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# Multi-mode Intelligent Storage and Retrieval Systems in Automated Warehoue

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**Abstract:** In this paper, we study the multi-mode intelligent storage and retrieval systems in automated warehouse. Automated warehouse is the important component of modern Logistics. The storage and retrieval efficiency is an important problem in automated warehouse. Robot technology was used in the design of warehouses aiming to improve the efficiency greatly. The RFID technology is first applied to locate the target roughly and to obtain the attributes of the target. Then the onboard vision is used to recognize and locate the target precisely. Finally, the teaching mode and remote mode are used to assist robot to grasp the target successfully, which can not only reduce the complexity of robot control, but also make full use of the results of image processing. An Intelligent storage and retrieval system in Logistics automated warehouse had been put forward in the paper. A lot of experiments demonstrate the feasibility of the proposed system.

**Keywords:** Automated warehouse, computer vision, intelligent storage and retrieval systems, multi-mode, RFID, robot control technology

## INTRODUCTION

With the rapid development of modern logistics technology, automated warehouse was widespread accepted as an important part of modern logistics system (Fig. 1). The development of automation technology applying in bin storage fell into four successive phases: manual bin storage phase, mechanized bin storage phase, automatic bin storage phase and intelligent bin storage phase. In the first phase, the transportation, storage and management of materiel are realized by person. In the second phase, the materiel can be moved and carried by conveyer belt, vehicle and lifter. In the third phase, servomechanism can be manipulated by person in automated warehouse. In the last phase, the technology of artificial intelligence is applied, the higher phase of automated warehouse, which can be take on a wide foreground (Hagras and Callaghan, 2001).

Automated warehouse now mainly stays at automated level, it is consist of goods frame, hay stacker, in or out store conveyer automatic control system and management information system, it can automatically complete the deposit and withdrawal work of cargo according to the instruction and also it can carry on the automated management to the warehouse cargo and make the material move and storage more reasonable. But when this kind of automated warehouse is doing selection work, it requires manpower to identify cargo and operate in or out of warehouse work which greatly reduced the warehouse operating efficiency.

Fig. 1: The sketch map of automated warehouse

The current warehouses which are often operated manually usually include palletizing robots, carton flow order picking systems, automated guided vehicles, rotary storage cabinets and automated storage and retrieval systems (Amato *et al.*, 2005). The main shortcoming of the current warehouse is that the efficiency of its storage and retrieval systems is very low, which is also a bottleneck to restrict the development of automated warehouse. Therefore, how to improve the efficiency of automated storage and retrieval systems and realize intelligent control without

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manual intervention becomes a very important issue. The application of computer vision technology and robot technology in logistics automated warehouse, provide a effective way to resolve this difficult problem which has the major practical project significance.

In recent years, because of its ubiquity, Radio Frequency Identification (RFID) technology has becoming the hotspot in the field of object location (Cerrada *et al*., 2009; Kim *et al*., 2009). RFID systems use radio transmissions to send energy to a tag which, in turn, emits a unique identification code back to a reader linked to an information management system. If the RFID tags with unique codes are embedded in objects, the identification of the objects can be greatly simplified. Furthermore, RFID has a lot of advantages, such as contactless communications, long lived, high data rate, non line-of-sight readability and low cost (Kamol *et al*., 2007). For the above reasons, RFID technology has been often employed to recognize objects for navigation, manipulation, etc.

In this paper, we study the multi-mode intelligent storage and retrieval systems in automated warehouse. Automated warehouse is the important component of modern Logistics. The storage and retrieval efficiency is an important problem in automated warehouse. Robot technology was used in the design of warehouses aiming to improve the efficiency greatly. The RFID technology is first applied to locate the target roughly and to obtain the attributes of the target. Then the onboard vision is used to recognize and locate the target precisely. Finally, the teaching mode and remote mode are used to assist robot to grasp the target successfully, which can not only reduce the complexity of robot control, but also make full use of the results of image processing. An Intelligent storage and retrieval system in Logistics automated warehouse had been put forward in the paper. A lot of experiments demonstrate the feasibility of the proposed system.

## RFID AND COMPUTER VISION IN INTELLIGENT STORAGE AND RETRIEVAL SYSTEMS

RFID and computer vision based intelligent storage and retrieval systems mainly include two parts: RFID and computer vision. RFID technology is used to localize the target roughly and computer vision is used to localize the target precisely.

**RFID localization system:** The RFID system mainly includes three parts: reader, antenna and RFID tag. Because of the uniqueness of the RFID tag, the reader can locate and track the target once it is attached on an RFID tag. Passive tags are used to attach on the target object because they are much cheaper, long lived, lightweight and have a smaller foot print. The reader can communicated with host computer through RS232. The CCD camera is mounted on the end of the arm, which can distinguish the target using color and shape of the object. Inspired by LANDMARC positioning system (Ni *et al*., 2003), the conference tag is introduced in the paper. The conference tags divided into 5 rows 6 columns are distributed on the bottom of a tray, shown in Fig. 2. The real position of each conference tag is recorded in it. Furthermore, each of the considered target objects of the database is also attached to an RFID tag, which is called as target tag. When the reader detects the conference tag and the target tags, the robot can know the name and count of real targets in its detecting field, which can reduce the number of matching items in the database and the rough position of object can also be calculated at the same

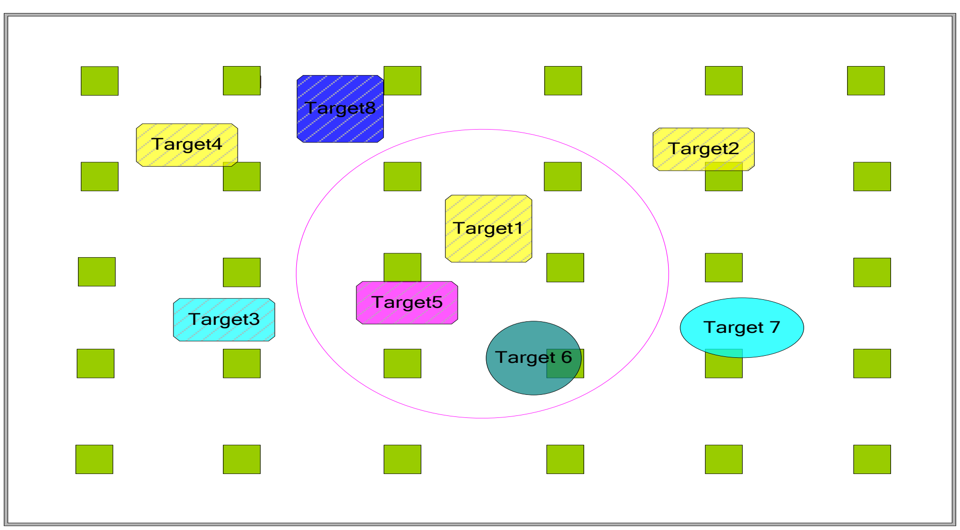


Fig. 2: Distribution of reference tags

time. In Fig. 2, the green box indicates the conference tag and the red circle represents the detection range of the RFID antenna. The other colored shapes mean different targets. From Fig. 2, we can conclude that there are 6 conference tags and 3 targets in the detection range of RFID, so the rough position of the target can be calculated as:

$$(X_T, Y_T) = \left[ \sum_{i=1}^{N} (X_i, Y_i) \right] / N \tag{1}$$

where, N is the number of conference tags.

**Computer vision system:** Computer vision can be easily seen as using camera to substitute for human's eyes, using computer instead of human's brain, so as to complete recognition and explanation of circumstance and objects. Computer vision system is mainly consisting of three parts: picture obtaining, picture processing and the analysis, the output or the demonstration. The large amount of data of picture information is a big difficulty for picture processing, it requires the situation of processing picture information at high speed and it should join the special-purpose image processor, while general picture processing may directly send into the computer to carry on processing. The work which computer complete are mainly image underlying bed disposing, image characteristic withdraws, pattern recognition and understanding and so on.

Computer vision is a new discipline which develops so rapidly, since the 1980's, the robot vision research has experienced the phase from laboratory towards the practical application development. From simple binary image processing to High-resolution and multi-gradation imagery processing, from general two-dimensional information disposing to three-dimensional visual mechanism as well as the model and algorithm research have all made very big progress. While the computer industry improve so rapidly and the development of discipline such as artificial intelligence, parallel processing and neuron network, promoted the robot vision system's practical application and steps in many complex visual processes the research. At present, robot vision is widely applying to the visual examination, robot visual guidance and in the automated assembly domain.

The robot vision system first uses the CCD photographic camera to absorb the image and to transform as the digital signal, then it uses the advanced computer hardware and the software technology to carry on processing to the image digital signal, therefore obtains each kind of required picture target characteristic value and from which realize many kinds of functions such as pattern recognition, coordinates computation, gradation distribution map and so on. Then according to its results completes automated procedure such as display image, output data, send out the instruction, complete adjusting the position in harmony with implementing agency, data statistics and so on. Compared with artificial vision, the most advantages of machine vision are precise, fast, reliable and digital.

When the rough position of target is determined, the manipulator recognizes the target using the onboard camera. In this paper, the color and shape information are used to recognize the target.

The video provided by camera is in RGB space. In order to reduce the influence of light, we transform the RGB space to YCbCr space which can separate the illumination from hue. Gaussian model is used to color detection because the parameters are easily to calculate and the detection rate is high. For the image transformed to YCbCr space, the similarity degree to the target is calculated as:

$$p(CbCr) = \exp[-0.5(x-m)^T C^{-1}(x-m)] \tag{2}$$

where,

$x = (C_b\, C_r)^T$
$m = E(x) = (\bar{C}b, \bar{C}r)$
$\bar{C}b$ = the mean of Cb
$\bar{C}r$ = the mean of Cr
C = the variance matrix

Next, the similarity image is transformed to a binary image and the white regions are the interesting areas where the target may exist. The interesting areas still include some other regions whose color is similar to the target, so the shape information is used to extract the target accurately. Median filtering is a non-linear smoothing method that reduces the blurring of edges, in which the idea is to replace the current point in the image by the median of the brightness in its neighborhood. The median of the brightness in the neighborhood is not affected by individual noise spikes and so median smoothing eliminates impulse noise quite well. Further, as median filtering does not blur edges much, it can be applied iteratively. Clearly, performing a sort on pixel within a rectangular window at every pixel position may become very expensive. A more efficient approach is to notice that as the window moves across a row by one column, the only change to its contents is to lose the leftmost column and replace it with a new right column. Median smoothing is a special instance of more general rank filtering techniques, the idea of which is to order pixels in some neighborhood into sequence. And also median filtering keeps the image's edge effect, which facilitate edge extraction and easy to realize.

Then it uses the method of linear substitution to strengthen the image contrast gradient, through gradation scope linear substitution to increase the contrast between background and cargo, to arrive at the effect of enhancing edge characteristics and favor the edge examination. Suppose that the gradation scope of input picture $f(x, y)$ is [a, b], the gradation scope of

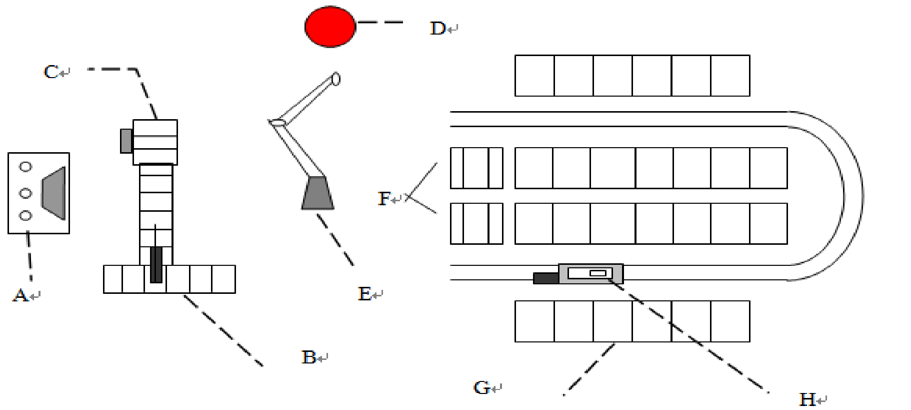


Fig. 3: Composition of automated warehouse

output picture $g$ $(x, y)$ is [m, n], then the contrast gradient strengthens may be represented as:

$$g(x,y)=\begin{cases}[(n-m)/(b-a)][f(x,y)-a]+m & a\le f(x,y)\le b\\ m & f(x,y)<a\\ n & f(x,y)>b\end{cases} \quad (3)$$

Regardless of to the humanity or machine vision, the image's edge information is of most importance, the image's edge has the advantages of outlining the region shape, being defined in part and delivering most part of image information, consequently, edge examination can be seen as a key to deal with many image problems. Edges are often used high in image analysis for finding region boundaries. Provided that the region has homogeneous brightness, its boundary is at the pixels where the image function varies and so in the ideal case without noise consists of pixels with high edge magnitude. It can be seen that the boundary and its edges are perpendicular to the direction of the gradient.

## ROBOT CONTROL TECHNOLOGY IN INTELLIGENT STORAGE AND RETRIEVAL SYSTEMS

The composition of automated warehouse is as Fig. 3 shows. There are four rows of automated shelves including 120 cargo spaces divided into two tunnels, an automated stacker, two storage and retrieval platforms and a SK6 manipulator with six-freedom, etc. SK6 produced by Yaskawa is used in the warehouse. The controller of SK6 is YASNAC MRC II, which adopts interactive programming language INFORM II. There are two programming ways: teaching and remote control. In this paper, we combine the two ways together to simplify the system design.

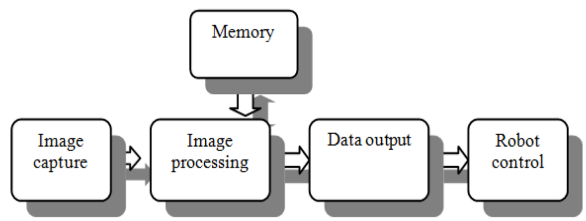


Fig. 4: Composition of robot control system

Take in warehouse work in logistics automated warehouse as an example (Fig. 4). First of all, we should put the cargo waiting to go into warehouse on even chain conveyer, in the transport process of cargo the bar code recognizer reads the bar code pastes on the cargo and delivers the value to the controlled computer, then weigh the cargos on weighing machine. At the same time, we start the robot, the robot hand rotates above to the weighing machine, the camera captures the image underneath and gathers the image into computer through image gathering card which installs in the mainly controlled computer, carries on image processing, calculates the central point and transform the robot's working coordinates, with sucker installed on robot hand captures the cargos and put them to enters goods. Then the hay stacker starts, delivers the cargo assigned the storage space. Work process of out warehouse on the contrary.

The control system of the automated warehouse include management/monitor computer, master PLC and lower PLC, which are connected by Modibus and wireless networks and can build up a complete multi-level computer monitoring system. The whole automated warehouse system integrated cargo storage, retrieval, distribution and transportation together, realizes intelligent operations in the whole system and is an intelligent warehouse without any manual

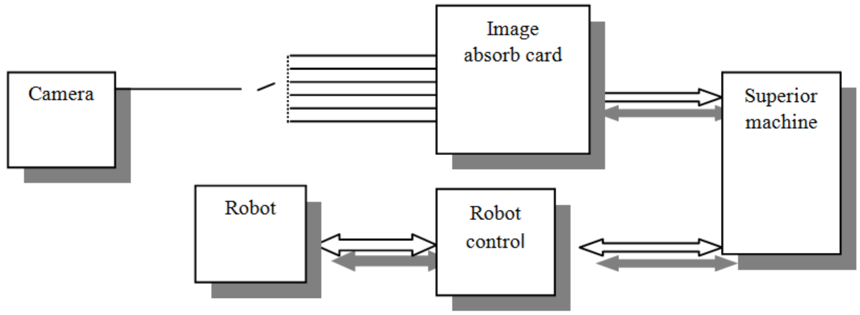


Fig. 5: The control system of automated warehouse

operation. In the process of robot control, we use the method which unifies the demonstration programming and the long-distance communication; transmit the cargo's central point data and the long-distance control order to robot controller from the main controlling machine (Fig. 5), to achieve the control of robot's flexible control and the cargo transporting.

In order to realize the information interoperability and context interconnected, the information representation and acquisition model should be built to provide different levels information to the robot. In traditional pattern, the relationship between robot and sensing devices is one to one occupying mode, the robot and the computational environment is fixed and bounded in advance. While in the intelligent space, the computational resources and all kinds of devices tend to be public and sharing. The information services in intelligent space can not only provide the primitive signal, but also can provide multi-level information based on multi-sensor data fusion. A new information acquisition system based on distributed data fusion tree is proposed to provide multi-level information to users; the experiments demonstrate that the robot control system based on multi-pattern information acquisition can improve the positioning precision and the visiting efficiency.

## EXPERIMENTS AND ANALYSES

Taken automated retrieval operation as an example. The target is placed on the rotary platform, the manipulator first localize the target using RFID, then recognize and trace the object using onboard vision, finally grasp the target and place on the weighing platform. From a lot of experiments, we can conclude that:

- The manipulator can trace the planned path accurately.
- The host can read the data file and generate the command sequence correctly and can save the data to the variable to control the robot grasping the target.

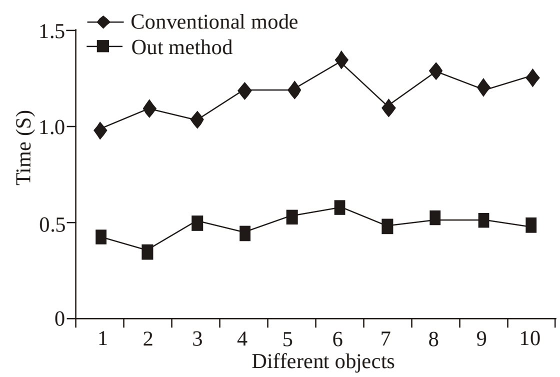


Fig. 6: Efficiency of retrieval system

- The teaching and remote modes are used flexibly in the paper, which can not only simplify the programming, but also can improve the flexibility of the automated storage and retrieval system.

Figure 6 shows the efficiency in different methods. We can see that our method adopts multi-mode information provided by RFID and vision and can improve the efficiency about 50%.

## CONCLUSION

Automated warehouse is the important component of modern Logistics. How to improve the efficiency of the goods' recognition and picking is the pivotal problem in modern Logistics technology. The robot technology is used in the automated warehouse in the paper and a kind of target recognition, localization and storage/retrieval scheme based on RFID and vision technology is proposed in order to improve the efficiency of automated storage and retrieval systems. The experiments demonstrate the feasibility of the system.

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