A MICRO-SIMULATION OF AIRPORT PASSENGERS WITH ADVANCED TRAITS

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Abstract

An approach for modeling passenger flows in airport terminals by a set of devised advanced traits of passengers is proposed. Advanced traits take into account a passenger's cognitive preferences which would be the underlying motivations of route-choice decisions. Basic traits are the status of passengers such as travel class. Although the activities of passengers are normally regarded as stochastic and sometimes unpredictable, we advise that real scenarios of passenger flows are basically feasible to be compared with virtual simulations in terms of tactical route-choice decision-making by individual personals. Inside airport terminals, passengers are goal-directed and not only use standard processing check points but also behave discretionary activities during the course. In this paper, we integrated discretionary activities in the study to fulfill full-range of passenger flows. In the model passengers are built as intelligent agents who possess a bunch of initial basic traits and then can be categorized into ten distinguish groups in terms of route-choice preferences by inferring the results of advanced traits. An experiment is executed to demonstrate the capability to facilitate predicting passenger flows.

1 Introduction

The world-wide airline industry has grown rapidly in the last two decades, especially in the Asia-Pacific area. Large growths of air travelers make the role in transportation of people served by airports become much more important nowadays. Together with changing policies and new technologies implanting into airport terminals, handling passenger flows faces a big challenge. Increasing the efficiency of the existing airport facilities and optimizing passenger flows for full usage of terminals are regarded as desired solution for the growth issue. For passengers in particular, their behaviours are not easy to define in models due to the stochastic patterns. Although previous studies are at an aggregated level and almost say nothing of how individual passengers behave when traveling through airport terminals, the relations among passenger logistics and the presence of bottlenecks and their causes are worth of investigating.

Instead of conventional macroscopic passenger flows studies [1-3], we take a "bottom-up approach" to observe route formation of passenger flows in microscopic. Due to the presence of standard processing check-points throughout airport terminals, i.e. check-in, security screening, immigration, customs, quarantine inspection and boarding, so queue-based models initially dominate airport system models [4]. Later on, many models were applied to estimate terminal capacity, passenger delays and spatial configuration [5-7]. In this paper, we consider to describe pedestrian underlying motivates which would predict how and why the pedestrian moves. We choose an agent-based approach to simulate passenger flows in airport terminals. Agent-based model can instantiate agent interactions with other agents and the environment instead of processes within the system which control entity [8-9]. Typically it presents a sense of agent autonomy which is not present in entity-based models.

There is a major shortfall that discretionary activities of passengers are not incorporated to model passenger flows [10-11]. Fig. 1 illustrates intuitive passenger flows which can be easily observed in airport terminals. In this regard, we first demonstrate a lack of advanced passenger behaviours in airport terminals in previous airport simulation studies (Section 2), and provide a set of advanced passenger characteristics which indicate behaviours in virtual simulated airport terminals. In Section 3 we develop a route-choice decision-making model based on proposed traits and carry out a simulation of passenger flows. In Section 4, we summarize our conclusion and propose some areas of future works.

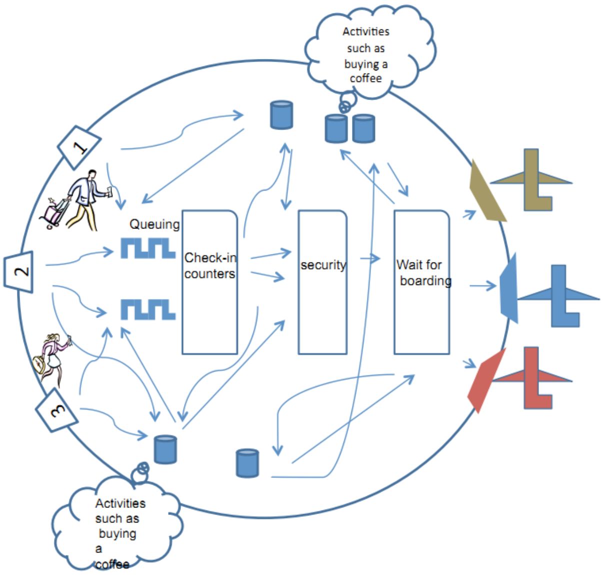

Fig. 1 Overview of passenger flows in departure process

2 Advanced Traits of Passengers

In an airport environment, passenger behaviour is guided by socio-economic factors and by short-term or long-term goals, for example buying a coffee or a bottle of water because of thirst or in preparation for boarding a flight that does not have in-flight service (e.g., on a low-cost carrier). These are assumed as discretionary activities. Standard processes refer to check-points where passengers have to proceed such as check-in, security, immigration and boarding. We pose passenger's movement in airport terminals as a series of continuous route-choice optimizations which would enable to determine an alternative route with respect to cognitive preferences.

Advanced traits are devised in this paper to represent cognitive preferences of passengers. Aiming to cover all potential mandatory processing activities and discretionary activities in airport terminals, we investigated service facilities provided by 15 major airports around the world. This review included three airports in Europe (London Heathrow, Amsterdam Schiphol and Frankfurt), three airports in the United States (Atlanta, Chicago O'Hare and Los Angeles), three airports in Asia (Singapore Changi, Hong Kong and Tokyo Haneda), two in Australia (Melbourne and Brisbane), one in the Middle East (Dubai), and a few limited examples in other parts of the world. By making this selection, we ensure that any cultural/regional variability is able to be represented.

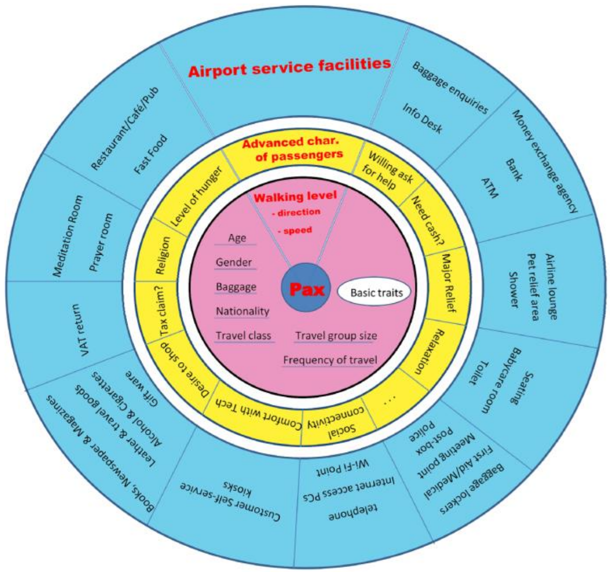

Fig. 2 Advanced traits and corresponding activities that passenger would undertake

Following this review, we were able to categorize universal airport service facilities into eleven major categories. Fig. 2 shows the eleven categories of airport service facilities and their relations with passenger activities. The outer ring shows the airport facilities, the medium ring describes some characteristics which influence a passenger's use of a particular facility, and the inner ring shows the basic traits of a passenger. Basic traits facilitate walking function of an individual agent – avoiding obstacles, keep a tolerance distance with other passengers and walls, walking speed and walking direction. Advanced traits are used for decision-making of individual passengers – medium- and long-range rout choice, service facilities choosing, dwell time at different facilities. Advanced traits evidently can impact on the most inner circle - walking level. These characteristics form the basis of our proposed advanced passenger characteristics.

Facilities in every category cater passengers for a particular purpose. Restaurant, Café, Pub and Fast Food are formed as a group because they provide food for passengers. Similarly, Baggage enquires and Info Desk provide information services and so that they are categorized in the same group. Except standard processing, services being provided to passengers can be concluded as ten major fields in this way. They are food service, information service, cash service, major relief, basic relaxation, social connectivity, fast self-service, shops, tax return and religion-related service. Advanced characteristics of passengers are devised according to the ten.

3 Route-Choice Decision-Making

Three level dynamics of passenger movement are devised. They are localized, tactical and strategic respectively. Localized dynamics denote small-scale walking capability, i.e. desired walking speed, avoiding obstacles and tolerance distance with other passengers, which is applied by a force-based model [12]. Strategic dynamics represent destinations that passengers should go to, i.e. boarding gate for departing passengers. Route-choice decision-making model of passenger agents was next devised to fulfill the tactical dynamics. Since route-choice decision-making mechanisms are hard to be observed in real world, we addressed the underlying motivations of passengers of deciding alternative target and route by the advance traits.

In this paper, a simulation scenario is devised firstly (Fig.3). It is a departing process. Cross denotes the entrance of check-in hall. Beside normal check-in desks, seven other service facilities are included as well. Each facility is the target that passengers would choose based on corresponding advanced traits (Table 2). *Time Stress* is an environmental element. It refers to whether there is enough time left till boarding. If not, passengers must not behave any discretionary activities and proceed standard processing procedure as quickly as possible lest they miss flights.

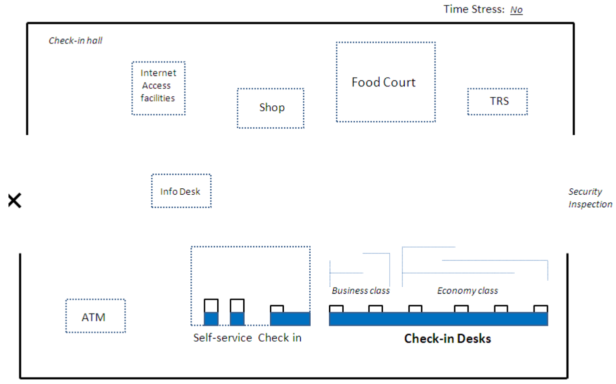

Fig. 3 The simulation scenario

Table 2 Selected advanced tratis of passengers

Advanced traits	Target preferences
Hunger and thirsty	Food court areas
Desire to shop	Shop areas
Willing ask for assistant	Info Desk
Comfort of Technology	Self-service Check-in
Need cash	Automatic Teller Machines (ATMs)
Social connectivity	Internet access PC desks
Tax claim	Tax Refund Scheme (TRS) counter

3.1 Inference of Advanced Traits

Bayesian network is used to possess the initial basic traits of passenger agents. It is an acyclic graphical model with the ability to model causal relationships from parent nodes to child nodes [13]. It is implemented here to model cognitive preferences of passengers, although it was first not designed for this purpose. During the simulation process, six basic traits are stored while passenger agents are initially generated. Also, every passenger attains random values assigned to his basic traits as evidences. In this paper, basic traits are age, gender, frequency of travel, travel class, nationality and hunger level, whose data type are illustrated in Table 3. The seven advanced traits can be inferred by the basic traits based on conditional probability tables assigned into the Bayesian networks. The causal relationships between basic traits and advanced traits are clearly demonstrated in Fig. 4. For instance, a passenger age of 65 who use the airport for the first time would most possibly “Willing ask for assistant”. Since the probability results need long-term studies, thus conditional probability tables of the Bayesian networks are constructed by empirical data at this stage.

Table 3 The data type of basic traits

Trait	Data Type	Value Example	Note
Age	Integer	28	Age information on the ticket; Discrete Normal distribution if the information is unavailable, alpha = 42
Frequency of travel	Integer	2	Records from airlines or airport, i.e. *Frequent Flyer*; Uniform “0,1,…,10” if the information is unavailable
Baggage	Boolean	True	“Carry-on only” is *False*, others are *True*; 10% chance *True*, if the information is unavailable
Travel class	Boolean	True	“Economy” is *True*, others are *False*; 20% chance *False*, if the information is unavailable
Nationality	Boolean	False	“Native” is *True*, others are *False*; 40% chance *False*, if the information is unavailable
Gender	Boolean	True	“Male” is *True*, “Female” is *False*; 50% chance *True*, if the information is unavailable
Hunger Level	Boolean	True	“Hungry” is *True*, others are *False*; 50% chance *True*, if the information is unavailable

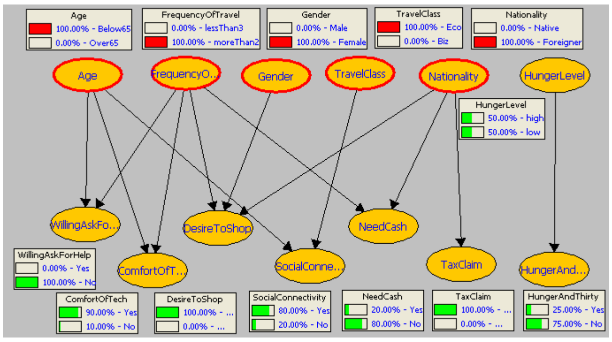

Fig. 4 Conditional probabilitis of advanced traits

3.2 Tactical Route-Choice Decision

The model framework of tactical route-choice decision of passenger agents is as shown in Fig. 5. In the simulated check-in hall environment, route-choice decisions of passenger agents are controlled by both *Advanced traits* and *Time stress* (Fig. 6). A passenger agent has six alternative targets when he enters the check-in hall. As long as the value of *Time Stress* is “*No*” – there is enough time for a passenger agent to pass all standard check points and get on board on time, discretionary facilities, i.e. food court, shops, ATMs and internet access PC desks, may have a certain probability of being utilized by passengers.

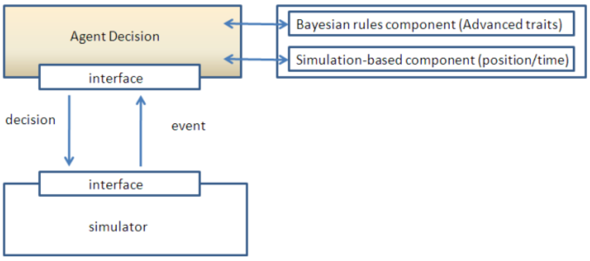

Fig.5 Tactical decision framework of passenger agents

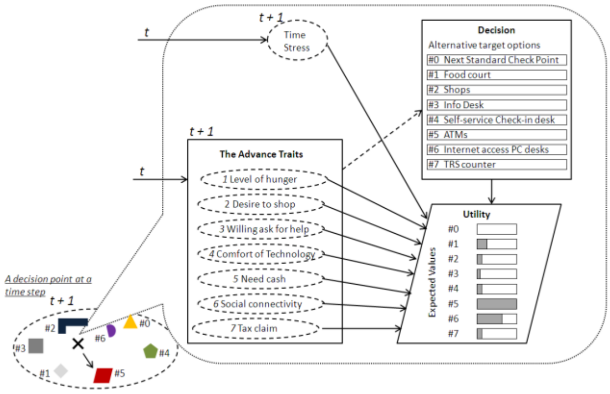

Fig. 6 Illustration of route-choice at a decision point

Route-choice decision-making is made by utilizing a devised utility table, which represent the utilities for all distinguished *Decision*. The dash line from *Advanced traits* to *Decision* demonstrates that decisions are made with the initial knowledge of values of the traits. To acquire a sequential route-choice, targets are chosen at every decision point along time steps. Basically, the traits related to direct standard processing operations have the highest priority. Other traits are assigned with different utility values according to urgent circumstances or special needs. If a passenger has been to a discretionary facility, the value of that advance trait is changed to negative automatically. For example, a passenger agent went to food court at last time period and surely fulfils his desire to eat food, and meanwhile the value of the node *Hunger level* becomes negative. At next decision point, it is compulsory that the utility value of using *Food court* is negative. In addition, *Time stress* is used to evaluate the utilities of choosing a target as well.

The instance decision-making procedure by the graphical model in Fig. 6, constructed four portions of nodes together – The advanced traits, Time Stress, Decision and Utility. Since the expected utility value of the fifth action is the highest, the passenger agent chooses the corresponding target instantly. After fulfilling current activities the agent will repeat the same decision-making procedure, however some values of advanced traits are changed because of accomplished activities. Once the simulation time reaches the condition of time constrain, which means the value of *Time Stress* changes and so the utility of directly proceed check points is the highest due to the results of expected values.

3.3 Simulation Outcomes

With the above route-choice decision-making model, ten rounds simulation of passenger flows were executed. The average dwell time of passengers at service facilities are listed in Table 4, which was acquired from the surveys conducted by the Airport of the Future project. Facility utilizations were estimated in the simulation model. Two scenarios are compared with regard to dwell time in check-in hall. Scenario 1 only consists of standard processing procedures. Scenario 2 integrated discretionary activities of passengers within the whole passenger flows process.

Table 4 Average dwell time at service facilities

Standard Check Points	Dwell time (minutes)	Processing time (seconds)
Check-in	1020s – 1200s	22s
Ancillary facility	**Dwell time (seconds)**	**Distribution**
Shop	300s – 450s landside	Normal distribution, alpha = 371s
Food court	1650s – 1750s landside	Normal distribution, alpha = 1709s
Internet	1600s – 1700s	uniform
ATMs	60s – 70s	uniform
Information Desk	5s – 60s	uniform

Time spends in check-in hall in check-in hall in Scenario 2 is divided into two portions. The cross shapes in Fig. 7 stand for dwell time of passengers who behave discretionary acuities. The short-line shapes represent the time spend of passenger who only use standard check points and evidently are similar with those in Scenario 1. By integrating discretionary activities within the whole passenger flows processes, passengers would spend about double time in check-in hall other than directly proceed to security inspection counters, which seem intuitive with regard to real scenarios in airports.

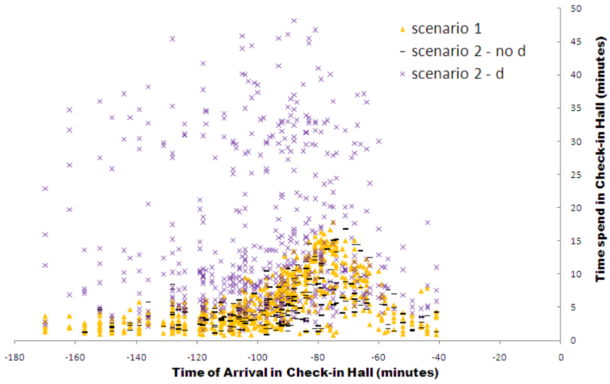

Fig. 7 Time spend in Check-in hall

In addition, the dispersing passenger movement brings about convincible numbers of passengers occupying standard check-point areas in Scenario 2. We believe that by enabling these types of interactions, passenger flows simulation in airport terminals can be more realistic and reliable for use in planning exercises.

4 Conclusion & Future Work

Conventional studies concentrated standard processing facilities such as check-in, security, immigration. However, in fact passengers spend a significant portion of time in airport terminals outside these facilitates. To make passenger behaviours more intuitive as expected, it is therefore embedding advanced traits within the passenger flows model. Although it is not hard to distinguish standard processing and discretionary activities of passengers in airports, implementing a model of describing passenger' underlying motivations to predict how and why the passenger moves is more complex. The paper aims to devise a feasible route-choice decision-making model based on the envisaged advance characteristics, which may best serve to answer the question of how small-scale actions that occur along the way can be important to decide the formation of movement flows.

Furthermore, Simulation outputs can be generated for the interests of different stakeholders. For example, retailers prefer the information of the dwell time of passengers at duty-free shops areas according to simulation statistics. Airport operators also have interests of queue length and average queuing time before standard processing counters.

This initial model of route-choice model with regard to advanced traits of passengers will be further developed to integrate other major traits of passenger and will be validated through real scenarios.

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