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A fast airplane boarding strategy using online seat assignment based on passenger classification

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ABSTRACT

The minimization of the turnaround time, the duration which an aircraft must remain parked at the gate, is an important goal of airlines to increase their profitability. This work introduces a procedure to minimize of the turnaround time by speeding up the boarding time in passenger aircrafts. This is realized by allocating the seat numbers adaptively to passengers when they pass the boarding gate and not before. Using optical sensors, an agility measure is assigned to each person and also a measure to characterize the size of her/his hand-luggage. Based on these two values per passenger and taking into account additional constraints, like reserved seats and the belonging to a group, a novel seat allocation algorithm is introduced to minimize the boarding time. Extensive simulations show that a mean reduction of the boarding time with approximately 15% is achieved compared to existing boarding strategies. The costs of introducing the proposed procedure are negligible, while the savings of reducing the turnaround time are enormous, considering that the costs generated by inactive planes on an airport are estimated to be about 30 $ per minute.

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1. Introduction

Airlines only generate profit when their airplanes are flying, therefore a common issue in airline industry is the minimization of the time they spend at the airports. This time, usually referred to as *turnaround time* (TAT), requires special attention. Several different ground operations are performed during TAT. Most of them can take place simultaneously, others, such as passengers boarding, cannot start until other processes, such as fueling, cleaning and catering, have been successfully completed. The boarding process plays an important role with respect to the TAT, since it is on its *critical path* Steiner and Philipp (2009). In this case, a substantial reduction of the boarding time can reduce the TAT by approximately the same amount.

This topic has been previously investigated by many authors. An overview of their study can be found in Mas et al. (2013). Many strategies have been simulated under several assumptions for finding the strategy which minimizes the total boarding time through the minimization of passenger interferences. Since each of the mentioned studies focused on different components of boarding delay, the authors do not agree on the best overall approach. On the other hand, the problem of practical implementation of these strategies has not been studied in deep in the previous literature.

In this paper we present a novel technique based on passengers classification which results in a new strategy for reducing boarding time. Our work has been influenced by Jason H. Steffen who, in Steffen (2008), presented an optimum boarding method that works only if passengers are placed in a specific position in the boarding line that depends upon their ticketed seat location. In addition, Steffen method does not consider all the variables that come into play in a real boarding scenario, such as reserved seats and passengers who travel in group, making it inconvenient to implement in reality, as well as incompatible with passengers satisfaction and thus with airline plans.

The approach presented in this paper extends Steffen method

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both making the boarding faster and allowing a streamlining of the gate infrastructure. This is achieved by assigning seats to passenger based on their hand-luggage, as considered also in Milne and Kelly (2014), and on their agility. Moreover, our algorithm takes into account the constraints created by passengers with reserved seats and it is also able to handle passenger groups.

Our study is addressed to solve real implementation issues of the presented technique by designing a new seat allocation algorithm based on real data recorded at the airport gates. The proposed system is based on cameras and makes use of computer vision algorithms in order to detect hand-luggage and to estimate people agility, which constitute two input parameters for the seat allocation algorithm. We performed various simulations using Mathworks® MATLAB for validating it in different relevant scenarios. The results of our simulations reveal a significant reduction of the boarding time with respect to other algorithms and therefore a considerable cost saving. What has to be pointed out too, is that our approach does not require gate modifications or training of the groundcrew in order to be applied.

This paper is organized as follows. In this section we provide an overview of the existing boarding strategies highlighting advantages and drawbacks of their practical implementation. In Section 2 the theory behind the developed boarding strategy is presented: the algorithm, as well as the evaluation of the parameters on which it depends, are explained in detail. Section 3 is dedicated to the simulations and its results. Section 4 concludes the paper and reports future work that has been planned to do.

1.1. State of the art

Several passenger boarding strategies have been investigated in order to board passengers as fast as possible. Among these, the commonly adopted ones by most of the airlines are reported below and depicted in Fig. 2:

Ferrari and Nagel (2005) present a survey on the different boarding strategies that are currently used by companies. It also proposes ways to model passengers, bin occupancy, seating and disturbances. In McFadden and Nyquist (2008) boarding strategies are discussed too. They also present an overview on the airlines and on their most adopted boarding procedures. As discussed also later, in their work there is also an analysis of the financial impact of the TAT.

Both the WilMA method and the reverse pyramid method eliminate seat interferences (within a given seats row) and aisle interferences. Bazargan (2007), starting from the reverse pyramid model, proposed a mixed integer linear program approach which attempts to further minimize the total interferences among the passengers.

Conventional wisdom would suggest the *back-to-front* boarding as the fastest. This strategy is actually employed very often and, besides the arrangements that have to be made at the gate, is not even the optimal method. Studies on airplane boarding use a variety of approaches: van Landeghem and Beuselinck (2002) found that there is much room for improvements over traditional back-to-front boarding (even the random boarding can be faster than many traditional methods). Later studies van den Briel et al. (2005) also confirmed that traditional methods are not optimal. Since each of the mentioned studies focused on different components of

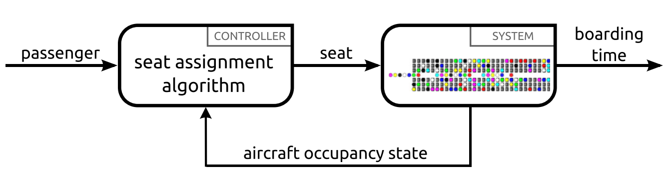

Fig. 1. Control scheme of the presented boarding method.

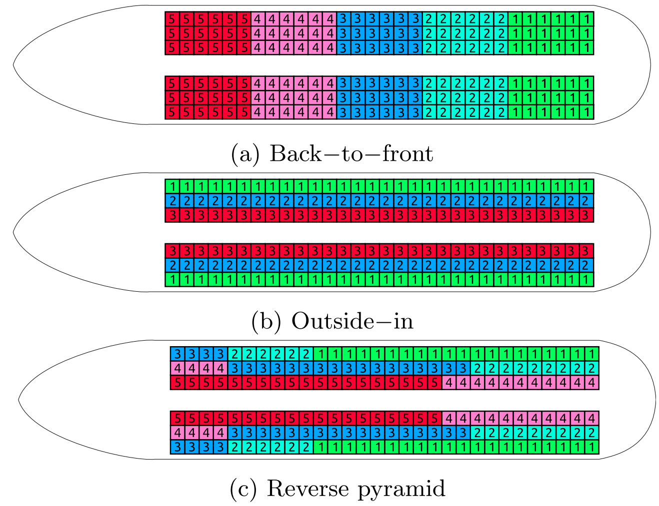

Fig. 2. Most popular boarding methods.

- **Back-to-front**: it consists in boarding first class firstly. Then, passengers are called in groups to board the aircraft, following the sequence from back to front (Fig. 2a).
- **Outside-in**: it is also called *WilMA*, acronym of Window-Middle-Aisle. First class passengers are boarded first. Then, passengers in window seats are boarded, then middle seats, and finally aisle seats (Fig. 2b).
- **Reverse pyramid**: it is a hybrid approach between the traditional back- to- front and the outside- in boarding strategies derived using a nonlinear model including all the different interferences that could possibly occur during boarding van den Briel et al. (2005) (Fig. 2c).
- **Rotating zone**: it consists in boarding passengers sitting in the middle of the aircraft last. Thus, passengers are grouped into zones and board the aircraft first in the front, then in the back, then front again, then back, and so on.
- **Random boarding** this strategy does not specify any condition to board passengers and the aircraft is boarded in one zone randomly. First class passengers are also boarded firstly. Then, passengers board the airplane in a first-come first-serve basis.

boarding delay, there is not a generally accepted method. A different approach was given by Jason H. Steffen who, in Steffen (2008), defined an optimal sequence to board assuming that the time that a passenger requires to load her/his luggage is the dominant reason of delay. However, as already mentioned, Steffen method does not consider all the variables that come into play in a real boarding, making it inconvenient to implement in reality.

In this paper we overcome these limitations, while guaranteeing a faster boarding in every situation, still allowing passengers to reserve a seat or to stay with their families or in a group of friends.

Also, after experiencing the advantages of the proposed method, the number of passengers that will choose their seats could significantly decrease, allowing the algorithm to reach its maximum performances.

1.2. Main contributions

The main contributions of the presented work are:

- Extension of the Steffen method by using a seat allocation algorithm based on real parameters,
- Use of computer vision techniques for obtaining in real-time the desired input parameters for the algorithm.

The application of computer vision in the airports is not a new subject: Schreiber and Rauter (2012) used cameras to count people; Vaddi et al. (2013) proposed a vision based surveillance system; Spreeuwers et al. (2012) a face recognition system for automatic border control, with real tests at Schiphol airport, which has become state of the art nowadays. Our method, however, makes

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