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Effectiveness of Cellular Phone with Active RFID Tag for Evacuation - The Case of Evacuation from the Underground Shopping Mall of Tenjin

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***Abstract*—**The underground shopping mall has the constructional problem of the fire evacuation. Also, the people sometimes lose their direction and information of current time in the mall. If the emergencies such as terrorist explosions or gas explosions are happened, they have to go out soon. Under such circumstances, inside of the mall has high risk for life. In this research, the authors propose a way that he/she can go out from the underground shopping mall quickly. If the narrow exits are discovered by using active RFID (Radio Frequency Identification) tags and using cellular phones, they can evacuate as soon as possible. To verify this hypothesis, the authors design the model and carry out the agent-based simulation. They treat, as a case study, the Tenjin mall in Fukuoka Prefecture in Japan. The result of the simulation is that the case of the pedestrian with using active RFID tags and cellular phones reduced the amount of time to spend on the evacuation. Even if the diffusion of RFID tags and cellular phones was not perfect, they could show the effectiveness of reducing the time of evacuation.

***Keywords*—**Evacuation, active RFID tag and cellular phone, underground shopping mall, agent-based simulation.

I. Introduction

THE underground shopping mall has a similar sight. Therefore, if someone has to evacuate from the underground shopping mall, he/she tends to overlook exits. Also when everyone evacuates from the mall, they sometimes pass through the narrow exit without stopping. At last, the wide exits, which can be found easily, will be crowded. If the emergencies such as terrorist explosions or gas explosion are happened, they have to go out soon. Also, under such circumstances, inside of the mall has high risk for life. In this research, the authors propose a way that he/she can go out from the underground shopping mall as soon as possible. If the narrow exits are discovered by using active RFID tag and using cellular phone, they can use this information and will evacuate as soon as possible. To verify this hypothesis, the authors design the model and carry out the agent-based simulation. They treat, as a case study of the Tenjin mall in Fukuoka Prefecture in Japan.

First, the authors explain the RFID tags. The RFID tags have two general categories, which are active and passive, depending on their source of electrical power [1]. Active RFID tags contain their own power source, usually an on-board battery. Passive tags of power source depend on the signal of an external reader. RFID readers also come in active and passive varieties. The active RFID tags can communicate with readers across 20 to 100 meters. The active RFID tags are used for information management such as management of international logistics, management inside container and management of children on the way between their school and home. On the other hand, the passive RFID tags can communicate with readers across less than one meter. The passive RFID tags are also used for information management such as card system of railways, card systems of government, card systems of public telephone, and access control system. The RFID tags are gradually paid to attention in the world as mentioned above. Japan is not an exception either. Japan is trying to contribute internationally to the advancement of ICT as the frontrunner. Therefore, the Ministry of Internal Affairs and Communications (MIC) planned “u-Japan Policy” to achieve “Ubiquitous Network Society” in 2004 [2]. Using RFID technologies are also included in this policy. It should be noted that MIC approved the specific districts of ubiquitous to achieve “Ubiquitous Network Society” in 2008. MIC gives the specific districts to limited Japanese districts. A radio law is deregulated in the districts for carrying out the demonstration experiment of using ubiquitous technology. MIC selected the district of 22 projects in 2008. One of the selected areas is introduced RFID tags for the management of health. The authors think the purpose of this policy means to expand application of RFID tags and other ICT technologies, not only commercial use but also public use.

While the public use of RFID tags are not popular yet. The issue in the diffusion of RFID tags has two points [3]. The one is the technical problem such as safety in use. The other one is social task such as reliability of information management.

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There are serious problem in practical use of RFID tags. An example of using active RFID tags for public is management of junior high school students on the way between their school and home. As for this system, when the child with active RFID tags arrives at the school, e-mail is sent to parents. That was carried out in a junior high school in Osaka from 2005 to 2006. Ministry of Economy, Trade and Industry Japan summarize the results of questionnaire about the demonstration experiment [4]. According to the report, while the reader rarely caused problem of accuracy of reading, the social tasks such as information leak are nothing. The success of this demonstration experiment is due primarily to the observation of operational guideline. Unless users do not observe operational guideline, activity range of active RFID tags will be gradually expanding.

The research for evacuation with active RFID tags was performed by agent-based simulation which the student evacuation in the case studies of elementary school [5]. The student was required to have a RFID tag in this research. The research shows that children with RFID tags can evacuate more safely and quick than usual acts.

This is noteworthy in terms of the advantage of RFID tags. The authors paid attention to evacuation behavior in the underground mall. They think above system is effective for finding exit in the underground shopping mall where the exit is not discovered easily. They carry out agent based simulation of the evacuation which used active RFID tags in the underground mall. The RFID readers are placed above the path. They gather data from active RFID tags and transmit the data to the computer, which manage exits of direction. The direction of proper exit is indicated on the cellular phone from the computer.

II. The Evacuation in Underground Shopping Mall

The underground shopping mall has the constructional problem of the fire evacuation [6]. In the mall, smoke and heat are the rapidly expanding. Due to this, rescue activity and fire fighting are difficult. Such respect shows the environment of evacuation. On the other hand, the underground shopping mall has the difficulty of understanding about space [7]. For example, the underground shopping malls lack the sun and landscape. The people sometimes lose their direction and time information for that reasons. This is fatal for evacuation. To solve this problem, some researches have been done. One of researches is memory of the sign for exit [8]. According to the research, it depends a great deal on the position of sign. However, optimal layout for exit sign has limit in the mall. Also, the stairs of exit are crowded by pedestrians who evacuate from the mall. To direct the evacuation, the rescue team will be not able to come down the stairs. Therefore, the authors think the individual evacuation is required in underground shopping mall.

III. The Necessity of the Active RFID Tag and the Cellular Phone

One engineer group developed 3D simulator and experiment in subway station of Kyoto [9]. In this simulator, they use cameras and cellular phones. They also use 3D virtual space and supervise victims at the control center.

In this research, the authors do not introduce such a complex computer system. They introduce simpler system with RFID tags and cellular phones. In this simulation, they direct evacuation for individual.

The active RFID tags can communicate with readers across about 20 meters. The authors think it is suited to using in underground space. For example, GPS is a major location system that uses satellites to locate objects on the ground. But, GPS will not work underground. Therefore, using RFID tags is proper in this situation.

In this simulation, active RFID tags and reader communicate with each other. The interaction of active RFID tags and RFID readers is shown in Fig. 1. If pedestrian has cellular phone, the computer sends e-mail for direction of evacuation. The pedestrian see displayed map in their cellular phone and find their evacuation direction.

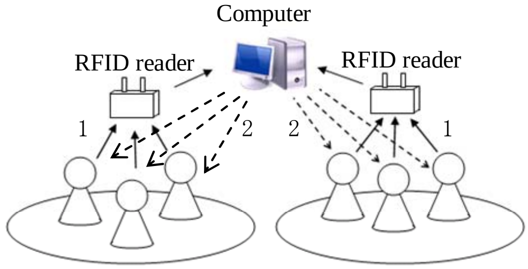


Fig. 1 Interaction of active RFID tags and RFID readers

At the 1st phase, the active RFID tags communicate with RFID readers. Then, RFID readers send the information to the computer. the 2nd phase the computer send e-mail for direction of evacuation to each cellular phone.

IV. The Model of Agent Based Simulation

A. Agent's Type and Rule of Behavior

In this model, the authors set pedestrian agent, exit agent, and RFID reader agent. Each agent's role and rule of behavior are as follows.

1) The exit agent represents the exit.

2) The pedestrian agent represents pedestrian. The attributes of this consist of age, sex, active RFID tag, and cellular phone. They repeat behavior rules. The behavior rules are shown in Fig. 2. If there is the wall in their traveling directions, they change direction. If they recognize the exit agent, they turn to the exit and acts according to the rule of flow. If they have active RFID tags, the active RFID tags communicate with the RFID reader agent, which shows reader of the active RFID agent, in the radius 13 cells.

3) RFID reader agent receives and reads from the active RFID tags of pedestrian agents.

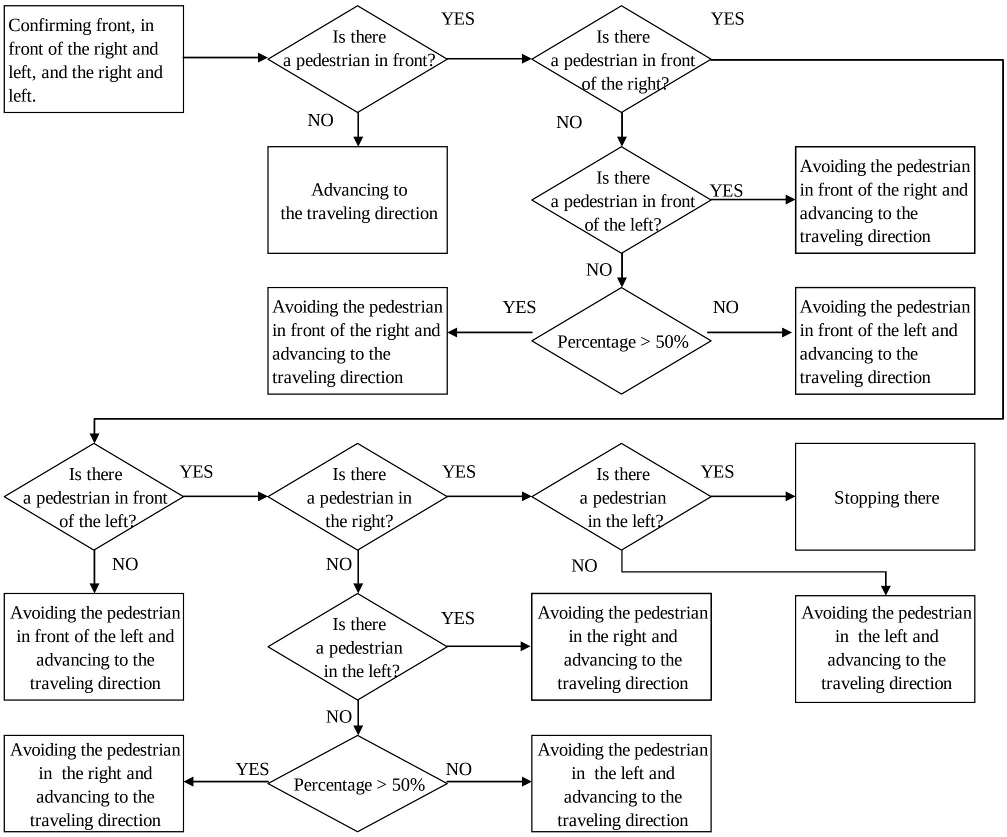
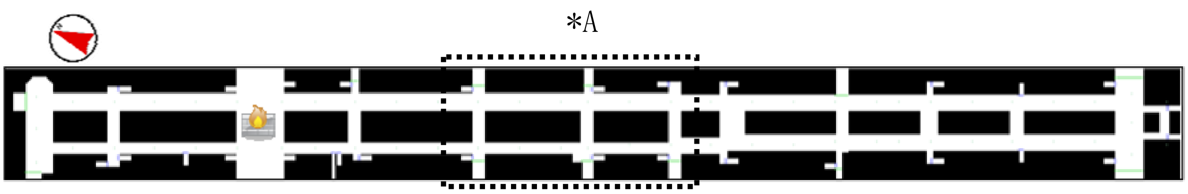
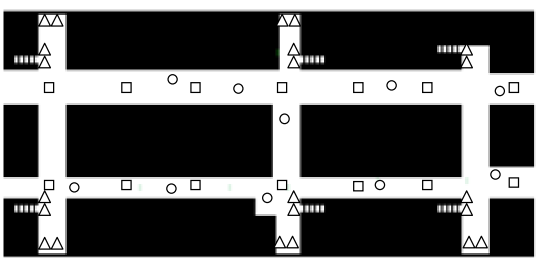


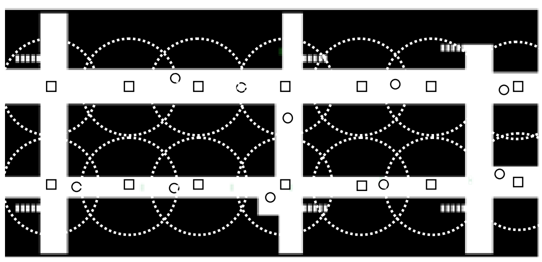
Fig. 2 The behavior rules of pedestrian agent



(a) The map of underground shopping mall of Tenjin



(b) The map of enlargement *A



(c) The interaction of active RFID reader and pedestrian agent

Fig. 3 Underground shopping mall of Tenjin

B. Layout of the Agents

The map of underground shopping mall of Tenjin is shown in Fig. 3(a). A cell measures 75 centimeters square. The black color outside frame shows the walls or shops, and a white color inside part shows the path. The path is consisted on 19,921 cells. Fig. 3(b) shows enlargement of *A in Fig. 3(a). Hatched area shows stairway of exit. The narrow exits have the width under three cells. The wide exits have the width over three cells. The triangle of Fig. 3 shows the fixed point of exit agent. The square shows the fixed point of RFID reader agent. Every agent occupies one cell. The mall of Tenjin has Tenjin station of subway in north side. The authors set starting point of fire at Tenjin station (see Fig. 3(a) mark of fire). At the initial step of simulation, the pedestrian agent is set at random on the path, and they turn to opposite side of starting point of fire.

The underground shopping mall of Tenjin has 590 meters street in a north-south direction. The authors categorized narrow exit which is inside of 2.5 meters wide. The other exit is categorized wide exit. They set 12 wide exits and 25 narrow exits in the simulation.

C. The Relation between RFID Reader Agent and Pedestrian Agent

The relation between RFID reader agent and pedestrian agents are shown in Fig 3(c). The dot shows the pedestrian agent. The RFID reader agent shown in the square is set above the path. The RFID readers collect the number of active RFID tags in the radius 10 meters. The RFID readers communicate with the computer, which manage exits of direction in the mall. The pedestrian agents get the direction information of evacuation by the computer.

TABLE I
WALKING SPEED OF PEDESTRIAN AGENT

	Walking speed, one cell per step	
Age groups	Male	Female
15-19	1.000	0.903
20-29	0.947	0.854
30-39	0.935	0.844
40-49	0.898	0.810
50-59	0.854	0.771
Over 60	0.836	0.754

TABLE II
ATTRIBUTE OF PEDESTRIAN AGENT: CASE1, CASE2 AND CASE3

	Having rate of ActiveRFID tags and Cellular phones	Age composition ratio	Male-Female ratio
Case1	0%	50%	50%
Case2	50%	50%	50%
Case3	100%	50%	50%

TABLE III
COMMON ATTRIBUTE OF PEDESTRIAN AGENT

		Male-Female ratio (%)		Diffusion ratio of cellular phones (%)	
Age groups	Ratio of age (%)	Male	Female	Male	Female
15-19	17	6.12	10.88	82.30	88.80
20-29	33	11.88	21.12	96.00	97.30
30-39	11	3.96	7.04	95.30	93.20
40-49	9	3.24	5.76	94.20	93.10
50-59	17	6.12	10.88	89.30	82.50
Over 60	13	4.68	8.32	53.00	40.78

TABLE IV
ATTRIBUTE OF PEDESTRIAN AGENT:
CASE4, CASE5 AND CASE6

	Having rate of ActiveRFID tags and Cellular phones	Age composition ratio	Male-Female ratio
Case4	0%	Data of survey (shown in Table3)	Data of survey (shown in Table3)
Case5	Data of survey (shown in Table3)	Data of survey (shown in Table3)	Data of survey (shown in Table3)
Case6	100%	Data of survey (shown in Table3)	Data of survey (shown in Table3)

D. The Attribute Data of Pedestrian Agent

The pedestrian agents belong to the age group which is separated into six groups. The six groups are categorized into age of 15-19, 20-29, 30-39, 40-49, 50-59, and over 60. The pedestrian agent also separated with sex. In this research, the authors consider the difference of the evacuation activity by the age group and the sex. The walking speed is shown in TABLE I. The walking speed per one step, male of the pedestrian agent, is converted by the ratio of data [10]. The walking speed per one step of female is converted by the ratio of data [10]-[12]. The pedestrian agent can see around 10 cells. The pedestrian also can recognize the wide exit by 80 percent per a step and the narrow exit by 20 percent per a step in the range of their field of view. This is a reflected of the result of the research for evacuation [13].

Case1, Case2 and Case3 are shown in TABLE II. Authors set pedestrian agents with age groups and sex. For investigating the effectiveness of active RFID tags in diffusion, the authors set equal proportion of age groups and sex. The 500 pedestrian agents are set on the simulation field.

The actual ratios of age groups and sex vary according to characteristics of underground shopping mall. Therefore the authors take the work on the questionnaire survey on underground shopping mall of Tenjin [14] to their model. As the diffusion rate of the cellular phone, they reflect the released data on the resent diffusion rate of cellular phone by MIC [15] to their model. Diffusion ratio of the active RFID tags cannot be examined. Therefore, the authors assume that diffusion ratio of the active RFID tags and that of cellular phones are same. The common attribute of pedestrian agents is shown in TABLE III. Next, Case4, Case5 and Case6 are shown in TABLE IV. Fundamental settings of these cases are incremented survey data.

E. Settings and Outputs of Agent Based Simulation

When the pedestrian agent completely evacuated from the underground shopping mall, the simulation ends. There are four kinds of data used for the analysis as follows.

The authors carry out above six cases every ten times.

1) The ratio of evacuated pedestrian agents from each exit
2) The end time of evacuation of each pedestrian agent; the pedestrian agent is separated with the age group and the sexes.
3) Amount of pedestrian agent in the underground shopping mall at the mid-period of evacuation
4) Final time of evacuation completion of all pedestrian agents

The ratio of evacuated pedestrian agents from each exit shows pedestrian agent had chosen either narrow or wide exit for evacuation. For comparison with end time of evacuation by age group and sex, they get the end time of evacuation according to the attribute of pedestrian agent.

To confirm the number of pedestrian agents by age group and sex who have been left in the underground shopping mall at

TABLE V
PEDESTRIAN AGENTS IN THE MALL AT THE MID-PERIOD: CASE1, CASE2, CASE3

		Age groups						Sexes	
		15-19	20-29	30-39	40-49	50-59	Over 60	Male	Female
Case1	Average of left pedestrians	22.85	24.35	23.00	22.45	24.05	23.65	23.32	23.47
	Standard deviation	4.03	4.51	3.31	4.80	3.95	2.71	4.30	3.47
	Maximum	28.95	28.85	29.95	30.40	29.95	28.80	29.12	29.85
	Minimum	15.45	14.35	19.45	15.40	18.45	20.30	15.45	19.02
	Percentage of left pedestrians	57.19	58.25	57.55	57.69	63.34	60.93	58.65	59.67
Case2	Average of left pedestrians	19.30	20.25	18.35	19.95	23.50	22.40	19.58	21.67
	Standard deviation	4.38	3.36	4.86	3.90	4.02	4.78	4.19	4.25
	Maximum	24.30	25.95	28.40	24.95	30.85	28.45	25.42	28.88
	Minimum	10.80	14.95	9.90	12.45	18.35	14.45	12.25	14.72
	Percentage of left pedestrians	52.45	52.58	47.78	51.89	58.05	54.53	50.99	54.78
Case3	Average of left pedestrians	13.85	17.50	15.40	16.75	18.85	18.80	15.50	18.22
	Standard deviation	5.17	5.31	5.20	3.98	4.11	4.89	4.99	4.57
	Maximum	21.05	24.00	22.85	23.60	24.60	28.30	22.68	25.45
	Minimum	6.05	8.00	5.85	10.60	12.60	11.30	6.85	11.28
	Percentage of left pedestrians	37.39	46.02	38.67	42.62	50.39	47.43	40.31	47.20

TABLE VI
THE END STEPS OF EVACUATION: CASE1, CASE2 AND CASE 3

		Age groups						Sexes	
		15-19	20-29	30-39	40-49	50-59	Over 60	Male	Female
Case1	Average end steps of evacuation	302.00	376.65	379.45	375.95	409.40	389.05	363.13	381.03
	Standard deviation	46.71	85.17	88.00	85.38	63.43	68.30	81.70	63.97
	Maximum	382.50	494.50	566.00	512.50	524.50	531.50	505.00	498.83
	Minimum	226.00	232.00	234.50	216.50	282.50	278.50	210.83	279.17
Case2	Average end steps of evacuation	282.90	336.20	293.40	324.15	318.60	347.85	292.15	342.22
	Standard deviation	71.36	100.82	72.86	98.82	80.02	112.67	74.85	104.00
	Maximum	406.00	498.00	392.50	490.50	419.50	556.50	408.50	512.50
	Minimum	163.50	170.00	184.00	214.00	204.50	218.50	177.67	207.17
Case3	Average end steps of evacuation	201.00	224.30	192.00	186.70	240.40	260.60	216.67	218.33
	Standard deviation	95.80	90.68	53.16	50.63	88.59	97.59	86.25	72.57
	Maximum	414.00	440.50	302.00	257.00	397.00	464.50	394.67	363.67
	Minimum	100.00	133.00	139.50	123.00	135.50	118.50	121.00	128.83

the 50 steps, they count the pedestrian agents at the 50 steps. They also get the final time of evacuation.

V. Results and Disscussion

In this section the authors discuss the results of six cases of their simulation. The first, they discuss the results of Case1, Case2 and Case3. Next, they discuss the results of Case4, Case5 and Case6.

A. Results and Discussion about Age Groups and Sexes: Case1, Case2 and Case3

The number of the pedestrian agents at the 50 steps of simulation is shown in TABLE V. To analyze the number of pedestrian agents in the underground shopping mall, each age groups and sexes of pedestrian agents are shown in TABLE V. Comparing the age groups of Case1 with that of Case2, it can be seen that the average number in Case2 of pedestrian agents, which left in the underground shopping mall, was smaller the number of agents than that of Case1. Even in comparing average of total number of age groups in Case1 with that of Case2, the number of pedestrian agents in Case2 was 16.60 agents smaller than that of Case1. Authors compare the percentages of pedestrian agents, which left in the underground shopping mall, in Case1 with that of Case2. Comparing the each age group of Case1 with that of Case2, Case2 was smaller percentage of pedestrian agents than in each group of Case 1. Percentage of pedestrian agents with total number of age groups in Case2 was 6.28 percent smaller than that of Case1. Also comparing sex of Case1 with that of Case2, average the number of pedestrian agents in Case2 was 5.53 agents smaller than that of Case1. In the case that pedestrian agents have 50 percent of RFID tags and cellular phones, the number of pedestrian agents which left in the underground shopping mall is reduced more than that of normal evacuation in the initial 50 steps of simulation.

Next, the authors compare the age groups of Case2 with that of Case3. Comparing the age groups of Case2 with that of Case3, it can be seen that average number of pedestrian agents, which left in the underground shopping mall, in Case3 was smaller number of agents than that of Case2. Even in comparing average of total number of age groups in Case2 with that of Case3, the number of pedestrian agents in Case3 was 22.60 agents smaller than that of Case2. Authors compare the percentages of pedestrian agents, which left in the underground shopping mall, in Case2 with that of Case3. Comparing the each age group of Case2 with that of Case3, Case3 was smaller percentage of pedestrian agents than in each group of Case 2. Percentage of pedestrian agents with total number of age groups in Case3 was 9.13 percent smaller than that of Case2. Also comparing sex of Case2 with that of Case3, average the number of pedestrian agents in Case3 was 7.53 agents smaller than that of Case2. In the case that pedestrian agents have 100 percent of RFID tags and cellular phones. The number of pedestrian agents which left in the underground shopping mall is reduced more than that in case of introducing 50 percent in the initial 50 steps of simulation.

Comparing the result of Case1 and Case3, total of pedestrian agents with age groups of Case3 is reduced 15.41 percent. Comparing sex of Case1 with that of Case3, it can be seen that average of pedestrian agents in Case3 could evacuate 13.07 agents earlier than that of Case1.

The result of Case1, Case2 and Case3 shows that introducing the RFID tags and cellular phones has the effect of reducing pedestrian agents, which left in the underground shopping mall, in the initial 50 steps.

To analyze the end time of evacuation, step end time of age groups and sexes is shown in TABLE VI. Comparing the age groups of Case1 with that of Case2, it can be seen that average end time for evacuation of each age group in Case2 was earlier

TABLE VII
USED EXITS FOR EVACUATION: CASE1, CASE2 AND CASE3

		The type of exits		
		Wide exits	Narrow exits	Average of simulation end time
Case1	Average of passed pedestrian agents	21.52	8.81	507.50
	Standard deviation	4.23	2.37	59.86
	Maximum	29.46	13.08	593.00
	Minimum	15.85	5.72	408.00
Case2	Average of passed pedestrian agents	21.52	8.81	496.70
	Standard deviation	4.80	2.40	67.73
	Maximum	30.00	12.48	607.00
	Minimum	14.23	5.20	429.00
Case3	Average of passed pedestrian agents	21.25	8.95	348.50
	Standard deviation	3.93	2.24	102.66
	Maximum	27.46	12.72	573.00
	Minimum	15.38	5.92	211.00

than that of Case1. Even in comparing average of total number of age groups of Case1 with that of Case2, end time of evacuation in Case2 was 54.90 steps earlier than that of Case1. Also comparing sex of Case1 with that of Case2, average end time of evacuation of males in Case2 was 70.98 steps earlier than that of Case1. The average end time of evacuation of females in Case2 was 38.82 steps earlier than that of Case1. The result shows that the time of evacuation could be reduced by introducing 50 percent of RFID tags and cellular phones.

Next, the authors compare the age groups of Case2 with that of Case3. Comparing the age groups of Case2 with that of Case3, it can be seen that average end time of evacuation of age groups in Case3 was smaller than that of Case2. Even in comparing average of all age groups of Case2 with that of Case3, end times for evacuation of pedestrian agents in Case3 were smaller than that of Case2. Also comparing sex of Case2 with that of Case3, average end time for evacuation of males in Case3 was 75.48 steps smaller than that of Case2. The average end time for evacuation of females in Case3 was 123.88 steps smaller than that of Case2. The result shows that the time of evacuation could be reduced by introducing 100 percent of RFID tags and cellular phones.

Comparing the result of Case1 and Case3, average end time for evacuation of pedestrian agent with age groups in Case3 was 154.58 steps smaller than that of Case1. Comparing sex of Case1 with that of Case3, it can be seen that average end time for evacuation of males in Case3 was 146.47 steps smaller than that of Case1. The average end time for evacuation of females in Case3 was 162.70 steps smaller than that of Case1.

The result of Case1, Case2 and Case3 shows that introducing the RFID tags and cellular phones has the effect of preventing time loss of evacuation.

B. Results and Discussion about Exits of Evacuation: Case1, Case2 and Case3

TABLE VII shows the average number of pedestrian agents, which passed wide exits or narrow exits at the evacuation. Average of wide exits consists of average of 12 exits. Average of narrow exits consists of average of 25 exits. Also standard deviation, maximum and minimum consists of average of wide exits and narrow exits.

The authors compare the number of pedestrian agent, which passed wide exits, in Case1 with that of Case2. The wide exits were passed nearly the same number of pedestrian agents in Case1 and Case2. Also, the narrow exits were passed nearly the same number of pedestrian agents in Case1 and Case2. The average of simulation end time of Case2 was 10.80 steps earlier than that of Case1.

Next, they compare the number of pedestrian agent, which passed wide exits, in Case2 with that of Case3. The wide exits in Case3 were passed 0.27 of pedestrian agents smaller than that of Case2. On the other hand, the narrow exits in Case 3 were passed 0.14 of pedestrian agents larger than that of Case 2. Average of simulation end time of Case3 was 148.20 steps earlier than that of Case2.

The results showed that the pedestrian agents, who passed wide exits, were decreased slightly by introducing the active RFID tags and cellular phones. On the other hand, the

TABLE VIII
PEDESTRIAN AGENTS IN THE MALL AT THE MID-PERIOD: CASE4, CASE5 AND CASE6

		Age groups						Sexes	
		15-19	20-29	30-39	40-49	50-59	Over 60	Male	Female
Case4	Average of left pedestrians	20.65	45.70	16.35	12.95	25.65	18.30	15.93	30.60
	Standard deviation	2.99	4.37	3.11	2.89	3.85	3.02	3.04	3.70
	Maximum	25.55	52.75	21.30	17.65	30.80	22.50	19.72	37.13
	Minimum	17.05	39.75	11.80	8.65	18.80	13.00	10.72	25.63
	Percentage of left pedestrians	53.17	57.69	58.29	58.80	61.92	63.14	58.13	59.54
Case5	Average of left pedestrians	16.25	33.65	10.80	9.35	18.20	15.95	11.83	22.90
	Standard deviation	4.44	5.08	4.09	3.70	4.62	4.66	3.77	5.09
	Maximum	27.90	42.20	17.05	14.60	24.15	22.15	17.92	30.17
	Minimum	10.60	25.70	3.55	2.60	10.65	7.65	6.08	14.17
	Percentage of left pedestrians	42.07	41.07	43.19	44.67	47.29	53.22	43.52	46.98
Case6	Average of left pedestrians	15.25	32.85	10.15	9.25	19.95	14.30	11.27	22.65
	Standard deviation	4.50	3.54	3.67	2.75	3.77	3.81	3.01	4.33
	Maximum	24.95	39.30	15.65	13.95	26.00	19.50	15.80	30.65
	Minimum	9.95	27.80	3.65	4.95	15.00	7.50	6.80	16.15
	Percentage of left pedestrians	41.45	42.87	39.40	42.67	47.91	44.98	40.94	45.49

pedestrian agents, who passed narrow exits, were increased slightly by introducing the active RFID tags and cellular phones. Average of simulation end time Case3 was earlier than that of Case1 and that of Case2.

It is thought that the active RFID tags and cellular phones prevented pedestrian agents from being lost in the underground shopping mall. In addition, it is thought that some of pedestrian agents could avoid the crowded wide exits and passed the narrow exits. Next chapter, they discuss Case4, Case5 and Case6.

C. Results and Discussion about Age Groups and Sexes: Case4, Case5 and Case6

The number of the pedestrian agents at the 50 steps of simulation is shown in TABLE VIII. To analyze the number of pedestrian agents in the underground shopping mall, each age groups and sexes of pedestrian agents are shown in TABLE VIII. Comparing the age groups of Case4 with that of Case5, it can be seen that average number of pedestrian agents in Case5 was smaller than that of Case4. Even in comparing average of all age groups in Case4 with that of Case5, the number of pedestrian agents in Case5 was 35.40 agents smaller than that of Case4. The authors compare the percentages of pedestrian agents, which left in the underground shopping mall, in Case4 with that of Case5. Comparing the each age group of Case4 with that of Case5, Case5 was smaller than in each group of Case 4. Pedestrian agents with all age groups in Case5 were 13.58 percent smaller than that of Case4. Also comparing sex of Case4 with that of Case5, average the number of pedestrian agents in Case5 was 11.80 agents smaller than that of Case4. In

TABLE IX
THE END STEPS OF EVACUATION OF EACH PEDESTRIAN AGENT: CASE4, CASE5 AND CASE6

		Age groups						Sexes	
		15-19	20-29	30-39	40-49	50-59	Over 60	Male	Female
Case4	Average end steps of evacuation	351.50	410.50	346.15	338.05	368.95	356.60	322.28	401.63
	Standard deviation	60.85	85.51	85.60	88.48	68.42	69.92	89.88	63.05
	Maximum	431.00	588.00	511.50	487.50	469.50	462.50	480.33	503.00
	Minimum	246.50	298.00	233.00	204.50	236.50	268.50	191.17	304.50
Case5	Average end steps of evacuation	235.60	252.85	205.95	199.55	269.75	327.05	213.93	282.98
	Standard deviation	88.65	77.94	60.30	92.15	107.84	63.97	72.75	90.86
	Maximum	487.00	379.50	322.50	403.50	470.50	446.50	356.00	450.83
	Minimum	135.00	157.00	138.00	108.00	135.50	230.00	128.17	173.00
Case6	Average end steps of evacuation	211.95	231.35	187.50	180.20	185.80	228.55	177.28	231.17
	Standard deviation	72.03	53.15	71.62	67.48	42.35	87.42	67.58	63.77
	Maximum	340.50	302.50	304.00	310.50	243.50	402.50	293.33	341.17
	Minimum	101.50	158.50	101.50	124.50	124.50	149.50	106.17	147.17

TABLE X
USED EXITS FOR EVACUATION: CASE4, CASE5 AND CASE6

		The type of exits		
		Wide exits	Narrow exits	Average of simulation end time
Case4	Average of passed pedestrian agents	21.48	8.83	485.50
	Standard deviation	3.46	2.20	49.17
	Maximum	27.62	12.16	594.00
	Minimum	16.00	5.84	432.00
Case5	Average of passed pedestrian agents	21.45	8.84	433.70
	Standard deviation	4.30	2.54	64.59
	Maximum	28.23	13.24	542.00
	Minimum	14.77	5.20	344.00
Case6	Average of passed pedestrian agents	20.88	9.14	332.00
	Standard deviation	4.21	2.11	54.74
	Maximum	27.54	12.52	416.00
	Minimum	14.92	5.88	243.00

the case that pedestrian agents have RFID tags and cellular phones, the number of pedestrian agents which left in the underground shopping mall is reduced more than that of normal evacuation in the initial 50 steps of simulation.

Next, the authors compare the age groups of Case5 with that of Case6. Comparing the age groups of Case5 with that of Case6, it can be seen that average number of pedestrian agents with almost every age group except for 50-59 in Case6 was smaller than that of Case5. Comparing average of all age groups in Case5 with that of Case6, the number of pedestrian agents in Case6 was 2.45 agents smaller than that of Case5. The authors compare the percentages of pedestrian agents, which left in the underground shopping mall, in Case5 with that of Case6. Comparing the each age group of Case5 with that of Case6, Case6 was smaller than in each group of Case 5. Pedestrian agents with total number of age groups in Case6 were 2.03 percent smaller than that of Case5. Also comparing sex of Case5 with that of Case6, average the number of pedestrian agents in Case6 was 0.82 agents smaller than that of Case5. In the case that pedestrian agents have 100 percent of RFID tags and cellular phones, the number of pedestrian agents which left in the underground shopping mall is reduced more than that in Case 4 in the initial 50 steps of simulation.

Comparing the result of Case4 and Case6, total of pedestrian agents of Case6 is reduced 15.62 percent. Comparing sex of Case4 with that of Case6, it can be seen that average of pedestrian agents in Case6 could evacuate 12.62 agents earlier than that of Case4.

The result of Case4, Case5 and Case6 shows that introducing the RFID tags and cellular phones has the effect of reducing pedestrian agents, which left in the underground shopping mall, in the initial 50 steps.

To analyze the end time of evacuation, step end time of age groups and sexes is shown in TABLE IX. Comparing the age groups of Case4 with that of Case5, it can be seen that average end time for evacuation of almost every age group except for 50-59 in Case5 was earlier than that of Case4.

Comparing average of all age groups of Case4 with that of Case5, end time of evacuation in Case5 was 113.50 steps earlier than that of Case4. Also comparing sex of Case4 with that of Case5, average end time of evacuation of males in Case5 was 108.35 steps earlier than that of Case4. The average end time of evacuation of females in Case5 was 118.65 steps earlier than that of Case4. The result shows that the time of evacuation could be reduced by introducing RFID tags and cellular phones.

Next, they compare the age groups of Case5 with that of Case6. Comparing the age groups of Case5 with that of Case6, it can be seen that average end time of evacuation of age groups in Case6 was smaller than that of Case5. Even in comparing average of all age groups of Case5 with that of Case6, end times for evacuation of pedestrian agents in Case6 were smaller than that of Case5. Also comparing sex of Case5 with that of Case6, average end time for evacuation of males in Case6 was 36.65 steps smaller than that of Case5. The average end time for evacuation of females in Case6 was 51.82 steps smaller than

TABLE XI
PEDESTRIAN AGENTS IN THE MALL AT THE MID-PERIOD: CASE5-1, CASE5-2, CASE5-3

		Age groups						Sexes	
		15-19	20-29	30-39	40-49	50-59	Over 60	Male	Female
Case5-1	Average of left pedestrians	17.95	35.25	12.95	9.85	18.95	13.20	13.53	22.52
	Standard deviation	4.74	6.64	3.72	2.62	3.22	3.53	3.52	4.64
	Maximum	28.00	44.50	19.00	16.00	24.00	18.50	19.83	30.17
	Minimum	11.50	26.00	8.50	7.00	13.50	8.00	8.67	16.17
	Percentage of left pedestrians	53.73	54.14	52.55	51.10	54.15	56.27	52.41	54.91
Case5-2	Average of left pedestrians	20.55	39.60	14.40	8.50	20.60	12.05	14.75	23.82
	Standard deviation	4.76	5.66	3.28	2.31	5.28	2.55	3.54	4.41
	Maximum	27.00	48.00	19.50	11.00	30.50	16.00	20.33	30.33
	Minimum	10.50	30.50	9.00	4.00	12.00	7.00	9.17	15.17
	Percentage of left pedestrians	48.97	48.33	49.12	55.57	45.90	60.50	50.40	52.40
Case5-3	Average of left pedestrians	20.35	40.75	12.95	10.95	19.60	13.70	14.65	24.78
	Standard deviation	3.91	6.02	3.57	2.75	5.03	3.31	3.31	4.88
	Maximum	27.00	51.50	20.00	16.50	26.50	19.00	20.33	33.17
	Minimum	15.00	32.50	8.00	7.50	12.50	8.00	10.33	17.50
	Percentage of left pedestrians	46.21	45.93	47.48	47.41	50.94	56.81	47.12	51.14

that of Case5. The result shows that the time of evacuation could be reduced by introducing 100 percent of RFID tags and cellular phones.

Comparing the result of Case4 and Case6, average end time for evacuation of pedestrian agent with age groups of Case6 was 157.73 steps smaller than that of Case4. Comparing sex of Case4 with that of Case6, it can be seen that average end time for evacuation of males in Case6 was 145.00 steps smaller than that of Case4. The average end time for evacuation of females in Case6 was 170.47 steps smaller that of the Case4.

The result of Case4, Case5 and Case6 shows that introducing the RFID tags and cellular phones has the effect of preventing time loss of evacuation.

D. Results and Discussion about Exits of Evacuation: Case4, Case5 and Case6

TABLE X shows the average number of pedestrian agents, which passed wide exits or narrow exits at the evacuation.

The authors compare the number of pedestrian agent, which passed wide exits, in Case4 with that of Case5. The wide exits in Case5 were passed 0.03 of pedestrian agents smaller than that of Case4. On the other hand, the narrow exits in Case 5 were passed 0.02 of pedestrian agents larger than that of Case 4. Average of simulation end time of Case5 was 51.80 steps

TABLE XII
THE END STEPS OF EVACUATION OF EACH PEDESTRIAN AGENT: CASE5-1, CASE5-2, CASE5-3

		Age groups						Sex	
		15-19	20-29	30-39	40-49	50-59	Over 60	Male	Female
Case5-1	Average end steps of evacuation	303.10	370.25	294.85	292.35	371.70	301.75	299.90	344.77
	Standard deviatio	68.95	68.76	95.72	94.27	74.51	104.52	89.03	79.88
	Maximum	409.00	512.50	488.00	439.00	490.50	477.00	451.83	486.83
	Minimum	200.50	282.00	181.00	142.00	255.00	161.00	179.00	228.17
Case5-2	Average end steps of evacuation	294.25	317.55	287.45	253.50	300.55	334.90	261.77	334.30
	Standard deviatio	79.84	81.60	73.49	110.31	88.40	74.34	82.71	86.62
	Maximum	434.50	467.00	403.00	491.00	463.50	441.50	411.33	488.83
	Minimum	190.00	191.00	167.50	126.00	182.00	226.50	157.00	204.00
Case5-3	Average end steps of evacuation	275.80	309.30	246.95	230.70	307.60	350.50	256.98	316.63
	Standard deviatio	79.86	70.43	110.85	99.51	91.98	94.36	81.36	100.97
	Maximum	420.50	439.00	462.50	408.00	450.00	495.00	394.67	497.00
	Minimum	186.50	205.50	125.00	112.50	172.00	219.00	155.00	185.17

TABLE XIII
USED EXITS FOR EVACUATION: CASE5-1, CASE5-2, CASE5-3

		The type of exits		
		Wide exits	Narrow exits	Average of simulation end time
Case5-1	Average of passed pedestrian agents	20.23	9.31	473.1
	Standard deviation	4.03	2.36	45.17
	Maximum	26.75	13.48	543
	Minimum	14.25	6.12	421
Case5-2	Average of passed pedestrian agents	20.11	9.20	470.60
	Standard deviation	4.64	2.49	45.39
	Maximum	27.92	13.24	551.00
	Minimum	12.83	5.72	431.00
Case5-3	Average of passed pedestrian agents	19.94	9.18	469.30
	Standard deviation	4.63	2.34	51.00
	Maximum	28.08	13.08	544.00
	Minimum	13.50	6.04	382.00

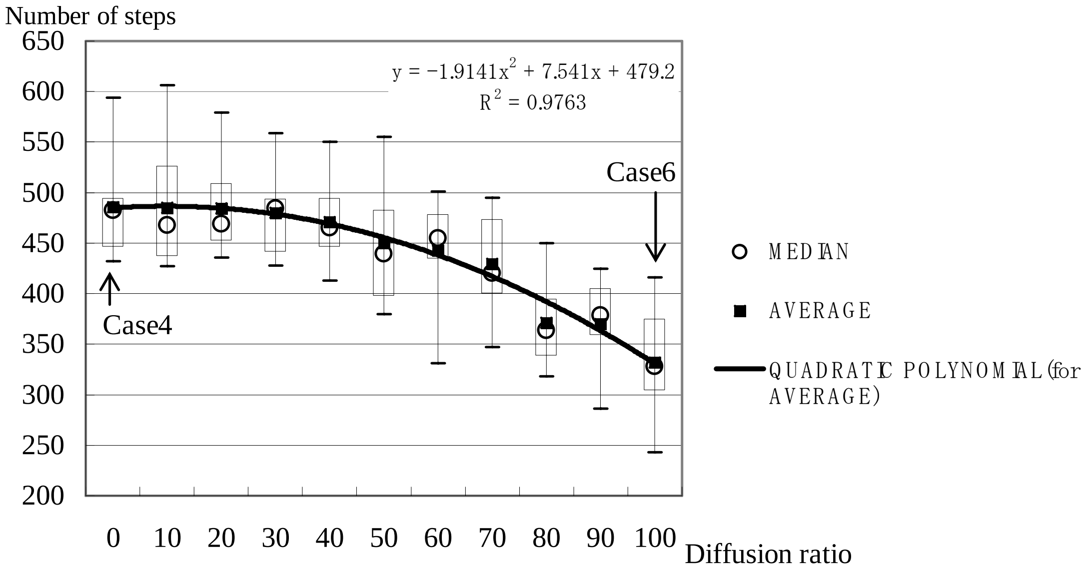


Fig. 4 The relationship between number of steps and diffusion ratio of active RFID tags

earlier than that of Case4.

Next, the authors compare the number of pedestrian agent, which passed wide exits, in Case5 with that of Case6. The wide exits in Case6 were passed 0.58 of pedestrian agents smaller than that of Case5. On the other hand, the narrow exits in Case 6 were passed 0.30 of pedestrian agents larger than that of Case 5. Average of simulation end time of Case6 was 101.70 steps earlier than that of Case5.

The results showed that the pedestrian agents, who passed wide exits, were decreased slightly by introducing the active RFID tags and cellular phones. On the other hand, the pedestrian agents, who passed narrow exits, were increased slightly by introducing the active RFID tags and cellular phones. Average of simulation end time in Case6 was earlier than that of Case4 and that of Case5.

It is thought that the active RFID tags and cellular phones prevented pedestrian agents from being lost in the underground shopping mall. In addition, it is thought that some of pedestrian agents could avoid the crowded wide exits and passed the narrow exits. Even if the diffusion of RFID tags and cellular phones was not perfect, they could show the effectiveness of reducing the time of evacuation.

E. Results and Discussion about the Ratio of Checking the Cellular Phone

The Case 5 is demonstrated closest actual one in above cases. But, pedestrians are not always checking their cellular phone in the case of evacuation. Therefore the authors take this into account. They add the ratio of checking the cellular phone into Case5. The cellular phones are checked by the 25 percent (Case5-1), the 50 percent (Case5-2), and the 75 percent (Case5-3) of pedestrian agents. Pedestrian agents in the mall at the mid-period, at the 50 steps of every simulation, are shown in TABLE XI. Comparing Case5-1 with Case5-2, the range of age groups of Case5-2, 15-19, 20-29, 30-39 and 50-59, shows fewer percentages of left pedestrian agents in the mall. Also, comparing Case5-2 with Case5-3, the range of age groups of Case5-3 except 50-59 shows fewer percentages of pedestrian agents left in the underground shopping mall.

The end steps of evacuation of each pedestrian agent are shown in TABLE XII. Comparing Case5-1 with Case5-2, the range of age groups of Case5-2 except over 60 shows fewer average end steps of evacuation. Also, comparing Case5-2 with Case5-3, the range of age groups of Case5-3, 15-19, 20-29, 30-39 and 40-49, shows fewer average end steps of evacuation.

The average of simulation end time is shown in TABLE XIII. Comparing Case5-1 with Case5-2, The Case5-2 shows fewer time of end of simulation. Also, comparing Case5-2 with Case5-3, The Case5-3 shows fewer time of end of simulation.

In this research, the authors verified that active RFID tags and cellular phone help decreasing of evacuation time. Also, they verified that if the ratio of pedestrians who check the cellular phone in the evacuation is increased, end time of simulation is also decreased.

When the manager of underground shopping mall adopts the RFID tags system, he/she should announce function of this system to pedestrians very often.

F. Overall Discussion

To verify the effectiveness of introducing active RFID tags, the authors add diffusion ratio of active RFID tags by ten percent to Case 4. Also, they carry out simulation every ten times. Fig. 4 shows the average, maximum and minimum number of end of simulation steps. Also, that shows the relationship between number of steps and diffusion ratio of active RFID tags. If safety evacuation time is limited in 450 steps, diffusion ratio of active RFID tags should be needed more than eighty percent. Therefore, perfect diffusion ratio of active RFID tags is not always needed.

If the effect of active RFID tags is only seen from average, the effect may be seen as a few improvements for evacuation. However, seeing maximum and minimum, the grate effect can be seen. Maximum number of end of simulation steps in Case4 stand at 594 steps. Minimum numbers of end of simulation steps in Case4 stand at 432 steps. If safety evacuation time is assumed within 450 steps, pedestrians in Case 4 have a low chance of survival. If diffusion ratio of active RFID tags progressed, pedestrian can improve the chances of survival. Also, if one simulation step is assumed 2 second, maximum time of Case4 is calculated as almost 20 munities. Minimum numbers of end of simulation steps in Case6 stand at 243. If this minimum into 2 second, minimum numbers of end of simulation steps in Case 6 is calculated as almost 8minutes. The active RFID tag can improve more than twice evacuation time.

Needed diffusion ratio should be determined from time limit of safety evacuation. That is depending on the number of user, size, shape and characteristics of underground shopping mall.

VI. Conclusion

In this paper, the authors performed agent based simulation for proposing the system which the pedestrian discovers the exit and evacuates from the underground shopping mall quickly. As the result of the simulation, in the case of the pedestrian with using active RFID tags and cellular phones, the amount of time to spend on the evacuation was reduced. It is thought that the active RFID tags and cellular phones prevented pedestrian agents from being lost in the underground shopping mall. In addition, it is thought that some of pedestrian agents could avoid the crowded wide exits and use the narrow exits. Even if the diffusion of RFID tags and cellular phones was not perfect, they could show the effectiveness of reducing the time of evacuation. Especially, seeing maximum and minimum, the active RFID tag can improve more than twice evacuation time.

To help the pedestrians, the managers of underground shopping mall can not provide these systems perfectly. They have budget restraint. If the managers think optimum investment of these systems and evacuation guidance way, they can get information for making a decision by using this simulation model.

However, in the case of considering the age group like as Case1, Case2 and Case3, the time for evacuation of elderly pedestrian such as age group of 50-59 and over 60 was needs more than it of other age groups. Reflecting on the results, it may be desirable that elderly pedestrians are directed to the near exit from them with priority. However, this modeling remains their tasks.

In this paper, the authors focused on the pedestrian of individual evacuation. However, some pedestrian may evacuate with group or be directed by people who guide the exit. There is also user of wheel chairs in the underground shopping mall actually. The authors think that the model design of including people with more different attribute is also remaining their tasks.

The parameters of the simulation model assume evacuating from underground shopping mall, but their model is also directly applicable to the department store and another commercial construction and so on.

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