An Intelligent Guide Vehicle by Fuzzy Guide Target Considering Tiredness

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Abstract: Recently, automatic guide robot such as vehicle in nursing facilities for elderly people has been developed. In this paper, we describe a guide knowledge from care worker who can provide flexible guidance with consideration of supported person's tiredness, and construct an intelligent guide vehicle based on the knowledge. Then, we perform an automatic guide simulation for a person who cannot keep walking to the goal because of tiredness. The simulation result shows that the guide vehicle is able to flexibly guide the person to the goal using rest area.

Keywords: Fuzzy guide target, Intelligent control, Four while vehicle, Fuzzy control, Automatic guide system

1. INTRODUCTION

Recently, autonomous guide robot has been developed[1]. Guide robots or guide vehicles guide a person to the goal by leading them instead of human. For example, they are used to guide elderly people to the goal instead of care workers in nursing facilities. Elderly people usually become tired easily. So, it is difficult for them to keep following to the guide vehicle. Care workers flexibly guide the elderly people to the goal with consideration of their tiredness. So, the guide vehicle is requested to have the same function as care workers.

Fuzzy set expresses human vague subjectivity by the grade from 0.0 to 1.0 and allows machines to handle the subjectivity[2]. Fuzzy control method is incorporated human control knowledge by use of fuzzy set[3], and its effectiveness in the real system was confirmed[4]. Moreover, the fuzzy target based controller to be incorporated the knowledge of human driving four-wheeled vehicle was constructed, and its flexibility for the situation change was confirmed by a simulation[5][6]. Where, fuzzy target is composed by some target candidates and their grades which are from 0.0 to 1.0.

Then, we aim at developing an intelligent controller of the guide four-wheel vehicle and a intelligent guide vehicle that is able to guide the supported person flexibly with consideration of his tiredness like a care worker. In this paper, we construct the guide vehicle, and perform a guide simulation. And, it is confirmed that the guide vehicle is able to guide a supported person flexibly in consideration of his tiredness by a guide simulation.

2. GUIDE OF CARE WORKER

A care worker always detects obstacles and observes the locations of goal, sub goal, the supported person, and himself. The care worker thinks about the target to which he should lead the supported elderly person, based on some target candidates like Fig.1. The care worker considers target candidates to approach the goal or sub-goal and target candidates to approach rest areas. Therefore, he can lead the supported person to not only goal but also a rest area.

Moreover, he thinks about the target to which he should lead the supported person, in consideration of "Closeness between target candidate and goal (or sub-goal)" and "Movement ability of the supported person after he reached to the sub-goal". And, the care worker wants to take the supported person to the goal as early as possible. So, he thinks, "A target candidate near goal (or sub-goal) is good". At the same time, he considers the tiredness of the supported person. He observes the movement speed and deceleration of the supported person, expects the distance which we can walk, and considers his movement ability after reached the sub-goal. So, the care worker thinks about target candidate's goodness based on the movement ability. At this time, with regard to the candidate for approaching a rest area, he considers the supported person have enough ability to walk continuously. Because he considers that tiredness of the supported person recovers in rest areas.

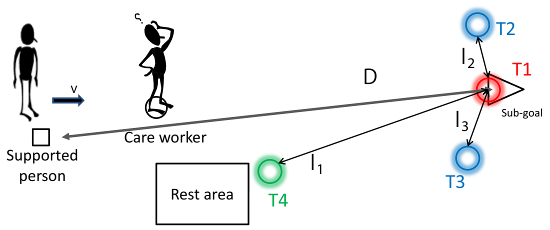


Fig. 1 Guide knowledge of Care worker

And, he decides the action which he should take from some action candidates and the target to which he should lead the supported person based on some target candidate, closeness of target candidate and sub-goal and the movement ability of the supported person after he reached to sub-goal.

As a result, the care worker can flexibly guide the supported person to goal or rest areas with consideration of his tiredness.

3. CARE WORKER'S GUIDE KNOWLEDGE

Based on the care worker's guidance described above, his knowledge is discussed in this chapter. A care worker's guide knowledge is described on the assumption that the knowledge is applied to a intelligent controller.

3.1 Detector

The care worker detects obstacles, observe the positions of the goal, sub-goals, rest areas, the supported person, the present target, and himself. And, he estimates movement speed v and movement acceleration a of the supported person. He judges whether they reached the goal.

3.2 Target Setting

The care worker sets three kinds of target candidates as follows: Main target candidate, Sub target candidate, and Rest target candidate. Then, he estimates distance l_n between sub-goal and each target candidate, and calculates the target candidate T_n's belonging grade $\mu_1(l_n)$ for a fuzzy set that shows "It is near sub-goal." at Fig.2.

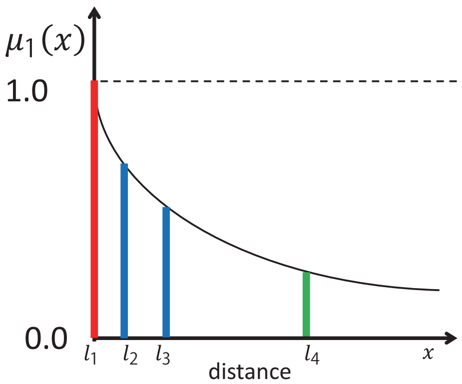


Fig. 2 Fuzzy set "It is near sub-goal."

Then, It estimates distance W that the supported person can move, based on his movement speed and movement acceleration and the supported person's movement speed model which is shown by Fig.3.

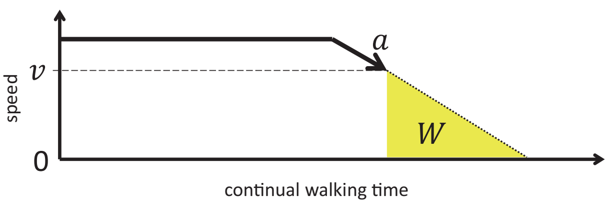


Fig. 3 Supported person's movement speed model

And, he estimates distance D between the sub-goal and the supported person. After that, he estimates his movement ability F after he reaches sub-goal, which is calculated by equation1.

$$F = \begin{cases} \frac{W-D}{W} & (if \ \ W - D > 0) \\ 0 & (otherwise) \end{cases} \tag{1}$$

He considers thet each target candidate's goodness $\mu_{ft}(T_n)$ is minimum value of $\mu_1(T_n)$ and F. It is calculated by equation3.

$$\mu_{ft}(T_n) = \min\bigl(\mu_1(T_n), F\bigr), \tag{2}$$

where n=1...N, N is number of target candidates.

However, with regard to rest target, he think of its goodness $\mu_{ft}(T_n)$ considering F is 1.0. Here, we define the set of target candidates and their goodness as "Fuzzy guide target". Its example is shown by Fig.4.

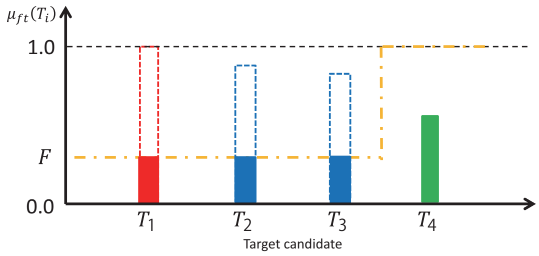


Fig. 4 Fuzzy guide target

3.3 Automatic Driving

Automatic driving knowledge is extracted based on the care worker's action decision and considered based on paper[6].

He decides the target to which he should lead the supported person and action which he should take, based on fuzzy guide target. Where, "action" means "movement". He considers some action candidates C_m to each target candidate T_n. And, he pairs each action candidate with its target candidate. Then, he predict the future state of himself when he executed the action candidate. He considers the future state's belonging grades for fuzzy sets that show "It is far from the obstacles" and "Its location deviation from sub-goal is small". And, he considers that operation candidate's goodness is minimum value in two belonging grade. After that, he estimates that the minimum value of target candidate's goodness and operation candidate's goodness. And, he considers the minimum value is the evaluation value of the pair. He considers the evaluation value of each pair. Then, he decides the pair with the highest evaluation values. Finally, he excuses the action of the pair for the target of the pair.

When "action" is replaced "operation", an intelligent controller based on fuzzy guide target is constructed like Fig5.

4. AUTOMATIC GUIDE PROBLEM

Automatic guide condition map is shown by Fig.6
Details of the condition are showed as follows.
Map:$40m \times 40m$
Vehicle initial state:$\{x, y, \theta\} = \{-16.5, -17.5, 0\}$
Goal:$\{-18, 17.5, \pi\}$
Sub-goal1:$ST_1 = \{17, -17.5, 0\}$
Sub-goal2:$ST_2 = \{17.5, 17, 0.5\pi\}$
Sub-goal3:$ST_3 = \{-18, 17.5, \pi\}$

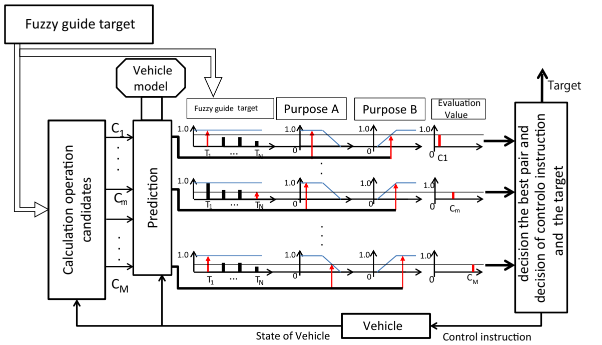


Fig. 5 Intelligent Controller based on fuzzy guide target

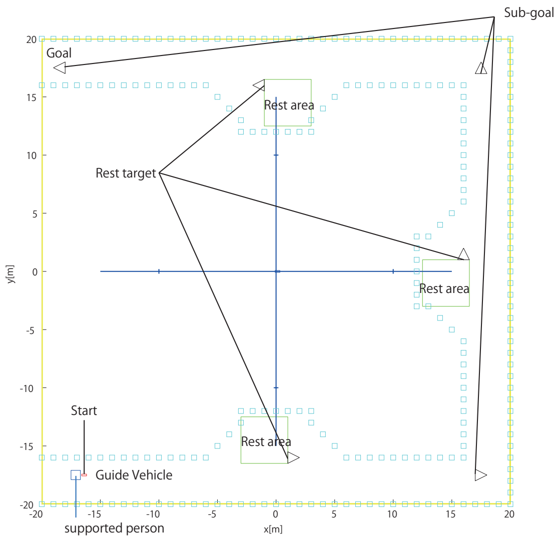


Fig. 6 Simulation Condition

Rest target1:$RT_1 = \{1, -16, 0\}$
Rest target2:$RT_2 = \{16, 1, 0.5\pi\}$
Rest target3:$RT_3 = \{-1, 16, \pi\}$
Rest area:$(-3 \leq x \leq 1) \cap (-16.5 \leq y - 12.5)$
$(12.5 \leq x \leq 16.5) \cap (-3 \leq y \leq 1)$
$(-1 \leq x \leq 3) \cap (12.5 \leq y \leq 16.5)$

Locations of the guide vehicle and the supported person can be observed. Locations of the obstacles up to 7meters in surroundings can be observed.

Inputs to the guide vehicle are information of goal and sub-goal, rest target, state of guide vehicle and locations of obstacles and the supported person.

5. INTELLIGENT GUIDE VEHICLE CONFIGURATION

Locations of obstacles and the supported person, information of goal, sub-goal, rest area, state of guide vehicle are input to an Inteligent Guide Vehicle. Information of number i sub-goal ST_i is defined of x-cordinate, y-cordinate and direction, and information of number j rest areaRT_j is defined of x-cordinate, y-cordinate and direction as follows,

$$ST_i = \{STx_i, Sty_i, STs_i\}, \tag{3}$$

where $i = 1...3$,

$$RT_j = \{RTx_j, RTy_j, RTs_j\}, \tag{4}$$

where $j = 1...3$.

It guides the supported person to the goal by it leading him. It is composed of four modules, which are Detector Part, Target Setting Part, Automatic Driving Part, and vehicle. The outline is shown by Fig.7.

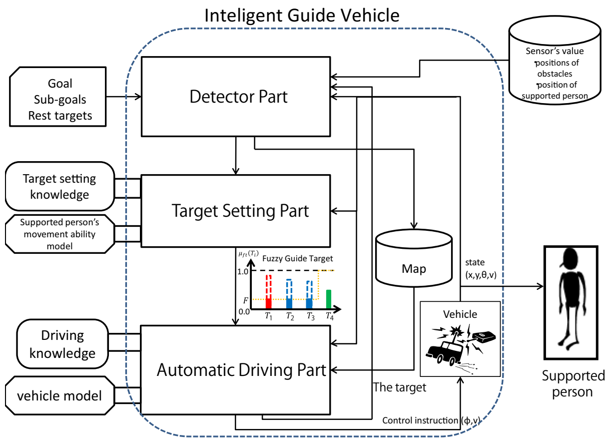


Fig. 7 Outline Of Intelligent Guide Vehicle

5.1 Detector Part

Information of the goal, sub-goals, rest areas, present target, locations of obstacles and the supported person, and present state of vehicle are input to Detector Part. This part judges whether it arrived at goal or sub-goals. It writes down the location of the obstacle in the map. It writes down the location of the person who is supported in the map. And, it calculates movement speed v and movement acceleration a of the supported person. Then, it outputs the renewed map, the information of next sub-goal and rest target, the supported person's location, speed v and acceleration a.

5.2 Target Setting Part

The information of next sub-goal and the rest area, the supported person's location, speed v and acceleration a are input to Target Setting Part. In this paper, by use of information of ST_i and RT_j, Target Setting Part sets three kind four target candidates $T_n(n = 1...4)$ as follows: Main target candidate T_1 is set as

$$T_1 = \{STx_i, STy_i, STs_i, STv\}. \tag{5}$$

Sub target candidate T2 and T3 are set as,

$$T_2 = \{STx_i - \cos(STs), STy_i + \sin(STs_i), STs_i, STv\}, \tag{6}$$

$$T_3 = \{STx_i + \cos(STs_i), STy_i - \sin(STs_i), STs_i, STv\}. \tag{7}$$

Rest target candidate T_4 are set as,

$$T_4 = \{RTx_j, RTy_j, RTs_j, RTv\}. \tag{8}$$

Where, STv is set to " $+1$" if the guide vehicle is located posterior to ST_i, otherwise STv is set to " -1". And, RTv is set to " $+1$" if the guide vehicle is located posterior to RT_i, otherwise RTv is set to " -1".

And, this part calculates distance D between target candidate T_n and sub-goal ST_i. Then, it calculates its belonging grade $\mu(T_n)$ for a fuzzy set that shows "It is near sub-goal". The membership function of the fuzzy set is shown by Fig.8. Then, it calculates distance W which

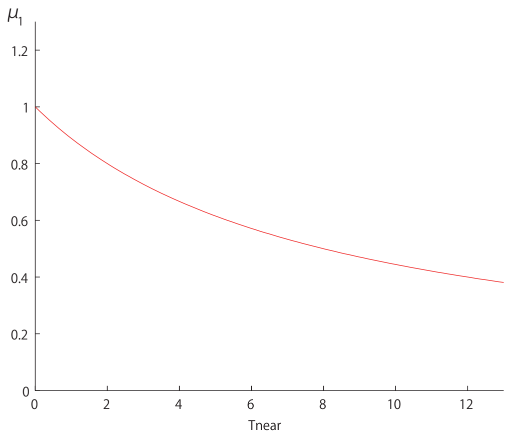


Fig. 8 fuzzy set "it is near sub-goal"

the supported person can move by use of v, a and the supported person's moving speed model. Next, it calculates distance D between present location (x_{user}, y_{user}) of the supported person and the location of sub-goal (STx_i, STy_i). After that, it calculates his movement ability F after he reaches subgoal by the equation1. And, it calculates the goodness of target candidate $\mu_{ft}(T_n)$ by equation1. It calculates goodness of each target candidate. Where, with regard to rest target candidate, it calculates the goodness assuming F is always 1.0.

It composes the fuzzy guide target by combining the target candidates and their goodness. It outputs the fuzzy guide target to the Automatic Driving Part.

5.3 Automatic Driving Part

Present state of the guide vehicle and the location of obstacles, and the fuzzy guide target are input to Automatic Driving Part.

In this paper, Automatic Driving Part generates 5 operation candidates to Main target candidate, 1 operate candidate to each Sub target candidate, and 1 operation candidate to Rest target candidate. It makes up 8 pairs of one target candidate and one operation candidate$C_m = \{\phi_m, v_m\}$, where ϕ_m is steering angle and v_m is velocity of the vehicle, where v_m is decided based on target candidate's forth element value. The pairs are

$$\begin{aligned} P_1 &= \{T_1, C_1\}, \\ P_2 &= \{T_2, C_2\}, \\ P_3 &= \{T_3, C_3\}, \\ P_4 &= \{T_4, C_4\}, \\ P_5 &= \{T_1, C_5\}, \\ P_6 &= \{T_1, C_6\}, \\ P_7 &= \{T_1, C_7\}, \\ P_8 &= \{T_1, C_8\}. \end{aligned} \tag{9}$$

It predicts future state s_m of vehicle when operation candidate C_m is executed based on the vehicle model and vehicle's present state. Then, it calculates the future state's belonging grades$\mu_2(s_m)$ and $\mu_3(s_m)$ for fuzzy sets that show and "Future state's location deviation from target candidate is small." and "Distance between future state and obstacles is large.", which are shown by Fig.9 and Fig.10.

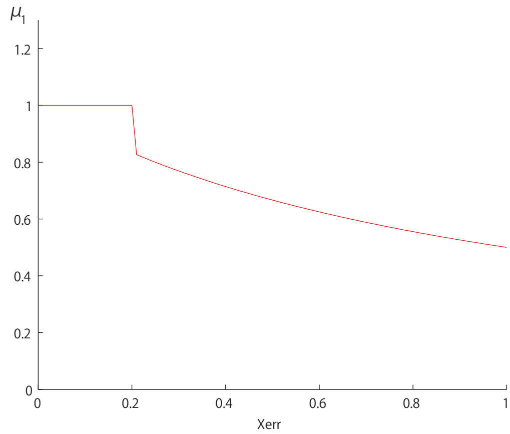


Fig. 9 fuzzy set "Future state's location deviation from target candidate is small."

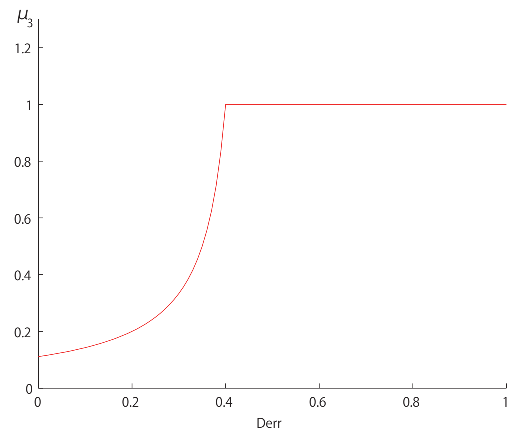


Fig. 10 fuzzy set "Distance between future state and obstacles is large."

It calculates operation candidate's goodness $G(C_m)$ based on equation10.

$$G(C_m) = \min\big(\mu_2(s_m), \mu_3(s_m)\big) \tag{10}$$

It calculates the evaluation value $E(P_m)$ of the pair based on equation11.

$$E(P_m) = \min(\mu_{ft}(T_n), G(C_m)) \tag{11}$$

It calculates the evaluation value of each pair. Then, it decides the pair $P^* = \{T^*, C^*\}$ with the highest evaluation value E^*. After that, it decides the operation candidate C^* as the operation instruction and the target candidate T^* as the present target.

It outputs them to Guide vehicle and Detector Part.

5.4 Guide Vehicle

It is input operation instruction (ϕ, v), and runs. It outputs actual steer corner ϕ_r, velocity v_r, position (x, y) and direction θ after it moves.

6. AUTOMATIC GUIDE SIMULATION

6.1 Case A

In this case, it is assumed that the supported person gets tired easily as follows :

He approaches the location of the guide vehicle at speed of $0.35 m/s$.

He decelerates at $0.005 m/s^2$ in 120 seconds (tiredness).

If he enters the area in the rest room, he approaches the center of the rest room.

He stops for 20 seconds when he reached near of the center of the rest area, and afterward he approached the guide vehicle again afterwards.

His movement speed recovers to its original value if he enters the area in the rest area.

6.2 Result Of Case A

Fig.11 shows trajectory of the guide vehicle and the supported person in the simulation 1.

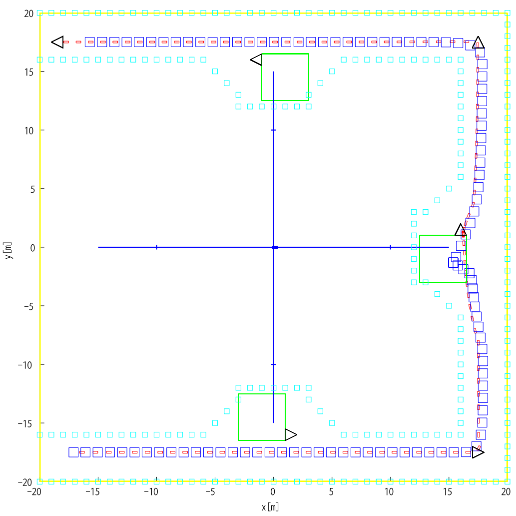


Fig. 11 Trajectories of the guide vehicle and the supported person while 0 to 326 sec. in case A

6.3 Case B

In this case, it is assumed that the supported person doesn't get tired easily as follows:

He approaches the location of the guide vehicle at speed of $0.35 m/s$.

He doesn't decelerate.

When he enters the area in the rest room, he approaches the center of the rest room.

He stops for 20 seconds if he reached near of the center of the rest area, and afterward he approaches the guide vehicle again.

6.4 Result Of Case B

Fig.12 shows trajectories of the guide vehicle and the supported person in the simulation 2.

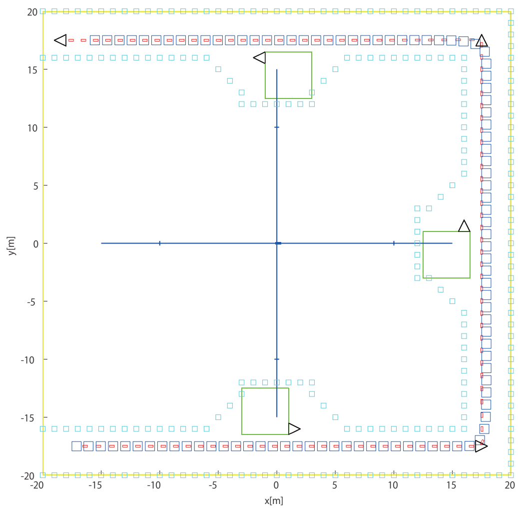
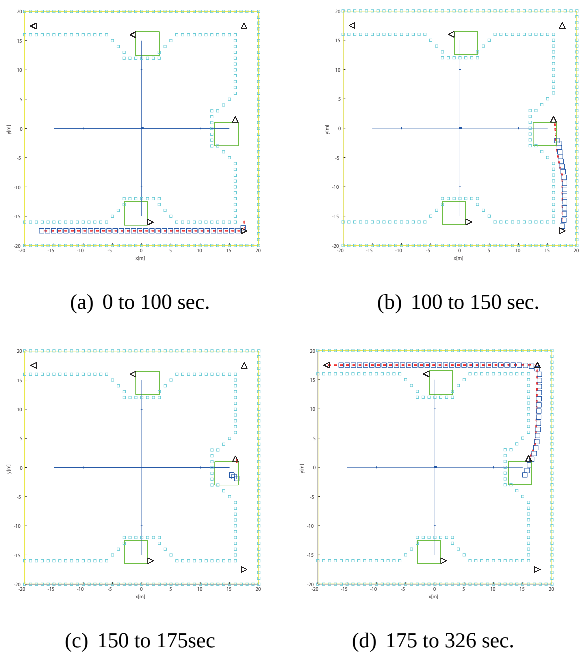


Fig. 12 Trajectories of the guide vehicle and the supported person while 0 to 293 sec. in case B

6.5 Consideration

In the case A, the guide vehicle did not head for the target which existed in the first rest area, and approached sub-goal. That is shown by Fig.13(a). The supported person decelerated after passing over the first sub-goal. At this time, the guide vehicle led the supported person to a rest area by approaching the rest target candidate as the target not sub-goal, that is shown by Fig.13(b). The guide vehicle kept standing at the rest target candidate while the supported person stopped in the rest area, that is shown by Fig.13(c). When the supported person started following the guide vehicle again, the guide vehicle approaching the next sub-goal. The guide vehicle did not head for the rest target after it passed over the second sub-goal and led the supported person to goal by approaching next sub goal, that is shown by Fig.13(d).

In the case B, the supported person didn't decelerate. So, the guide vehicle considered that he was not tired and the guide vehicle did not head for the target that existed in rest targets, headed for goal straightly, and led the supported person to goal.



(a) 0 to 100 sec. (b) 100 to 150 sec.

(c) 150 to 175sec (d) 175 to 326 sec.

Fig. 13 Divided trajectories in Case A

Consequently, the simulations showed that the intelligent guide vehicle guided to the supported person to goal by using rest area in the case A and it guided to the supported person to goal without using rest area in the case B. So, it is confirmed the intelligent guide vehicle is able to guide the supported person to the goal by using the rest area in consideration of his tiredness.

7. CONCLUSION

In this paper, the guide knowledge of care worker who guides flexibly in consideration of the supported elderly person's tiredness was discussed. Then, an intelligent guide vehicle that is built of the guide knowledge of care worker was constructed. And, guides simulations that handled two models of supported person is performed. In the simulation case A, it was the supported person gets tired easily, who cannot keep walking to the goal by tiredness. And, in the simulation case B, it was assumed that the supported person doesn't get tired easily. By the simulations, it was showed that the guide vehicle guided the supported person to the goal by using rest area in the case A and it guided to the supported person to goal without using rest area in the case B. As a result, the simulations showed the intelligent guide vehicle is able to guide flexibly the supported person in consideration of his tiredness.

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REFERENCES

[1] Y. Mizobuchi, S. Wang, K. Kawata, M. Yamamoto, "Trajectory Planning Method for Guide Robots Based on Distance-Type Fuzzy Reasoning Method", *journal of Japan Society for Fuzzy Theory and Intelligent Informatics* , 17(1), 112-121, 2005-02-15.

[2] L. A. Zadeh, "Fuzzy sets", *Information and Control*, vol. 8, pp.338-353, 1965.

[3] Seiji Yasunobu, "fuzzy Engineering", *Syokodo*, 1991.

[4] S. Yasunobu and S. Miyamoto, "Automatic Train Operation System by Predictive Fuzzy Control", *Industrial Applications of Fuzzy Control (M. Sugeno ed.)*, North-Holland, pp1-18, 1985.

[5] Y. Chen and S. Yasunobu, "Fuzzy Target Based Soft Decision for Mobile Vehicle in Dynamic Environment", *7th World Congress on Intelligent Control and Automation*, pp.800-805, 2008.

[6] T. Ogawa and S. Yasunobu, "An intelligent car driving based on fuzzy target with safety zone", *SCIS2012*, Kobe, Japan, November 20-24, 2012, pp.1850-1855 (2012).