# Evaluation of the Effect on Viewer Recognition of Viewing at an Angle a Sign with Arrow Markings

Masaaki Koyama[1], Yuki Takahashi[2] and Hisao Shiizuka[3]

*[1,2] AIWA Advertisement Co., Ltd.,Tokyo 194-0023,Japan, [1] koyama@aiwa-ad.co.jp, [2] y-takahashi@aiwa-ad.co.jp*

*[3] Kogakuin University, Tokyo 163-8677, Japan, shiizuka@cc.kogakuin.ac.jp, Fuzzy Logic Systems Institute (FLIS), Fukuoka 820-0067, Japan, shiizuka@flsi.or.jp*

**Abstract:** This paper presents an evaluation of the effect on viewer recognition of viewing at an angle a sign with arrow markings. Focusing on the case in which a sign at an intersection is marked with an arrow pointing in the direction of a given destination, this paper (a) investigates, using linear transformation, how to represent such an arrow in a manner which ensures that drivers follow the proper direction, even when the arrow is viewed from different angles, and (b) proposes a specific approach to representing such an arrow. It has been shown that the direction and magnification of a given arrow marking are important factors in the recognition of the proper direction on the part of observers.

**Keywords:** Evaluation, viewer recognition, sign, arrow marking.

## 1. INTRODUCTION

The presence of signs plays an important role in all commercial activities, as illustrated by the fact that we constantly encounter them in daily life [1-3]. One key role of a sign is to make us aware of the presence of something we may be looking for, and to guide us in reaching it.

Focusing on the case in which a sign at an intersection is marked with an arrow pointing in the direction of a given destination, this paper (a) investigates, using linear transformation, how to represent such an arrow in a manner which ensures that drivers follow the proper direction, even when the arrow is viewed from different angles, and (b) proposes a specific approach to representing such an arrow. It has been shown that the direction and magnification of a given arrow marking are important factors in the recognition of the proper direction on the part of observers.

## 2. EFFECT OF VIEWING A SIGN AT AN ANGLE

We do not always view a sign straight on. When a sign is viewed at an angle, as shown in Figure 1, factors leading to recognition error naturally increase; and when a sign includes an arrow pointing in the direction of a location shown on the sign, and the sign is viewed at an angle, the recognition error rate is likely to further increase.

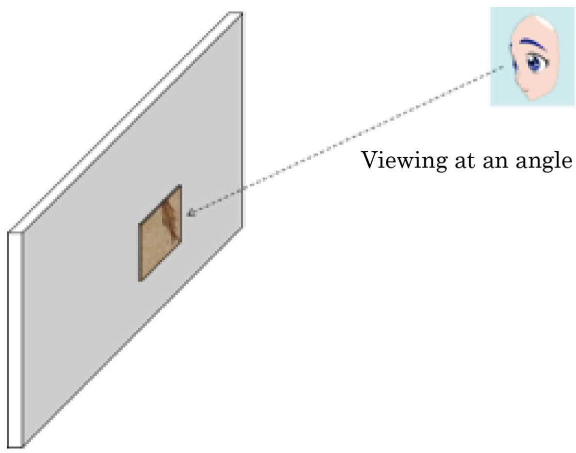



**Figure 1:** Viewing a sign at an angle

The factors leading to recognition error, which arise when a sign is viewed at an angle, can be explained by Figure 2. When we look at Sign A from angle α, we are actually perceiving the Acosα (or Asinβ) image of the sign, rather than the sign itself. Naturally, the letters and arrow on the sign appear distorted. In this study, we focus on the arrow marking on such a sign, and propose a transformation drawing approach using a linear transformation of the distorted image of the sign, based on the nature of a linear transformation matrix, which enables viewers to determine the proper direction indicated by the arrow. When we follow the direction of an arrow on a sign, we may assign an incorrect path to the given destination; thus, here we evaluate the role of representing a transformed arrow in reducing such recognition error.

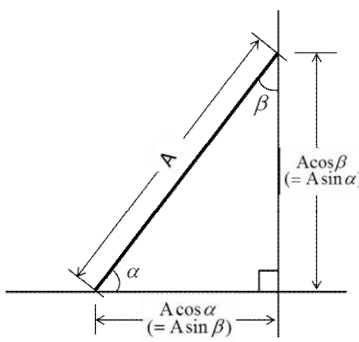



**Figure 2:** Effect of viewing Sign A at an angle

Imagine that Sign A, for example, as shown in Figure 2, is located at one of the four corners of an intersection. A driver can choose 'straight,' 'left' or 'right.' How should the arrow be drawn, in order to properly guide drivers, coming from any direction, to their destination? In fact, this is a difficulty commonly faced by road-sign manufacturers.

## 3. LINEAR TRANSFORMATION

Generally, to map point onto point by linear mapping, the linear transformation matrix is given by

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \tag{1}$$

Solving Equation (1), we obtain the following equation:

$$\begin{bmatrix} x_1 \\ y_1 \end{bmatrix} = \frac{1}{ad - bc} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix} \begin{bmatrix} x_2 \\ y_2 \end{bmatrix}. \tag{2}$$

This linear transformation has the following characteristics.

(1) The origin does not move.

(2) The original straight line is transformed to a straight line.

(3) The ratio of the segment lengths of the original straight line is retained.

Characteristic (1) means that the origin is transformed to an origin, and (2) and (3) ensure linearity. This is why a given shape remains essentially unchanged when it collapses or rotates. A shape may completely collapse in a transformation. The determinant of a coefficient transformation matrix is expressed as

$$\Delta = \begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc$$

(1) The shape faces right if $\Delta > 0$.

(2) The shape faces left if $\Delta < 0$.

(3) The shape collapses into a line if $\Delta = 0$.

(4) The value of $|ad-bc|$ shows the magnification factor of a parallelogram.

As shown above, this transformation equation determines how a line drawing collapses in a transformation, based on the value of the determinant $\Delta$. Table 1 shows four typical linear transformations.

A combination of linear transformations may be obtained by performing two transformations in succession. For example, transformation matrices A and B are combined as follows:

$$\begin{array}{ccc} & \mathrm{B} & \mathrm{A} \end{array}$$

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} e & f \\ g & h \end{bmatrix} \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$

$$= \begin{bmatrix} ae + cf & be + df \\ ag + ch & bg + dh \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$

This may be calculated as a product of matrices, no matter how many transformations are performed in succession. Using these linear transformations, we may investigate a basic method for properly interpreting an arrow marking at an intersection.

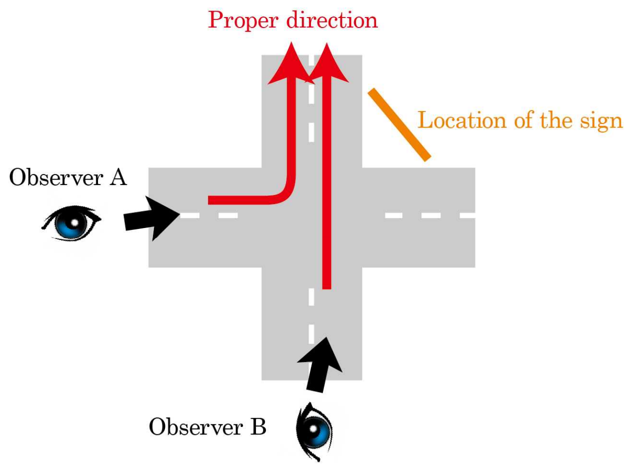
**Table 1:** Four typical linear transformations

| Method of Transformation | Examples of Transformations | |
|---|---|---|
| Zoom in/zoom out (Similarity transformation) | Magnification by a factor of *k* in the *x* direction $\begin{bmatrix} k & 0 \\ 0 & 1 \end{bmatrix}$ | Magnification by a factor of *k* in the *y* direction $\begin{bmatrix} 1 & 0 \\ 0 & k \end{bmatrix}$ |
| Symmetrical displacement (*x*-axis, *y*-axis) | Displacement symmetrical to the *x*-axis $\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ | Displacement symmetrical to the *y*-axis $\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$ |
| Rotational displacement | A rotation of $\theta$ about the origin in the forward direction $\begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$ | |
| Shift | A shift of $k$ in the direction of the $x$-axis $\begin{bmatrix} 1 & k \\ 0 & 1 \end{bmatrix}$ | A shift of $k$ in the direction of the $y$-axis $\begin{bmatrix} 1 & 0 \\ k & 1 \end{bmatrix}$ |

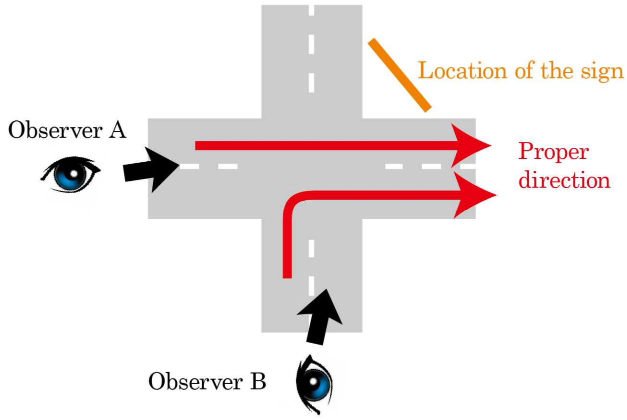
## 4. RECOGNITION OF THE PROPER DIRECTION INDICATED BY AN ARROW MARKING AT AN INTERSECTION

We here consider the case of signs located as in Fig. 3 (Observers A and B wish to go in the same direction).

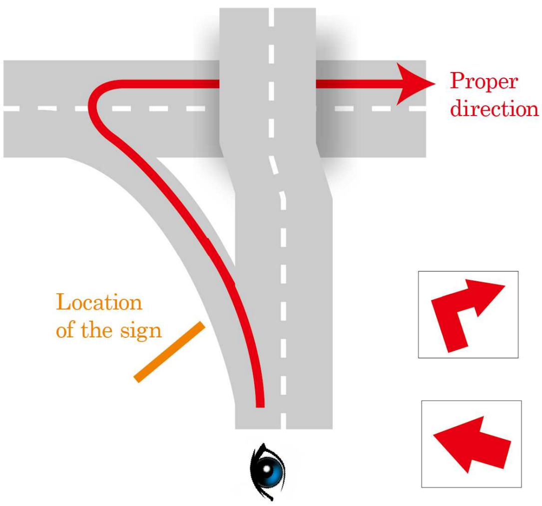
First, we examine the case of Figure 3(a). Observer A wishes to turn left at the intersection, and will definitely turn left if the sign has the arrow shown in Figure 4(a). However, Observer B too will recognize it as indicating ‘turn left.’ In this case, how should the arrow appear, in order for Observer B to recognize it as indicating ‘go straight’? When the arrow is linearly transformed into a shape slightly tilted to the left, as shown in Figure 4(b), we understand that it means ‘turn left’ for Observer A and ‘go straight’ for Observer B.




(a) Observer A turns left and observer B goes straight.

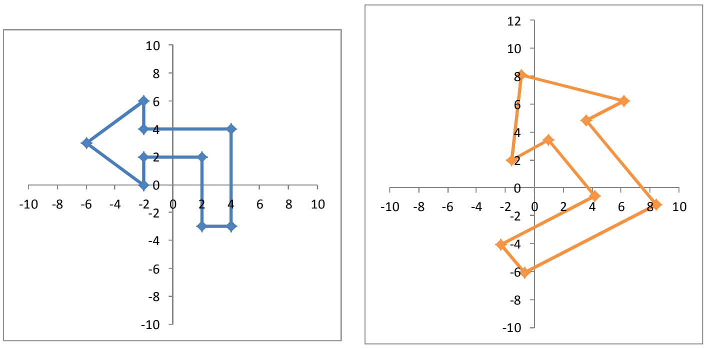



(b) Observer A goes straight and observer B turns right.




(c) Arrows at a crossing with an overpass (a right turn).

**Figure 3:** Location of signs at intersections, and corresponding arrow markings




(a) (b)

**Figure 4:** Proper arrow orientation to ensure that drivers coming from different directions can recognize 'turn left' and 'go straight', respectively: (a) Both Observer A and Observer B will recognize the arrow as indicating 'turn left; (b) Observer A will recognize the arrow as indicating 'turn left' and Observer B will recognize it as indicating 'go straight.

The following transformation matrix was used for the transformation from Figure 4(a) to 4(b):

$$\begin{bmatrix} 0.8 & 1.3 \\ -1 & 0.7 \end{bmatrix}$$

Figure 3(b) shows a case in which Observer A goes straight and Observer B turns right. The arrow shown in Figure 5(b) is generated for this case.

The transformation matrix is given by

$$\begin{bmatrix} 1 & -0.5 \\ 0.5 & 1 \end{bmatrix}$$

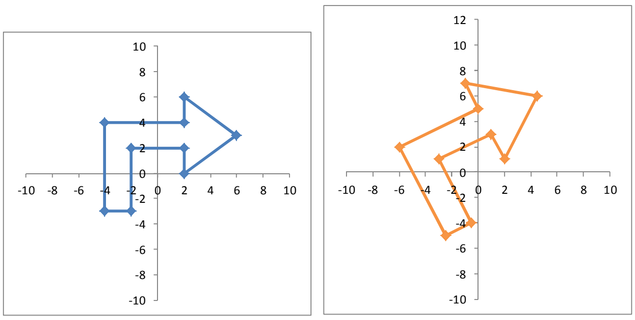



**Figure 5:** Proper arrow orientation to ensure that drivers coming from different directions can recognize 'go straight' and 'turn right,' respectively: (a)Both Observer A and Observer B will recognize the arrow as indicating 'turn right'; (b) Observer A will recognize the arrow as indicating 'go straight,' and Observer B will recognize it as indicating 'turn right.'

## 5. EXPERIMENTAL METHOD

We considered a typical suburban intersection, as shown in Figure 6. In the experiment, to guide observers to the right (in Figure 6), we placed a roadside sign, with an arrow at a 45° angle from the direction of travel, at one corner of the intersection. We presented 24 subjects with signs with different arrow angles and information. The road consists of 3-m lanes, with two opposing lanes and a dedicated 40-m right-turn lane. When each observer recognizes the arrow on the sign as indicating 'turn right', and changes to the right-turn lane 40 m before the intersection, the viewing angle on the sign is 36.6° for Observer A, and 34.1° for Observer B. Six different arrow markings commonly employed on roadside signs (Figure 7) were used. The following three-dimensional transformation matrix was used to ensure that the respective arrow markings would appear as perceived by Observers A and B:

$$\begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$

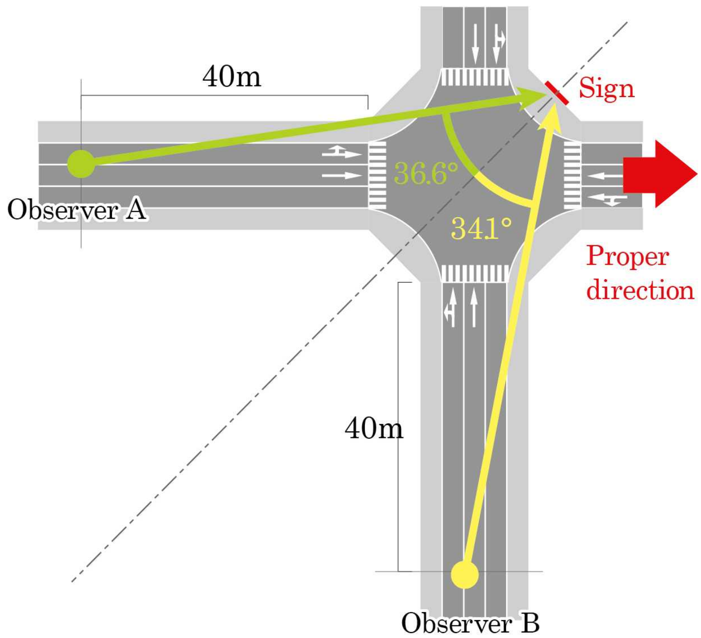



**Figure 6:** Configuration of the intersection

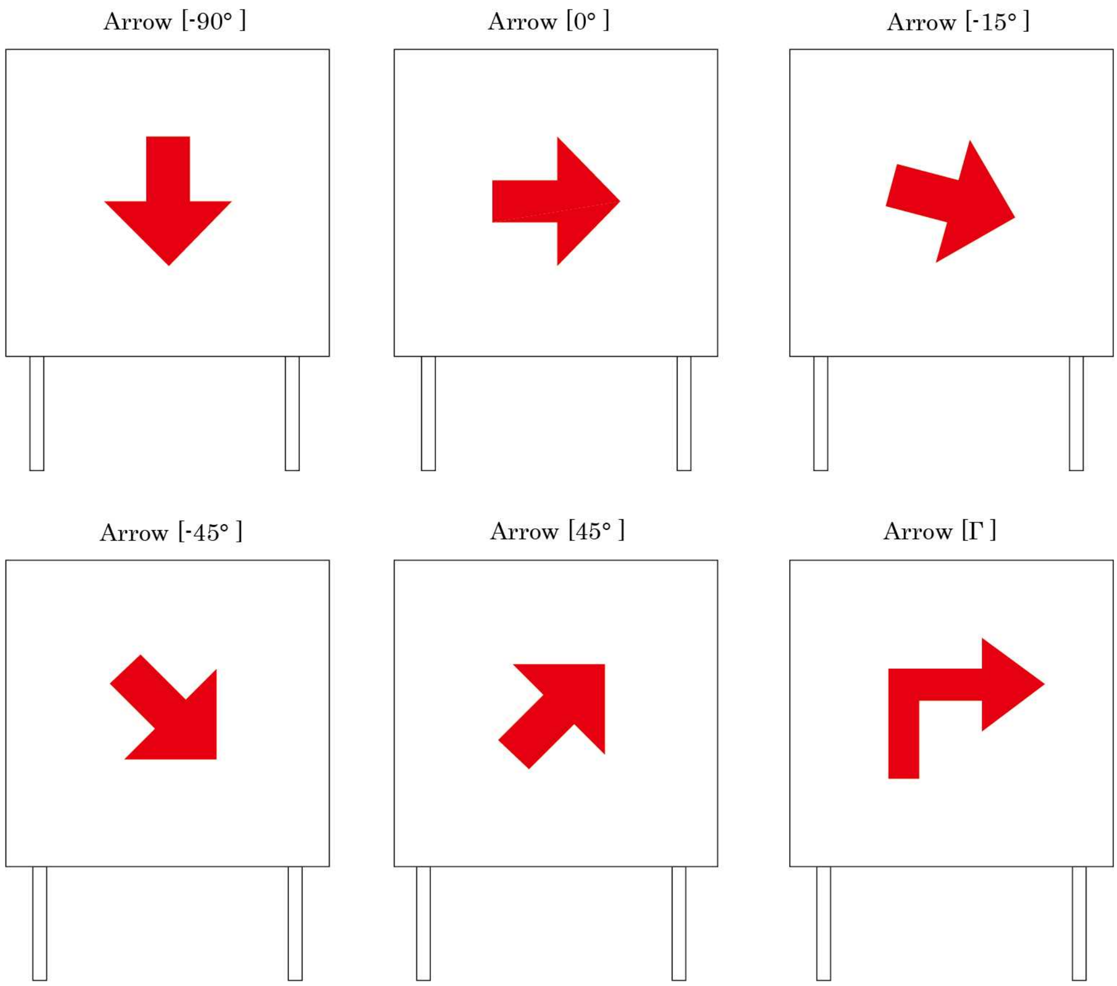



**Figure 7:** Six different arrow markings used in the experiment.

In the experiment, images of the intersection were generated such that the arrow markings would appear as perceived by Observers A and B, respectively. These images were presented to the subjects, and a questionnaire survey was conducted, in which they were asked to select a direction (forward/reverse and left/right turn) (Figure 8).

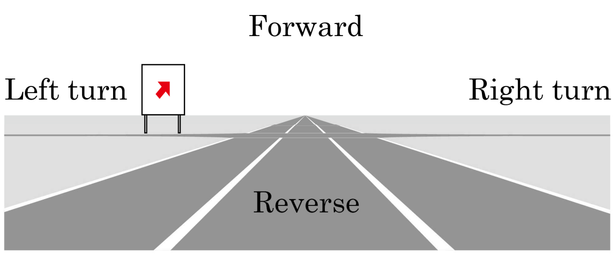
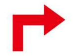
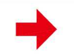



**Figure 8:** Example of a sign presentation (45°-angle arrow as viewed by Observer A)

## 6. RESULTS

The results are tabulated in Figure 9.

(1)

| Arrow marking | Correct answer rate for both observers |
|---|---|
|  | 4% |
|  | 0% |
|  | 4% |
|  | 25% |
|  | 38% |
|  | 54% |

(2)

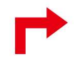
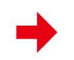
| Arrow marking | Observer vantage point | Correct answer rate |
|---|---|---|
|  | A | 25% |
| | B | 71% |
|  | A | 4% |
| | B | 21% |
|  | A | 29% |
| | B | 71% |
|  | A | 46% |
| | B | 92% |
|  | A | 4% |
| | B | 100% |
|  | A | 96% |
| | B | 58% |

Fig. 9 Correct answer rate for different arrow markings

(1) To perform its function, a roadside sign must guide both observers A and B in the proper direction. As shown in Figure 9(1), the arrows were not designed such that the observers were guided in the proper direction with 100% accuracy. Of the candidate arrows, the 45°-angle arrow had the highest overall correct answer rate, of 54%. The correct answer rate can be increased by providing additional character-based information on the sign.

(2) If there is a large volume of traffic in one lane at the intersection, it may be especially desirable for the correct answer rate of one of the observers to be high. With this in mind, we calculated the correct answer rate for each observer. When the angle of the arrow was set at 45°, to increase the correct answer rate of Observer A, the respective rate increased to up to 96%. When the angle of the arrow was reduced to 0°, to increase the correct answer rate of Observer B, the rate was 100% for Observer B, and very low for Observer A, at 4%. When a sign with an arrow angled at -15° was presented, the correct answer rate was 46% for Observer A and 92% for Observer B, indicating that a sign with this arrow orientation is relatively effective.

## 7. DISCUSSIONS

In this experiment, a variety of arrow markings were selected from those in common use. Angled arrows were found to be relatively effective; however, the design of the arrow must be improved to achieve a nearly 100% correct answer rate for both observers. For example, we must investigate how to represent an arrow rotated parallel to the surface of the sign, as shown in Figures 4 and 5, as well as an arrow with a map, and an arrow designed to look three-dimensional. In future studies, we will pursue this investigation into approaches to more effective representation of arrows.

In the next stages, more generic and practical studies are needed, which employ as parameters the width of the road, the installation angle of the respective sign, and the length of the right-turn lane. In addition, we will investigate which arrow marking is most effective for a left turn.

In this experiment, in order to represent how a given arrow marking appears to respective observers, we represented how the given arrow appears at an intersection, approximated by a linear transformation of rotation about one directional axis. Given our three-dimensional perception, the arrow is actually viewed in perspective. However, this approximation is considered adequate for representing an arrow on a sign more than 40 m ahead, and is confidently expected to be applicable to practical sign design.

As a potential extension of this study, the approach to representing signs in buildings may be reconsidered. Arrows on signs in buildings, such as train stations or public facilities, are typically viewed in a complex context and from a shorter distance than in the case of roadside signs. Therefore, such arrows are often viewed in perspective, and the perception of the arrow will be more complex.

The use of linear transformation in this study made it possible to conduct a presentation experiment which takes into account sign representation nearer in appearance to that which is actually perceived. Many signs are forms of advertising media involving a number of external factors. Sign manufacturing requires craftsmanship and experience that takes into account these external factors, and has traditionally been a subject about which it is difficult to generalize. The linear transformation-based representation approach makes it possible to achieve results that take into account the installation location of a sign as an external factor.

## REFERENCES

Masaaki Koyama (2012). Stores choosing customers are favored by customers - Stories of six stores reborn to be profitable stores with signs, Nikkei BP (in Japanese)

Masaaki Koyama, Yuki Takahashi and Hisao Shiizuka (2013). Analysis and Evaluation of the Sign by Deviation Value – Proposal of the Sign Deviation Value for Improving Custpmer Satisfaction – Transactions of Japan Society of Kansei Engineering, Vol.12, No.1 (pp.193-205).

A Guide to Road Structure, 2011.

## BIOGRAPHY

**Masaaki Koyama:** He is a President of Aiwa Advertisement Co., Ltd., who has been worked for many advertisements and signs, and also lectured his ideas about new advertisement and sign art and technology.

**Yuki Takahashi:** He is a Chief Designer of Aiwa Advertisement Co., Ltd. He graduated from Chiba University. He has also contributed from technical aspects and education of employees.

**Hisao Shiizuka:** He is a Professor of Kansei Engineering, Information Design and Soft Computing at Faculty of Informatics, Kogakuin University since 2006, Tokyo Japan, after having contributed for 11 years as a Professor of Artificial Intelligence System, Linear System Theory and Electric Circuits, to the Department of Computer Science and Communication Engineering at Kogakuin University since 1995, Tokyo Japan. He was a director of Japan Society for Fuzzy Theory in 1995-1997, and was a director of Japan Society of Kansei Engineering in 1999-2001. He was the President of Japan Society of Kansei Engineering in 2007-2013. Now he is a Senior Research Scientist of Fuzzy Logic Systems Institute (FLSI).