material 35 parameter change principle

Option 5: Use infrared temperature measuring device

For special express items, it may be necessary to collect special environmental parameters, including but not limited to temperature, humidity and weight. To meet this demand, the team used GY906 and DHT11 sensors for temperature and humidity acquisition.

Evaluation: This scheme has little effect on the improvement of ordinary express goods, and is easy to worsen the complexity of the system, resulting in unnecessary increase in manufacturing difficulty and cost.

Based on the above investigation and analysis results, the team proposed the design of the region of interest extraction of the express tracking number and the detection device of human face data.

Scheme idea: Through dynamic extraction of express tracking number, face identification, multi-layer and multi-channel infrared sensor measurement and infrared sensor window structure transformation, the system can improve the sorting speed, accuracy and efficiency, reduce logistics costs, and provide accurate information for logistics tracking and management. These solutions can lead to higher sorting efficiency and accuracy, providing better service to the express delivery industry.

6. Conclusion

In this paper, an intelligent sorting device based on image recognition technology is designed to solve the sorting pressure caused by the rapid increase of express business volume. The equipment integrates computer vision, image processing, database query and other technologies to realize the automatic identification of express tracking number, sorting location determination and logistics information input, significantly improving the sorting efficiency and reducing labor costs. The system analysis shows that the equipment is suitable for small and medium-sized logistics centers and has a wide application prospect. As the e-commerce industry continues to develop, the equipment is expected to provide delivery companies with reliable and efficient sorting solutions, boosting their competitiveness and customer satisfaction. In addition, it also has the potential to be applied in other industries and fields, such as warehousing management. This paper provides a reference for the design and application of intelligent express sorting equipment.

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