BigARM: A Big-data-driven Airport Resource Management Engine and Application Tools

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Abstract. Resource management becomes a critical issue in airport operation since passenger throughput grows rapidly but the fixed resources such as baggage carousels hardly increase. We propose a Big-data-driven Airport Resource Management (BigARM) engine and develop a suite of application tools for efficient resource utilization and achieving customer service excellence. Specifically, we apply BigARM to manage baggage carousels, which balances the overload carousels and reduces the planning and rescheduling workload for operators. With big data analytic techniques, BigARM accurately predicts the flight arrival time with features extracted from cross-domain data. Together with a multi-variable reinforcement learning allocation algorithm, BigARM makes intelligent allocation decisions for achieving baggage load balance. We demonstrate BigARM in generating full-day initial allocation plans and recommendations for the dynamic allocation adjustments and verify its effectiveness.

Keywords: Airport resource management · Inbound baggage handling · Big data analytics · Load balance.

1 Introduction

Resources management is one of the most critical issues in airports [1]. In 2018, the Hong Kong International Airport handled more than 1,170 daily flights and served over 72 million passengers, which increased almost 3 times in the past 20 years [2]. However, it only has twelve baggage carousels and no additional one has been added since the terminal opened in 1998. Allocating the best mix of flights per carousel with baggage load optimization is a crucial factor in providing excellent customer services. Traditional systems only consider incoming bag load against the number of carousels based on the flight schedule [3, 4]. However, there are various operation factors, such as flight arrival punctuality, baggage removal profile, weather conditions, etc., affecting the allocation [5]. These factors are highly dependent on each other and dynamically change over time making carousel allocation with a balanced baggage load become challenging.

We propose a Big-data-driven Airport Resource Management (BigARM) engine to manage the airport recourses with big data analytic techniques and develop a suite of application tools. We demonstrate BigARM in baggage carousel allocation, which aims to balance the overload carousels and reduce the workload of operators on planning and rescheduling the allocations. BigARM engine consists of three major components including big data collection and storage, flight arrival time prediction, and intelligent allocation decision making. Besides, we develop application tools together with a web-based graphical user interface for full-day allocation plan generation and real-time dynamic adjustments. The flight information, airfield operation data and weather conditions are automatically collected from an Airport Operator and stored into a MongoDB database. We design a data-driven approach to predict flight arrival time using features obtained by cross-domain data fusion, which makes BigARM aware of the dynamic change of flight status on time. A multi-variable reinforcement learning algorithm is proposed to make intelligent allocation decisions for achieving baggage load balance that is measured by the standard deviation of bag load across all carousels. Once flights' baggage load or predicted time of arrival has any update, BigARM will pop-up recommendations for operators to perform adjustments. Comparing to the estimated time of flight arrival (ETA) currently used by the airport, BigARM reduces the prediction error from 14.67 minutes to 8.86 minutes. Besides, BigARM achieves 36.61% and 33.65% improvement of baggage load balance in the initial allocation plan and day-end final plan respectively.

2 System Design

The system includes a BigARM engine and a suite of application tools as presented in Fig. 1. The BigARM engine consists of modules of the airport big data collection and storage, flight arrival time prediction, and intelligent allocation decision making for supporting the functions of application tools such as full-day allocation plan generation and recommendations of dynamic adjustment.

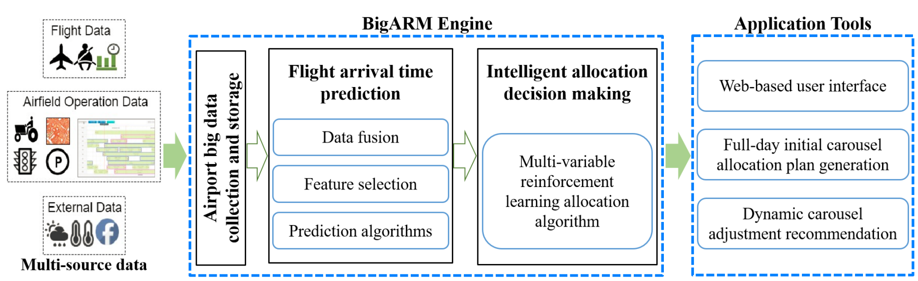

Fig. 1. Design of BigARM system.

2.1 Airport Data Collection and Storage

Cross-domain data on flights and airfield operations are collected from multiple entities owning the airport resource. Flight data contain the flight number, aircraft type, time of flight arrival, passenger count, baggage load, parking stand, etc. For airfield operation data, we have collected the on-belt-delivery time of first and last baggage for every flight, carousel allocation plan, allocation update transactions, etc. Since the airfield operation highly depends on the weather condition, we further collect the dew point, humidity, air pressure, temperature, visibility, wind direction, and wind speed from the Observatory. All data are collected at fixed time intervals and stored into a MongoDB database.

2.2 Flight Arrival Time Prediction

Flight delay is one of the key factors affecting the in-bound baggage handling. We perform feature engineering on flight information, real-time flight data, landing information, and weather conditions. After correlation analysis, 25 features that are statistically significant to the actual time of flight arrival are selected to predict the flight arrival time. To make better use of the information from cross-domain data, we perform feature level fusion by concatenation. Lastly, we train a Huber regression model to predict the flight arrival time which reduces the estimation error of ETA used by the airport from 14.67 minutes to 8.86 minutes.

2.3 Intelligent Allocation Decision Making

We design a multi-variable reinforcement learning algorithm to allocate the arrival bags to carousels such that the baggage load balance across all carousels is maximized. Each flight is regarded as a generator unit to generate allocation policies indicating how to select an allocation action under the current carousel status and maximize the accumulated rewards. To achieve the baggage load balance, the generator gets higher rewards when the standard deviation of the baggage load across all carousels becomes smaller. Overall, with the input of flight arrival time, baggage load and the predicted bags removal profile based on bags dwell time on the carousel, our proposed algorithm allocates the coming flights and achieves balanced baggage carousel throughput and utilization.

3 Demonstration

We demonstrate the full-day initial baggage carousel allocation plan generation and the recommendations of dynamic adjustment using BigARM and its application tools. The airport would schedule a full day carousel allocation plan the day before as a template for planning the next day operations. After login the BigARM system, the operator only needs to select a date and click a button named BigARM plan. BigARM will query the scheduled flight arrival time and its baggage load on that day from the database and run the allocation algorithm to generate a full day allocation plan as shown in Fig. 2. The color of each flight represents the baggage load from the lightest (green) to the heaviest (red). Besides reducing the time of generating the initial plan from hours to seconds, BigARM's initial plan achieves 36.61% more balanced than the one made by experienced operators in the airport.

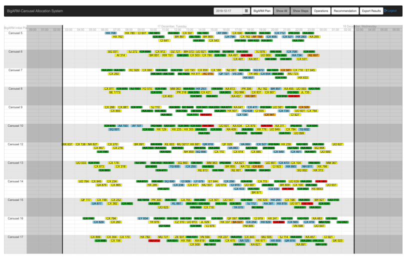

Fig. 2. Initial plan generation.

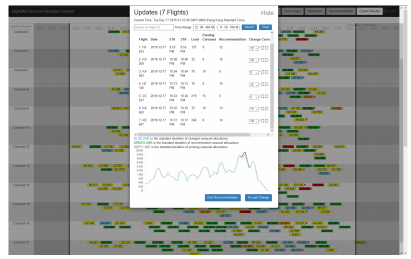

Fig. 3. Recommendation of adjustments.

In daily operations, operators have to frequently adjust the allocation due to flight delay and other factors. Once BigARM received the updated flight data, it will continuously predict the flight arrival time. If either flights' baggage load or predicted time of arrival has any update, the allocation algorithm will be triggered and pop-up recommendations for operators to perform the adjustment, which is presented in Fig. 3. Meanwhile, a load balance comparison curve are plotted out to highlight the impact of new allocation on baggage load balance for helping them make decisions. Comparing to the day-end plan made by the airport, BigARM achieves a 33.65% improvement in baggage load balance.

Acknowledgement. The work has been supported by the Innvoation and Technology Fund (ITP/024/18LP) and RGC General Research Fund (PolyU152199/17E). Thank Alan Lee, Patrick Yau, Gavin Lee, and Jiandong Li's effort in this work.

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