Intelligent Airport Management System

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Abstract— ***King Abdul Aziz Airport in Jeddah receives over 3 million visitors who come to complete the pilgrimage in Mecca. The airport administration is challenged by the high number of passengers and must setup an optimum management airport system to provide a high level of services during their transition at the airport and to reduce the waiting time. In this work, we propose the use of genetic algorithms to build an intelligent airport management system for an optimal passenger transition time in order to improve the logistics during the Hajj seasons.***
The efficiency of the proposed system is demonstrated through a real case-study using real data from an airport, we were able to apply an NGSAII algorithm that proved to optimize up to 29% of time in some cases.

Keywords— Smart Airport management, Artificiel Intelligence, metaheuristics, genetic algorithms.

I. Introduction

The topic of airports' digitization is an important topic due to the huge increase of air travellers which is a challenge for scientists. Many researchers worked on various technologies to improve airports internal procedures, whether it is for security, maintenance or enhance the passenger experience. For example, waiting time is always a concern not only for passengers, but also for staff and airlines because time is an important factor in this transportation sector as it may imply delays, negative experiences, and additional costs.

Reducing passenger wait times allows airlines to reduce turnaround times and increase revenues. Airport managers also benefit: for example, a study [1] shows that one minute saved by a passenger during the various stages of his or her journey on the ground translates into an average $0.70 spent on duty free.

The airport of King Abdulaziz is extremely busy during pilgrimage (Hajj) season as it receives over 3 million pilgrims just before Hajj period in addition to regular travelers. The pilgrimage travel is annual and passengers start to arrive anywhere between a day and 2 months before the Hajj begin. The airport management is challenged by the high number of passengers during this period and they must find a smart management system to guarantee a smooth and fast transition of these passengers.

One of main challenges for optimal transitions of the passengers is the irregular pattern of the arrival of the passengers. It is possible to have heterogeneous behaviors depending on the day, e.g. week-ends might be busier than week days. Also, during a specific period of a day, e.g. in the morning, it is possible to have a more important number of large flights versus a smaller number of flights in the evening. So, to accommodate these kind of dynamic flow of passengers, a smart and intelligent tool needs to optimally utilized the airport resource in order to appropriately accommodate these passengers within a reasonable time frame.

Evolutionary computation would be a good alternative for a such problem. However, the problem with single objective optimization is that is generates single objective solutions which are not appreciated by decision makers that prefer to have a variety of choices. These choices are characterized by different configuration settings. For example, in this problem you might have a solution which is very costly because of the high number of employees to accommodate travelers but very efficient in terms of processing time. On the other hand, we might have a solution with a minimum number of staff which is slower in terms of processing time at the airport. But, the decision makers appreciate to see the various trade-off solutions in between. Multi-objective optimization (MOO) do exactly that by considering multiple conflictual objectives, in our case number of employees vs the processing time. The generated solutions, referred to as pareto-optimal solutions, will offer a variety of solutions to decision makers that can select the most appropriate solution to their needs by considering various aspects such as their budgets, the average processing they are targeting, or just consider the differences between the various neighboring solutions.

One of most know MOO algorithms is NSGA-ii which the most cited algorithm in optimization which has been utilized in variety of problems ranging from networking, logistics, engineering, and finance to name a few due to its robustness. In this work, we have selected NSGA-ii algorithm and test it on airport scheduling.

In this work, we use the MOO NSGA-II to improve the traveling experience by minimizing the waiting time through the airport for the passenger and using the minimum resources, namely staff numbers at immigration and customs, select most appropriate reception salon and luggage belt, based on real data.

II. Literature Review

Nowadays, it is common to travel by planes, so air traffic is overwhelmed, some airports are on the verge of congestion: digital technologies and artificial intelligence are invading terminals to virtually push back the limits by improving passenger flow through a better interactive approach with travelers. The airport has moved from Airport 1.0 to Airport 4.0, called the "smart airport," and the service paradigm is shifting to provide targeted benefits to customers [2]. New technologies have been implemented to digitalize and modernize airports to improve various aspects: Security, baggage handling, operations, etc. IOT is one of the most used technologies [3]

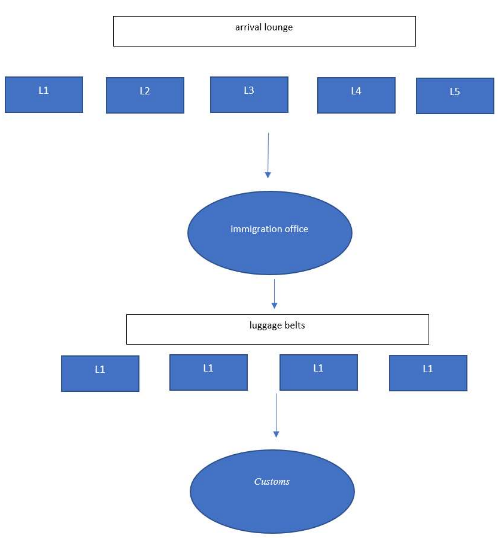
Similarly, many IOT-based management systems have been proposed with different purposes and services that lead to a common aim; improving the passenger experience [4] [5] .

The Internet of Things is probably the most widely used and well-known technology in the trend toward digitalization of airports, but that doesn't prevent several technologies that have already proven their effectiveness, such as digital twins [6] and Virtual reality [7].

As it has been explained above the topic of airport digitization has been approached from several sides. Our interest in this work is to focus on the reduction of passenger waiting time, several approaches have been proposed for this purpose, many articles have focused on the baggage claim phase [8] [9]. Other research and surveys have focused more on the improvement of self-check-in services in order to facilitate all procedures and consequently save time with a guaranteed security [10] [11]. In a similar work that was established in 2019 in Saudi Arabia with a general objective of improving the experience of passengers at the Hajj terminal in Jeddah and in particular reducing the waiting time based on exclusive simulation [12] which is not smart to adapt itself to various scenarios such as a significant increase or decrease of passengers like the that happens during hajj season.

In this work, we propose a smart airport management system that is based on real data collected at King Abdul Aziz Airport. The proposed system can generate various trad-off solutions to be selected by decision makers considering the irregular flow of passengers to the airport by minimizing the waiting time through the airport for the passenger and using the minimum resources including the number staff members (i.e. reducing cost).

III. Methodology



King Abdulaziz Airport Terminal Layout

The objective of this work is to reduce the waiting time for travelers at king Abdul Aziz airport, Hajj Terminal, to the shortest possible time with the minimum resources while ensuring a high level of dynamicity (i.e. none of the weekdays will have the same number of flights, passengers, or staff) considering various parameters such as:

- Distribution of passengers to most appropriate arrival lounge based on arrival time and number of passengers.
- Assign appropriate number of passport officers based on the number of total passengers at the airport during that time.
- Assign appropriate number of customers based on the number of total passengers at the airport during that time.
- Assign the closest luggage belt based on the arrival lounge.

To solve this problem, briefly described above, we need to:

1) develop a model for this problem in order to represent its objective(s) and constraints; in order to obtain faster or more accurate results.

2) compare the proposed results with the available *real* data and conduct a comparative study

IV. Model for Multiple flights

V. Model

This section desbribes data and the proposed model for optimization purposes.

A. Weekly data

We followed steps to arrange the flights data according to the number of passengers with the date and time. The number of flights varies from day to day, and the number of passengers varies from one flight to another. There are flights carrying an equal number of passengers, and they are few. We consider those multiple flights as a single flight and take the average time and average number of employees to prevent repetition.

1. We exclude flights with less than 10 passengers because they are insignificant.

There could be several ways of modelling the problem; here we propose to have a model for 1-day of arrival flights since we work with real data that are already have been divided daily.

Arrival Flights:

For now, we propose solutions for only 1-day i.e. 24hours by simulating every day independently. However, the model can be extended to multiple consecutive days or week time stamps. In each stage of the flight arrival process, we provide simple formula to calculate the current time and the total time; the current time refers to the time at a particular point in the arrival process, while to total time refers to the overall total time at the given stage. For each arrival flight we create an object that saves the details and complete record as:

Stage 0: Generate Flight Objects

Initiate an object for each arrival flight with the following variables: Flight ID, Arrival Time, and Number of passengers.

Stage 1: Arrival Lounges

The optimizer assigns the fastest lounges based on historical data analysis. There are 14 Lounges [1-14] that are sorted based on how close they are to immigration area. The optimizer uses the fastest lounge (nearest to immigration), when another flight comes it uses second next lounge. The optimizer also tries to match the number of passengers with the appropriate lounge.

After passengers passed through, we release the lounge so, next flights might use it and so on. Based on the real data analysis, we found that in average, it takes 5 seconds for one passenger to pass through an arrival lounge. It may differ a bit for the 14 lounges. For the arrival lounge stage, we calculate the current and total time as follow:

Current Time = Arrival Time + overall lounge time

Total Time = overall lounge time

Stage 2: Immigration

For immigration, we use first come first serve FCFS Job Scheduling model. Assume we have M number of staff at time flights arrived. We will give details about staff shifts later. For now, we model flow of passengers at immigration stage:

Based on historical airport data, we found in average, one immigration officer can serve one passenger in 2 minutes of time.

Passengers flow scheduling at immigration works based on two scenarios:

If there is only a single flight, all M staff resources passengers will serve one queue at immigration counters who serve all the passengers of a single flight.

In the event of having multiple flights arriving at the same time, the passenger's queue, M staff resources are equally divided to serve passengers from multiple flights. Here we keep into account, time stamp and number of remaining passengers for available flights.

For each flight update object:

Current Time += Immigration time

Total Time += Immigration time

Example: 10-staff shift from 00:00 to 08:00

Flight-1 with 200 passengers, first passenger reaches immigration at 00:10

Flight-2 with 250 passengers, first passenger reaches immigration at 00:20

From 00:10 to 00:20, only flight-1 passengers served in FCFS fashion. So, 10-staff serve 50 passengers in 10-minutes, based on heuristic above.

From 00:20, both flight 1 and 2 are served, the 10-staff resources are shared for remaining 150-passengers of flight-1 and 250-passengers of flight-2.

Till 01:20 all passengers of flight-1 are processed, where for flight-2 150-passengers processed

From 01:20 to 01:40, only flight-2 100-remaining passengers served in 20-minutes

Immigration Time for flight-1 = 70 minutes

Immigration Time for flight-2 = 80 minutes

Stage 3: Baggage Belts

Same as optimal use of arrival lounges, where baggage belts from 1-10 are sorted from faster to less faster based on historical data analysis. The optimizer tends to select the most appropriate belt based on arrival time and number of passengers.

Total Time += Baggage belt time

Stage 4: Custom

Same as immigration use FCFS Job Scheduling and staff resource sharing.

For each flight update object:

Total Time += Custom time

Staff Resources:

We have used number of staff per flight independently, for number of staff at immigration and custom counters:

Number of staff per flight independently: with 30 staffs at immigration counters and same at customs counters.

This assumption is based on historical analysis of airport dataset number of working staffs, more details in the next section.

B. *Model*

Let flights i = 1, 2, ..., N

P_i denotes the number of passengers on flight i

S_i denotes the number of staffs assigned to flight i

Chromosome as a variables X = (x_1, x_2, x_3, x_4) * N

Given the above abbreviation, we can describe the function that are being minimized by NSGAII.

F1 is the total time it takes a traveler from the landing until the leave the airport; and F2 is the total number of staff working in the immigration office and the custom office.

$$F1 = \sum_{i=1}^{N}(lounge(x_1 * i) + immigration(P_i) + belt(x_3 * i) + customs(P_i))$$
$$F2 = \sum_{i=1}^{N}(x_2 + x_4) * i$$

VI. Experimental Results

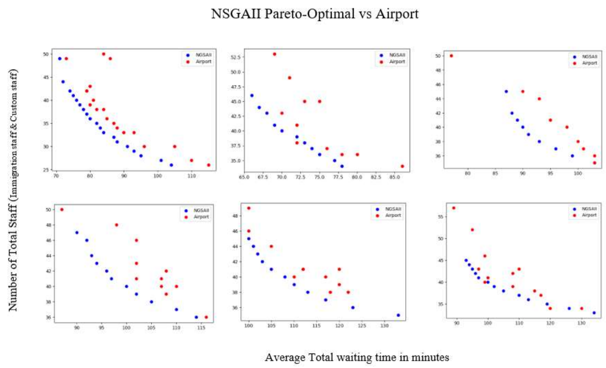


Fig. 6: The pareto-optimal of the NSGA-II for all six weeks. Upper left corner is the week 1, the lower right corner is the week 6.

We have selected NSGAII algorithm with the following parameter settings: Crossover, Mutation, Number of interactions and population size and test it on airport scheduling

Parameter	Value
Population size	200
Offspring size	200
Swarm size	200
Leaders	200
Crossover	0.7
Mutation	1/L
Termination	500 generations

TABLE 1. PARAMETERS SETTINGS FOR MULTI-OBJECTIVE ALGORITHMS

To evaluate performance of NSGA-II optimizer in comparison with the actual results, we consider every week dataset as follows:

1. For the selected weekly dataset, we find:
   - Average of time: sum flights total time divided by the number of flights
   - Average of staffs: sum of flights staffs divided by the number of flights
2. From pareto-optimal of every evolutionary algorithm, we find example solution such that:
   - The solution total time not worse than airport average total time
   - The solution total staffs not worse than airport average total staffs

Week	Airport		NSGAII	
	Time in minutes	Staff	Time in minutes	Staff
First week	86	49	71	49
Second week	75	46	68	46
Third week	90	45	87	45
Fourth week	87	50	90	47
Fifth week	99	48	100	45
Sixth week	95	52	93	45

TABLE 2
EXPERIMENTAL RESULTS BY MINUTES

Table 1&2 shows a difference in the time and staff used based on the following observations:

- The airport uses the same lounge multiple times and the majority of lounges are far from the immigration office.
- A small number of baggage belts are used for many flights, and the airport doesn't utilize the full capacity of luggage belts except in rare occasions.

Our proposed solution, NSGAII, to this problem uses every resources available and especially the ones near to the immigration office and customs.

In week 6, most of the time saved around 68% were due the optimal selection of the lounge and belt. 32% of the remaining time was saved due to the appropriate scheduling of customs and immigration staff and it is important to mention that in this case the number of staff was lower, and time was still reduce. We notice a difference in waiting time for travelers where we see the NGSAII model taking shorter time than reported in airport dataset; and that difference was due to NGSAII model's intelligent selection of the nearest lounge to custom office. Furthermore, the model was choosing the faster luggage belt which resulted in significant drop in waiting time.

A. Saved time and staff

Week	Airport		NSGAII	
	Time in minutes	Staff	Time in minutes	Staff
First week	86	49	72	44
Second week	69	53	66	46
Third week	77	50	88	42
Fourth week	87	52	92	46
Fifth week	95	53	100	45
Sixth week	89	57	93	45

TABLE3
EXPERIMENTAL RESULTS BY STAFF

Figures 1 to 5 shows that pareto-optimal results of NSGA-II are more compact based on time duration and passport officer's resources. Moreover, Table 1 shows the total time duration ranges from 66 to 100 minutes and staff ranges from 42 to 46. These results are much closer to airport dataset analysis and prove the correctness of our heuristics for multi-objective algorithms. In consideration of the average saving time duration for the six weeks experiments, Table 2 shows that NSGA-II is equivalent to airport analysis by zero time

saving in fever to saving 7 staff resources. In another words, NSGA-II using heuristics can schedule arrival flights taking same time duration but saving much of staff resources.

VII. Conclusion and future work

In this paper, the objective was to exploit the data collected at King Abdul Aziz Airport and generate algorithms to reduce the waiting time and Improve the logistics quality during the Hajj season. To achieve this, we considered using the NSGAII algorithm which has proven many potential results in saving time and staff. A reduced staff number has been proven by this algorithm on the whole 6 weeks data.

Our future work will be on testing many other algorithm and trying to compare the results.

References

VIII. References

[1] [Online]. Available: https://www.transportshaker-wavestone.com/retour-sur-le-paris-air-forum-2018/.

[2] Z. Alansari, S. Soomro and M. R. Belgaum, "Smart Airports: Review and Open research Issues," *International Conference for Emerging Technologies in Computing,* vol. 285, pp. 136-148, 2019.

[3] H. Zhang, "Study on IoT Solutions in Smart Airports," *International Conference on Artificial Intelligence and Security,* vol. 1253, pp. 170-179, 2020.

[4] S. Bouyakoub, A. Belkhir, W. Guebli and F. M. Bouyakoub, "Smart airport: an IoT-based Airport Management System," *Proceedings of the International Conference on Future Networks and Distributed Systems,* pp. 1-7, 2017.

[5] A. Alghadeir and H. A.-. Sakran, "Smart Airport Architecture Using Internet of Things," *International Journal of Innovative Research in Computer Science & Technology (IJIRCST),* p. 8, 2016.

[6] A. Newbold, "Transforming a functional airport to a smart, digital one," *Journal of Airport Management,* vol. 14, pp. 106-114, 2020.

[7] N. C. E. P. University, "Research on Airport Security Based on Virtual Queuing Theory," in *International Conference on Network, Communication, Computer Engineering*, China, 2018.

[8] I. O. Y. Bengu Sevil Oflac, "IMPROVING PASSENGER SATISFACTION AT AIRPORTS: AN ANALYSIS FOR SHORTENING BAGGAGE ACCESS TIME," *Journal of Management, Marketing and Logistics – (JMML),* vol. 1, no. 4, 2014.

[9] V. Falcão and A. Correia, "Analysis of waiting times in the baggage claim area of an airport passenger terminal," *Journal of Airport Management,,* vol. 8, pp. 57-70, 2014.

[10] J.-H. Kim and J.-W. Park, "other researches and surveys have focused more on the improvement of self check-in services in order to facilitate all procedures and consequently save time with a guaranteed security," *Sustainability,* vol. 11, 2019.

[11] H. Samy, "STUDYING TRAVELER'S USE OF SELF CHECK-IN TECHNOLOGIES IN SMART AIRPORTS," *Journal of Association of Arab Universities for Tourism and Hospitality ,* vol. 14, pp. 79-90, 2017.

[12] A. Alrabghi, "Modelling Passengers Flow at Hajj Terminal in Jeddah," *International Journal of Simulation: Systems, Science & Technology,* vol. 20, p. 4.1, 2019.

[13] R. a. A. G. a. A. L. a. A. S. N. S. a. B. O. a. N. N. AlMashari, "IoT-based Smart Airport Solution," in *2018 International Conference on Smart Communications and Networking (SmartNets)*, Yasmine Hammamet, Tunisia, 2018.

[14] S. V. Khadonova, A. V. Ufimtsev and S. S. Dymkova, "“Digital Smart Airport” System Based on Innovative Navigation and

Information Technologies," *2020 International Conference on Engineering Management of Communication and Technology (EMCTECH),* pp. 1-6, 2020.