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Research on the Improvement of American Security Process Based on Cellul ar Automaton Simulation

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Abstract: Nowadays, with the continuously strengthening of the security system, the US security system has been criticized a lot because of the overly cumbersome security steps. In order to study how to improve the current process, the research in the paper uses mathematical modeling methods and bases on the Theory of Queuing to establish Cellular Automata Security Simulation Model. After verifying its reliability, we use the model to simulate the security process in different situations. We draw suggestions as follows: Airports should scatter people flow in the B area and reduce the proportion of Pre-check visitors. After that, we use simulation to verify the practicality of the suggestions. The proposed modification has a reliable reference value for the security systems' efficient operation.

Keywords: Airport Security; Queuing Theory; Cellular Automaton(CA); Security simulation model

1. Introduction

Nowadays, the process that the US Transportation Security Administration(TSA) developed is mainly followed by the US airport security. The flow chart shown in Figure 1:

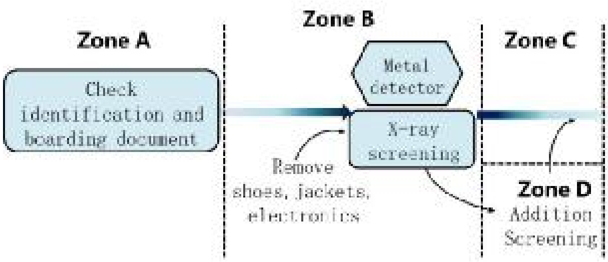

Figure 1. TSA Airport Security Process

Firstly, passengers line up in zone A to check their identifications and documents. Secondly, passengers must remove shoes, belts, jackets, metal objects, electronic, and containers with liquids, placing them in a bin to be X-rayed in zone B, and meanwhile they process through a millimeter wave scanner. Thirdly, if they pass the scanner, they can enter into zone C and then leave. But if passengers that fail the step, they will receive a pat-down inspection by a security officer in zone D. Also, about 45% passengers join a plan called "Pre-check". This part of passengers can accelerate their security process but the effect is not so apparent.

In order to propose feasible suggestions, we use the CA to model the security process. By this way, we can not only find the problem through its dynamic changes, but also verify the validity of the improvement.

2. The Establishment and Verification of Simulation Model of CA

2.1. Modeling Assumption

Assuming the degree of congestion has no effect on the service time.

2.2. Relationship between temperature and air temperature at different depths of Asphalt Pavement

Assuming the passenger cell speed is the speed of the people's flow on the airport security channel
Assuming the travel status of each passenger only affects the person who closest to him.
Assuming each passenger does not accidentally affect the status of his travel in the traveling status.

2.3. The establishment of simulation model of CA

The CA model is based on a simple set of states and local interactive rules, which can be represented by a quaternion:
Among the formula, A represents a cellular automaton, L represents the dimension of cell space, S represents finite state sets of cells and N represents a combination of cells within neighborhoods In this question, the security simulation model is established as follows:

Table 1. Number

Symbols	Definition

T	Arrival time of different passengers
F	Average number of arrivals
v	Real time speed of passenger cell
a	Acceleration of passenger cells
	Distance between passenger cell and front cell
	The cell value of the current cell D
	The time for passengers to stay at the service station cell

2.3.1. The definition of the cells' state

Cells are basic components of Cellular automaton. In this paper, the security channel is divided into equidistant lattice in the cellular automaton security model and each lattice represents a cell. The system updates its state according to a given ruleIn this problem, we define 6 kinds of cells.

Slow Passenger Cell: It means that the passengers who are in a slow speed because of the cumbersome baggage. Its value is 1. Its probability of occurrence is 85%.

Fast Passenger Cell: It means that the passengers who carry baggage fewer than slow passengers therefor they have fast speed. Its value is 2. Its probability of occurrence is 17%.

Dangerous Passenger Cell: It means the passengers who take dangerous goods. Its probability of occurrence is 3%.

Security Channel Cell: It constitutes the passenger cell's motion path. The security channel consists of cells with value 0.

Channel Boundary Cell: It is placed on both side of security channel with value -1.

Service Desk Cells: It consists of three cells and its value is 3.

After the defining the cells, we can use MATLAB 2014a to simulate the cellular automaton security simulation initialization model. Its schematic diagram is shown in Figure 2:

Figure 2. The Demonstration of Security Simulation Model

2.3.2. Determine local rules

Local rules are the most important steps in building a cellular automaton simulation model and the passenger cell moves according to the rules. The security model used in this article is Von. Neumann-type neighbor, that is, the next step's state of the central cell is only affected by its own and the surrounding four cells. [3] In this problem, because the passenger cell only runs on the security channel cell, so the state of the central cell is affected only by the two cells before and after. Its rules only need to be developed according to cells before and after.

Since queuing theory can dynamically describe the queuing characteristics in the stochastic service system and the average waiting time of customer queuing, the four components of input queuing, queuing rules, number of service desk, service time, and customers are finite in this paper respectively. It is reflected in the arrival time of passengers, waiting for queuing rules, the number of parallel service desks, and the service time obeying the negative exponential distribution. Therefore, here the relevant rules are formulated according to the queuing theory.

Passenger cell access to cellular automaton security simulation model of the rules:

According to the queuing theory, although the arrival time of different passengers is not uniform, in this model the arrival time T of each passenger obeys the Poisson distribution, that is, the mean and variance of T are equal: Where is the number of variables.

Three types of passenger cells into the cellular automaton security simulation model rules: As the airport there are normal passengers, fast passengers, the probability of different speeding passengers, according to experience here to determine the probability of two types of visitors to the cell is: The maximum speed of the passenger rules

In this model, each simulation of the security channel congestion degree is different here to set the maximum rate of passenger cells and the minimum speed are:

The speed here is expressed in terms of the number of cells in the channel per unit of time.

Passenger acceleration rules

In this model, passengers are allowed to select acceleration or deceleration depending on congestion conditions, and empirically set the acceleration of each passenger cell as follows: That is only allow the passenger cell per unit step to increase or decrease a speed unit.

Passenger cell acceleration rules, Whether the acceleration of the passenger cell is based on the distance L from the front of the cell to judge to come here to set the following judgment:

Where v is the current speed of the passenger cell, and the is the time factor in the cellular automaton, which is a prerequisite for the acceleration of the passenger cell. However, even if the passenger cell satisfies this condition, it is still possible to give up acceleration because of the different character of the passenger, so here we empirically set an acceleration probability, is 70% of the possible choices are accelerated. The speed of each acceleration is updated in the model as: Deceleration rules of passenger cells. The same passenger cell before deceleration must also be judged, the judge is as follows:

If the judge should slow down, the passengers in order to avoid the collision will choose to slow down; at the same time even if L is a safe distance, the passenger cell will be a certain probability deceleration, deceleration rate update:In the decelerating case ,The above is the operating rules of the passenger cell in the model simulation.

2.4. Practical verification of security simulation model

In order to verify whether the simulation model of cellular automaton can simulate the airport security process accurately, iGrafx simulation software is introduced to simulate the airport security process.

IGrafx simulation software is a globally recognized, leading and comprehensive business analysis software, which can output the time report after setting the parameters of "transaction", "activity", "resource" and "cost".

Finally, we compare the output of a single cell of the two models with the average step size of the security system (Table 2) to verify the practicality of the model.

Table 2. The Output Comparison between CA and iGrafx

	1	2	3	4	5	Average
CA	321	271	283	315	280	294
iGrafx	263	313	298	349	277	300

In order to verify whether there was significant difference between the two groups of data, using SPSS Statistics 21.0 for significant difference analysis, the results showed that 95% confidence in the two models can be considered the output of the data no significant difference, so we verify that this paper the simulation model is correct and suitable for the security process simulation, and the output is credible and worthy of reference.

3. Make Changes to the Current Process and Verify its Effectiveness

3.1. Proposed amendments

After several simulation statistics, We find that Zone B is the bottleneck among the whole process and congestion in Zone B will also cause the congestion in Zone A. On one hand, the main cause of the congestion in Zone B is that security process is far too cumbersome and there is too much time wasted in this area. Meanwhile, the problem will be easier to be exposed when the length of the channel is short.

On the other hand, although the former process had added Pre-check channels, because of the large proportion of the passengers is not accustomed to the proportion of the Pre-check channels. So in spite of the reducing normal channels' pressure, but it will also cause congestion of the Pre-check channel when the passengers' flow is large.

Combined with the above factors, we propose two suggestion aimed at reduce the waiting time.

·Increasing the number of Zone B security channels. So that passengers through the Zone A can be triaged again, to ease the original one-one corresponding pressure of security in the Zone B and shorten the total time to check all passengers.

·Reducing the proportion of Pre-check passengers. So that Pre-check channel can not only reduce the pressure of other ordinary channels, but also not prevent itself blocked when the flow of passengers is large.

3.2. Demonstration modification proposal and analysis

In the CA constructed above, we modify the rules to describe the increase of the B-zone security channel and the increase of the VIP channel, and then compare the two proposals with the original process of passenger throughput and per step through the security process.

For the increase of Zone B security channel, we make the passenger cell in the service desk A to do their judgment to the two channels in accordance with the previously developed out of the service desk rules before departure, moved to the front channel without passenger cell, if the two Channels in front have no passengers, then choose a channel out of the service desk in the probability of 0.5 randomly.

For reducing the proportion of Pre-check travelers, we let the proportion of passengers entering the Pre-check Pass be:

After the new rules are established, simulate the original process, the process after adding B-zone security channel, the process after adding the VIP channel through CA. The three operating states are shown in Figure 3:

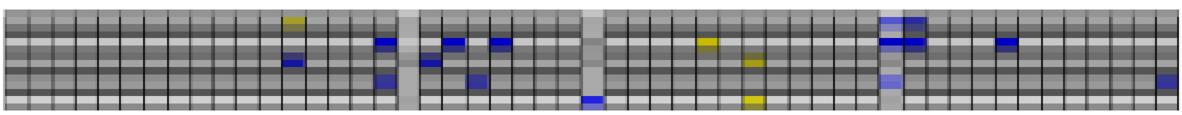

Figure 3. Comparison between the Original Situation and Modified Situations

In order to more intuitively describe the above three states how impact the final passenger throughput and per capita security through the step size, here we use MATLAB 2014a simulation to make its output in three states of each cell through security steps to draw as contrasted with Figure 4, Figure 5

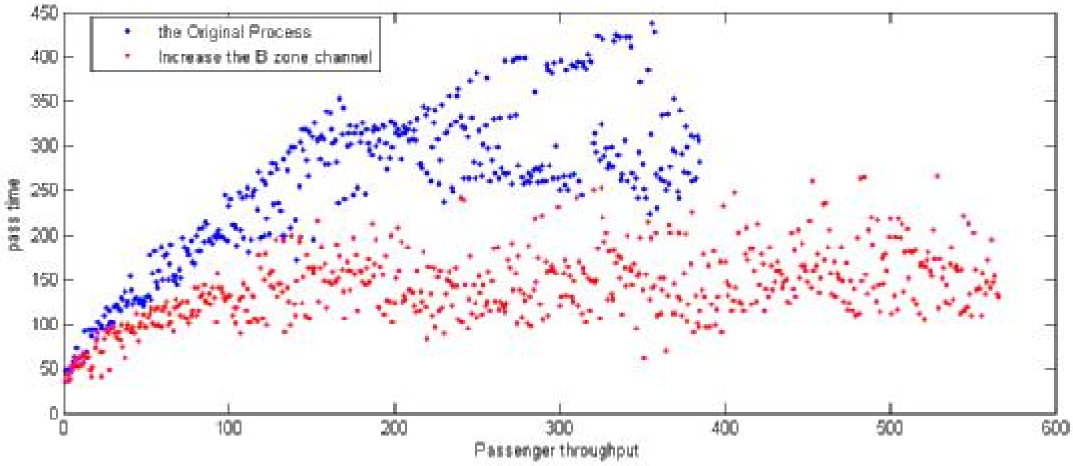

Figure 4. The Comparison between the Original Process and the Situation of Increasing the B Zone Channel

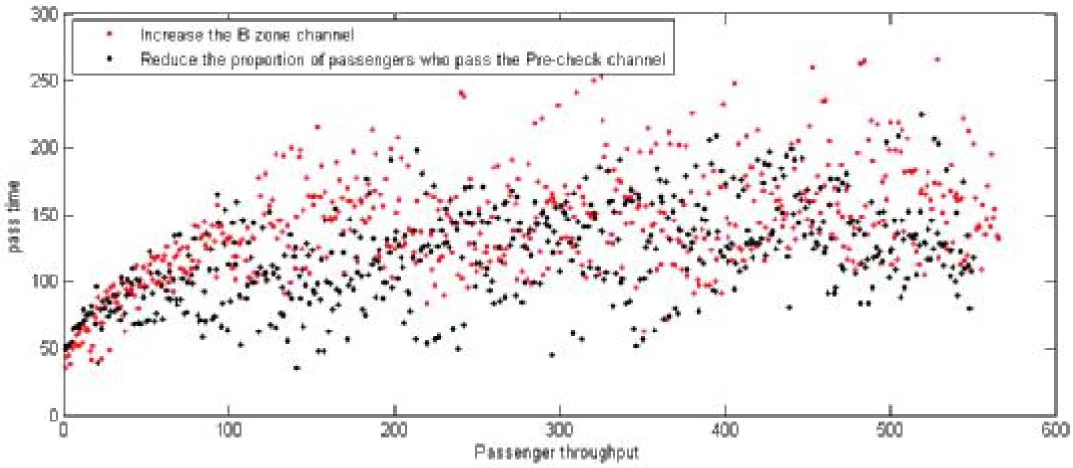

Figure 5. The Comparison between Situations of Increasing the B Zone Channel and Reducing the Passengers Who Pass the Pre-check Channel

The abscissa of visitors in both graphs reflects the throughput of the security process; the ordinate is the total step size of the individual through the security process. As can be seen in Figure 5, when the number of passengers cells entering the cell simulation model is equal:

·Longitudinal contrast, increasing Zone B security channel can significantly shorten the total step length of passenger cell crossing security, so the measure can effectively reduce the difference of passenger's waiting time.

·Horizontal contrast, when the model tends to be smooth, the number of passengers after increasing channels is more than the number of passengers in the original process, so increasing the security channel can also greatly improve the passenger throughput of security process.

Through the comparison of the ratio of the B-zone shunt and the decrease of the Pre-check channel in Figure 5 we can see:

·Moderate reduction of the proportion of passengers in the Pre-check channel, there is a significant improvement in the passenger throughput and the time passenger crossing security, so reducing Pre-check passenger ratio is an effective modification of the proposal.

From the local comparison, when the passenger throughput of the model at (100,220) or so, open the VIP channel can also speed up the time to cross security, when the increase in passenger volume happen, this advantage gradually disappears. It shows that adding VIP channel can be superior to the Zone B diversion in the interval of a certain passenger volume. When the passenger volume exceeds this interval, this advantage gradually loses or even becomes a disadvantage.

4 . Conclusions

By establishing the simulation model of CA to analysis current process of the security process in US, the paper has verified the model's practicality several times. Then we make a diversion in section B and reduce the proportion of Pre-check aimed to increase passenger throughput and reduce waiting time. And we verify the practically of the suggestions. Finally, we propose more scientific and reasonable suggestions to improve the situation of security process in the US.

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