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A Real-time Video Measurement System for Quality Control Applications

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Video measurement system,
Non-contact measuring,
Quality control,
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Computer vision

Abstract: Quality control is extremely important for manufacturing compatible parts to supply products that meet production requirements. It provides track and control of the stages of the process and minimizes waste by supporting high levels of productivity. In industrial quality control applications, most manufacturers prefer a video measurement system (VMS), which offers non-contact high accurate measurement results, for evaluating machined parts and products. However, due to the advanced technology and low competition, the price of non-contact measurement devices is high. Besides some facilities and some research laboratories couldn't reach these high-cost devices. Today, with the help of evolving technology and open-source image processing libraries, it is possible to offer cost-effective and accurate non-contact measurement systems for industrial measuring applications. This study aims to put forward a VMS to measure parts/products in two dimensions with swift and accurate results. The proposed system has an error below 1% and the linear regression coefficient (r^2) was found over 0.95. It works in real-time and the minimum frequency was found 10 Hz for repetitive measurements, real-time measurement applications. The proposed cost-effective device can be adapted into various quality control applications in industrial manufacturing.

Kalite Kontrol Uygulamaları için Gerçek Zamanlı Bir Video Ölçüm Sistemi

Anahtar Kelimeler
Video ölçüm sistemi,
Temassız ölçüm,
Kalite kontrol,
Görüntü işleme,
Bilgisayarlı görü

Öz: Kalite kontrol, imalat aşamalarına uyumlu parçaların üretimi sağlamak açısından oldukça büyük bir öneme sahiptir. İmalat aşmalarının takibi ve denetimini, bunun yanında imalat atıklarının azaltılarak üretim veriminin yükseltilmesini sağlamaktadır. Endüstriyel kalite kontrol uygulamalarında genellikle video ölçüm sistemleri (VMS), temassız ölçüm ve yüksek doğruluk sonuçları sağlaması nedeniyle, çoğu üretici tarafından tercih sebebidir. Ancak, ileri teknoloji barındıran bu cihazlar ve rekabetin az olmasın nedeniyle bu ölçüm sistemlerinin piyasa fiyatları yüksektir. Bunun yanında sadece bazı araştırma merkezleri ve laboratuvarlar bu cihazlardan faydalanabilmektedir. Günümüzde, gelişen teknoloji ve açık kaynaklı görüntü işleme kütüphaneleri sayesinde, düşük maliyetli ve yüksek doğruluğa sahip temassız ölçüm sistemlerinin endüstriyel uygulamalarda kullanımı mümkün hale gelmektedir. Bu çalışmada, imalat parçaları ve ürünlerin boyutsal ölçümlerinde hızlı ve yüksek doğruluklu bir VMS ortaya çıkarılmıştır. Sunulmakta olan sistemin %1'in altında hata oranı bulunmaktadır. Doğrusal regresyon katsayısı (r^2) 0.95 olarak bulunmuştur. Bu sistem gerçek-zamanlı olarak 10 Hz frekans ile tekrarlı ölçümlere uygun olarak alışmaktadır. Önerilen bu düşük-maliyetli cihaz, endüstriyel uygulamalarda birçok kalite kontrol aşamasına uyarlanabilmektedir.

1. INTRODUCTION

A VMS offers a fast and accurate solution for quality control applications. Manufacturing processes, especially mass production lines are sequentially required quality-checking processes [1,2]. There are various techniques with the help of contact and non-contact measurement devices for controlling the quality of a work material, which are used to measure the dimensions of the work material [3]. For example, a mechanical caliper requires contact with the work material to accomplish the measurement duty [4]. Besides, it requires a labor force of the quality control expert to complete the measuring process [5,6]. In many industries, the quality of a work material depends on contactless procedures for evaluating the possible dimensional error and surface properties [7].

Today, advanced technology offers a wide range of contactless, non-destructive evaluation (NDE), techniques for quality control procedures [8]. In the literature, there are sound, light, and displacement-based surface and dimension measurement devices referring to NDE applications. Typically, an NDE device is used with an active or passive sensing method according to the application area [9–11]. Most of the active sensing applications, infrared light sources are preferred for non-contact measuring duties in many studies [12–14]. There are also ultrasonic approaches for active sensing NDE methods using sound-based devices for quality control applications [15–19]. In one example, ultrasonic sources are used as sound-based devices for quality control applications [19]. A VMS is proper for both active and passive sensing methods that are suitable for NDE quality control applications [8,20–22].

The NDE approaches are offering a fast and accurate option when compared to the mechanical contact-based measurement approaches [23,24]. In addition to contactless operation, the NDE approaches are minimizing the user-dependent measurement errors. For most measurement applications, concerning the accuracy and performance of the quality control devices, a VMS is a good example of an NDE quality control application using light reflectance for measuring processes. [25,26].

In this study, a cost-effective VMS is developed for NDE quality control applications to measure parts/products with the capacity of two-dimensional measurements. The proposed system provides fast, accurate, and automated measurements. The system has an accuracy of around 98% and the linear regression coefficient (r2) was found over 0.95. The presented VMS accomplishes measurements in real-time with a minimum 10 Hz measuring frequency. The proposed cost-effective device can be adapted into various quality control applications in industrial manufacturing, especially for real-time measurement applications.

2. MATERIAL VE METHODS

The VMS is composed of an imaging device, a light table, and image processing software with a Personal Computer (PC). The block diagram of VMS used for image capturing and processing duties is shown in Figure 1.

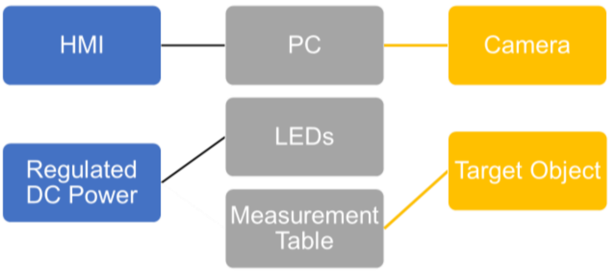

Figure 1. The block diagram of VMS

2.1. Experimental setup

The actual image of VMS with assemble is shown in Figure 2. The figure presents the actual image of the VMS, the imaging device, and the light table. The light table also determines the limits of the measurement area of the system. It is a combination of a light source and a transparent plexiglass material. The surface of this material is filled with white dots to distribute the light in a uniform structure.

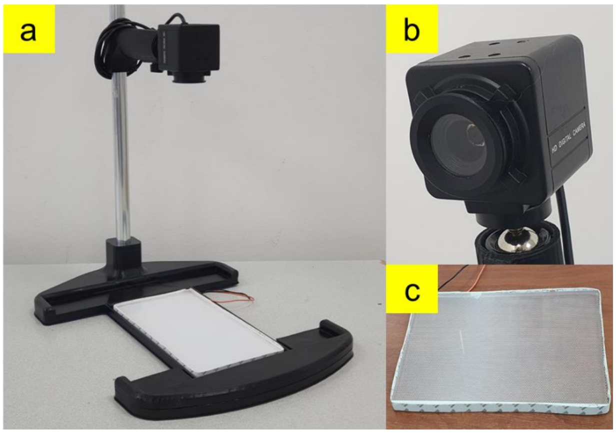

Figure 2. The video measurement system, (a) assembled device, (b) CCD camera, (c) light table

The camera (Figure 2 (b)) with CMOS image sensor (Imx214, Sony exmor rs, Japan) is connected to a PC via USB function. The images are captured with the camera device using custom-written computer vision (CV) software.

The light table (Figure 2 (c)) consists of an LED series that surrounded a transparent measurement table [27]. Thus, the illuminated light table provides a smooth white background for the measuring area. A regulated 12-volt power source is supplied to the light table.

Here, the CV software uses image-processing techniques for detecting the edges of the work material and calculating the distances for two axes. To achieve these duties the Open Source Computer Vision Library (OpenCV) is used as an image processing library [28,29], which is suitable for real-time CV applications. The software is written with the C++ programming language using this image processing library [30].

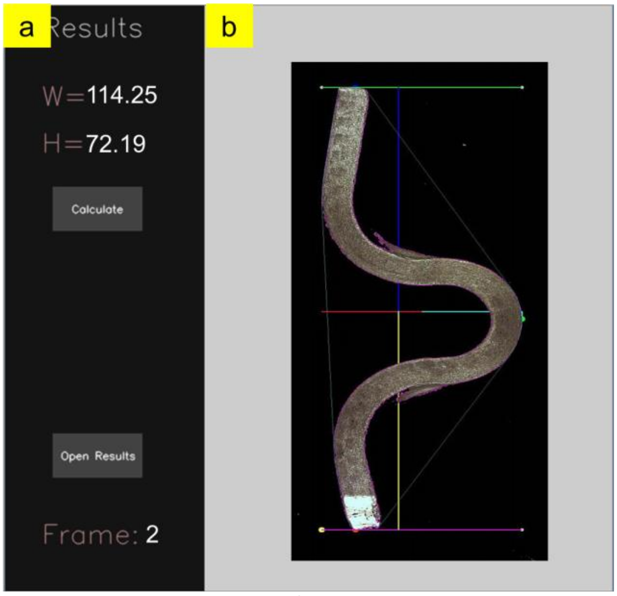

Figure 3. The graphical user interface, (a) result screen, (b) monitoring screen

The graphical user interface (GUI) of the software is shown in Figure 3. This interface has two screening areas, the first one is used to show the measurand and the second one is for screening the measured material in real-time. Additionally, with the help of custom-written software, users have the ability to conduct both automated and manual measurements together.

The spatial calibration of the imaging device is conducted by referring to the pixels and a known sample [31]. A square material is used as a sample and both axes of the sample are measured using a precise caliper (0.01 mm). The VMS software is calculated the pixel numbers of the sample for these two axes. In the last stage, a ratio is determined to determine the slope formula from both axes. Thus, a relationship is obtained for the X and Y axes of the measurement are for converting pixel numbers to meter units. The equations (Eqn. 1 and Eqn. 2) are representing the conversion of pixels into millimeters.

$$X_l = m_x\,(X_{max} - X_{min}) + n_x \qquad (1)$$

$$Y_l = m_y\,(Y_{max} - Y_{min}) + n_y \qquad (2)$$

The VMS software uses image processing procedures in addition to Eqn. 1 and Eqn. 2. for calculating the length and width of the work material, which is placed into the measuring area. The image processing procedures are starting with the image capturing step. In the next stage, the image is cropped to the region of interest (ROI) area. Next, the ROI is converted to hue saturation value (HSV) and grayscale colors. A threshold is applied to the grayscale image to obtain a black-white (BW) colored image. In the next stage, the contour detection process is applied. The work material on the light table is detected in this stage and contouring points are recorded. The minimum and maximum values for the X and Y axes are extracted from the contour numbers to calculate the width and height of the work material. The distances are obtained in pixel numbers for both the X and Y axes. In the last stage, the distances in pixel numbers are converted from the pixel numbers to meter units using the equations (Eqn. 1 and Eqn. 2).

3. RESULTS AND DISCUSSION

The spatial calibration results show that there is a linear relationship between length and pixel numbers. Four different lengths from five to fifteen mm. are measured for both X and Y-axes using the image processing software of the VMS. The result of the obtained relationship between pixel number and the actual length is shown in Figure 4.

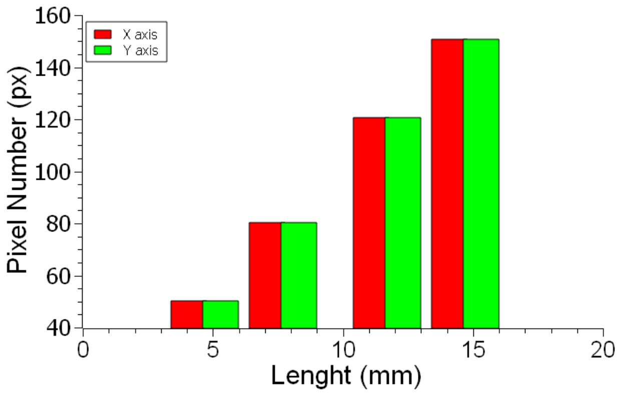

Figure 4. The relationship between pixel number and actual length

In the next stage, a test material was placed in the measurement area for correction. Four repetitive measurements are conducted for both axes. The actual value of the test material and the measurand for X and Y-axes are shown in Figure 5.

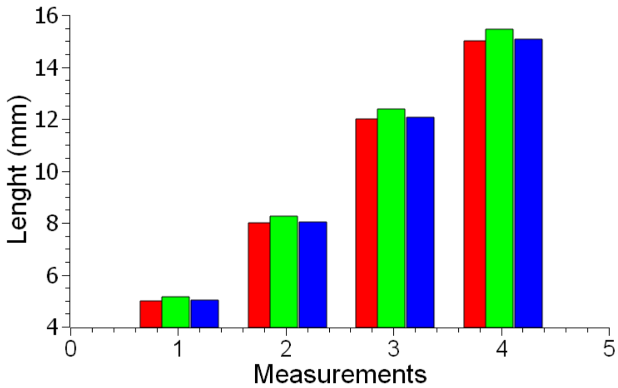

Figure 5. The test material and the measurement results for X and Y-axes

The VMS is evaluated after the calibration and correction stages using different work materials. The work materials with different lengths are placed in the measurement area. In Figure 6 the results of the measurements are shown for these work materials. In total 8 different material lengths are measured with four-time repetitions. The error bar obtained from repetitive measurements and linear fit values are shown in Figure 6. The VMS error is found below 1%. The linear regression coefficient (r2) was found over 0.95 while the VMS is tested in real-time.

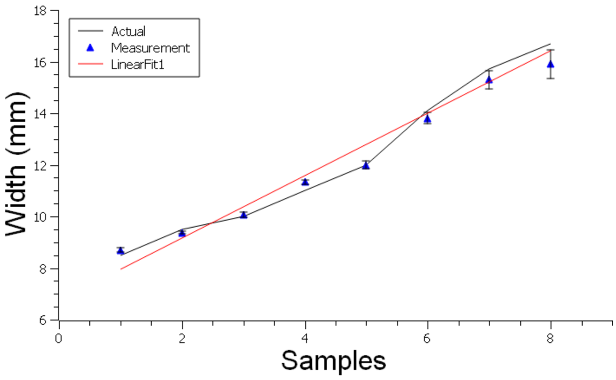

Figure 6. The measurements of work materials.

4. CONCLUSIONS

In industrial applications, it is a necessity to evaluate the outputs of the manufacturing process. In the present study, a VMS using an image-acquiring device and a light table is demonstrated. The VMS produces fast and accurate results while it is working in real-time. It accomplishes measurements in real-time with a minimum 10 Hz measuring frequency.

The cost-effective system achieves measuring a work material with the capacity of two-dimensional measurements. It also provides automated measurements in addition to the fast, accurate measuring process.

The system successfully operated with an accuracy of around 98% and the linear regression coefficient (r2) was found over 0.95. The proposed cost-effective device can be adapted into various quality control applications in industrial manufacturing, especially for real-time measurement applications.

Manufacturers in industrial applications and researchers in the laboratories can use the proposed VMS for evaluating the quality of a produced work material in real-time using an inexpensive, fast, and accurate measuring device. Thus, the offered VMS is a cost-effective and accurate quality control system with the help of advanced CV systems.

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