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# Supporting for Visually Handicapped to Walk Around with RFID Technologies

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**Abstract:** Visually handicapped use their white cane to find obstacles. They follow tactile walking surface indicators to find routes and intersections. They use all sensory organs they can use to acquire the surrounding information. They match the surrounding information with routing information they have, to find their current location and target direction. However, even if tactile walking surface indicators are installed, it is difficult for them to visit unknown places because they have no correct routing information. When they go outside depending on tactile walking surface indicators, they have to follow them. They cannot plan their walking routes for themselves in unknown places. It is impossible for them to walk around various places such as shopping malls and station concourses as sighted persons, which is indispensable to enjoy their daily life. In this work, we propose a method which supports visually handicapped people to visit and walk around in their unknown places. We use RFID technologies to achieve voice navigation with the direction to their destination from their current location and their moving direction. To verify effectiveness of our system, we navigate blindfolded people experimentally. In the experiment, we have confirmed the success rate is 81 %. *Copyright © 2015 IFSA Publishing, S. L.*

**Keywords:** Visually impaired, Navigation, RFID.

## 1. Introduction

Though people get most of their surrounding information using their eyes, visually handicapped have lost their vision. They cannot spend their life as the same way as sighted persons. In particular, visually handicapped suffer from many difficulties to go out. Tactile walking surface indicators are indispensable for visually handicapped to walk outside. They are paving blocks with uniformly arranged studs. They are ”tactile” because they are detectable with feet at walking. They are used to alert visually handicapped of hazards, such as a road cross before moving car traffic or the edge of a drop at subway station platforms. Visually handicapped use not only their feet but also white canes to recognize studs of tactile walking surface indicators. White cane is also used to find the surrounding obstacle. However, tactile walking surface indicators might bring nuisance to people poor at walking such as the elderly and persons on wheelchairs. Because of the nuisance, they not installed all over a town, much less in wide public spaces where many people come and go in various directions. Even if tactile walking surface indicators are installed, it is difficult for visually handicapped to plan their walking courses for themselves. A support method is required for visually handicapped to walk wherever they want like sighted persons.

When visually handicapped go outside, they use all sensory organs which they can use to acquire the surrounding information. To find their current location and target direction, they compare information they acquire with routing information to their destination [1]. However, they do not always have correct routing information in unknown places. Though several methods have been proposed to guide visually handicapped persons [2-4], none of them support for them to walk around unknown places. When they go out in unknown places, they have to memorize tactile maps or ask familiar sighted people such as family members or helpers to accompany with them [5]. It is burdensome for them to memorize tactile maps. If they ask familiar people to accompany, it is burdensome for the familiar people to help them. It is necessary to navigate visually handicapped without burden of their familiar people or themselves.

In this work, we propose a navigation method to support visually handicapped persons walking outside like sighted persons even in unknown places which are not covered with tactile walking surface indicators. We guide the visually handicapped, presenting the direction to their destination with voice navigation. We use RFID technologies to identify the current location and the moving direction of them, from which the direction to their destination is calculated. In the work, a reader is attached on foots to acquire the ID of tags embedded in floors of buildings and roads in outside. Acquired ID of tags allows us to know the exact location, which derives the exact moving direction. To navigate visually handicapped, our system conveys direction to their destination using voice. To verify effectiveness of our system, we have conducted an experimental to navigate blindfolded people. In the experiment, we have confirmed the success rate is 81 %.

The following is an outline of the remaining chapters of this paper. Section II summarizes related works to navigate the visually handicapped. Section III proposes a model to navigate the visually handicapped, as well as a method to acquire the current location and the moving direction for the destination. Section IV explains an experiment to navigate blindfolded people using the proposed method. We also present results, which are discussed in Section V. Section VI provides the summary of the work.

## 2. Related Works

Many navigation systems have been proposed for visually handicapped. To convey information necessary to walk, the systems have to acquire the current location and the moving direction in a real time manner. A navigation system is proposed to convey surrounding information using RFID technologies [6]. This system installs a reader on a white cane to acquire tags embedded in tactile walking surface indicators. It matches the acquired ID of a tag with a tag map recording the location of all embedded tags in order to the acquire current location and the moving direction. First, visually handicapped specify their destinations using their voice when they use this system. Next, system conveys routes leading to the destinations. They can walk alone using this system. However, this system has some problems, because it installs readers on their white canes. First, increase of the white cane weight enlarges the burden of visually handicapped. Next, searching embedded tags with white case could cause accidents, because white canes are also used to detect surrounding obstacles. The visually handicapped have to search embedded tags and surrounding obstacle at the same time, when they use this system. Distracting visually handicapped could cause accidents. Finally, it is difficult for this system to acquire the exact location and the exact moving direction. To plan walking routes, navigation system should acquire the exact location and the exact moving direction in any place in a real time. To achieve it, it is necessary to embed tags in the whole of the floor and roads. If a reader is installed on a white cane, many tags are detected irregularly because the visually handicapped swing it to find surrounding obstacles. Therefore, it is difficult for this system to acquire exact location and the exact moving direction.

Some navigation systems conveys surrounding information using Ultra Wide Band (UWB) technologies [7]. In the systems transmitters are mounted on the ceiling or pillars to transmit current location to users terminals. Terminals which receive signals can recognize the current location and the moving direction anywhere. However, the usage of UWB technologies is limited in Japan. The radio act in Japan constrains the use of UWB system only indoors. Therefore, this system cannot be used in wide public spaces or street in the outdoors.

## 3. Navigation Using Tag Block

### 3.1. Landmark Spot and Navigation Area

In this work, we define a model to allow visually handicapped to walk in a town using flat paving blocks in which tags are embedded. The paving block is studs free to avoid bringing nuisance to poor walkers likely the elderly and people using wheel chairs. It is infeasible to embed tags in all position of a town. We define two kinds of spaces to navigate the visually handicapped in terms of their roles. One is a landmark spot, while the other is a navigation area. To navigate the visually handicapped, we make the best use of them in accordance to purposes of navigation. Fig. 1 illustrates Landmark Spots and Navigation Areas. A landmark spot is a space of several meters square to notify the visually handicapped of a town landmark such as a crossroads and a host office. Landmark Spots are settled at surroundings of various landmarks all over the town.

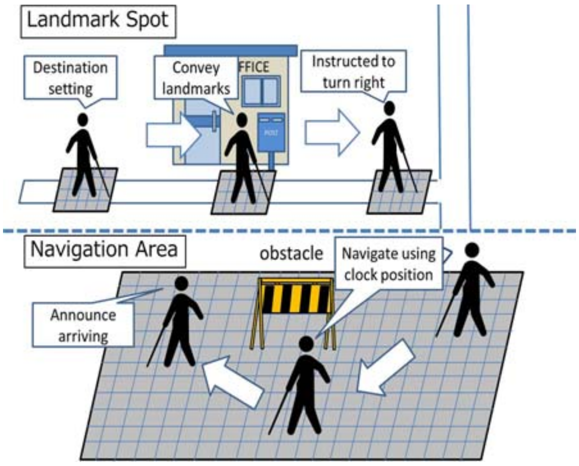


**Fig. 1.** Landmark Spots and Navigation Areas.

The visually handicapped can arrive their destination, traversing one landmark spot to other on the route to the destination. Navigation system acquires the current location and the moving direction of the user in a landmark spot, to convey the direction to the next landmark spot using voice navigation. Landmark spots are settled, skipping from one to another, to reduce cost. Though it is impossible to navigate the visually handicapped in a fine grade, is effective measures to navigate the visually handicapped according to a specific route, which consists of sidewalks and narrow streets.

On the other hand, in a navigation area, tags are embedded all over it to navigate visually handicapped precisely. A navigation area is effective to navigate them in a shopping mall, the concourse of a big station, and a wide open space like a plaza. The proposed navigation system conveys the direction to their destination in a navigation area. The navigation system acquires the current location and the moving direction of the user in a real time way for the navigation. The navigation system conveys the direction to the destination to the visually handicapped, using a speaker of their handy terminals. The system can navigate them at any position inside the navigation area. Users can avoid obstacles and shorten the path to destination in a navigation area. In this paper, we focus on a navigation area.

### 3.2. Navigation Method

In this work, we use RFID technologies to achieve voice navigation for the visually handicapped. A navigation system should acquire the current location and the moving direction of the user in a fine grade. To achieve it, we embed tags in flat blocks, while a user wear a reader on user shoes. The detection of tags by the readers attached on shoes allows the navigation system to acquire the current location and the moving direction. The readers attached on shoes also make it possible to use a white cane only for search surrounding obstacle. Compared with the conventional methods [6-7], our method is safer and more in expensive for the visually handicapped. Fig. 2 illustrates the outline of our navigation method. Readers are installed on the tiptoe of shoes, because the tiptoe is touching quite frequently. Tags are embedded in a flat blocks at even intervals like a chessboard. Each tag is associated with a unique number, which is bound to two-dimensional location information. We refer to this block as a tag block. The navigation system acquires the current location, consulting the location information corresponding to the unique number. The position of the both foot is regarded as the location information acquired from the readers attached to the both toes. In each step, the angle from the previous step of one side foot to the current step is calculated to get the current moving direction. It is referred to as the angle of the step. The proposed method calculates it separately left and right. It takes their average of them. The average is the moving direction of the user at that time. The method figures out the difference of the moving direction from the angle to the destination. It is converted to the clock position to convey direction for visually handicapped persons. Clock position is conveyed to the visually handicapped using voice to navigate them. The visually handicapped can understand the direction to destination. The method enables the visually handicapped to walk around like sighted persons.

### 3.3. Current Location and Moving Direction

It is important to acquire correctly the current location and the moving direction of a walking visually handicapped person to navigate him. In this work, tags are arranged in a small distance all over the ground to acquire the precise location. A navigation system acquires the current location of the user every step, detecting tags on the ground. Let $P(X_{in},Y_{in})$ denote the current location at time point i.

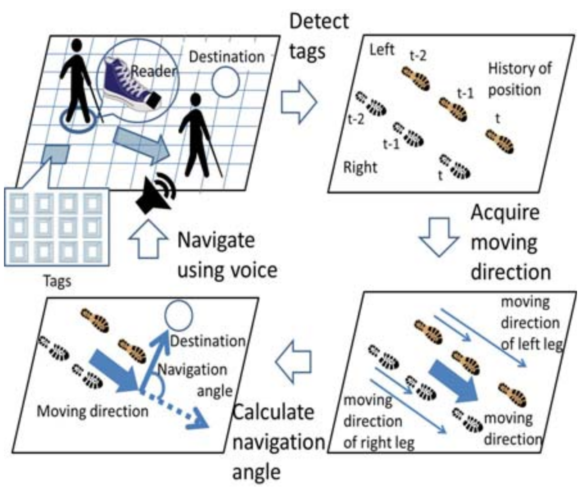


**Fig. 2.** Outline of our navigation method.

Suppose $P_0$ ($X_{i0}$,$Y_{i0}$) indicates the user location n steps before. The user location at any of these n steps is represented with $P_j(X_{ij},Y_{ij})$, where 0 =< j =< n. The moving direction of one foot is calculated with (1).

$$\theta_i = \frac{\sum_{j=1} \tan^{-1}\left(\frac{x_{ij} - x_{i0}}{y_{ij} - y_{i0}}\right)}{n} \quad (1)$$

Fig. 3 illustrates how to derive the angle of the step when n = 3. θi is derived as follows. $P_0(X_{i0},Y_{i0})$ is the origin in the calculation of the angle at every step. The navigation system creates coordinate plane at every step. Let P0 denote the coordinate plane. Its origin is $P_0(X_{i0},Y_{i0})$. The user stands at $P_j(X_{ij},Y_{ij})$ after he takes J steps, where 1 =< j =< n. The navigation system calculates the angle of the vector from P0 to Pj at every j. It is the angle of the step. Since j varies from 1 to n, n angle values are obtained every i. Each of them corresponds to the angle from the first step (θ1) to the angle of the $n^{th}$ step (θn). The average from (θ1) to (θn) is the moving direction of one foot at i. The average of the moving direction of both feet is the moving direction of the user at. We define it as (θd). The navigation system calculates (θd) every step. Sine tags are arranged in a small distance on the ground, a reader detects several tags at one step. It makes an error in the calculation of the moving direction. If a reader detects tags arranging right and left at one step, the navigation system calculate as if the user turns the right or the left. If reader detects tags arranging right and left, the navigation system use only one of them to calculate the moving direction of the user.

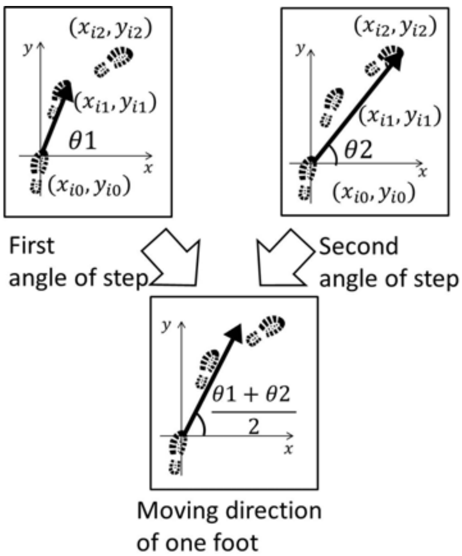


**Fig. 3.** How to derive the angle of the step.

Let $D(X_g,Y_g)$ denotes the location of the destination. Since the user currently stand at P, the angle of the vector from P to D is the one from the current location to the destination. We refer to it as the destination angle, $\theta_{ig}$, which is calculated using (2).

$$\theta_{ig} = \tan^{-1}\left(\frac{x_g - x_{in}}{y_g - y_{in}}\right) \quad (2)$$

The navigation system derives the navigation angle, $\theta_l$, subtracting $\theta_d$ from $\theta_{ig}$. It derives θ1 every step so that it can navigate the visually handicapped in any time.

### 3.4. Navigation Using Clock Position

The conveying method is important to navigate the visually handicapped persons. Suppose a visually handicapped person try to reach a specific destination. The destination is not necessarily located in the front of the visually handicapped person. Sometime, it is located in the diagonal right ahead, while it exits in the just left of the visually handicapped person in other time. In an open space like a plaza, it is preferable for him to move to the destination straightforward without any turn. The visually handicapped cannot understand abstract navigation, such as advance the diagonal right ahead. It is necessary to navigate the visually handicapped using special phrases such as the northeast regarding your front as the north. The clock position is often used by the visually handicapped. In this work, we use the clock position to lead the visually handicapped to their destinations straightforward because we can specify the precise direction with the clock position. The navigation system should convert the navigation angle into the clock position. If the moving direction of a specific visually handicapped person is equal to the destination angle, the navigation angle is equal to 0 degree. In the clock position, 0 degree corresponds to the direction of 12 o 'clock. Clock position c is calculated using Equations (3), (5), where x is an integer.

$$c = \arg\min f(x), \quad (3)$$

$$f(x) = |\theta_l - \theta_x|, \quad (4)$$

$$\theta x = \begin{cases} 30x & if\,(1 \le x \le 6), \\ -30(12 - x) & if\,(6 \le x \le 12) \end{cases} \quad (5)$$

## 4. Experiment

### 4.1. Experiment Environment

We have conducted an experiment to navigate blindfolded people using a navigation system based on the proposed method.

We have examined whether the system can navigate blindfolded people from one point to another. We have navigated 13 male and 2 female subjects. Fig. 4 illustrates the position of the starting point, the goal point and the two relay points. Before starting, each subject stands at the starting point, facing relay point 1. In this experiment, we prepare three paths as follows. One of the paths is selects randomly for a subject, to prevent the subject from suspecting the path the subject is following. In this experiment, we have navigated the subjects 15 times in each path.

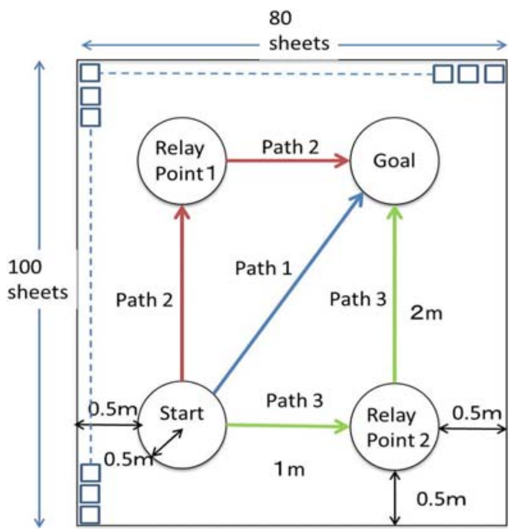


**Fig. 4.** The position of the starting point, goal point and relay points.

An arrival is regarded as the entrance of a subject within a radius of 50 cm from the center of the point. If a subject arrives the goal point using only the navigation system, we regard that the navigation has succeeded. On the contrary, we consider the navigation has failed, if the navigation is stopped to avoid a danger. The effectiveness of the proposed method is evaluated with the success rate, which is calculated with (6).

$$success\ rate = \frac{arriving\ score}{15} \tag{6}$$

We have used 5 cm square tags in the experiment. Every tag is installed every 5 cm, being spread over the 4-by-10 meter floor. Tags are covered with a plastic sheet. A reader is attached at the position 5 cm away from the toe of the shoes. In this experiment, the navigation system uses the recent 3 steps to calculate the moving direction of the subject.

### 4.2. Results

Fig. 5 illustrates the success rate of each subject for every path. The horizontal axis of the graph represents subjects, while the vertical one represents the arriving score. The average of the success rate is 95 %, 80 %, and 68 % in path 1, path 2, and in path 3, respectively. The maximum of the success times is 15 in any path. The minimum of the success times is 9, 4, and 3 in path 1, 4 in path 2, and in path 3, respectively. The navigation is highly reliable in path 1, where each of the subjects takes a straight way. However, the navigation is not trustworthy in path 2 and in path 3 where each subject has to take a turn, compared with in path 1.

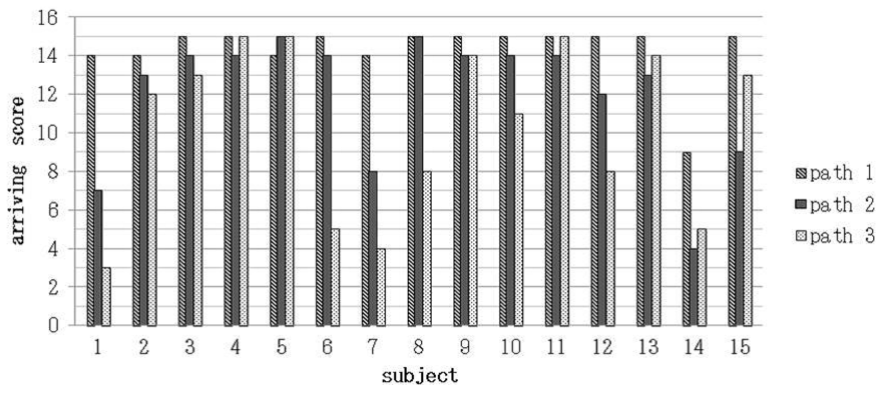


**Fig. 5.** The success rate of each subject for every path.

## 5. Discussion

### 5.1. Improvement of Success Ratio

It is necessary to improve the success ratio in path 2 and path 3 to navigate the visually handicapped safely. In the experiment, failures mainly attribute to the following three causes.

The first one is misinterpretation of the clock-position by subjects. Failures coming from them are found in all paths. All the subjects it are sighted persons, who are unfamiliar with the clock position. They cannot map the clock position specified in navigation messages into the direction to which they should proceed. Because of the failures in the mapping, they have and walked incorrectly, which swerves them from the desired paths. The second cause is wrong calculation of the navigation angle by the system. The wrong calculation arises in path 2 and path 3. In the experiment, the navigation system calculates the navigation angle uses with the foot location in recent 3 steps, assuming a user walks straightforward during the steps. The calculation gets wrong, if the user changes the direction rapidly during the steps. The moving direction before the change works as the inertia for the calculated moving direction. Actually, a subject turns quickly at the third step in the experiment. At that time, the system calculates a wrong value for the navigation angle, because the first and the second step influence the calculation of the moving direction of the subject. The calculated moving direction is much closer to the one before the rapid turning than the actual one after it. Quick turns of users make the system figure out erroneous values for the navigation direction. To deal with the error, the system should not navigate users when they turns quickly. Rapid turns can be detected from the movement of each foot. We move each foot in turn to take a turn. In the turn, the moving direction of each foot is renewed in turn. When a user walks straightforward, the angle vector from one step to the next of the right foot is close to that of the left foot. On the contrary, the user is considered to take turn, if the vectors differ with each other. In this work, the navigation system averages the vectors of each foot to calculate the moving direction. However, the calculation is valid only when the user walks straightforward. When the vectors of one foot largely differs from that of the other, the navigation system should not issue any navigation message to users to deal with the error in the calculation of the navigation direction. The final cause is the walking speed of subjects. It takes place in path 2 and 3. In the experiment, the navigation system navigates every 3 seconds. If the walking speed of subjects is fast, the navigation is too late to lead them to desired directions. Fig. 6 illustrates the relationships between the success rate and the walking speed.

The horizontal axis of the scatter diagram is the walking speed, while the vertical axis represents the success rate.

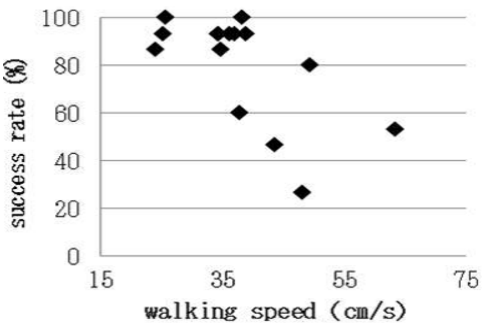


**Fig. 6.** The relationships between the success rate and the walking speed.

The walking speed is negatively correlated with the success rate, where the correlation coefficient is −0.64. The faster the walking speed, the lower the success rate. If the walking speed is over 38 cm/sec, the success rate gets worse rapidly. It implies that it is difficult for subjects to turn at relay points, when they are walking the speed over 38 cm/s. To address the problem, the navigation system has to convey voice messages more frequently. However, the visually handicapped persons would get too enormous information to respond properly, if the navigation system conveys voice messages more frequently. The navigation system should changes the frequency of the navigation in response to the working speed of users.

## 5.2. Failure Causes

Navigation timing is an important to navigate visually handicapped persons. They cannot turn at specific points if they do not prepare turning in advance. The navigation system must notify them of the turn before they arrive the turn point to make them prepare the turning. In our experiment, the navigation system gave navigation to subjects every 3 second. The turn points ware near for edge of the navigation area. The subjects could not turn if the navigation was delayed. They went out of the navigation area. Our system cannot acquire their current location if they go out of the navigation area. Because of this, navigation failed. To deal with this error, the navigation system should acquire the walking speed of subjects. The navigation system should accommodate the timing of the navigation with their walking speed.

We need to analyze the reaction time of subjects who listen to voice messages for the navigation. We define the reaction time as the time from the issue of the voice message to the change of the moving direction. We analyzed the reaction time using walking logs of subjects from the start point to the relay point 1. The subjects could walk straight between the start point and the relay point 1. The navigation system informed the turning once between the start point and the relay point 1. Fig. 7 illustrates the reaction time of every subject. The horizontal axis of the graph represents each subject, while the vertical one represents the reaction time. The average of the reaction time is 2.3 second. The standard deviation is 0.8. It means many subjects can react on time, if the system navigates 2.3 second before they reach the turn point.

Note that the system must change the navigation timing depending on the situation. Fig. 8 illustrates the histogram of the reaction time and the reaction probability. The subjects can react with the probability of 82 %, if the system navigates 3 second before they reach the turn point. If the system navigates 4 second before, they can react with 98 %. It means the system should issue a navigation message 4 second before subjects reach the turn point, if it must navigate them near the edge of navigation area.

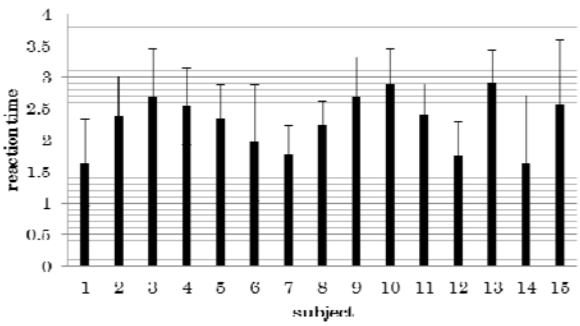


**Fig. 7.** Reaction time of each subject.

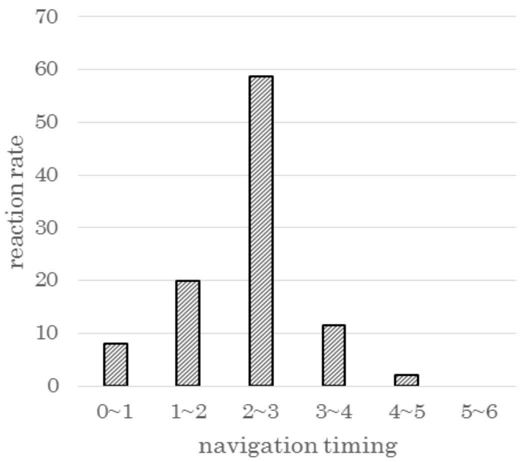


**Fig. 8.** Reaction rate of each navigation, timing.

## 7. Conclusions

In this work, we have proposed a navigation method to support the visually handicapped persons walking around like sighted persons in their unknown places. On a landmark spot, the navigation system leads the visually handicapped to proper routes while suppressing cost. In a navigation area, it directly navigates them to the destination with the clock position. The method founds on RFID technologies to get precisely the current location and the moving direction of users. It figures out the navigation direction to their destination from their current location and the moving direction.

To verify effectiveness of the system, we have an experiment to navigate blindfolded people. The average of the success rate in the straightforward path, is 95 %, while that in paths containing turns is 68 %.

It is necessary to improve the precision to navigate the visually handicapped persons safely routes where they have to turn. The paper has discussed the causes of failures in the navigation to improve the precision. The discussion suggests additional studies to solve issues to improve the precision.

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