International Journal of Control and Automation
Vol. 9, No. 6 (2016), pp.59-68
http//dx.doi.org/10.14257/ijca.2016.9.6.05

Baggage Recognition in Baggage Position Control System for Handling the Adjoined Bags in Airport

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Abstract

Medium or large sized airports that can serve increasing number of airlines and passengers from all over the world have been expanding. As a result, the amount of baggage processed at an airport has also been increasing. Therefore, for fast and reliable handling of baggage, the importance of Baggage Handling System has gradually increased. A checked-in bag is top-loaded on a conveyor belt to a high-speed tray for high-speed processing. Before being top-loaded, the bag may be unstably positioned, dropped, or double loaded on a tray in various situations. Baggage Position Control System in an airport controls a position of the bag just before top-loading to solve problems. In this paper, we discussed the methods that distinguish whether baggage be adjacent to another and that decide the arrangement types to be able to process unstable baggage in the control part of Baggage Position Control System.

***Keywords**: Baggage Position Control System, Mishandled Baggage, Baggage Handling, Image Processing*

1. Introduction

According to 2014 ICAO annual report, the total number of passengers is approaching 3.3 billion, which is 74% bigger than that in 2003 [1]. With the growth of airport passengers, the throughput in Baggage Handling System (BHS) has been increasing. To treat a lot of baggage effectively, BHS has gradually become important. The 2014 SITA report showed that the investment for baggage handling is ranked 4th in the investment priority of airport [2].

With the consistent growth of airline demand, in the scale point of view, the number of medium or large sized airports has been increasing. In structural terms, the layout of airport facilities has changed into the form that are separated a terminal and a concourse to solve the congestion problem in baggage handling. As the change demands the long distance transport of baggage, High Speed System (HSS) is applied to BHS. The checked-in baggage in an airport is top-loaded on a conveyor belt and moved to a tray of HSS for long distance transport. Just before top-loading, a bag may be unstably positioned or closely adjoined to another bag due to various factors.

So, the unstable position of baggage such as these causes falling or double loading of them from/on a tray. Eventually, the falling or double loading of baggage can cause the mishandled-baggage problems such as failed load, incorrect arrival, or delay of baggage. Figure 1 (a) shows the top-loading section of HSS. Figure 1 (b) shows an unstably loaded bag on the tray. Figure 1 (c) and 1 (d) show the examples of double loaded bags on the tray.

ISSN: 2005-4297 IJCA

(a) Top-loading section (b) Unstably loaded baggage

(c) Double loading by adjacent baggage (d) Double loading by adjacent baggage

Figure 1. Top-Loading and Unstable Baggage Loading

Recently, several airports examined the introduction of Baggage Position Control System (BPCS) to reduce the number of mishandled baggage caused by top-loading process. BPCS consist of a vision part and a control part. The vision part recognizes a bag, and extracts its shape features such as size and location. Then, the vision part sends the features of the bag to the control part. The control part handles the position of baggage using the information about the features received from the visual part. We distinguished between the vision part and the control part of BPCS and limit the discussion to the vision part. Therefore, this paper described the methods for recognizing adjacent baggage and for classifying its type in the vision part of BPCS.

This paper is organized in the following ways. Section 2 discusses types of adjacent bags and describes the process to treat them. Section 3 introduces our methods to recognize the adjacent bags. Section 4 describes the experimental results from the proposed method. Finally, Section 5 presents conclusion.

2. Adjacent Baggage and Arrangement types

BPCS is a system that controls the unstable position of a bag before top-loading it onto a tray to prevent it from falling or double-loading. Currently, BPCS consists of the vision part for scanning a bag and the control part for handling its position. Figure 2 shows the overview of BPCS.

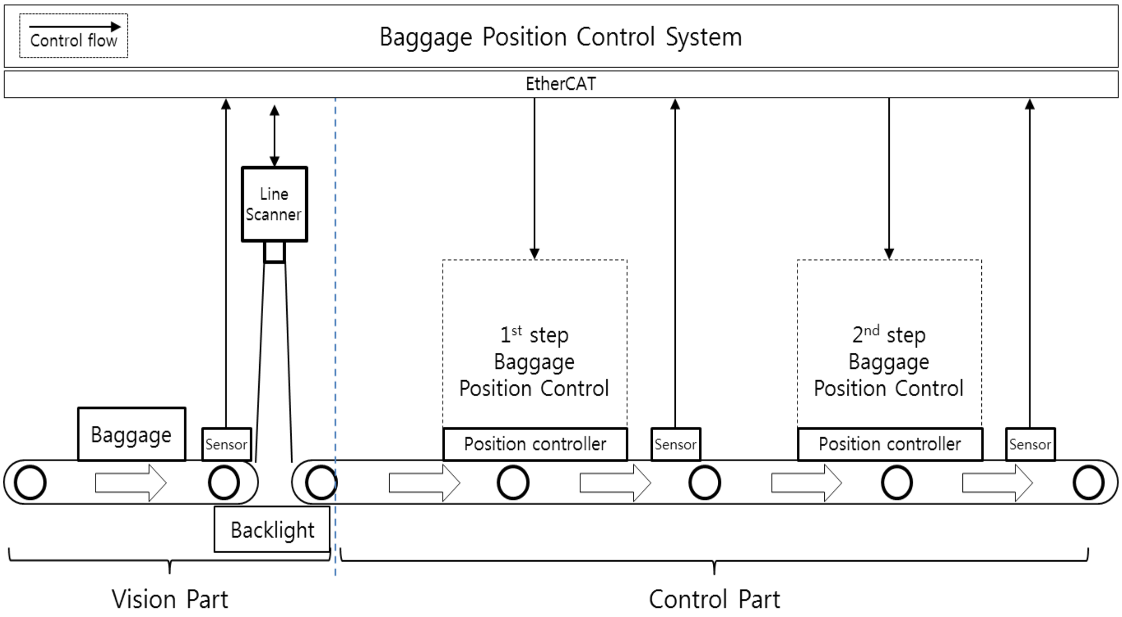


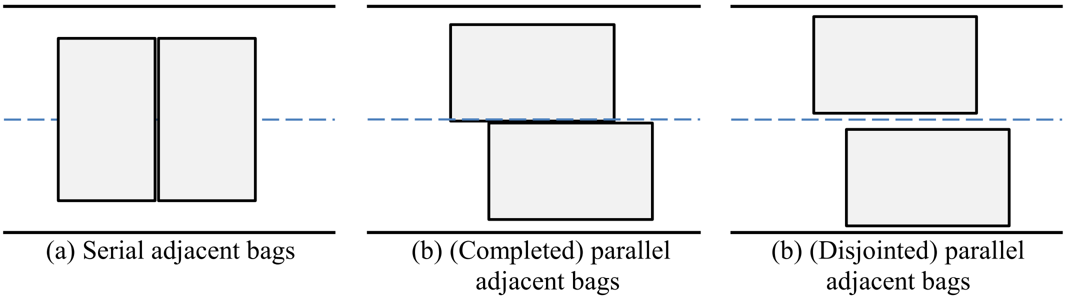
Figure 2. **Baggage Position Control System**

The vision part of BPCS recognizes the adjoined bags and determines its arrangement type. The control establishes the position control plan based on the information about the shape of the bag recognized from the vision part. The specific control method of the control part is not the concern of this paper.

First, the vision part waits until a bag is recognized by the baggage recognition sensor. If the sensor recognizes a bag (the state of sensor is changed *on* to *off*), the baggage is scanned by line scan camera at top of BPCS. When the state of the sensor is *on* again, the scan process ends. Next, the vision part makes the data available for controlling the position of the bag. However, in process of creating an image of the bag through the line scanning, the vision part recognizes the adjacent two bags as a single bag. The bags recognized as one in the vision part cannot be establish a proper control plan. So, in the top-loading process, the falling and double loading of baggage may occur. Therefore, it is important to identify adjacent bags in the vision part in order to handle them properly in the control part.

The adjacent bags should be controlled in order to maintain steady intervals and to prevent bags from falling and double-loading problems of baggage. Before top-loading, adjacent bags can be classified two types as follows: 1) serial adjacency arrangement; and 2) parallel adjacency arrangement. Additionally, the parallel arrangement can have two sub-types: completed parallel adjacency and disjointed parallel adjacency arrangement.

Serial adjacency arrangement of adjacent bags means that two bags are completely adjoined in a serial form. Because the sensor is turned to *off* while bags are scanned in the vision part, the adjacent bags are recognized as one bag. The parallel adjacency arrangement of the adjacent bags means a situation in which two bags at the same time are in parallel on the conveyor belt. Because the baggage recognition sensor is positioned on the side of the conveyor belt, two bags that are simultaneously moved are recognized as one bag. Therefore, the parallel type of adjacent bags can be classified into completed and disjointed adjacency. Figure 3 shows all types of adjacent bags.


(a) Serial adjacent bags

(b) (Completed) parallel adjacent bags

(b) (Disjointed) parallel adjacent bags

Figure 3. Two Arrangement Types Of Adjacent Baggage

In the following section, methods to identify adjacency types and to separate bags will be discussed. Furthermore, ways to determine arrangement types to establish a proper control plan of adjacent bags in the control part will be described.

3. Recognizing the Adjacent Baggage

This section describes two methods: 1) a method to distinguish whether or not a bag is adjacent to another in a digital image generated by the line scan camera; and 2) a method to separate the adjacent baggage into individual baggage.

As the first step to distinguish a bag, a bag is represented as a rectangle in black, and its background in white in a binary image. The bag in the binary image is segmented with connected-component labeling [3]. Then, if the number of the counted label is two, the baggage is recognized as the adjacent bags. The information about the shape of the two bags with its arrangement type on a conveyor belt is sent to the control part in BPCS. In the control part, the adjacent bags recognized by the connected-component labeling method refer to two bags disjointedly positioned in parallel. If the number of counted label is one, the bag should be checked whether or not it adjoins another bag. The adjacency possibility of the segmented bag is identified with a shape measurement, *Solidity* [4], or its size. First, *Solidity* is defined as follows.

$$Solidity\ (B) = \frac{Area\ (B)}{Convex\ (B)} \tag{1}$$

Here, B represents a bag recognized by the connected-component labeling, and $Area(\cdot)$ represents the area of the bag. The $Convex(\cdot)$ means a convex hull of the given object as parameter. If the recognized bag is a single object, its size and its convex hull have very similar values. Therefore, the solidity value of the recognized bag is used to determine whether or not two bags are adjacent. That is, the adjacency possibility of the segmented bag can be determined if the solidity value of the bag is less than threshold T. Another way to determine whether or not two bags adjoin each other is the size of a segmented bag. The oversized bag is processed by Out OF Gauge (OOG) process. Thus, we can still determine whether a segmented bag adjoins another bag even if the bag is over-sized.

In the next step, the algorithm for separating the adjacent bags is applied to the image with an adjacency possibility. In this process, if an object is not identified by the algorithm, the bag is recognized as a single object. The algorithm divides the baggage object with an adjacency possibility into two individual objects.

First, the boundary, B^O, from baggage object, B, is obtained. Here, B^O is a clockwise sequence (p_1, p_2 ,…, p_n) that consists of n points. Next, for convenience of the application of the proposed algorithm, we first find the corner points of the baggage object. After that, the identified corners are aligned in the sequence of B^O. The ordered corner points are marked as B^C. The detection of corner points is performed by Harris corner detection [5]. Then, the baggage object is represented as B^C.

Furthermore, nodal points from the bag are identified to distinguish two adjacent bags. The nodal points are created by a contact of two bags. Identifying the nodal points is very important for separating adjacent two bags. After a pair of nodal points generated by the adjoined bags is identified, they are used to separate the adjacent bags into two objects. The separation of adjacent bags is performed by *AdjacentBaggageSplit* algorithm.

Algorithm1. *AdjacentBaggageSplit*

```
Input: List<Point> $B^C$          //Corner points for the baggage boundary, $B^O$
Output: List<Object> R  //Separated Objects, Object is defined as List<Point>

1   List<bool> NodalPointsMarking        //initialized as the array size of $B^C$
2   List<Object> R                       //initialized as the empty array,
3   int nodalPointCnt $\leftarrow$ 0           //for counting nodal points
4.
5   for i $\leftarrow$ 0 to $B^C$.length-1
6       if internal angle at $B^C$[i] > $\pi$ then
7           NodalPointsMarking[i] $\leftarrow$ true
8       else
9           NodalPointsMarking[i] $\leftarrow$ false
10      endif
11      if NodalPointsMarking[i] = true then nodalPointCnt $\leftarrow$ nodalPointCnt + 1
12  endfor
13
14  if nodalPointCnt < 2 then R.add($B^C$)
15  else SplitObject(NodalPointsMarking, $B^C$, R)
16
17  return R
```

AdjacentBaggageSplit receives the image of the bag, B^C, as input and returns the list of separated objects as output. Line 1 indicates an array of *bool* type to represent whether each point of B^C is a nodal point or not. The *NodalPointCnt* of line 3 is a variable for counting the number of nodal points identified in B^C. Through the loop of line 5 to 12, the elements of *NodalPointMarking* array are marked to represent whether or not each point of B^C is a nodal point. A nodal point at each point of B^C depends on whether the internal degree at the point exceeds π.

Figure 4 shows the nodal points detected from the image of adjacent bags. In line 14, if the number of nodal points below two, the bag is identified as a single bag. The result R that is only included B^C is returned. If the number of nodal points is two, the baggage object is separated into two objects by the nodal points. Line 15 calls *SplitObject* with nodal points for separating the adjacent bags if the nodal points are above two.

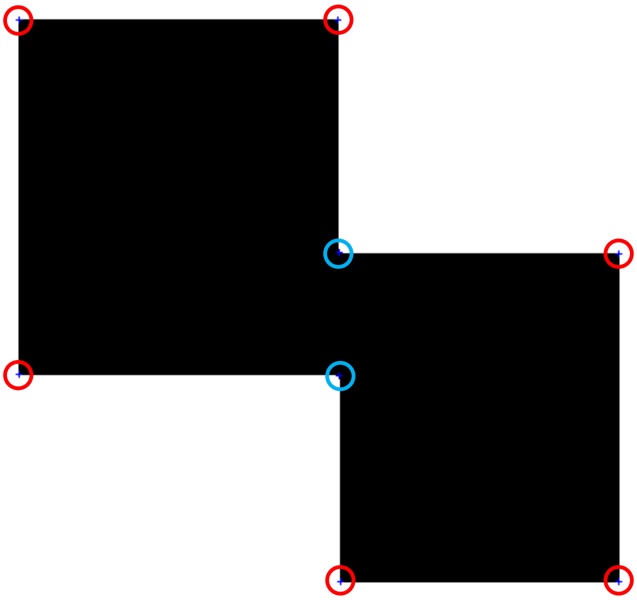


Figure 4. Corner Points (Red) and Nodal Points (Blue) For an Ideal Adjacent Baggage Image

Algorithm2. *SplitObject*

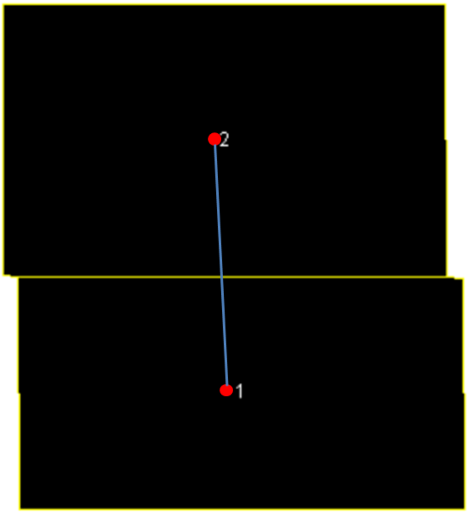
```
Input:
    List<bool> NodalPointsMarking   //the list for marking nodal points
    List<Point> $B^C$
    List<Object> R           //the list for including the separated baggage objects
1   R.add(new List<Point>)        //for the first separate baggage object
2   R.add(new List<Point>)        //for the second separate baggage object
3   int flag $\leftarrow$ 0               //the index for selecting baggage object in the list, R
4.
5   for i $\leftarrow$ 0 to $B^C$.length-1
6           R[flag].add($B^C$[i])
7           if NodalPointsMarking[i] = true then
8                   flag $\leftarrow$ ~flag  // inverse flag value
9                   R[flag].add($B^C$[i])
10          endif
11  endfor
```

SplitObject is an algorithm for separating the baggage object into two bags using the detected nodal points. Line 1 and 2 add the lists for adding the boundary points of the separated baggage objects to the result *R*. Line 3 defines a variable, *flag*, for selecting the one of lists added in line 1 and 2. In lines 5 to 11, each point of corner points, B^C, is checked if it is a nodal or not. If it is a nodal, the *flag* is reversed for selecting another object list. After that, the corresponding object list from the list *R* is selected by using *flag*. The points that are accessed through the loop of B^C are added to the object list selected by *flag* for representing separated object. In other words, this process separates two bags by adding each points of B^C into the object list selected by *flag*.

Finally, the arrangement type of adjacent bags can be identified by an angle generated by the center points of two separate bags. In other words, if the angle relative to the moving direction of the conveyor belt of the line formed by the center points of two bags is between $-\pi/4$ rad and $\pi/4$ rad, the arrangement type of these bags is identified as serial arrangement. Otherwise, it is decided as the parallel arrangement type. Eq. 2 shows the equation to determine the arrangement type of two adjacent bags.

$$\mathit{ArrangementType}\,(p_1, p_2) = \begin{cases} \mathit{SerialType}, & \text{if } \left| \arctan\left(\dfrac{p_2.y - p_1.y}{p_2.x - p_1.x} \right) \right| < \dfrac{\pi}{4} \\ \mathit{ParallelType}, & \mathit{Otherwise} \end{cases} \tag{2}$$

Here p_1 and p_2 are the center points of two separated baggage objects. As shown in Figure 5, bags in parallel can be identified as the absolute angle value of the line formed by center points of two bags is bigger than $\pi/4$.



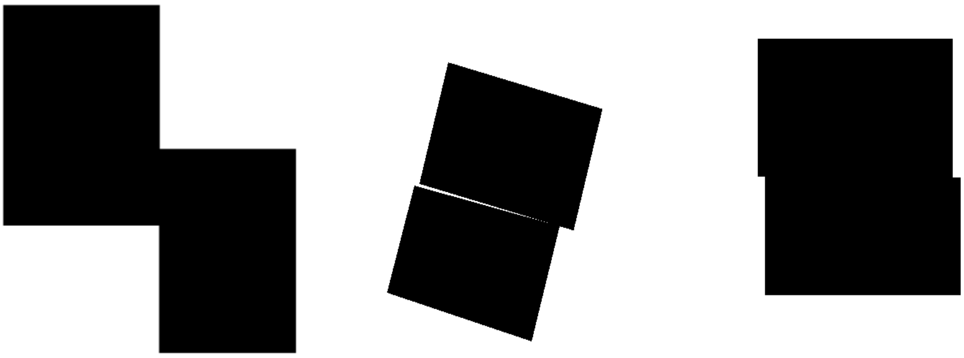
Angle : -1.5076 rad

Figure 5. The Angle of Line Formed By Center Points, P_1 And P_2.

4. Experimental Results

This section discusses the experimental results from the application of the proposed method for ideal adjacent baggage image examples. The experiment environment for testing the proposed methods was performed on a computer with an Intel Core 2 Duo 3GHz CPU and 2G RAM running Windows7 64bit. The proposed algorithms were implemented by using ImageJ [6], an image processing package based on the JAVA programming language.

First, there are three images that were used in the experiment. Figure 6 shows the images of three virtual types of adjacent bags.



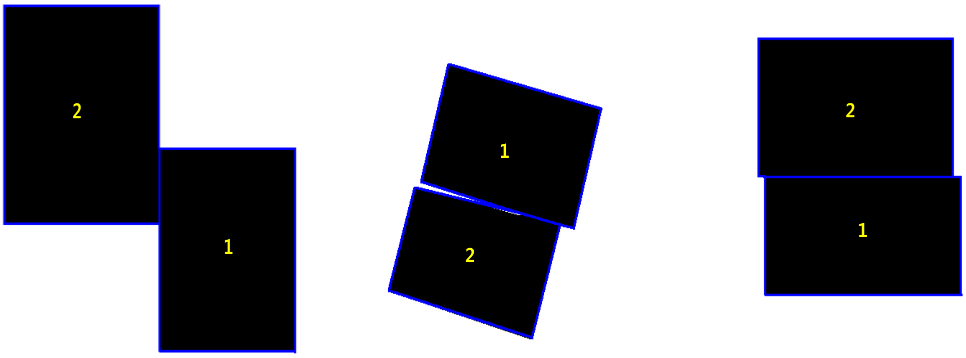
(a) (b) (c)

Figure 6. Three Potential Types of Adjacent Bags

As shown in Figure 6, two bags in each image are recognized as one baggage object, which results in mishandled-baggage problems such as failed loading, incorrect arrival, and delay. After applying the proposed algorithm, an image of two adjacent bags can be separated into two different objects. An arrangement type is determined by angle. Table 1 shows the values of solidity and arrangement types determined by angle. Figure 7 shows the results from the application of Algorithm 1, shown in Figure 6.

Table 1. Solidities, Angles, and Arrangement Types of Adjacent Bags

	Figure 6 (a)	**Figure 6 (b)**	**Figure 6 (c)**
Solidity	0.76	0.95	0.98
Angle (rad)	-0.63	1.23	-1.50
Arrangement Type	*SerialType*	*ParallelType*	*ParallelType*



(a) (b) (c)

Figure 7. The Results of Application *Adjacentbaggagesplit* Algorithm For The Ideal Adjacent Baggage Images, Figure 6

As shown in Figure 7, each object has a separate boundary line as indicated in blue. The bags separated in this process can be processed properly.

4. Conclusion

This paper discussed the methods of identifying two adjacent bags and to classifying arrangement types at the installed BPCS before top-loading and separating in order to reduce mishandled baggage problems. In this paper, we focused on identifying two adjacent bags in this project. However, future studies may consider how to identify three or more adjacent bags.–The proposed methods can contribute to a proper control of baggage position at the control part by recognizing adjacent bags in the vision part of BPCS. Currently, our project has been completed the structural design of BPCS. In the future, we plan to apply the proposed method to BPCS to handle adjacent bags.

Acknowledgments

This study was funded by Technology Advancement Research Program (14ATRP-C071004-02) from Korean Ministry of Land, Infrastructure and Transport.

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