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How can RFID Contribute to Disaster Rescue?
— Agent-Based Simulation Approach in Active RFID Dispersal Sensing —

Masatora DAITO†　　Noriyuki TANIDA††

Abstract

There were many difficulties in finding the victims after the earthquake which occurred in Japan's *Niigata Prefecture* in 2004. The earthquake might be caused a wired network disconnection. In addition, fixed-phone and cell-phone service systems crashed due to the rapid increase in the volume of communications. The systems' collapse above stated was due to the large number of users who were worried about the safety of their relatives. Also, the same thing happened during and often the onset of Hurricane Katrina in the U.S.A.

Reflecting on the situation described above, the Japanese Ministry of Internal Affairs and Communications is considering choosing one of several methods. One of the methods is to discover victims use RFIDs (Radio Frequency Identification) with computer sensors. The plan would be to 1) scatter sensors devices from helicopters when a large-scale disaster such as an earthquake occurs, 2) to make RFIDs self-organize into a network, and 3) to make self-organized networks pinpoint the position of victims without using GPS. However, the ministry has not get disclosed the method to be chosen. In addition to this, no matter what procedure is chosen, a certain amount of field testing may be necessary to confirm its effect. However, that needs a great amount of time and costs are high. Therefore, we have made an agent-based simulation.

In this paper, we pay specific attention to a simple and assured algorithm for discovering victims using RFIDs. First, we explain our method for confirmation of victims. Second, we explain our method for pinpointing the position of victims using trilateration. Finally, we present our simulation results.

Keywords: RFID, agent-based simulation, positioning algorithm for rescue, search and rescue, optimization

JEL Classification: C63

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1. Introduction

Japanese rescue workers experienced difficulties of finding victims in Japan's *Niigata Prefecture* in 2004. The earthquake might be caused a wired network disconnection. Also fixed-phone and cell-phone services were interrupted by inquiries about safety. In fact, victims could not answer the phone, because, for example, their houses had collapsed due to the earthquake. Thus, we may not be able to keep in contact with victims by using usual tools of communication in time of disaster.

Reflecting on the situation described above, the Japanese Ministry of Internal Affairs and Communications is considering choosing one of several methods. One of the methods is to discover victims use RFIDs with computer sensors. If the Ministry chooses the RFIDs plan, then the sensing devices would be scattered by helicopter evenly over the affected area of the high-intensity earthquake, and the devices would trigger their RFIDs to establish a self-organized network to pinpoint the location of victims. However, the ministry has not get disclosed the method to be chosen.

In this paper, we explore an algorithm of victims' discovery by simple 'instant' networks with Active RFIDs. With the assistance of bi-directional parallel interface, the RFIDs will self-organize anytime and anywhere. The RFIDs with temperature and voice sensors can sense victims' existence by their body heat and voice. However, when victims cannot be located, we use trilateration in order to ascertain their exact position and find them.

The distance to the victims' position is determined by and form is trans for matting the arrival time of the RFIDs' electric wave to the trilaterated point Victims' positions are found by using RFIDs scattered at random and doing iterative trilateration from the three points already positioned.

Actual experimentation to verify whether or not this method is precise and effective exacts a huge cost in time and money. Therefore, we used agent-based simulation. The simulation experiment is used to verify the optimal number of RFIDs and proper computations of RFIDs. First, we will demonstrate positioning methods, secondly, we will show the simulation settings; for agents and outputs, and, finally, we will state the results of agent-based simulation and analyze them.

2. Positioning method with calculation

2-1 Comparison of positioning methods

In this section, we examine previous positioning methods, developed with RFIDs' computational capability in mind. Then, we choose one of them, and explain its sufficient reason simplicity character which makes its use very attractive.

Different positioning methods are summarized as follows:

The first method is by triangulation (Figure 1 (a)). It is a positioning method that uses angles [1]. The main advantage of this method is that the separation of three points and the measurement of two angles is enough to identify the RFID position. The disadvantage of this method is that each device does need at least one directional antenna and one sensor affixed to measure angles.

The second method is by trilateration (Figure 1 (b)). This is a positioning method that uses the relative distances of three fixed points ([2], [3]). The main advantage of this method is that the numbers of links emerging from each point are constantly $N-1$, where N is the number of connected RFIDs. Because of the $N-1$, computational complexity is lower than in other methods. The disadvantage of this method is that errors of measurement are larger.

The third method is by multilateration (Figure 1 (c)). This positioning method is basically similar to trilateration. The main characteristic of multilateration is using the relative distance among three or more fixed points ([4]-[7]). The major advantage and the major disadvantage are the opposites these of trilateration. Easily, this method can obtain mere accuracy but extend multiply the complexity.

Proper positioning is of significance when computational complexity is lessened smaller, and the position of victims can be pinpointed as quickly as possible.

Also, in terms of total computational complexity, it is necessary to reduce the number of scattered RFIDs.

After examining the above methods, we have adopted trilateration as the most effective positioning method.

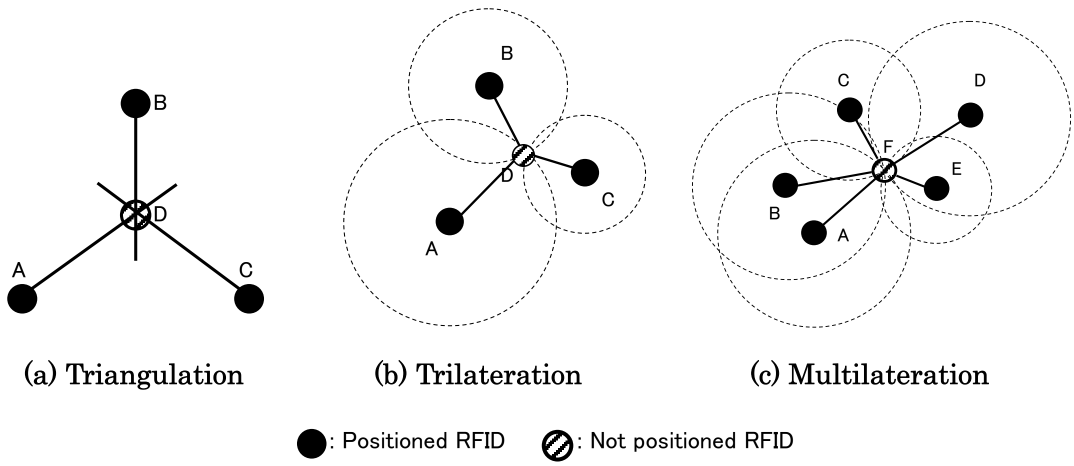


Figure 1. Positioning methods

2-2 Explanation of Trilateration

Figure 2 shows trilateration. Let points A, B and C be already positioned, and point D be unpositioned. In this setting, point D can be positioned by the intersection of circles w. r. t. A, B and C as shown in Figure 2.

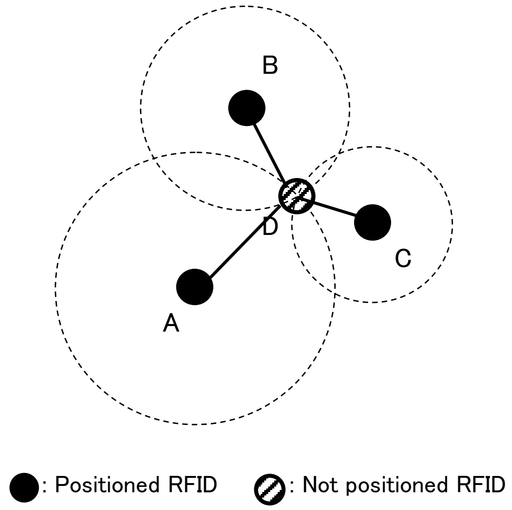


Figure 2. Positioning method by trilateration

3. Simulation Settings for agents

In our model, an outreach of radio waves which each RFID agent sends is 30 meters. A field of this simulation has a lot of cells. We define a cell as the square 3 meters on a side. In addition, we need three types of agents as follows:

1) Scattered RFID agent: The RFID to be scattered to find victims.

2) Target RFID agent: This agent is fixed RFIDs which is beside the victim.

3) Fixed RFID agent: The RFID to be fixed for a reference position.

On the beginning of a simulation, agents except fixed RFID agent are randomly scattered in the simulation field. Next, we show rules of each agent.

3-1. Rules of each agent at the start of simulation

At the start of simulation, the target RFID agent transmits information to the scattered RFID agents. If the scattered RFID agents received the information from the target RFID agent, they transmit information to other scattered RFID agents. The information that each scattered RFID agents have is transmitted in a concentric fashion. Then, the hop-count is accumulated.

In these situation, each agent acts in the following rules to the sixth steps.

1) Target RFID agent

They send information to scattered RFID agents or fixed RFID agents.

2) Scattered RFID agent

If they acquired information from the target RFID agent, they send information to the other scattered RFID agent or a fixed RFID agent.

3-2. Positioning rules of each agent

In this section, we explain about the rule at the seventh step in simulation. We can represent positioning way diagrammatically as in Figure 3. Figure 3(a) shows the positioning action which scattered RFID agent starts. It begins by using three fixed RFID agents. One of the fixed RFID agents (Black Square, called master) has the initiative in terms of selecting any scattered RFID agent. It is in alternating communicational range between a fixed RFID agent and an other one (Hatched Square). The other fixed RFID agent (Hatched Square) collects ID numbers in its neighborhood, and sends them to master. And master chooses one of the scattered RFID agents which are in the crossover the ID numbers. A chosen scattered RFID agent (Grid Line Dot) connects with three fixed RFID agents, and then the chosen scattered RFID agent (Grid Line Dot) is positioned by trilateration and takes over selective initiative from a fixed RFID agent (Black Square).

Figure 3(b) shows that a scattered RFID agent (Black dot) chooses two partners which are decided by hop-count number from the target RFID agent. In this case, two of the closest numbers are chosen (Hatched Square). After this, iterative trilateration is continued (Figure 3(c)).

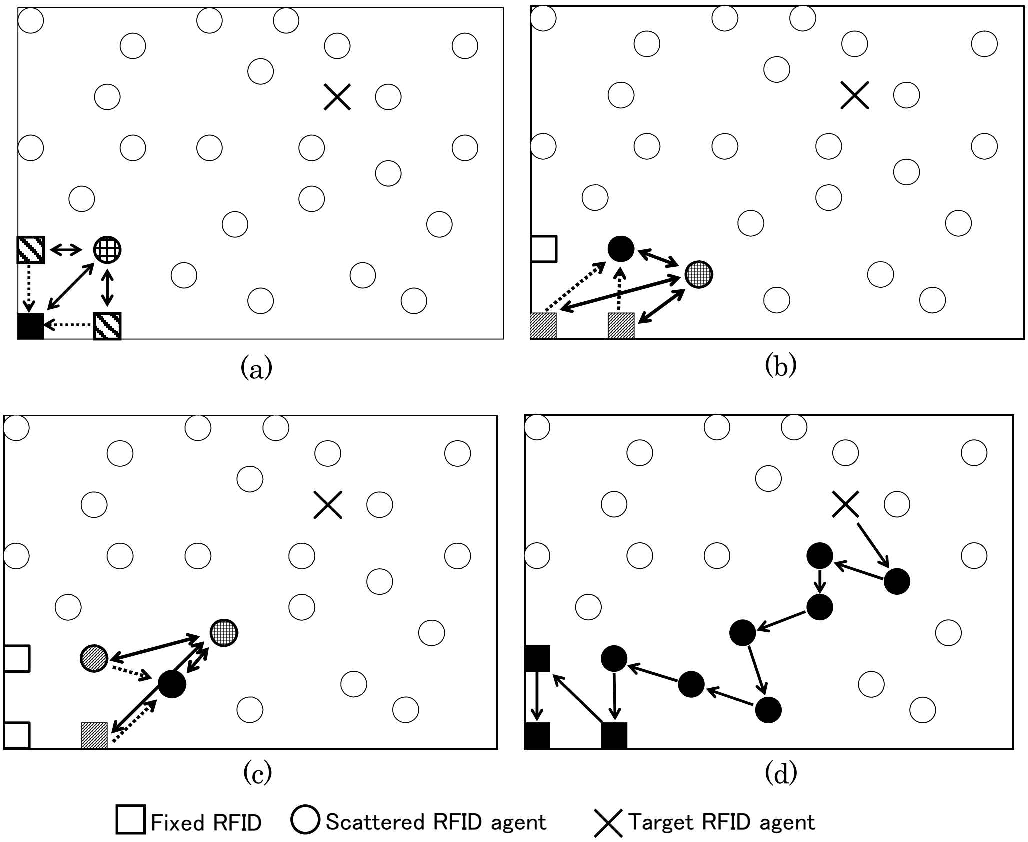


Figure 3. The positioning method in our model

Figure 3(d) shows that if the target RFID agent is positioned, the information on that position returns to the fixed RFID agent by as using access path. Therefore, simulation is finished.

4. Simulation settings and outputs

Figure 4 shows an image in which RFIDs are scattered by helicopter. When earthquakes occur, RFIDs are scattered for the purpose of discovering victims. However, the optimum number of scattered RFIDs, which is necessary for discovering victims, is not known. So, we carry out simulation and analyze the data.

As an initial stage of the simulation, we compare one case in which the scattered RFID agents are scattered continuously, with another case (Shown in Figure.6-(b)) in which the scattered RFID agents are scattered at points with same interval. In fact, the distribution of RFIDs may be affected by the cruising altitude of the helicopter and air current effects. We programmed air current effects for the former case, because the former case that gave better results than the latter case. In short, the former case gave positioning data concerning the target RFID agent more continuously certainly. We suggest the best case all of our simulations for discovering victims are with continuously scattered RFIDs.

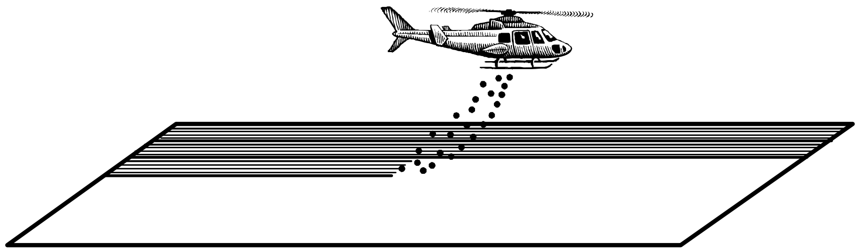


Figure 4. The image that RFIDs are scattered by helicopter

4-1. Fundamental simulation settings

In this section, we explain the initial conditions of our simulation: We set some initial simulation conditions in order to decide the number of scattered RFID agents. More precisely, we set 150 cells to the Y-axis and 150 cells to the X-axis. Also, we set three fixed RFID agents and one fixed target RFID agent in the field. We also put scattered RFID agents in the field. We fixed the position of the target RFID agent, because if we randomly changed the initial position of the target RFID agent, just as the simulation began, the results might have been greatly affected by its former beginning position. Even if we did randomly scatter that, RFID take such a setting, the generality of our simulation was not lost. We fixed the target RFID agent at X-axis of 140 and Y-axis of 140. Fixed RFID agents were put diagonally opposite to the target RFID agent. In this way, we could verify whether scattered RFID agents could accurately position the target RFID agent or not.

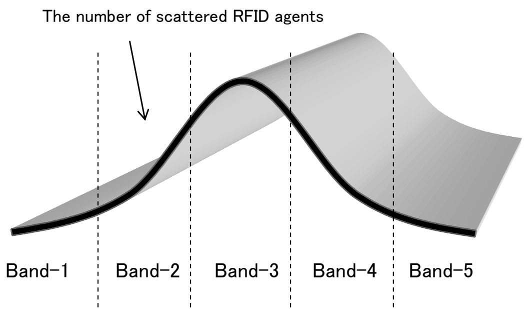
Based on previous simulation results, we managed to gradually scatter the number of RFID agents from 2400 units to 2850 units and, finally, 3300 units. Then we understood that the number of scattered RFIDs between 2400 and 3300 agents was desirable for data analysis. And densities of scattered RFID agents on the field were changed in every case.

We will show three cases. Case 1 is that the scattered RFID agents are scattered continuously but with no wind, rain, or element of weather. Case 2 is that the scattered RFID agents are scattered at 100 points with the same interval between them. Case 3 is that scattered RFID agents are scattered continuously and are affected by the air current. We carried out each simulation ten times and analyzed data from them.

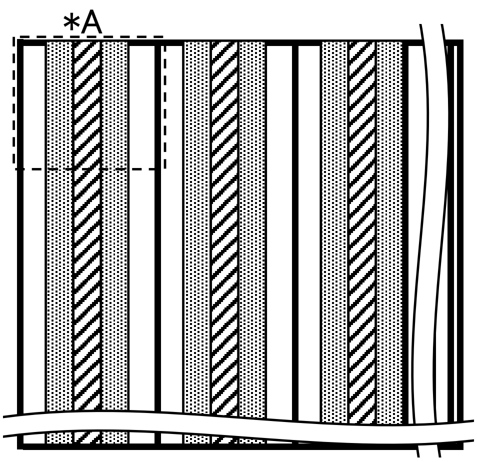
4-2 Explanations for each Case

1) Explanation for Case 1

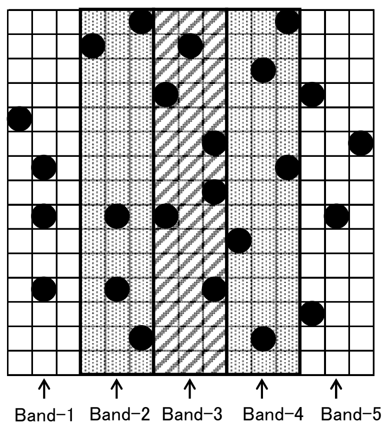
In this case, scattered RFID agents are scattered continuously. Figure 5-(a) shows a pattern of distribution for scattered RFID agents. Figure 5-(b) shows the image of the whole field of the simulation. And Figure 5-(c) shows the enlargement of *A and position of scattered RFID agents on a field, divided into Band-1, Band-2, Band-3, Band-4, and Band-5. Table1 shows the scatter rate. It shows that scattered RFID agents are scattered with a weighting in the hatched areas.



(a) Distribution shapes; the case that scattered RFID agents are scattered continuously



(b) The image of the whole field of the simulation



(c) The enlargement of *A:
The fundamental structures of agent

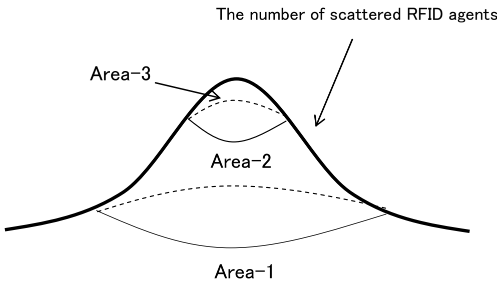
Figure 5. The case 1 that scattered RFID agents are scattered continuously

Table 1. A classified table of case 1, continuous scattering

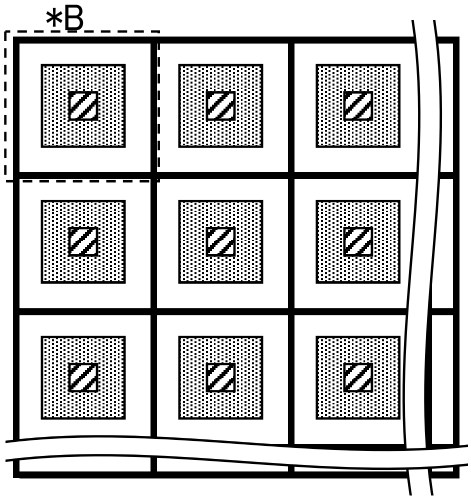
Distributions \ The number of scattered RFID agents	2400	2850	3300
Band-1and Band-5 = 20.0% Band-2and Band-4 = 30.0% Band-3 = 50.0%	Case 11	Case 12	Case 13
Band-1and Band-5 = 25.0% Band-2and Band-4 = 35.0% Band-3 = 40.0%	Case 14	Case 15	Case 16
Band-1and Band-5 = 33.3% Band-2and Band-4 = 33.3% Band-3 = 33.3%	Case 17	Case 18	Case 19

2) Explanation for Case 2

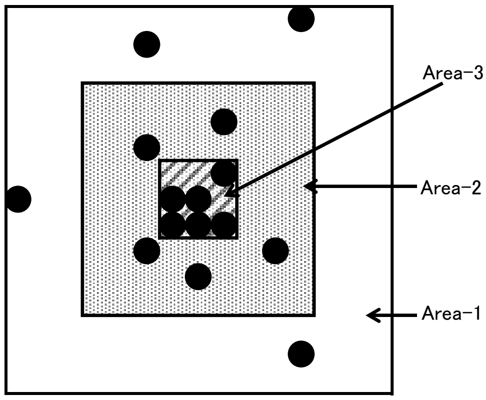
In this case, scattered RFID agents are scattered at 100 points with same interval between them. Figure 6(a) shows a pattern of distribution for scattered RFID agents. Figure 6(b) shows the image of the whole field of the simulation, which shows that scattered RFID agents are scattered, weighted in the hatched Area-3. And Figure 6(c) shows the distribution of scattered RFID agents, divided into Area-1, Area-2, and Area-3. Table2 shows the scatter rate.



(a) Distribution shapes: scattered RFID agents are scattered at every definite point



(b) The image of the whole field of the simulation



(c) The enlargement of *B:
The fundamental structures of agent sets

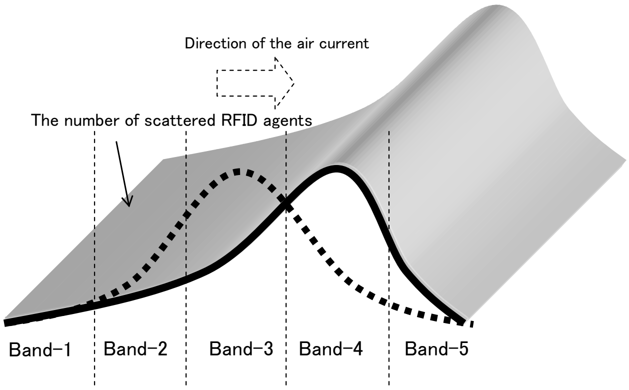
Figure 6. The case in which scattered RFID agents are scattered at every definite point

Table 2. A classified table of case 2

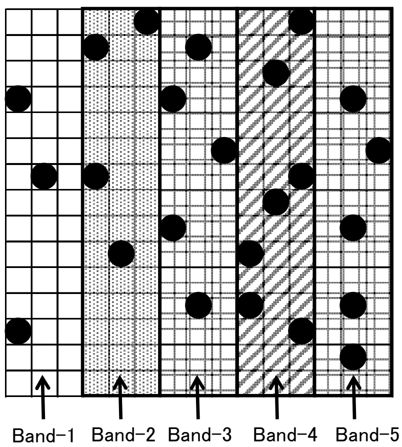
Distributions \ The number of scattered RFID agents	2400	2850	3300
Band−1 = 20.0% Band−2 = 30.0% Band−3 = 50.0%	Case 21	Case 22	Case 23
Band−1 = 25.0% Band−2 = 35.0% Band−3 = 40.0%	Case 24	Case 25	Case 26
Band−1 = 33.3% Band−2 = 33.3% Band−3 = 33.3%	Case 27	Case 28	Case 29

3) Explanation for Case 3

In this case, scattered RFID agents are scattered continuously. The distribution shapes are skewed to the left because of air current effects. (Figure 7(a)). And Figure 7(b) shows the distribution of scattered RFID agents, divided into Band-1, Band-2, Band-3, Band-4, and Band-5 areas. Table 3 shows the scatter rate.



(a) Distribution shapes; the case in which scattered RFID agents are scattered continuously.



(b) The fundamental structures of agent sets

Figure 7. Case in which scattered RFID agents are scattered continuously, and are affected by the air current.

Table 3. A classified table of case 3

The number of scattered RFID agents / Distributions	2400	2850	3300
Band-1 = 10.0% Band-2 = 15.0% Band-3 = 20.0% Band-4 = 35.0% Band-5 = 20.0%	Case 31	Case 32	Case 33
Band-1 = 8.0% Band-2 = 12.0% Band-3 = 15.0% Band-4 = 50.0% Band-5 = 15.0%	Case 34	Case 35	Case 36
Band-1 = 2.0% Band-2 = 8.0% Band-3 = 15.0% Band-4 = 60.0% Band-5 = 15.0%	Case 37	Case 38	Case 39

4-3. Simulation settings and outputs

In our analysis, we use outputs described below:

(1) *Arrival rate,* means the rate that the positioning of the target RFID agent is completed,

(2) *Number of steps,* signifies the number of steps which need to pinpoint the target RFID agent,

(3) *Difference of distance,* is the difference between the distances in a straight line and the sum of "real" distance that we need for positioning of the target RFID agent (see Figure 8),

(4) *Total number of agents,* means the only the number of RFIDs used to find the position of the target RFID agent.

5. Results and discussion

5-1. Result and discussion on case 1 (agents scattered continuously)

Figure 8 shows a general tendency of this continuously scattering model. One of the fixed RFID agents has the initiative, mentioned above in section 3-2. The initiative has passed from the fixed RFID agent to the target RFID agent by way of scattered RFID agents. The initiative proceeds in to a downward direction. When the initiative forwards nears the X-axis, and it is almost the same level as the target RFID agent, the initiative proceeds in the direction of the target RFID agent.

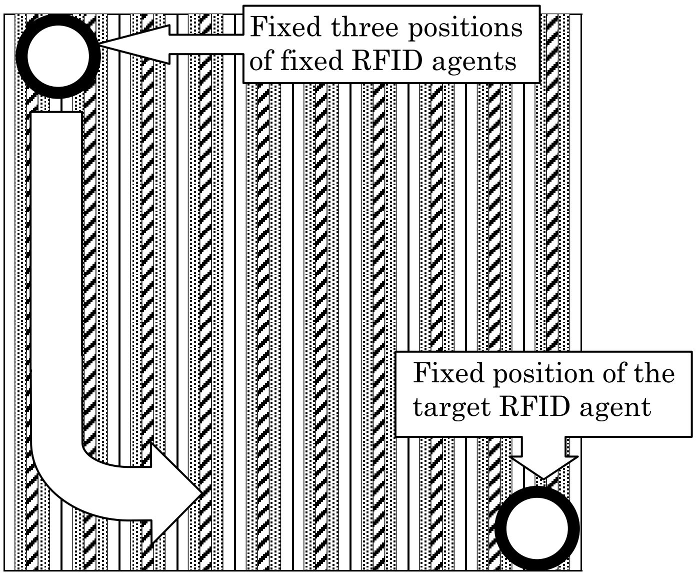


Figure 8. Transfers of initiative have a tendency of the shape like the letter "L"

1) Results and discussion on cases 11, 12 and 13

The results of these cases are as shown in Table 4. The rate of scattered RFID agents is concentrated in the Band-3 area. Therefore the selection of positioning is limited. In cases11 and 12, the *Arrival rate* (Table 4-(5)) is one third of the number of simulation. However, if we increase the number of scattered RFID agents (case 13), then *Arrival rate* times increases to more than half the number of simulation times. However, the average of the distance that we needed for positioning of the target RFID agent (Table 4-(3)), the average of the sum of RFIDs used to find the target RFID position (Table 4-(6)), and the average of the steps which used to the Target RFID positioning (Table 4-(7)), also increase with increase of scattered RFID agents. Therefore, we find that along with great accuracy the in pinpointing the target RFID agent, there is also a commensurate increase in complexity of calculation.

Table 4. The results of case 11, 12 and 13

	Case 11	Case 12	Case 13
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	4419.04	5502.65	7363.00
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	744%	926%	1240%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	30%	30%	60%
(6) Average of the RFID sum which used to the target RFID positioning	305.00	385.00	520.00
(7) Average of the steps which used to the target RFID positioning	935.50	1206.00	1605.50
(8) Average of the degree of progress per one step (meters) ((3) /(7))	4.72	4.56	4.59
(9) Average of Distance per one RFID (meters) ((3) / (6))	14.49	14.29	14.16

2) Results and discussion of cases14, 15 and 16

The results of these cases are as shown in the Table5. Band-3 area has a lower rate of scattered RFID agents than cases 11, 12 and 13. While the *Arrival rate* (Table 5-(5)) stands at one third of the number of simulation practice times in cases 11 and 12. In Table 5's cases 14 and 15 shown an increase in arrival rate at nearly half of the number of simulation times. Moreover, in case 16 it increased to more than half number of simulation practices. In the same way as cases 11, 12 and 13, the average of the distance needed for positioning of the target RFID agent (Table 5-(3)), the average of the sum of RFIDs used to find the target RFID position (Table 5-(6)), and the average of the steps which used to the target RFID positioning (Table 5-(7)), these number is also increasing with increase of scattered RFID agents.

Table 5. The results of case 14, 15 and 16

	Case 14	Case 15	Case 16
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	4253.25	5707.62	8008.82
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	716%	961%	1348%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	40%	40%	60%
(6) Average of the RFID sum which used to the target RFID positioning	299.00	411.00	557.50
(7) Average of the steps which used to the target RFID positioning	924.00	1282.00	1747.50
(8) Average of the degree of progress per one step (meters) ((3) /(7))	4.60	4.45	4.58
(9) Average of Distance per one RFID (meters) ((3) / (6))	14.22	13.89	14.37

3) Results and discussion of cases17, 18 and 19

The results of this case are as shown in Table6. Scattered RFID agents are scattered evenly, so the *Arrival rate* (Table 6-(5)) is dramatically improved in each. However, the average distance necessary for positioning the target RFID agent (Table 6-(3)), the average RFID sum which used to the target RFID positioning (Table 6-(6)), and the average steps which used to position the target RFID (Table 6-(7)), also increases with the increase of scattered RFID agents.

Table 6. The results of case 17, 18 and 19

	Case 17	Case 18	Case 19
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent(meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent(meters)	3926.89	5923.42	7578.54
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	661%	997%	1276%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	100%	100%	100%
(6) Average of the RFID sum which used to the target RFID positioning	262.33	418.67	527.00
(7) Average of the steps which used to the target RFID positioning	814.67	1316.33	1624.00
(8) Average of the degree of progress per one step(meters) ((3) /(7))	4.82	4.50	4.67
(9) Average of Distance per one RFID(meters) ((3) / (6))	14.97	14.15	14.38

5-2. Results and discussion of cases 2 (agents scattered at 100 points)

Figure 9 shows a general tendency of this model. One of the fixed RFID agents has the initiative. The initiative has passed from the fixed RFID agent to the target RFID agent by way of scattered RFID agents. So the initiative proceeds zigzags towards. the target RFID agent in a zigzag manner.

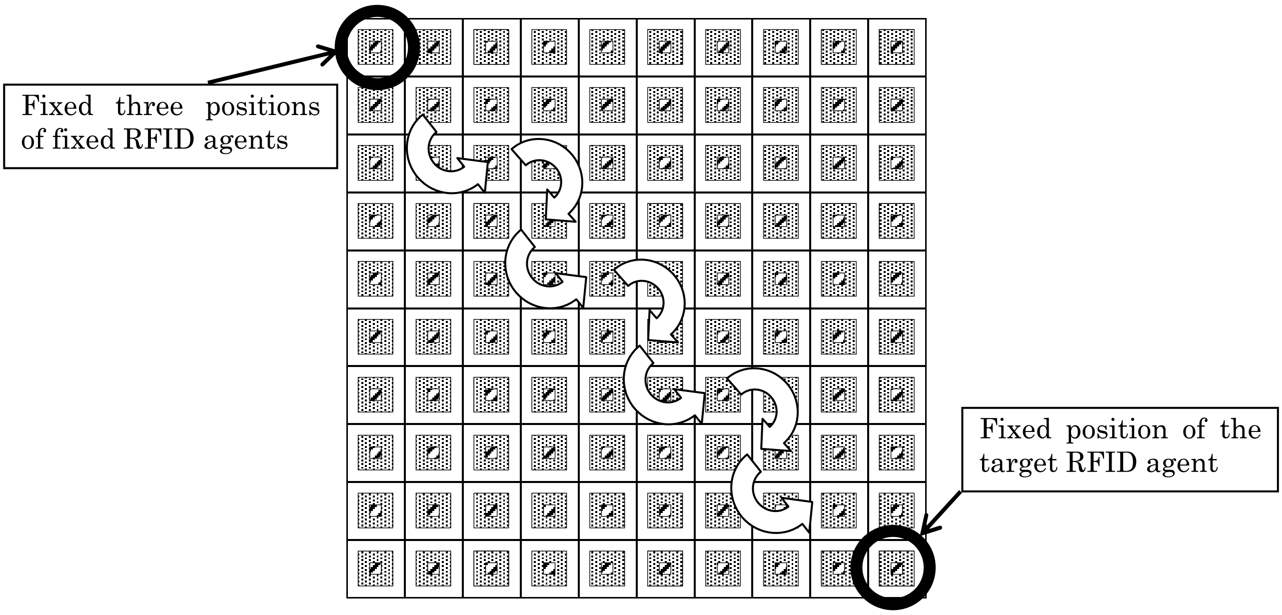


Figure 9. Case 2 has a tendency to proceed in a zigzag course

1) Results and discussion of cases 21, 22 and 23

The results of these cases are as shown in Table 7. The number of scattered RFID agents is concentrated in Area-3, the very center of each of Figure 9's squares. Therefore, the selection of positioning is limited. As in case21 and 22, the *Arrival rate* (Table 7-(5)) is zero. However, if we increase the number of scattered RFID agents, as in case 23, the *Arrival rate* is increased to one third of the number of simulation practice times.

Table 7. The results of case 21, 22 and 23

	Case 21	Case 22	Case 23
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	–	–	3548.68
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	–	–	597%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	0%	0%	30%
(6) Average of the RFID sum which used to the target RFID positioning	–	–	297.00
(7) Average of the steps which used to the target RFID positioning	–	–	929.00
(8) Average of the degree of progress per one step (meters) ((3) /(7))	–	–	3.82
(9) Average of Distance per one RFID (meters) ((3) / (6))	–	–	11.95

2) Results and discussion of cases 24, 25 and 26

The results of these cases are as shown in Table 8. The number of scattered RFID agents in Area-3 is lower a in cases 21, 22 and 23. While *Arrival rate* (Table 8-(5)) stands at zero in case 22, in case 25 it has increased to one third of the number of simulation practice times. Next, we study that Area-3 has lower rate of scattered RFID agents' number than case 24, 25 and 26.

Table 8. The results of case 24, 25 and 26

	Case 24	Case 25	Case 26
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	–	4351.62	4036.79
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) × 100)	–	733%	680%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times × 100)	0%	30%	30%
(6) Average of the RFID sum which used to the target RFID positioning	–	303.00	300.00
(7) Average of the steps which used to the target RFID positioning	–	946.00	917.00
(8) Average of the degree of progress per one step (meters) ((3) /(7))	–	4.60	4.40
(9) Average of Distance per one RFID (meters) ((3) / (6))	–	14.36	13.46

3) Results and discussion of cases 27, 28 and 29

The results of these cases are as shown in Table 9. The *Arrival rate* (Table 9-(5)) improves by one third of the number of simulation practice times in case 27, 30 percent in case 28, and more than half of the number of simulation practice times in case 29. However, the average of the distance that necessary positioning of the target RFID agent (Table 9-(3)), the average of the RFID sum which used to position the target RFID positioning (Table 9-(6)), and the average of the number of steps used to position the target RFID (Table 9-(7)), also increase with the increase in the number of scattered RFID agents.

Table 9. The results of case 27, 28 and 29

	Case 27	Case 28	Case 29
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	3390.76	3469.44	4775.47
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	571%	584%	804%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	30%	30%	60%
(6) Average of the RFID sum which used to the target RFID positioning	232.00	232.00	333.00
(7) Average of the steps which used to the target RFID positioning	722.00	744.00	1048.00
(8) Average of the degree of progress per one step (meters) ((3) /(7))	4.70	4.66	4.56
(9) Average of Distance per one RFID (meters) ((3) / (6))	14.62	14.95	14.34

As mentioned above, the general tendency of positioning is different between the major cases, 1 and 2. Case2 provides better positioning speed of the target RFID agent than dose case 1. On the other hand, case1 provides better the *Arrival rate* than dose case2. Also, the *Arrival rate* of case1 is more stable. If those RFIDs are scattered in order to discover a victim, the *Arrival rate* should take precedence over the positioning speed of the target RFID agent. Therefore, we believe that case1, continuous scattering of agents, is the proper method to employ.

5-3 Results and discussion of case 3
(agents scattered continuously and air current effects)

When scattering RFIDs by helicopter, air current effect occurs. As said above, case3 entails continuous scattering of RFIDs, as in case 1, with the addition of air current effect factor. As in the case 1, case 3 also has the general tendency for the initiative to proceed form the fixed RFID agent to the target RFID agent by way of scattered RFID agents in a downward "L" path.

1) Results and discussion of cases31, 32 and 33

The results of these cases are as shown in Table10. The sum of Band-1 and Band-2 areas are (seen in Table 7-(6)) accounting for 25 percent of the100 percent (as seen in Table 3 of case 3). And the sum of Band-3, 4, 5 areas account for 75 percent of the100 percent.

The *Arrival rate* in cases 17, 18 and 19 are perfect, but case 31 and 32 shows an

Arrival rate decreased by air current (Table 10-(5)).

On the other hand, the average distance that we needed for positioning of the target RFID agent (Table 10-(3)), the average of the sum of RFIDs used to find the target RFID position (Table 10-(6)), and the average of the steps which used to the target RFID positioning (Table 10-(7)), these the number is also decreasing with air current effect.

Table 10. The results of case 31, 32 and 33

	Case 31	Case 32	Case 33
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	3226.23	4550.66	5366.62
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	543%	766%	904%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	60%	60%	100%
(6) Average of the RFID sum which used to the target RFID positioning	213.50	310.00	365.33
(7) Average of the steps which used to the target RFID positioning	652.50	966.00	1133.67
(8) Average of the degree of progress per one step (meters) ((3) /(7))	4.94	4.71	4.73
(9) Average of Distance per one RFID (meters) ((3) / (6))	15.11	14.68	14.69

2) Results and discussion of cases 34, 35 and 36

The results of these cases are as shown in Table 11. Dew to the added air current effect, the sum of Band-1 and Band-2 areas account for 20 percent of the total. The sum of Band-3, Band-4 and Band-5 areas account for 80 percent of the total. The *Arrival rate* , in case 34, becomes zero by due to air current (Table 11-(5)).

Table 11. The results of case 34, 35 and 36

	Case 34	Case 35	Case36
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	–	4572.35	4463.43
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	–	770%	751%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	0%	60%	60%
(6) Average of the RFID sum which used to the target RFID positioning	–	306.50	325.00
(7) Average of the steps which used to the target RFID positioning	–	959.00	1014.00
(8) Average of the degree of progress per one step (meters) ((3) /(7))	–	4.77	4.40
(9) Average of Distance per one RFID (meters) ((3) / (6))	–	14.92	13.73

3) Results and discussion of cases 37, 38 and 39

The results of these cases are as shown in the Table11. The sum of Band-1 and Band-2 areas account for 10 percent of the total. The sum of Band-3, Band-4 and Band-5 areas account for 90 percent of the total. The *Arrival rate* of case 37 and 38 crashed to zero due to the air current effect (Table 12-(5)).

Table 12. The results of case 37, 38 and 39

	Case 37	Case 38	Case 39
(1) The amount of scattered RFID agents	2400	2850	3300
(2) Average of a straight line from a fixed RFID agent to the target RFID agent (meters)	593.97	593.97	593.97
(3) Average of the distance that we needed for positioning of the target RFID agent (meters)	–	–	6064.05
(4) Straight line and the distance that we needed for positioning of the target RFID agent (Between a fixed RFID agent and the target agent) ((3) / (2) ×100)	–	–	1021%
(5) Average of arrival rate to the target RFID (Arrival times / Simulation practice times ×100)	0%	0%	60%
(6) Average of the RFID sum which used to the target RFID positioning	–	–	431.00
(7) Average of the steps which used to the target RFID positioning	–	–	1374.50
(8) Average of the degree of progress per one step (meters) ((3) /(7))	–	–	4.41
(9) Average of Distance per one RFID (meters) ((3) / (6))	–	–	14.07

Case1 and case2 differ greatly in methods of scattering agents, simulating models of both cases. When scattered RFID agents are distributed density and in close proximity equality, blanketing the disaster area, we can position the target RFID agent (victim) the lowest number of scattered RFID agents, 2400 as found in case 17. The actual conditions, distribution are changed by helicopters and air current effects. Case 39 shows that by increasing of scattered RFID agents it is possible to keep the *Arrival rate* the same level. However, increasing the number of scattered RFID agents more than is necessary leads to toward loss of search time.

6. Conclusions and future research

According to case 17, if the distribution of agents is scattered over a large area, even the low number of 2400 is applicable. In reality, the number of the RFIDs must change depending on wind velocity.

The results of simulation, as found in cases 1, 2 and 3, should that as the number of scattered RFID agents decreased, the arrival rate to the target RFID agent also declined. It was also found that reducing in computational complexity and declining arrive probability are trade offs.

The research was carried out using trilateration algorithm in order to find the absolute position of the victims, but the authors did not design a multilateration algorithm. Trilateration should be compared with multilateration to see the differences in computational complexity. Furthermore, simulation would be better if geographic information were added, due to the fact that the stricken area is almost never flat. These points remain to be studied in the future. Computer simulation is an extremely effective method because actual experimentation requires a great amount of time and money for the method's verification.

The parameters of the simulation model assumed victim discovery to be on land, but our model is also directly applicable to the search for survivors at sea.

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