SIGN DETECTABILITY IN RAILROAD STATIONS CONSIDERING FLOW DIRECTION OF PEDESTRIANS

鉄道駅における歩行者の移動を考慮した誘導サインの検出可能性

Zongchao GU――――　＊1　**Ryuzo OHNO** ――――――　＊2

顧　宗超――　＊1　　大野隆造―　＊2

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The detectability of guide signs in a railroad station differs according to the spatial relation with pedestrians in motion. Based on the results of a sign detection experiment conducted in an actual station and because the global tendency of detectability includes the approach direction, this paper examines sign detectability using three spatial variables and three different directions of pedestrian motion. The results are applied to suggest appropriate sign planning in railroad stations.

1. INTRODUCTION

Because signage in railroad stations provides information and guides passengers to their destinations, it has been noted that these signs should be planned according to passengers' movements[1]. In large railroad stations where several lines interconnect, the trace of passengers' movements is complicated. Additionally, it is difficult for passengers, especially when in transit, to detect and recognize necessary signs in a short time because other signs tend to be nearby. Thus, this research focuses on sign detectability to improve the present situation.

Research on guide signs in railroad station has been carried out from different aspects. With respect to legibility, a study using stationary pictures found that the sign processing time and eye movement are affected by the surrounding environment[2]. A questionnaire study on advertisements and guide signs in a station found that unnecessary information in a station confuses pedestrian action[3]. Research on sign detectability while in motion has examined influential factors for sign visibility through immersive visual simulation experiments in the laboratory[4].

This study discusses sign detectability, which should be affected by its spatial relation with respect to pedestrian's position and body direction in motion. To study sign detectability in a real situation, a sign detection experiment was carried out in a railroad station in Tokyo. Participants were asked to walk along a designated route and search for target signs amongst the many signs along the route. Their motion traces and detection positions were recorded and mapped onto the floor plan. Then the graphical data were transformed into numerical data, which was used to calculate the probability of sign detection for various spatial relations between the sign and a pedestrian. Numerical analysis clarified the functional relationships of sign detectability with spatial variables. Finally the detectability tendencies in a railroad station considering the flow direction of pedestrians are demonstrated.

2. SIGN DETECTION EXPERIMENT IN REAL SPACE

2.1 Objective

The spatial relation between a target sign and a pedestrian is an influential factor for sign detection. As a pedestrian moves toward a destination, his or her relative position around a target sign is changing continuously. This experiment aims to elucidate the spatial relation between a target sign and detection by a pedestrian in transit, and clarify the variables influencing sign detection while in motion.

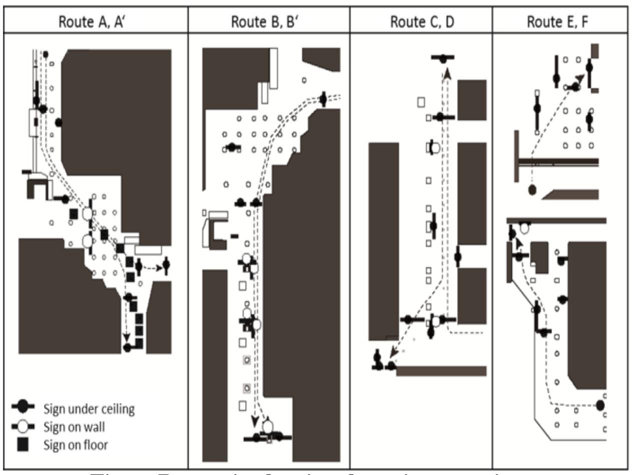

Fig. 1: Routes in the sign detection experiment

*1 Graduate student, Dept. of Built Environment, Tokyo Institute of Technology, M. Eng.
*2 Pro., Dept. of Built Environment, Tokyo Institute of Technology, Dr. Eng.

*1 東京工業大学総合理工学研究科人間環境システム専攻　修士（工学）
（〒226-8502　横浜市緑区長津田町 4259 J3-28）
*2 東京工業大学総合理工学研究科人間環境システム専攻　教授・工学博士

2.2 Experiment

Due to the amount of signage and variations in an architectural space, the experimental site, which was selected from several large railroad stations, was the T station. This experiment used eight routes that lead to exits or transfers to other metro lines. There are a number of guide signs along these routes (Fig. 1). The experiment evaluates the detectability of these signs by a pedestrian in motion.

To prevent other passengers from influencing the results, the experiment was carried out at midnight after the last train using 15 hired participants (7 male and 8 female). Their eyesight ranged from 0.8 to 1.5. Every participant walked all eight routes, and the whole process lasted 60–80 min.

Each participant was separately guided to the starting point and informed of his or her destination. Then the participant was asked to proceed to the destination, but to stop and point out each destination sign detected along the route. An experimenter followed the participant, recording the results with a video camera.

2.3 Experimental results

After the experiment, we used CAD files to save the experimental results. The CAD data recorded the architectural space, positions of the target signs, and the participant's spatial relation with each sign.

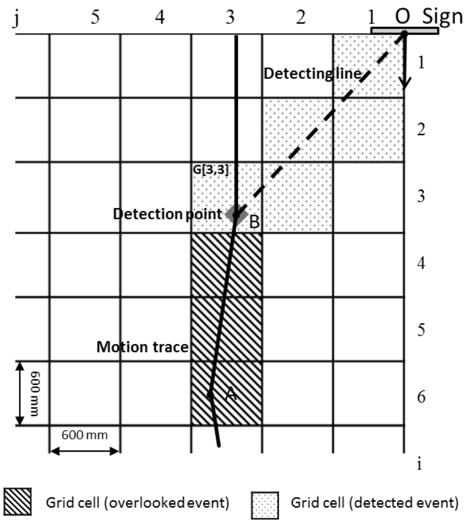

Fig. 2: Graphical data in the sign detection experiment

We then plotted the position of each sign on the floor plan and identified each participant's movements using the acquired video (Fig. 2). This process yielded motion traces and detection points. Additionally, a rectangle with an arrow indicates the direction that the guide sign faces. The participant's motion trace is approximated by sequence of connected vector lines. The detecting line is represented by a vector line leading from the detect point to the center of target sign, while a vector line indicates which sign is detected from which point.

3. NUMERICAL ANALYSIS FOR DETECTABILITY

Detectability in this study refers to the probability that a sign is detected by a pedestrian in motion. Although detectability can be affected by many factors, such as the size of the sign and the observer's vision, this paper focuses on the influence of the spatial relation between a sign and the observer. The detectable ratio is used to numerically represent sign detectability for a certain spatial relation with the observer.

3.1 Definitions

Although the detectable ratio is commonly determined by counting the number of pedestrians who detected the target sign relative to the total number of pedestrians, this study adopts a new method using graphical data. The following definitions are used in the new method:

Detectable ratio: Probability that a sign is detected by pedestrians at a certain location.

Grid cell: The area in front of a target sign is divided into grids (600 mm × 600 mm) (Fig. 2). Each "grid cell" represents a specific location with respect to a sign. The position of each grid cell is identified by a unique set of coordinates (i, j).

Sign examination event: An event where a participant passes through a particular grid cell in front of a target sign. There are two types of sign examination events: detected or overlooked event.

Detected event: An examination event where the participant detects a target sign. In Fig. 2, a participant detected a target sign at point B. A detected event is counted once. Because spatial relations affect detectability, we assume that if a participant detects a sign at a further distance (Point B), then he or she will be able to detect the sign in grid cells closer to the sign (between Point B and O Sign) along a linear path. Grid cells along this linear path (dotted cells in Fig. 2) are referred to as the detecting line in this study.

Overlooked event: An examination event where the participant misses or overlooks a target sign. Grid cells where the participant's motion trace occurs prior to detecting a target sign are considered overlooked events (lined cells in Fig. 2). In each of these cells, an overlooked event is counted once.

By counting sign examination events obtained from all the participants near a sign, the numbers of detected and overlooked events are determined for each grid cell. Then the detectable ratio for a certain grid cell (i, j) is determined by

$$P(i,j) = \frac{Nd(i,j)}{Nd(i,j)+No(i,j)} \times 100\% \qquad (1)$$

P: Detectable ratio

Nd: Number of detected event

No: Number of overlooked event

In this study, each event occurs in response to a specific spatial relation of a pedestrian and a target sign. This spatial relation is assumed to affect a sign detection event, and is defined by three variables (Fig. 3):

1) D: Distance between a participant's position and the target sign,

2) α: Angle between the direction from the target sign to the participant and the normal line of target sign's surface,

3) θ: Angle between the direction of participant's motion and the direction to the target sign.

Because other factors also affect sign detectability, we tried to exclude events that are beyond the scope of this study. Fig. 4 shows the relationship between the frequency of detection and angle θ of the detection point. Its cumulative percentage reaches

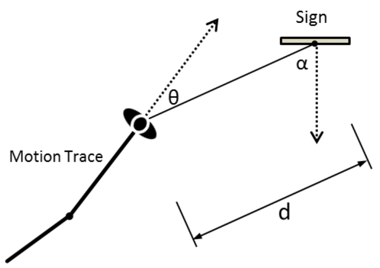

Fig. 3: Spatial variables in sign detection

92.8% when angle θ increases to 45 degrees. The probability of a detection event occurring when θ is larger than 45 degree is low, and grid cells between this detection point and the sign should not be considered detectable locations. Hence, the sign detection events where θ is larger than 45 degrees are excluded.

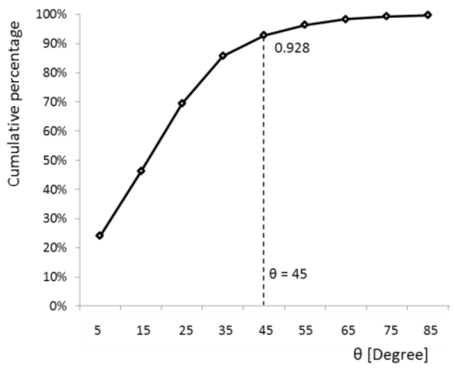

Fig. 4: Cumulative percentage of angle θ at the detection point

Additionally, more than 95% of detection points are within 40 meters of the sign. Thus, detection events further than 40 meters are excluded from our analysis.

3.2 Detectable ratio distribution

There are numerous sign detection events to be clarified and counted from the experimental result. Below is overview of data treatment using a computer to determine the detectable ratio for each grid cell.

1) Pre-treatment of graphical data

Because this study aims to determine the relation between sign detectability and the observers' relative position, all target signs are assumed to have identical readabilities. Below, one sign is used to demonstrate the operations to derive graphical data.

Taking the sign's position as the origin and the sign's normal direction as the positive direction of the Y-axis, sign-origin Cartesian coordinates are established. All the graphics absolute coordinate positions in the architectural floor plan are transferred to their relative coordinate positions in the sign-origin plan. Then graphics in the third and the forth quadrants and the meaningless motion trace segments (traces after the detection points and traces shielded by an architectural structure) are deleted.

Because a mirror operation does not alter the spatial variables in sign detection, we concentrated all graphics into the first quadrant to get more events into the grid cells. Using the Y-axis as a reference, the graphics in the second quadrant are mirrored into the first quadrant. In the case where one segment goes through the Y-axis and is divided in half at the intersection, the part in the second quadrant is mirrored into the first quadrant.

According to above definition, this coordinate system is divided into 600 mm × 600 mm grid cells. Graphics in a 42m × 42m area of the sign's first quadrant are used as the study field. Hence, the study field is divided into 70 × 70 grid cells.

2) Event cell clarification

To clarify a detection event between a detection point and a sign, initially a segment is drawn from each detection point to the origin. Next the motion trace curve is transferred into continual segments, giving two types of segment data to clarify different detection events.

The coordinate positions of the start and end points provide the segment's function in this coordinate system. Then clear grid lines (horizontal/vertical) are drawn intersecting segment, and each segment's intersection with the grid lines can be calculated. Finally a set of segment's intersections with grid lines (set I in Fig. 5) is acquired

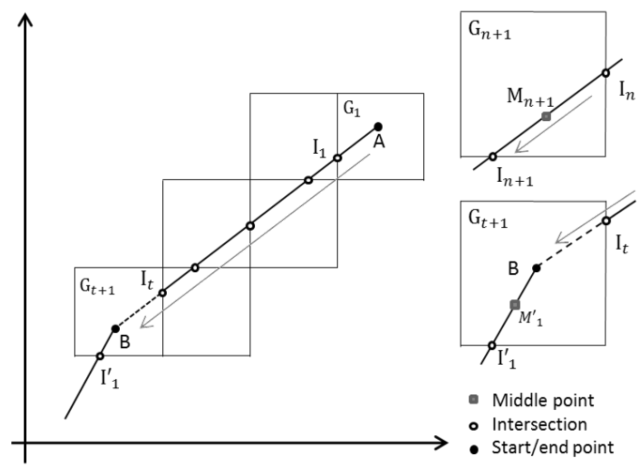

Fig. 5: Event point calculation

In Fig. 5, points of set I are sorted in order from A to B. Then two neighboring points can clarify a certain grid cell G in the coordinate system. The middle point of these two points M is considered to be the location for the sign detection event in this grid. M is called the event point. Participant's spatial relation with a sign at the event point is recorded as the spatial variables of event in a cell.

If the element amount of intersection I is t, there are t−1 grids that segment AB passes. Additionally, there are two grids that have only one intersection with this segment: G_0 and G_{t+1}. If a segment does not connect to other segments in the region with one intersection, such as G_1, we take the middle point of starting point A and intersection I_1 as the event point. If a segment connects with another segment in a cell like G_{t+1}, this grid's edge intersects with two segments. To prevent the region from being counted twice in a sign detection, we only count this grid as the event cell when we deal with the segment where B is the starting point.

3) Event availability test

Acquired event points can be used to calculate the spatial variables and test whether the variables satisfy the predefined limit. In the case of an overlooked event, its variable θ is assigned with a value at event point. In the case of a detected event, events clarified by a detecting line are presumed to occur along the line and are assigned with variable θ at the detection point.

In all events clarified by graphical data, if the spatial relation satisfies the condition $\theta < 45$ degrees, the event is plausible and the event attributes are saved for further analysis. Otherwise, the event is excluded.

4) Calculation of the detectable ratio

To save the results of events clarified by the graphical data, two matrixes with 70×70 elements are created: Matrix_detected and Matrix_overlooked for the detected and overlooked events, respectively. Each element in the matrix corresponds to one grid cell's coordinate position in the sign-origin system.

For example, if one sign detection event is clarified at event point (Xm, Ym) and the availability test of this event is available, its corresponding element Matrix (R, C) is obtained as

$$R = int\left(\frac{x_m}{g}\right) + 1 \quad (3)$$

$$C = int\left(\frac{y_m}{g}\right) + 1 \quad (4)$$

R: Serial number of a row in the matrix
C: Serial number of a column in the matrix
g: Size of the grid cell

If the result of this event is 'detected', the element at (R, C) in Matrix_detected adds 1. Otherwise, the element at the same position in Matrix_overlooked adds 1.

By carrying out the above operations for all segment data, the matrix of detectable ratio is determined as

$$Matrix\_ratio = (Matrix\_detected)/(Matrix\_detected + Matrix\_overlooked) \times 100 \quad (5)$$

5) Optimization of the results

In the 4900 grid cells, there are 58600 events clarified. If too few sign detection events occur in a grid, then the detectable ratio is unreliable. To get an accurate detectable ratio distribution, optimization of the results is necessary.

Prior to optimization, the lower limit of the number of events per grid must be determined. About 44% of the cells have less than 10 events. However, to ensure realistic results, the minimum number of events per cell was set to 10. Thus, the detectable ratio in cells with less than 10 events needs to be optimized.

Because neighboring cells have similar spatial variables, these variables are thought to be continuous. Consequently, cells with too few events are assigned the average value of the surrounding eight cells.

4. RESULTS AND ANALYSES

Through numerical analysis of the sign detection experiment in real space, the detectable distribution in the first quadrant of a sign is obtained.

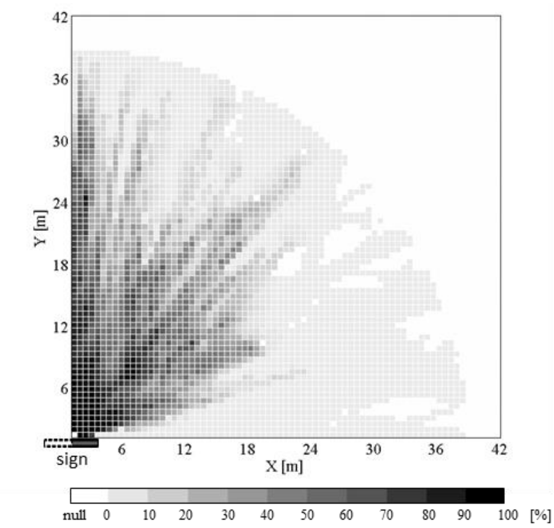

Fig. 6: Global distribution of the detectable ratio

4.1 Global tendency of sign detectability

A guide sign can be detected from a long distance in the normal and 45-degree directions (Fig. 6). However, a gap in the detectability appears between the direction of surface normal and 45 degrees, which ranges from 3 to 6 m in the horizontal direction. The detectable ratio in this gap region is lower than the surrounding regions. When α exceeds 70 degrees, the signs are barely detected.

Fig. 6 shows the global distribution of the detectable ratio. All events in a cell are considered to be same, although these events

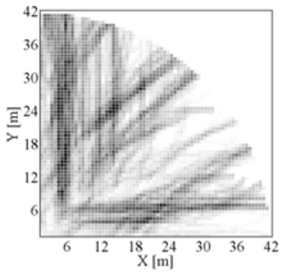

Fig.7: Motion trace distribution

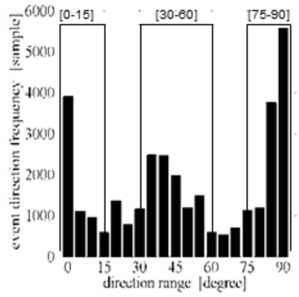

Fig. 8: Event direction frequency

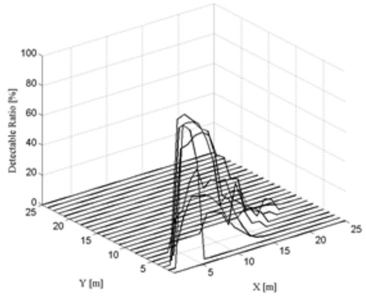

Fig. 10: Detectable ratio slice

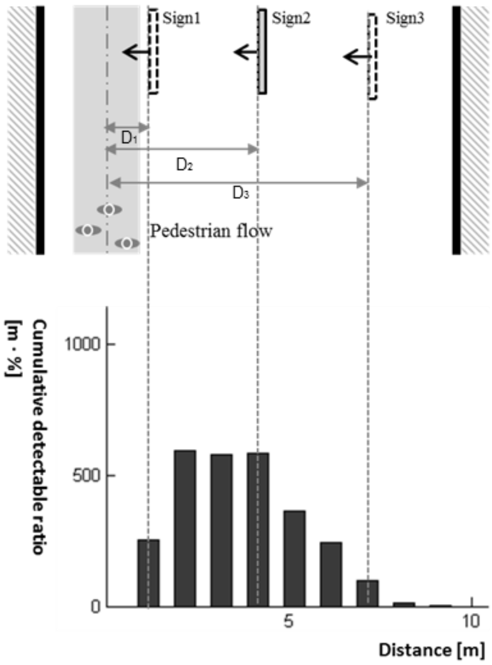

Fig. 11: Sign location evaluation in planning

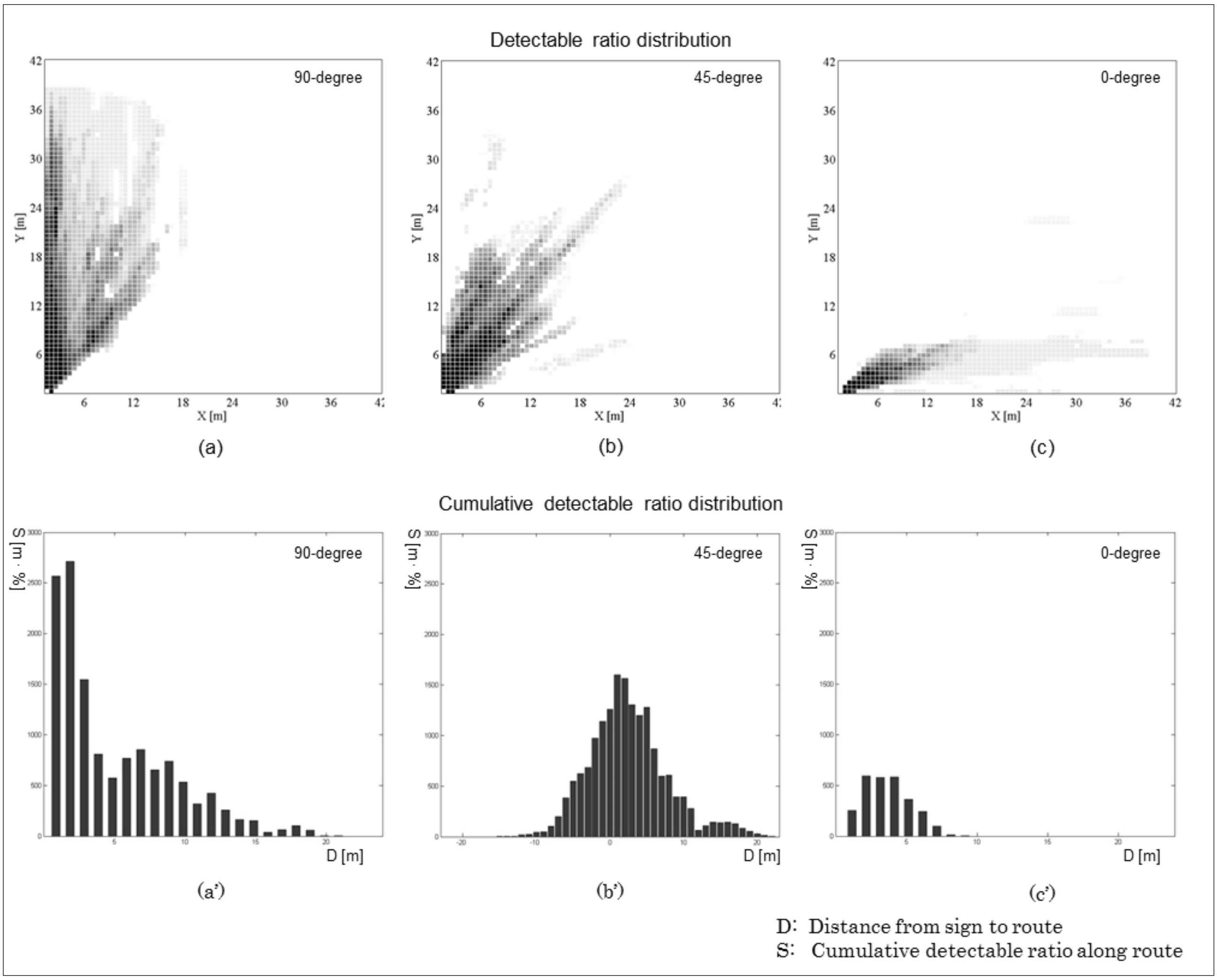

Fig. 9: Sign detectability for each sub-direction group

have different flow directions with varying spatial variables.

4.2 Tendency of sign detectability in the sub groups

Participants have motion trace frequencies in the 0-, 45-, and 90-degree directions (Fig. 7). Thus, we divided the detection events in these three directions into three sub groups, where each sub group includes events within 15 degrees from its own datum direction, giving event groups within range of [0–15], [30–60], and [75–90] (Fig. 8).

The three event groups correspond to participants' motion traces in different architectural spaces. The 0-degree and 90-degree direction groups appear more often in linear spaces, such as corridors. The 45-degree group appears when participant passes through an underground square along a diagonal direction.

In the 90-degree group, participants' movements are vertical to the sign's surface. Variables θ and α, which vary together, both affect detectability. Because θ is limited to less than 45 degrees, the detection events for all distributions are above the line y = x in Fig. 9(a). Grid cells with higher detectable ratios (P>60%) mainly occur along the sign's surface normal; in this 2–3 meter wide area, both angles α and θ are very small, so the sign is easily noticed and read. As the observation position departs from the normal line, angles α and θ increase, and sign detectability decreases rapidly.

In the 0-degree group, participants' movements are parallel to the sign's surface. The variable α is the main factor. Unlike the 90-degree group, even in the region with a smaller angle θ (along the X-axis direction), the detection rate remains low because along the X-axis, angle α is larger than the above case. Because the sign panel is almost parallel to the observer's sight line, it is difficult to detect, but angle α decreases as the participant moves closer to the sign. When angle α is small enough, the sign can be detected.

The 45-degree group includes events ranging from 30 degrees to 60 degrees. Variable θ is the most influential factor, and the region along the 45-degree direction has a probability of being detected. Additionally, the sign-detectable region above line y = x is larger than the corresponding region below this line because angle α in the former region is smaller than in the latter. Thus, when angle θ is similar, the sign with smaller angle α is more likely to be detected.

4.3 Method to assist in sign planning

Although there are several motion traces an observer can take around a sign, the above analysis clarifies sign detectability for observers along a specific direction. Fig. 10 divides and plots the results from the 0-degree group into 1 meter slices to give the detectable ratio along a flow direction. The area of the slice is the cumulative detectable ratio for observers moving along this trace, and its value can be used to present sign detectability along a specific motion trace. The larger the slice, the easier it is to detect a target sign. Fig. 9 (a')–(c') show the sign's cumulative detectable ratio along routes with different distances from the sign by sub group and show the spatial variables that influence each sub direction group.

Using these results, it is possible to determine the primary routes and maximize the detectable ratio by placing guide signs at the proper location (Fig. 11).

5. CONCLUSION

Based on a sign detection experiment, a method using graphical data is developed to obtain the detectable ratio to determine the distribution on the floor. According to the pedestrian flow direction, this paper separates sign detection events into three groups and uses three spatial variables to discuss sign detectability for each group. Sign planning in a station area should consider the position of the target sign, orientation of the sign surface, and the motion trace of the users. This numerical analysis method should assist in effective sign planning.

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