A Proposal to Apply Simple Photo-Reflector Elements to the Identification of Cans

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1. Introduction

A proposal for identifying cans is given of the use of simple photo-reflector(PR) elements. Sample cans practiced are those which are distributed to vending machines.

2. Setup and Procedure

The central part of the identification system is a PR element(p5589:Hamamatsu) consisting of an LED and a phototransistor(P-TRS). As represented schematically in Fig.1(a), light emitted from the LED is reflected on the surface of the sample can, and then arrives at the P-TRS. The amount of the light which reaches the test surface depends upon the geometrical factor G_{LED} between the LED and the surface. Similarly the final amount of the light which activates the P-TRS is also dependent upon the geometrical factor G_{PTRS} between the surface and the P-TRS. Let the emission spectra of the LED be $E_{LED}(\lambda)$, the reflection spectra on the surface be $R_{surf}(\lambda)$, and the spectral sensitivity of the P-TRS be $S_{PTRS}(\lambda)$. Then the P-TRS current $I_P(\lambda)$ is expressed as

$$I_P(\lambda) = G_{LED}E_{LED}(\lambda)R_{surf}(\lambda)G_{PTRS}S_{PTRS}(\lambda) \quad ---(1)$$

When the combined sensitive-range of the light concerned is between λ_1 and λ_2 , and the conversion coefficient of the $I \rightarrow V$ converter is A_{IV} , then the voltage output v_o becomes

$$\begin{aligned} v_o &= A_{IV} \int_{\lambda_1}^{\lambda_2} I_P(\lambda) d\lambda \\ &= A_{IV} (G_{LED}G_{PTRS}) \int_{\lambda_1}^{\lambda_2} E_{LED}(\lambda) R_{surf}(\lambda) S_{PTRS}(\lambda) d\lambda \end{aligned} \quad ---(2)$$

In the setup the product $A_{IV}G_{LED}G_{PTRS}$ is regarded as a constant K , and the function shapes of both $E_{LED}(\lambda)$ and $S_{PTRS}(\lambda)$ are kept unchanged. The only quantity which changes in eq.(2) is $R_{surf}(\lambda)$ because the reflected spot and, therefore, the reflection property changes when the can is replaced or the

Fig.1 The illustration of the setup, spectral property, and the measuring procedure.

spot is shifted. From this consideration eq.(2) is represented as

$$v_o = Kv[R_{surf}(\lambda)] \quad ---(3)$$

where

$$v[R_{surf}(\lambda)] = \int_{\lambda_1}^{\lambda_2} E_{LED}(\lambda) R_{surf}(\lambda) S_{PTRS}(\lambda) d\lambda \quad ---(4)$$

is a functional of the variable function $R_{surf}(\lambda)$ which represents the reflecting property of the can

surface depending on the painted color and the coated material⁽¹⁾.

Spectral characteristics of the PR used is represented in Fig.1-(b). Although the spectral range of the LED in the PR is outside the one used in the colorimetry⁽²⁾, ν_0 introduced in eq.(3) revealed differences in the experiments depending on the spots and cans.

Test data to identify cans were measured as explained in Fig.1-(c). Irradiation spots were selected along the circumferences C_1 through C_8 . To cover eight circumferences, eight PRs were arranged along a line l . In the practice eight lines l_1 through l_8 were set. Slight discrepancies in ν_0 between PRs were properly corrected.

3. Results and Discussion

In the prototype setup five different cans, can-A through can-E, were prepared for the investigation. To identify five cans, such similarity measure using Euclidean distances as explained schematically in Fig.2 was employed. In actual identification procedure, normalized distances introduced in Fig.2 were used.

Arranging ν_0 data, for example, concerning Can-A as below

$$\begin{array}{l}
 \text{Along } C_1, \dots, C_i, \dots, C_8 \\
 \text{On } l_1 \rightarrow (A_{11}, \dots, A_{i1}, \dots, A_{81}) \\
 \vdots \\
 l_j \rightarrow (A_{1j}, \dots, A_{ij}, \dots, A_{8j}) \\
 \vdots \\
 l_8 \rightarrow (A_{18}, \dots, A_{i8}, \dots, A_{88}) \\
 \downarrow \quad \downarrow \quad \downarrow \\
 \text{A mean vector} \\
 \text{is constructed as} \\
 \mathbf{a}_A = \left(\frac{\sum_j A_{1j}}{8}, \dots, \frac{\sum_j A_{ij}}{8}, \dots, \frac{\sum_j A_{8j}}{8} \right) \\
 = (A_1, \dots, A_i, \dots, A_8) \leftarrow \text{Can-A} \\
 \text{Likely } \mathbf{a}_B = (B_1, \dots, B_i, \dots, B_8) \leftarrow \text{Can-B} \\
 \mathbf{a}_C = (C_1, \dots, C_i, \dots, C_8) \leftarrow \text{Can-C} \\
 \mathbf{a}_D = (D_1, \dots, D_i, \dots, D_8) \leftarrow \text{Can-D} \\
 \mathbf{a}_E = (E_1, \dots, E_i, \dots, E_8) \leftarrow \text{Can-E} \\
 \downarrow \quad \downarrow \quad \downarrow \\
 \text{Making a} \\
 \text{reference vector as} \\
 \mathbf{a}_{\text{ref}} = (\text{ref}_1, \dots, \text{ref}_i, \dots, \text{ref}_8) \\
 \text{ref}_i = \frac{A_i + B_i + C_i + D_i + E_i}{5}
 \end{array}$$

Euclidean distances are derived like

$$d_A = |\mathbf{a}_A - \mathbf{a}_{\text{ref}}|, \dots, d_E = |\mathbf{a}_E - \mathbf{a}_{\text{ref}}|$$

By using

$$d_m = \max\{d_A, d_B, d_C, d_D, d_E\}$$

Normalized distances are set as

$$d_{AN} = d_A/d_m, \dots, d_{EN} = d_E/d_m$$

Fig.2 Data processing to obtain the similarity.

The result of the identification attempt is represented in Fig.3. In this instance the normalized distances differ from each other and the discrepancies well surpass the data fluctuation. Therefore, the proposed prototype system seems valid to identify cans, though further discussion is

necessary to apply the system to more kinds combination of sample cans.

Fig.3 An example of identification results with the prototype system.

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