XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

DEVELOPMENT OF MASS AND LENGTH MEASUREMENT SYSTEM ON CONVEYOR BELT

Takanori Yamazaki [1], *Akihiro Watanabe* [2], *Hideo Ohnishi* [3], *Masaaki Kobayashi* [3], *Shigeru Kurosu* [4]

[1] *Oyama National College of Technology, 771 Nakakuki, Oyama, 323-0806 Japan, yama@oyama-ct.ac.jp*
[2] *Utsunomiya University, 350 Minemachi, Utsunomiya 321-8505 Japan*
[3] *Shinko Co., 4219-71 Takasai, Shimotsuma, 304-0031 Japan*
[4] *Reserach Inst.,Crotech, 61-88 Ozakata, Chikusei, 308-0854 Japan*

Abstract: Our aim is to establish a measurement system that enables highly accurate measuring mass and length of moving products with a relatively high speed on a conveyor belt. In this paper, effectiveness of the proposed measurement system is demonstrated by an analysis of a digital image taken by a digital camera. In our experimental results, it can be found in the following: First, our discrimination method of colors is that there is no need to count the number of pixels for all three primary colors, but the only one component indicated the highest value of graduation should be counted. Second, the length measurements are performed using these six kinds of the reference unit pixels for the products having lengths within a range from 200 to 1200 mm. It is quite obvious that even through any refer- ence lengths used, the required accuracies less than ±5 mm cannot be achieved without calibration method.

Key words: mass and length measurement, digital image, conveyor belt

1. INTRODUCTION

In recent years, many studies on mass and length measurement of moving products on a conveyer belt have been made energetically in distribution and food industries. In the mass and length measurement of products on a conveyor belt, the size and mass of products are generally random. Long, short, high, low heavy and light products are passed over a conveyor belt at a high-speed.

Through previous papers on multi-stage conveyor belt scales, the continuous weighing method has been established with satisfactory performance [1-3]. In the multi- stage conveyor belt scales so far presented, not only a mass of a product, but also a length of the product has been dispensed with measurement by fits and starts. Continuous length measurement of moving products on a conveyor belt becomes a remained problem to be solved immediately. Therefore, not only the range in length of products can be widened, but also the number of products which can be treated within a unit time can be increased upon being compared with the known apparatus comprising a single weighting conveyor.

Successful length measurement depends mainly on what method may be done. The well-known laser beam system has been used so far, but this system is too expensive to put into practical use in field operations [4]. In this paper, we propose an entirely new method to measure the length of products in sequence by a handy digital camera.

2. LENGTH MEASUREMENT SYSTEM

The fundamental configuration of the length measurement system by a digital camera may be represented schematically as shown in Fig. 1. Specifications of products are length: 100~1200 mm, width: 100~900 mm, height: 30~ 900 mm, and color: not specified. Our method is assumed to deal with any colors. A product whose length to be measured is transported from an input side conveyor (right) into a multi-stage conveyor having a length 1400 mm and after measurement the product is transported onto an output side conveyor (left). The transportation speed ranges from 20 m/min to 80 m/min. And the accuracy ±5 mm is required.

In order to measure the length our method unavoidably leads to bottlenecks in the capture of data by a digital camera. As we are aware, it is intractable problem for us to give highly accurate length measurement on a conveyor belt under vibration-like moving conditions. The immediate aim of this study is to give a principle of the length measurement

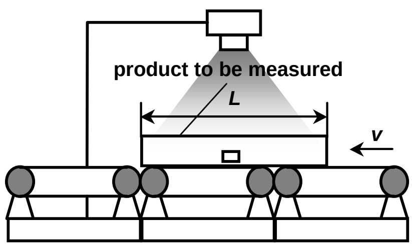
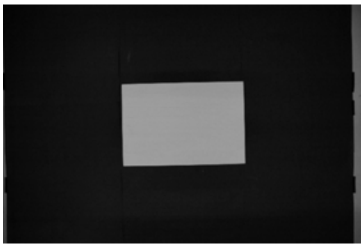
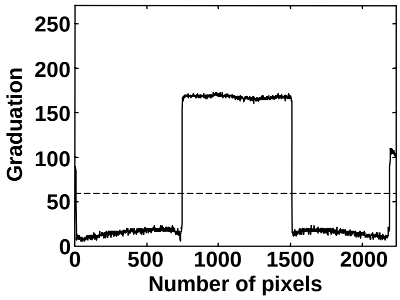


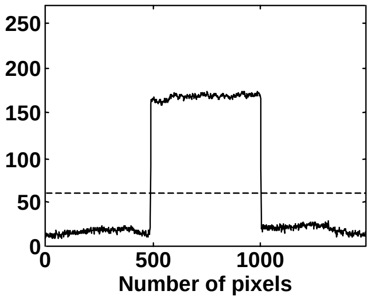
Fig. 1. Length measurement system



(a) White product (Black and white)



(b) Length pixel



(c) Width pixel

Fig. 2. Digital image and graduation

using a digital camera, and to give a fundamental information for practical applications. First, the photograph of the product in a stationary state is taken by a digital camera directly overhead. Second, the image processing unit acquires the intensity of a photograph and estimates the length of the product.

In this paper, let us outline fundamental method for the length measurement of products by image processing unit.

3. MEASURING METHOD

A digital image consists of a set of dot, called “pixel”, and constitutes 2240×1488 pixels. As you are well aware a digital image consists of a set of dots, called “pixels” and is arranged serially 2240×1488 pixels (horizontal×vertical components). In the digital camera used in our experiments we take use two typical function modes; namely, a black and white mode, and a color mode. In the black and white mode the grade between light and shade (a mixed color, i. e. “gray”) can be classified to 256 graduations for one pixel. On the other hand, in the color mode the grade between light and shade for three primary colors, such as red, green and blue, can be classified to 256 graduations for one pixel. Some insight into the relation between the black and white mode, and the color mode will be discussed in Chapter 4.

For convenience, the colors of a product and background are chosen as white and black, so the border line between a product and background is made clear. The digital image in a black and white finder taken by a digital camera, the number of pixels of greater than 60 gradations is counted as “white”. The digital image taken by a digital camera constitutes 2240×1488 pixels defined by the number of the vertical pixels and the horizontal pixels are p_V and p_H, respectively.

The length measurement of a product is carried out according to the following steps:

(1) From the digital images, the reference length for one pixel (simply called the reference unit pixel, defined later) can be obtained.
(2) The length of product can be estimated based on the product of the number of pixels observed by the reference unit pixel.

Fig. 2 (a) shows an example of the digital image obtained for the pure white product that is 600 mm in length and 400 mm in width. After processing the digital image, Fig. 2 (b), (c) shows the relation of the graduation to the number of pixels obtained form Fig. 2 (a). By counting the number of pixels of greater than 60 graduations along the length and the width, 765 px and 512 px can be obtained in Fig. 2 (b), (c). Assuming that the reference length in 600 mm, the reference unit pixels can be given by 600/765 = 0.784 mm/px. Using this reference unit pixel, the width of a product can be estimated as 512×0.784 = 401.4 mm. Since the actual width of a product is 400 mm, the required accuracy of ±5 mm has been successfully achieved.

4. DISCRIMINATION OF COLORS OF PRODUCTS

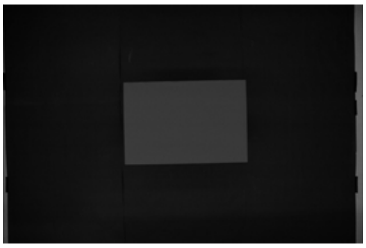
For convenience, the color of products has been by far chosen as pure white, but there are many different colors to be distinguished from the background (black). For demonstrating the discrimination of colors of products, various colors are examined by combining the three primary colors such as red, blue and green. Fig. 3 (a) and (b) show an example of digital images obtained for the red product (600 mm in length and 400 mm in width). Fig. 3 (a) presents the digital image in a black and white finder, and Fig. 3 (b) presents the digital image in color taken by a digital camera. Fig. 3 (c) shows the relations of the graduation the number of pixels in cases of Fig. 3 (a) and (b).

It can be seen from Fig. 2 that the number of pixels of greater than 60 graduations is required about 765 px since the product is 600 mm in length. However, the graduation in black and white finder in Fig. 3 (c), the number of pixels can be counted up to 36 px regretfully.

The relation of the graduation between the digital image in a black and white finder the digital image in a color is as follows.

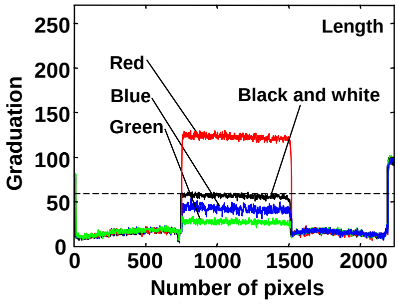
$$B\&W = 0.30R + 0.59G + 0.11B$$

So, it is clarified that the digital image in black and white finder has a merit of shortening the measuring time due to reduction of the number of data. However, the forthcoming experimental results obtained by a black and white finder will be satisfactory for practical use.

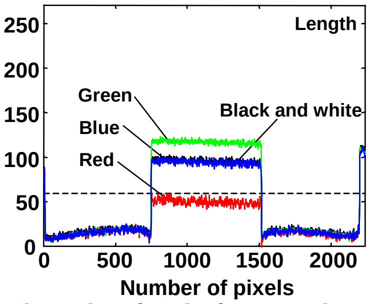


(a) Red product (Black and white)

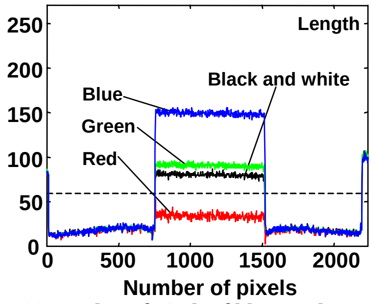
(b) Red product (Color)



(c) Number of pixels of red product

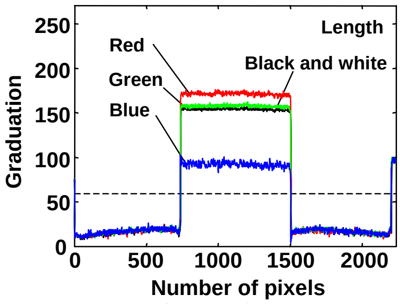


(d) Number of pixels of green product

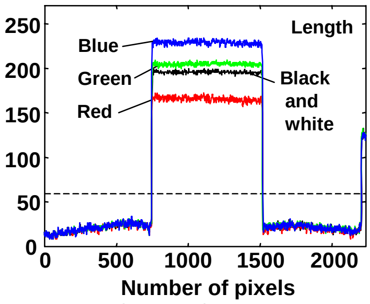


(e) Number of pixels of blue product

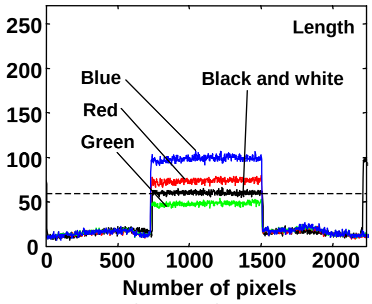
Fig. 3. Digital image and graduation



(a) Number of pixels of yellow product

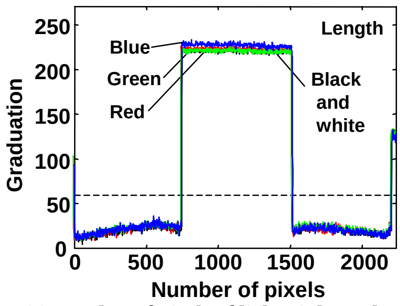


(b) Number of pixels of light blue product

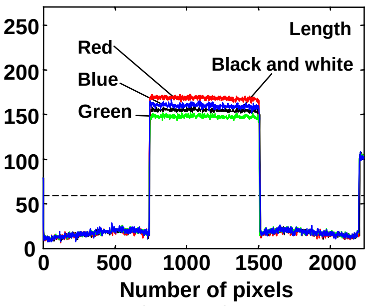


(c) Number of pixels of purple product

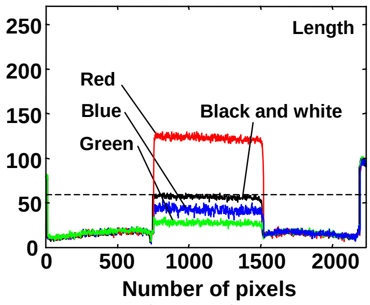
Fig. 4. Digital image and graduation



(a) Number of pixels of light pink product



(b) Number of pixels of pink product



(c) Number of pixels of red product

Fig. 5. Digital image and graduation

In comparing the graduations of red, green and blue components, it is observed that the numbers of pixels are counted as 765 px, 0 px and 0 px, respectively, when the threshold of 60 is provided. As far as the difference in chosen of products is concerned, one of the numbers of pixels exceeds the threshold value and the color of a product can be determined. Fig. 3 (d) and (e) were examined about green and each blue, respectively.

Next, we will distinguish the products of mixed colors of three primary colors, such as yellow, light blue, and purple. Fig. 4 (a), (b), and (c) show the graduation results from yellow, light blue, and purple products to compare the pefor-mance of direct and indirect analysis. By using the digital image in black and white the numbers of pixels for yellow, light blue, and purple colors can be counted as 767 px, 771 px, 368 px respectively. The only color of purple cannot be unsuccessfully distinguished.

To avoid such unwanted worst case, the digital image in a color can be applied to the purple product. The numbers of pixels for components of three primary colors can be counted as red: 767 px, green: 0 px, and blue: 766 px, respectively. This result by the digital image in a color suggests that the discrimination of colors may be satisfactory when the only one components of red or blue is intuitively chosen. In cases of yellow and light blue products, both methods produce successful results. That is to say, a purplish product could not be easily distinguished.

Moreover, a simple way to demonstrate the discrimination of colors associated with the lights and shades of a product is to conduct with a comparison test among light pink, pink, and red products. Then, applying two methods discussed above to three colors of products, Fig. 5 (a), (b), and (c) show the relations of the graduation to the number of pixels for three cases. As explained before, the color of red product (as shown in Fig. 5 (c)) cannot be unsuccessfully distinguished by the digital image in a color. On the other hand, it is clear that by the digital image in black and white exact discrimination of colors is possible. Fig. 5 (a) and (b) about light pink and pink products show that the graduation are getting higher than 60. Hence we can conclude that as a product lightens color the graduation reaches the equal value and gives significant difference.

In our experimental results, how to discriminate the colors of a product from the background (black) is determined by processing the graduation from the digital images and counting the number of pixels for one component of three primary colors greater than the threshold value. Also, it can be seen from Fig. 4 and 5 that since the background color (black) gives the graduation within a range from 20 to 30, it is reasonable to require that the threshold value is equal to 60, and the discrimination of colors can be effectively realized. The beauty of this discrimination of colors is that there is no need to count the number of pixels for all three primary colors, but the only one component indicated the highest value of graduation should be counted. It turns out that the digital image in black and white gives us an accurate and desirable length measurement under any color conditions.

5. EXPERIMENTAL RESULTS

To evaluate measurable range with respect to the length of a product, the products having lengths within a range from 200 to 1200 mm at 100 mm intervals can be measured by processing the reference unit pixels in accordance with a given reference length.

Fig. 6 shows an example of the digital images obtained for the two cases of the product's length, (a) 200 mm and (b) 1200 mm, respectively. The width and the height of the products are fixed 400 mm and 400 mm. The camera is 1800

Table 1. Shooting result

Length of products mm		200	300	400	500	600	700	800	900	1000	1100	1200
Number of pixels px	Length	256	383	512	639	765	889	1011	1133	1258	1378	1495
	Width	512	512	512	513	512	512	512	511	513	513	513

(a) Length 200mm (b) Length 1200mm

Fig. 6. Changing length of products

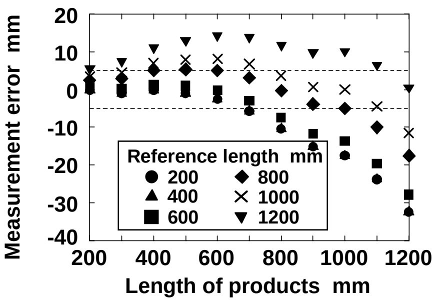


Fig. 7. Relation between estimated error and reference

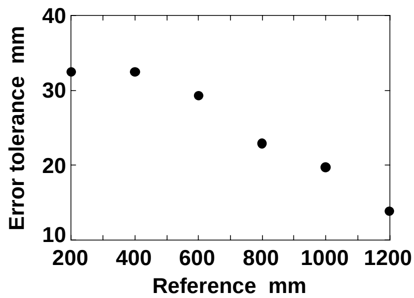


Fig. 8. Relation between reference and error span

mm in height. Thus, the relative distance from the product to the camera is fixed at 1400 mm. Table 1 shows the results of the number of pixels is precisely proportional to the length of a product within the small range (e.g., 256 px and 512 px for 200 mm and 400 mm, respectively), but as the length of a product increases the number of pixels

Fig. 6 shows an example of the digital images obtained for the two cases of the product's length, (a) 200 mm and (b) 1200 mm, respectively. The width and the height of the products are fixed 400 mm and 400 mm. The camera is 1800 mm in height. Thus, the relative distance from the product to the camera is fixed at 1400 mm. Table 1 shows the results of the number of pixels is precisely proportional to the length of a product within the small range (e.g., 256 px and 512 px for 200 mm and 400 mm, respectively), but as the length of a product increases the number of pixels gradually decreases. It may be noted that the number of pixels for the width of a product remains unchanged as the width is fixed at 400 mm.

Six kinds of the reference length within the range from 200 mm to 1200 mm at intervals 200 mm are provided for experimental results given in Table 1 and the length measurements are performed using these six kinds of the reference unit pixels. Fig. 7 shows the relations of the measurement error to the length of a product for various reference lengths. The measurement error can be defined by the difference between the estimated length and the reference one. It is quite obvious from experimental results that even through any reference lengths used, the required accuracies less than ±5 mm cannot be achieved. The results also suggest that the measurement error tends to be positive as the reference length increases.

Next, let us consider the error tolerance defined by the difference between the maximum error and the minimum one for a given reference length. Fig. 8 shows the relation of the error tolerance to the reference length. Then, comparing two cases, 200 mm and 1200 mm, about the reference length shows that the error tolerance of 1200 mm is less than half of that of 200 mm. That is to say, by applying our method to the lengths of products having lengths within a range 200 mm to 1200 mm, the error tolerance decreases as the reference length increases, but the required accuracies cannot be achieved even through the reference length of 1200 mm used.

To provide a novel and useful measurement which can mitigate the above mentioned problems and can satisfy the required accuracy of less than ±5 mm, the following configurations will be considered:

(1) Arranging a plurality of cameras in series and getting digital images in accordance will different relative distances, combined processing of digital images can be effective enough to practical applications.

(2) When different reference unit pixels are used by considering length of products, the lengths of moving products can be determined successively.

(3) The spherical aberration of a lens in a digital camera has a negative effect on the accuracy attainable. To compensate this aberration, the calibration must be made by using the experimental date.

As shown in Fig. 2 and 6, the digital image becomes distorted like a little round ball. Excessive distortion appears significantly at the edge of a digital image, while no distortion cannot be found in the vicinity of the center of a digital image. To avoid this aberration problem in future design, additional work should be done to the accurate length measurement of products. When this aberration in a digital image has almost been ignored, all computational process using the only one reference length can be completed within a shorter time. Calibration method associated with predicting this spherical aberration will be highlighted for future development.

6. CONCLUSION

In this paper, we presented an entirely new method for the length measurement of products by using an image processing unit. We discussed an algorithm to analyze the image obtained by a digital camera and to estimate the length of a product. As a result, even if the length of a product varies within the range between 200 mm and 1200 mm in the case that the height of camera is 1800 mm, estimated lengths of products are satisfied with the required accuracy ±5 mm. However, when the length of a product was getting to longer (longer than 900 mm), the image obtained became distorted due to the focusing limit of a camera. Therefore, the required accuracies were not achieved. Moreover, when the height of a camera has varied, the measuring accuracies have been exacerbated on the same reason due to the focusing limits of a camera. Finally we concluded that some technical problems should be solved for future development.

REFERENCES

[1] Y. Noda, et al.: Improvement of Accuracy for Continuous Mass Measurement in Checkweighers, The Journal of SICE, Vol. 38, No. 9, pp. 759–764, 2002

[2] R. Tasaki, et al.: Continuous Weighting by Multi-stage Conveyor Belt Scale, The Journal of SICE, Vol. 39, No. 11, pp. 1022–1028, 2003.

[3] R. Tasaki, et al.: Improved Continuous Weighing by Multi-stage Conveyor Belt Scale, The Journal of SICE, Vol. 40, No. 12, pp 1205–1210, 2004.

[4] F. Tomita: Versatile 3D vision system, IPSJ Magazine, Vol. 42, No. 4, pp. 370–375, 2001.