AUTOMATIC BAGGAGE SORTING SYSTEM FOR THE AIRPORT BASED ON RFID

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In order to improve the efficiency of automatic passenger-portable baggage sorting in the airport security check and ensure the sorting accuracy, this paper designs an automatic baggage sorting system. In hardware, RFID is used to realize the location and identification of passenger-portable baggage sorting. Meanwhile, the automatic reuse and transfer of pallets are realized by sensors and conveyor belts. For software, a demo software for processing information is proposed. Besides, the accuracy of baggage identification is guaranteed by a series of anti-cross reading and miss reading measures. Finally, the feasibility of the system is verified by the case study.

Keywords: airport baggage sorting system, anti-cross reading, automatic pallet transfer, hardware design, photo-electric sensor, RFID.

1. Introduction

The passengers' baggage in the airport is divided into passenger-portable baggage and check-in baggage. The passenger-portable baggage does not need to be consigned, but it needs to be inspected by X-ray machine, and it is sorted into qualified or unqualified baggage for the inspection. The unqualified baggage needs a manual inspection. With the increasing number of flights at airports, the workload of baggage security check and sorting is much heavier. In order to cope with this pressure, greater demands are being placed on the passing density of baggage. The traditional sorting system in airport is mainly supported by Automatic Tag Reader (ATR), but the poor print quality or abrasion of the barcode and aging of optical elements will lead to the rate of success recognition reducing a lot, which is only about 80% [1]. For a medium-sized airport that handles 25,000 to 30,000 pieces of baggage per day, the cost of manual handling and the loss of lost baggage are significant. In contrast, RFID transmits information through electromagnetic waves, so it has faster read-write speed, smaller size, stronger anti-interference ability, and even can protect passenger information by encryption [2]. Due to the advantages, Wal-Mart Inc. has promoted the application of RFID to its logistics, transportation and commodity

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procurement. In 1997, the Federal Aviation Administration (FAA) proposed the application of RFID technology in international airports to replace the one-dimensional bar code previously used [3]. Also, in 2014 International Air Transport Association (IATA) put forward the RFID specifications 1740c practiced to aviation industry [4]. Therefore, with the maturity of RFID technology and the reduction of cost, we try to apply RFID to the automatic baggage sorting system for the airport passenger-portable baggage.

2. Function design of the automatic baggage sorting system

This study divides the system into the baggage security check subsystem and the pallet recycling subsystem. The baggage security check subsystem is responsible for the baggage inspection, information binding, baggage sorting and pallet transhipment, and the pallet recycling subsystem is responsible for the recovery of empty pallets after sorting.

The function of the baggage security check subsystem:

- Identify passengers: Recognize the passenger face, and the passenger ID card number from the passenger information system is fetched and bound to the pallet number in the database.
- Security check and weigh: The baggage is checked by the X-ray machine and weighed by the scale.
- Sort: Security check results are divided into qualified and unqualified.
- Transfer: The baggage from security check to sorting is transferred by conveyor belt.

The function of the pallet recycling subsystem:

- Recycle empty pallets: After sorting, the baggage is removed by passengers, leaving empty pallets, which will be transported by pallet elevators to the starting of the pallet recycling subsystem.
- Transfer empty pallets: The recycled pallets will be transferred to the starting position of the security check subsystem for subsequent passengers to place their baggage.
- Clear the bound information of the empty pallets: After the security check, the entries have been created with the pallet numbers as the main key in the database. The system needs to clear the bound information of the empty pallet so that it can be reused.

3. Architecture of the automatic baggage sorting system

As to implementation, the baggage security check subsystem mainly relies on RFID readers tags to realize, and cooperates with software to judge whether the reading and writing is successful or not [5]. The pallet recycling subsystem is controlled by sensors and motors to realize the reuse of empty pallets. In physical space, the two subsystems are connected by pallets. The working principles of automatic baggage sorting system is shown in Fig. 1.

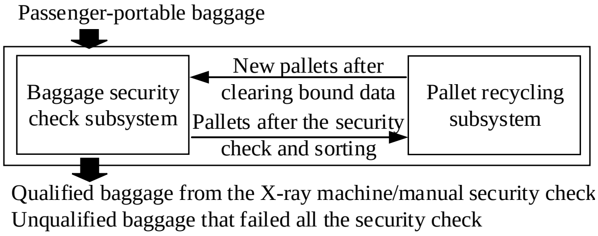

Fig 1. The structure of the automatic baggage sorting system for airport

3.1 Interface analysis of the automatic baggage sorting system

The external input information can be divided into two types, one is the contents of the passenger's baggage, and the other is the personal information of the passenger [6]. There is only one type of output information, that is, whether the baggage of a certain passenger passes the security check. Finally, the system will generate a security log in days for subsequent review and backup.

The data transmits between the subsystems by network ports in accord with TCP/IP protocol, the communication between the RFID reader and the tag complies with the ISO/IEC 18000-6 protocol [7]. Commands from the reader alternates with answers from the label.

3.2 The process of the automatic baggage sorting system

The baggage sorting system is divided into two layers, the upper layer is the baggage security check subsystem, and the lower layer is the pallet recycling subsystem. The views of the line are shown in Fig. 2.

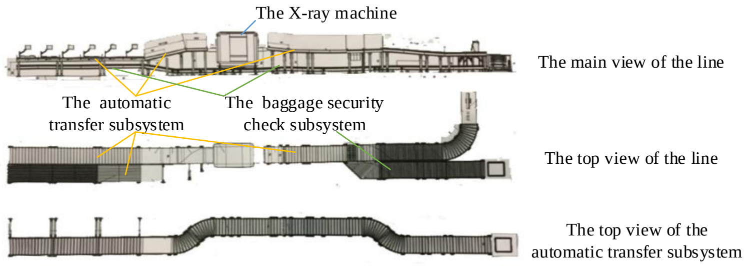

Fig 2. The views of transfer line

Passengers place their baggage into the pallets at the start position of the automatic baggage sorting system. The pallet is sent to the X-ray machine for security check. Then the pallet flows to two routes according to the results:

(a) The pallet is transferred to manual inspection area.

(b) The pallet is transferred to the automatic elevator for recycling. Before that, the baggage in the pallet will be removed by its owner.

Finally, the pallet is carried to the pallet recycling subsystem by the automatic pallet elevator, and along the conveyor belt, it is conveyed to the start of the automatic baggage sorting system. As is shown in Fig. 3.

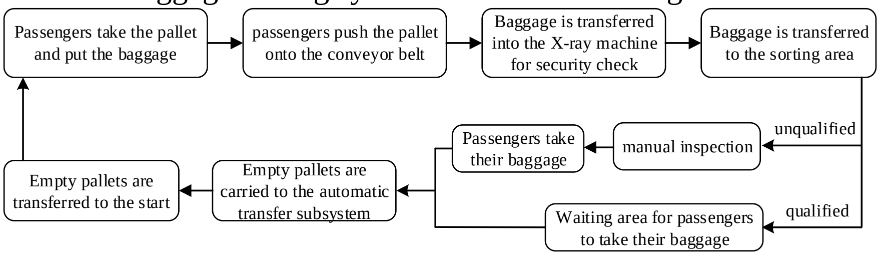

Fig 3. The process of the automatic baggage sorting system

4. Hardware design of the automatic baggage sorting system

4.1 Hardware design of the baggage security check subsystem

4.1.1 Layout of the baggage security check subsystem

In the baggage security check subsystem, an X-ray security check machine is equipped with n placing baggage areas and n transferring baggage areas, the conveyor belt for sorting, the baggage waiting area, manual security check area and so on. A placing baggage area correspond to a transferring baggage area. The number of the placing baggage area n is determined by the throughput of the airport. The function of each part is shown in Table 1, and the layout of the baggage security check subsystem is shown in Fig. 4.

Table 1

Function description of each part

Parts of the line	Function description
Placing baggage area	Passengers place their baggage in the labeled pallet for sorting.
Transferring baggage area	Passengers push the pallet with baggage to the corresponding transferring baggage area, and the pallet will be transferred by the conveyor belt.
Conveyor belt	Transit the pallets with baggage into the X-ray machine for security check.
X-ray machine	The security check for the baggage. Output the inspection screenshots and results.
Sorting area	Transfer pallets to different lines according to the inspection results
Baggage waiting area	The qualified baggage arrives in the area and waits for the passenger to take.
Manual security check area	Baggage that has not passed the X-ray security check will be manually checked here.

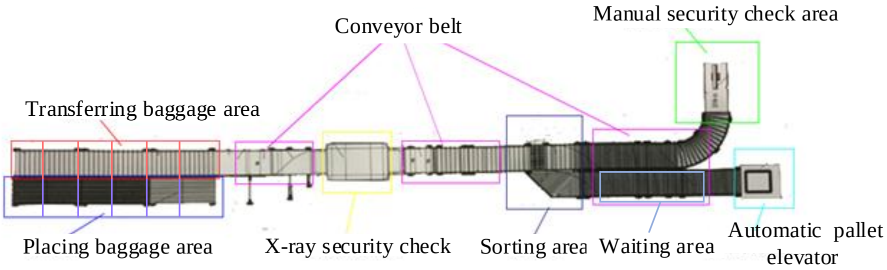

Fig 4. Layout of the baggage security check subsystem

4.1.2 Hardware design of the RFID reader

In the whole system, only one RFID tag is pasted on the fixed position of the pallet, which identifies the unique code of each pallet.

(1) Layout of the RFID readers

In the baggage security check subsystem, a photoelectric sensor is placed in the vicinity of each RFID reader to trigger the reader to start working or sense the position of the pallet. Its layout and function are shown in the Table 2. A schematic diagram of a set of placement and push bits is shown in Figure 5

Table 2

The layout of sensors in the security check subsystem

Position	Sensor	Function description
Placing baggage area	Photoelectric sensor	Trigger the face recognition probe in the corresponding placing baggage area to start working.
Transferring baggage area	Face recognition probes	Collect portraits.
	Photoelectric sensor	Trigger the corresponding RFID reader starts working
	RFID reader	Collect the pallet number, which will be send to the data processing system .
Position before the X-ray machine	Photoelectric sensor	Trigger the corresponding RFID reader starts working
	RFID reader	Collect the pallet number to query the database and check whether the passenger information is successfully bound. Detect whether there is a pallet enter the X-ray machine.
Position after the X-ray machine	Photoelectric sensor	Trigger the corresponding RFID reader starts working
	RFID reader	Bind the pallet number and baggage inspection result in the database. Check if the pallet leaves the X-ray

		machine.
Sorting area	Photoelectric sensor	Trigger the corresponding RFID reader starts working
	RFID reader	The information of the baggage arriving at the sorting area is send to the control system

Fig 5. Layout of the baggage security check subsystem

(2) Determining the parameters of RFID

The subsystem is in a complex metal environment. When the reader is triggered, it is close to the tag, and there is a large demand for the information capacity of the tag, so the UHF (ultra-high frequency) is a suitable choice [8].

Secondly, there are two common problems in the application of RFID technology, that is, the miss reading and the cross reading. The miss reading means that no tag is read when the RFID reader is triggered. Cross reading refers to the two adjacent RFID readers not only read the tag of their respective area, but also read the tag of each other's area, that is, one RFID reader reads two tags at the same time [9]. The cross reading can be improved by reducing the number of tags in baggage security check subsystem, optimizing the layout of RFID readers or a recognizing algorithm of the software system. The problem of miss reading can only be solved by increasing power of readers, the reading time or the number of antennas. Thus, the miss reading occurs mainly when passengers put their baggage into the pallet. For these areas, if the built-in antenna (a single-port communication module connected with a single antenna) cannot achieve read-write capability, a single port connected with an array of antennas or the four ports contribute to improve the power of RFID readers and reduce the miss reading.

In practice, due to the mismatch of the impedance between the antenna and the equipment, there is some energy reflected, which cannot be radiated through the antenna and interferes the operation of the communication module

[10]. To measure the matching of the antenna and port, the return loss is calculated by the formula (1):

$$\mathrm{Re}\,turnLoss(dB) = -10\log\frac{\mathrm{Re}\,flectedPower}{IncidentPower}(dB), \tag{1}$$

According to the airport standard and actual conditions, the design is acceptable when the accuracy rate of baggage and passenger recognition is above 99.2%. According to the throughput of the airport, this paper sets n=6, that is, 6 placing baggage area and 6 transferring baggage area with each X-ray machine. The model of the RFID reader is ANG-RF-1C, its antenna frequency is 922.5MHz, and the working power is 26dBm [11]. After tests, each time the RFID reader works for t = 0.5 seconds, there is acceptable success rate of reading. The effective reflection distance of the photoelectric sensor is between 20mm and 40mm, and the photoelectric sensor communicates with the RFID reader through the interface.

4.2. Hardware design of the pallet recycling subsystem

The hardware in the pallet recycling subsystem includes a RFID reader, some photoelectric sensors and an automatic pallet elevator. The RFID reader is located at the start of the pallet recycling subsystem. After it collects the number of the recycled pallet, the bound passenger and baggage information of the pallet will be cleared, and be transmitted to the baggage transfer information database and generate a security log for reference. The method of determine the parameters of RFID readers is the same with the baggage security check subsystem.

The automatic pallet elevator is responsible for transferring the empty pallets from the upper layer of the line to the lower entrance of the pallet recycling subsystem. The pallets will be transferred to the position below the placing baggage area by the convey belt [12]. Each end of the segments is equipped with a photoelectric sensor to sense whether there is a pallet to control the running or pausing of the conveyor belt to avoid the accumulation of pallets.

5. Software design of the automatic baggage sorting system

5.1 Software design of the baggage security check subsystem

With the architecture design of the automatic baggage sorting system, the data processing system is designed to achieve the following objectives:

- The data processing system should be able to support the entire process of baggage security check.
- There is a data interface between the baggage security check information collection module the face recognition module for the data processing system

to judge whether the baggage information is bound to the face information in real time.

- As the upper monitor, the data processing system is able to process the information from multiple RFID readers simultaneously.

In the complex metal environment of placing baggage area (including metallic objects of passengers, metallic roller bed for transferring and a lot of sensors), it is easily to cause the problem of cross reading and miss reading. For this issue, an algorithm can be provided to filter the cross reading information.

Each time the RFID triggers, the anti-cross algorithm will be enabled. Whether one tag or multiple tags are read, the algorithm will give a decision. [13] The principle of the algorithm is as follows: Since the tag signal of cross reading is transmitted from adjacent area or from reflection by the metal roller bed, its signal strength is weaker than that of the correct area. Thus, in the same working time t of the RFID reader, the reading times Count of the cross reading tag are less than the reading times of the correct tag. Meanwhile, the RSSI (Received Signal Strength Indication) value of the signal from cross reading is smaller than that of the correct signal. With these two criteria, the signal from cross reading can be filtered. The procedure of the algorithm is shown in Fig. 6. The screenshot in the software is shown in Fig.7.

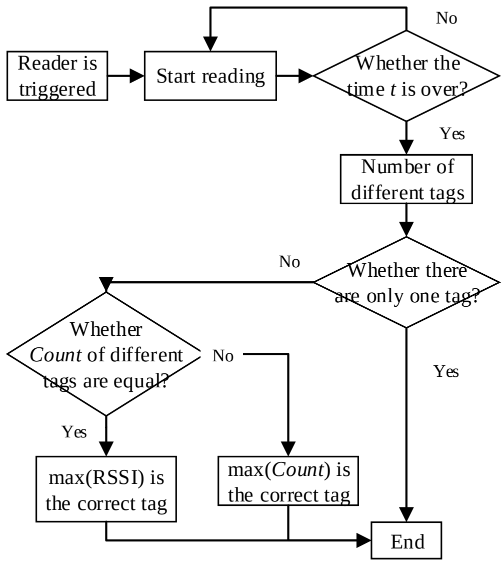

Fig 6. The procedure of anti-cross read algorithm

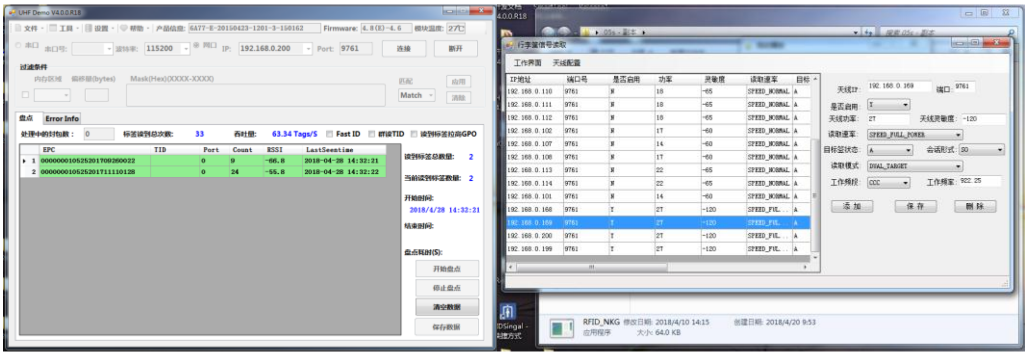

Fig 7. The procedure of anti-cross read algorithm

5.2 Software design of the pallet recycling subsystem

The software module of the pallet recycling subsystem can be divided into the temporary database clearing and the electromechanical control.

The temporary database clearing refers to clear the information of empty pallets. When the tag of the recycled pallet is read by an RFID reader located on the side of the conveyor belt, the information of the tag will be reported to the data processing system. The information of baggage and its owner is send and stored in the baggage transfer information database. After dumped, the entry of the recycled pallet will be cleared, and the pallet will be re-placed into the baggage security check subsystem for subsequent passengers to use.

The electromechanical control refers to control the running or pausing of each segment conveyor belt to avoid the pallets accumulating under the placing baggage areas [14]. The switch of photoelectric sensors is installed on the end of each segment. If the sensor senses the pallet, the conveyor belt of the segment will stop running.

6. Case study

The miss reading and cross reading are caused by the metal environment of this system, so the paper provides three possible cases of the pallets: no metal cover (empty pallet or non-metallic objects in the pallet), partial metal cover (side metal cover or bottom metal cover), metal objects in the pallet (metal suitcase or metal sundries). Besides, in the baggage security check subsystem, the placing baggage areas, the transferring baggage areas, and the transition areas (the position between the placing baggage area and the transferring baggage area) is adjacent. The concentrated RFID readers are prone to the problem of cross reading and miss reading. Therefore, position around the three kind of areas are taken as the position of interference pallets to test the possible status. The test pallet will be pushed from the placing baggage area to transferring baggage area.

Generally, the pallets in the pallet recycling subsystem are empty, and there are less RFID readers. The probability of mutual interference is pretty small, so there are no interference pallets for the pallet recycling subsystem. Only the accuracy of various types of pallets is tested. The test results are shown in the Table 3 and Table 4.

Table 3

The test result of the pallet recycling subsystem

Case of the test pallet	empty / Non-metallic debris	full metal cover	side metal cover	metal suitcase	metal compute
Number of errors/experiments	0/300	1/500	1/500	0/300	0/400

Table 4

The test result of the baggage security check subsystem

Interference pallet	Test pallet	Case of the test pallet（Number of errors/ experiments）: no metal cover	bottom/side metal cover	metal suitcase/ computer
Near the position B b)	no metal cover	0/90		
	bottom/side metal cover	7/350	2/120	0/90
	metal suitcase/ computer	0/170	0/60	
Near the position C c)	no metal cover	0/60		
	bottom/side metal cover	1/180	0/60	0/90
	metal suitcase/ computer	0/140	0/60	
Near the position A a)	no metal cover	0/120	0/60	0/60
	bottom/side metal cover	1/180	0/60	0/90
	metal suitcase/ computer	0/140	0/60	
Right below the position A	no metal cover	0/120	0/60	0/60
	bottom/side metal cover	0/120		
	metal suitcase/ computer	0/80		
Below the position A side	no metal cover	0/60		
	bottom/side metal cover	0/120		
	metal suitcase/ computer	0/80		

Notes: a) Position A represents the placing baggage area. b) Position B represents the transferring baggage area. c) Position C represents the transition area.

When there is a miss reading or the anti-cross reading algorithm fails to discriminate the correct RFID tag, it is recorded as an error. The baggage security check subsystem is tested 2,940 times in total, and 11 errors occurred, including 3 miss reading and 8 cross reading. The accuracy of reading tags and binding information is 99.62%. The performance of the system is pretty stable. The case with the most errors is that the test pallet is empty with the interference pallet of bottom or side metal cover. The RFID reader is prone to read the tag of the interference pallet. According to the principle of cross reading, it is possible to try to reduce the power of the RFID reader, thereby reducing the signal coverage of the RFID antenna and the probability of cross reading.

The pallet recycling subsystem is tested 2,000 times in total with 2 errors of miss reading, and the accuracy of reading tags and binding information is 99.90%. The RFID reader in the pallet recycling subsystem works stably, and the miss reading occurred when there is metal cover in the pallet. Besides, there is no metal cover in the recycling pallet in general, so the reading accuracy of this subsystem may be higher in the actual application. In summary, the design of the two subsystems meets the accuracy and manual workload requirements of the company's airport.

7. Conclusion

Aiming at the airport baggage sorting system, this paper presents the framework and the layout method of automatic baggage sorting system based on RFID technology. In this paper, it is divided the baggage security check subsystem and the pallet recycling subsystem, and its working procedures is proposed. The measures to avoid the miss reading and cross reading are as follows.

Anti-miss reading:

- The tag is attached to the fixed position of the pallet, so the position of is not affected by the size of the baggage.
- When passes by the RFID reader before the X-ray machine, each tag on the pallet will be queried its bound information in the database. The miss-reading tag will lead to the alarm.
- Increase the power of the RFID reader.

Anti-cross reading:

- Each RFID reader is equipped with a photoelectric sensor to make the reader work only when there is a pallet in its area.
- The anti-cross reading algorithm is use to recognize the correct information.

The effectiveness of the measures is verified by the case study, which can ensure the accuracy of baggage identification. The automatic baggage sorting system for airport has reference significance for improving the automation of the sorting system and reducing the workload of sorting passenger-portable baggage and recycling pallets.

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