A Real-Time Machine Vision System for Automatic Dimensioning of Various Shapes based on NI-VBAI

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Abstract. This paper presents a Real-Time machine vision system based on the NI vision builder for automated inspection (NI-VBAI) platform for automatic dimensions of various shapes. Leveraging advanced machine vision techniques and intelligent NI-VBAI algorithms, the system achieves real-time dimensional accuracy in various forms. Seamless integration with existing industrial setups enables fast and precise measurements without human intervention. Extensive validation and performance evaluation demonstrate the system's robustness, highlighting its potential to revolutionize industrial automation, simplify production processes and ensure timely quality control in manufacturing environments. In this study, we conducted experiments on four objects with two shapes and two sizes. Each measurement process was repeated four times. The processing time for the NI-VBAI experiment can measure an object with 720 ms. The error rate obtained from each measurement process is 1%. Furthermore, the final results show that Ni-VBAI can perform the dimensional measurement process accurately and quickly. The final results can be used directly with configurations in other applications or machines directly for further purposes.

Keywords: Machine Vision System, VBAI, Inspection Technology, Automation

1 Introduction

In the fabrication industry, many components are needed to measure dimensions and shapes. Measurements are made for various purposes as perceptions are achieved. The perception humans need is almost 70 percent based on vision [1]. The measurement of this vision is to monitor and study the characteristics of the object being seen. In the industrial world, these measurements are often implemented using the capabilities of machine vision systems [2]–[4]. Machine vision consists of the same components as humans, with vision and a brain to process them. This component consists of a camera, a group of lenses that replace the human eye, and an intuitive image-processing system in the human brain. The machine vision system, which served as the "eyes" of automation, could realize visual perceptions using various image processing techniques [5].

In previous studies, several researchers have considered machine vision-based evaluation tools for crack length [6], furniture manufacturing process [7], tracking floor eggs [8], grasping control robotic [9], review of surface defect detection [10], screening out conveyor lines [11],

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surveillance system [12], and dimensional measurement for in-process mechanical parts [13]. In previous research, measurements were carried out using a programming approach and mathematical models, which complicates the process of measuring and adjusting to be applied to various shapes or sizes. Apart from that, this programming language does not have direct I/O (input/output) connectors for existing machines in the industry. This connectivity between programming and work on the device often experiences difficulties.

However, this research used the NI-VBAI application developed by NI-LabVIEW. The purpose of this use is apart from many industrial components that support direct connections to applications, the configuration of NI-VBAI based on visuals is easier to understand, and the workflow can be monitored in real-time. NI-LabVIEW was a graphical programming environment provided by NI (National Instrument) corporation, with abundant functional libraries that significantly simplify the complexity of programming, robust expandability, and easy customization. Therefore, it was widely used in various industries. The Machine Vision Development Module is a LabVIEW add-on that can integrate machine vision into more extensive applications, incorporate deep learning models, and leverage Field Programmable Gate Arrays (FPGA) image processing capabilities. The plugin includes tools to set up the camera, customize image analysis, and generate results for production and validation testing. Furthermore, by utilizing the NI-VBAI module, an approach is taken to convert the shape and dimensions of the object to be measured into a signal, and also with additional hands that can be varied according to purposes. NI-VBAI 2023 is introduced in detail and is used by measuring dimensions in various shapes in this study.

2 Research Methods

2.1 Machine Vision and its fundamental techniques

The five procedures that comprise the fundamental machine vision process are explored more deeply below [14], [15]:

a. Image Capturing
   The first step in the process starts with taking images through the camera. When light is emitted from the source, the image in this illuminated form is converted into a digital image using an image sensor.
b. Image acquisition
   Digital images are created by converting or transforming optical images. This conversion method includes additional sub-steps like picture sensing, image data depiction, and image digitalization.
c. Image processing
   In this step, the pixel values of an image are prepared and organized. The display is changed during this procedure into a different format that can be processed further. The five sub-operators of this process are geometric operations, neighborhood operations, temporal, global, and point operations.
d. Feature extraction
   The inherent qualities of things, images, or objects are identified throughout this procedure.
e. Pattern classsification

The final and most crucial processing step in machine vision is pattern classification. A set of recognized things and images is used to identify unidentified and unknown objects and images.

2.2 System Design Model

The research method model used in this study consists of several components shown in Figure 1. First, the camera will capture images of objects in Real-Time. The object will transform to separate from the background using the threshold segmentation method. In this process, several processes will be carried out, such as enhancing image features, reducing noise, and extracting different colors from objects so that the image extraction process can be produced clearly. Objects will be detected to know the points and shapes first. The system will record information on each object detected by the system.

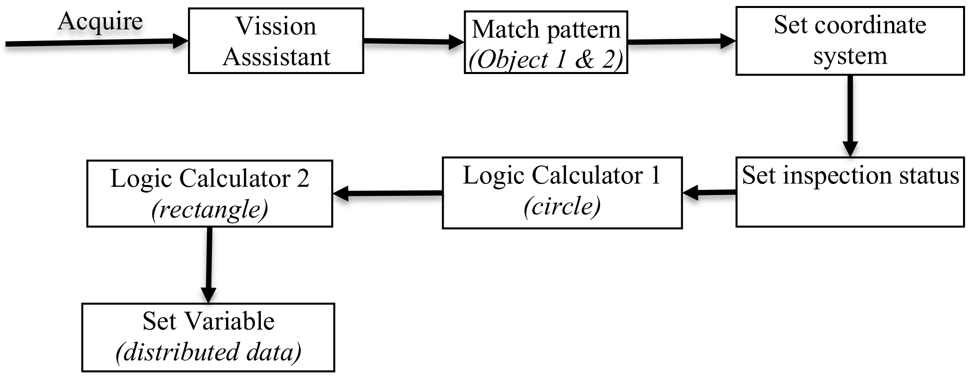

Fig. 1. System design model

The system development architecture for measurements using machine vision consists of several main components: a processor (PC) with NI-VBAI installed, a camera, lighting, and output. The architectural system design is shown in Figure 2.

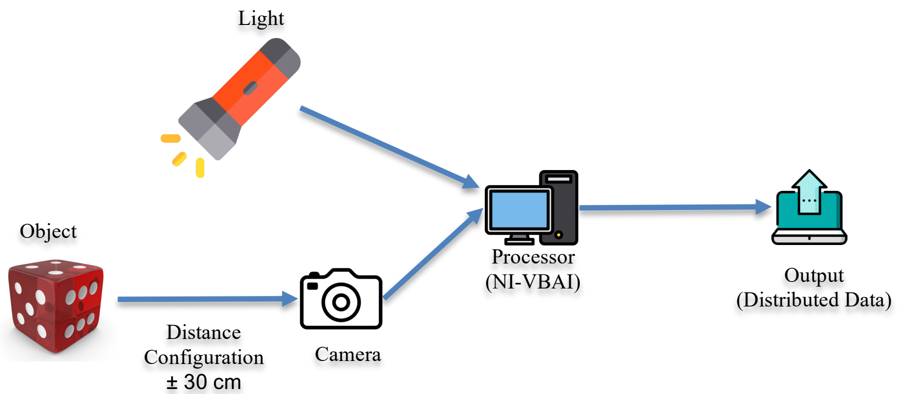

Fig. 2. The architecture system design

The program is divided into several important steps. These steps start with introducing the object's initial shape because different shapes will continue the measurement process to a separate step. In this study, there are two various shapes. The first object is a circle, while the second object is a square. This program is divided into two processes: inspect the beginning and then proceed to the state shape. The complete process of this research is shown in the flow diagram in Figure 3.

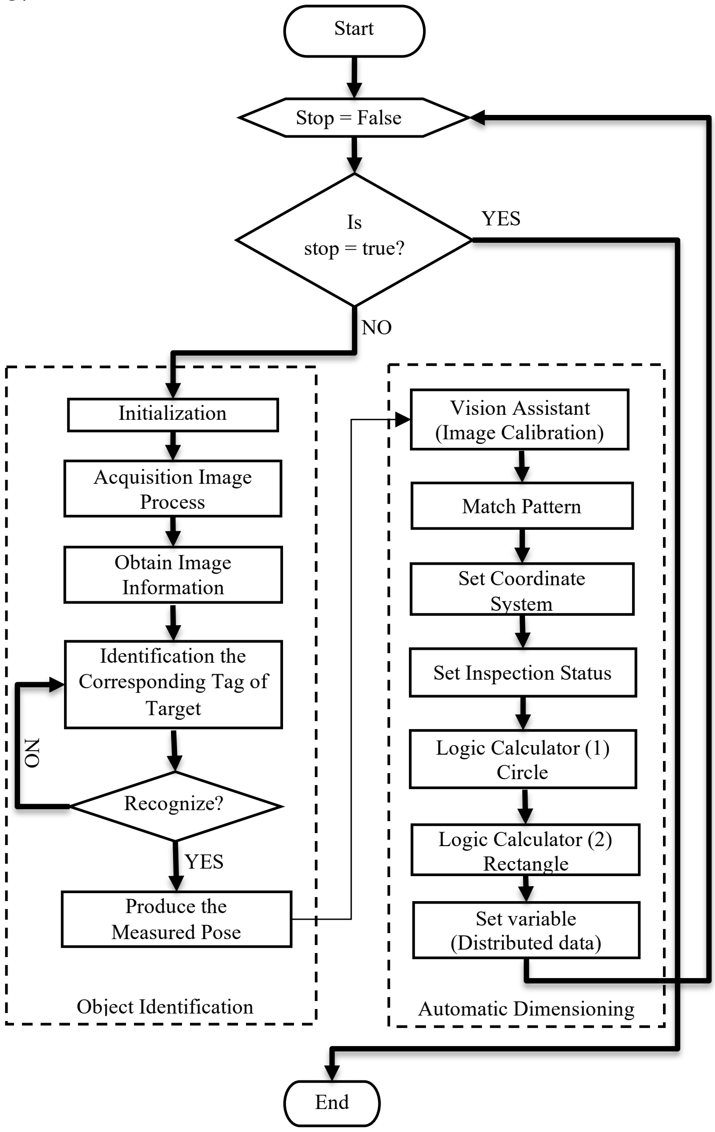

Fig. 3. Flow Diagram of the automatic dimensioning using NI-VBAI

In the logic calculator step, the process is to generate a boolean result based on the result of the previous check step. The previous step shows that the circle or square shape is in the fail or pass position. In this process, it is also required for each object to be determined to be able to decide on an object to be selected so that further processes can choose step 1 or step 2. VBAI can record a boolean logic calculator in the results list for classification purposes. For example, we can use the logged result to set a digital output line level or send a specific string down a serial line. Figure 4 shows a logic calculator when objects recognize the recorded object as a circle and rectangle.

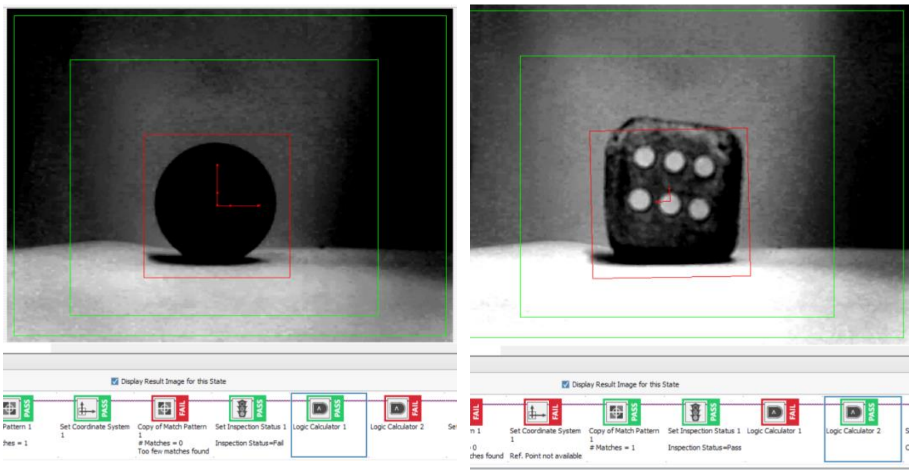

Fig. 4. Logic calculator with different shapes

3 System Implementation

3.1 Hardware configures

Except in cases when the video acquisition is already recorded on the local drive, the camera is perhaps the second most significant component of the system. All of the data being analyzed comes from the camera. A decent camera must meet its own set of requirements. It must produce high-quality images, be tiny and easy to repair, be inexpensive, have a lens that covers the most expansive possible area, and have a broad image resolution of at least VGA (640*480) and up to HD (1280*720). The higher the camera's image quality, the more data the system can collect.

This study used a Logitech C270 webcam, as shown in Figure 5 [16]. This camera has a resolution of up to 7200 pixels and can record sound. When compared to other digital cameras that use a spring and hinge combination, the simple construction of low-cost webcams like the C270 can be a benefit because the sensor and lens are directly attached. Furthermore, machine vision requires eyes. So, this study used a Logitech camera to test that low-cost cameras can be used for dimensional measurements. Cameras with other options can be used, but the quality of the images the camera can capture affects the image processing capacity. Furthermore, it is expected to be able to use minimum HD quality and adequate lighting.

Fig. 5. Logitech C270 HD webcam.

Most computer vision webcams focus on a single webcam with a basic calibration procedure. The precision and accuracy of 2D/3D coordination and the stability and dependability of the webcam system in terms of continuous 3D measurements have not been thoroughly researched and published in the computer vision arena. Table 1 summarizes the features of the C270 webcam as a whole, as used in this study.

Table 1. Logitech C270 technical specification

Max Resolution	720p / 30fps
Camera Mega Pixel	0.9 MP
Focus Type	Fixed focus
Lens Type	Plastic
Built-in Mic	Mono
Mic Range	Up to 3 ft (1 m)
Diagonal Field of View (dFoV)	55°
Weight	2.65 oz (75 g)

3.2 Software Structure

The first step in running the simulation in this experiment is configuring the object to be measured. This process uses a NI-VBAI program that runs on a computer. This program will read the captured objects in real-time and calibrate the detected pixels to their actual size. This program is divided into several steps according to the number of objects to detect. Figure 6 shows the program interface that runs in this experiment.

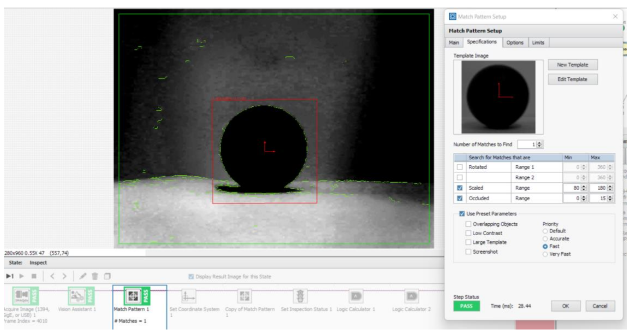

Fig. 6. The VBAI dimension measurement program interface

4 Result and Discussion

This chapter will discuss its direct application to a measurement system by taking samples from 4 objects. There are square and circle shaped objects with a total of 4 different sizes. Each object form will produce a different logic calculator and a different state. Figure 7 shows the sample data used in this study. The experiments were carried out four times each. Each measurement process shows the speed and the size of the object.

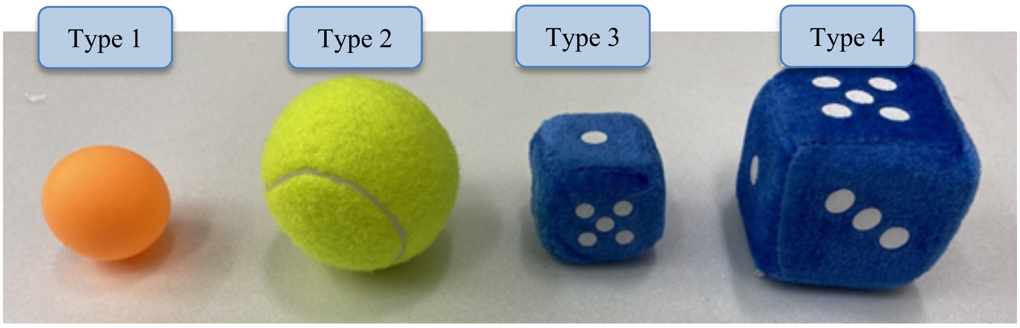

Fig. 7. Sample of Object Identification

At the automatic measurement stage, calibration is required for each state to get the actual size accurately. The samples measured in this study were signed with Circle Shape (CS) and Square Shape (SS). The last step is using the actual size for further use as data. This step is shown in Figure 8, where the system displays a CS in its actual state, and the circle variable shows the exact number from the search results for the sides of the circle. The data obtained can be used as a variable number for a particular purpose.

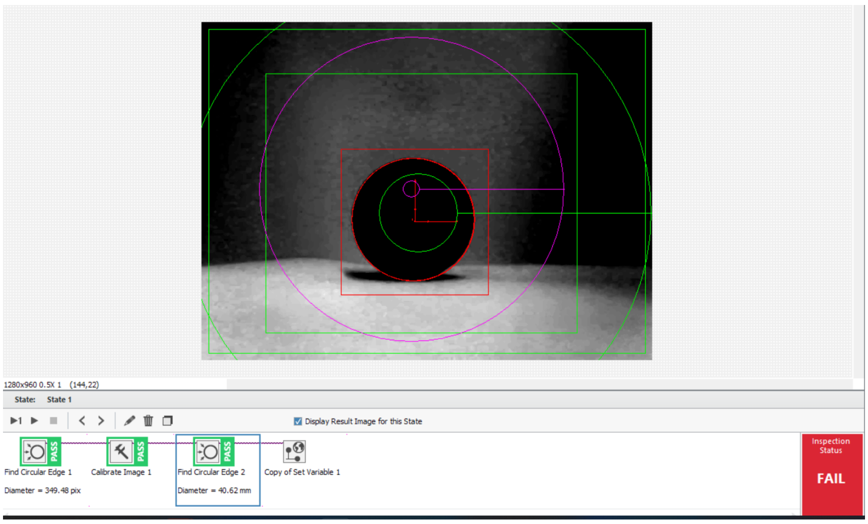

Fig. 8. Find the circle edge to measure the actual number

Automatic dimension measurements are carried out in less than 2 seconds with close to actual results. Table 2 shows the measurement process, and the average is obtained to see the error level in measuring the object's dimensions. In this process, data is manually input into the Excel table by looking at the final Inspect information, which is shown with the red box in Figure 9.

Table 2. Result for actual dimensioning for various shape

Object	Measurement (mm)				Average (mm)	Actual (mm)	Error percentage
	1	2	3	4			
Type 1 (circle)	40.34	40.62	40.05	39.88	40.2225	40	0.55%
Type 2 (circle)	65.90	64.70	65.24	65.15	65.2475	65	0.38%
Type 3 (Square)	48.12	46.81	47.75	47.15	47.4575	47	0.97 %
Type 4 (Square)	70.02	69.54	68.97	69.28	69.4525	69	0.65%

The final results show the dimensional measurements in NI-VBAI, as shown in Figure 9. The measurement processing time for the four objects is around 720 ms (0.72 seconds). This will take longer if the inspection process is performed on a more complex object shape and processor speed used to run the NI-VBAI application.

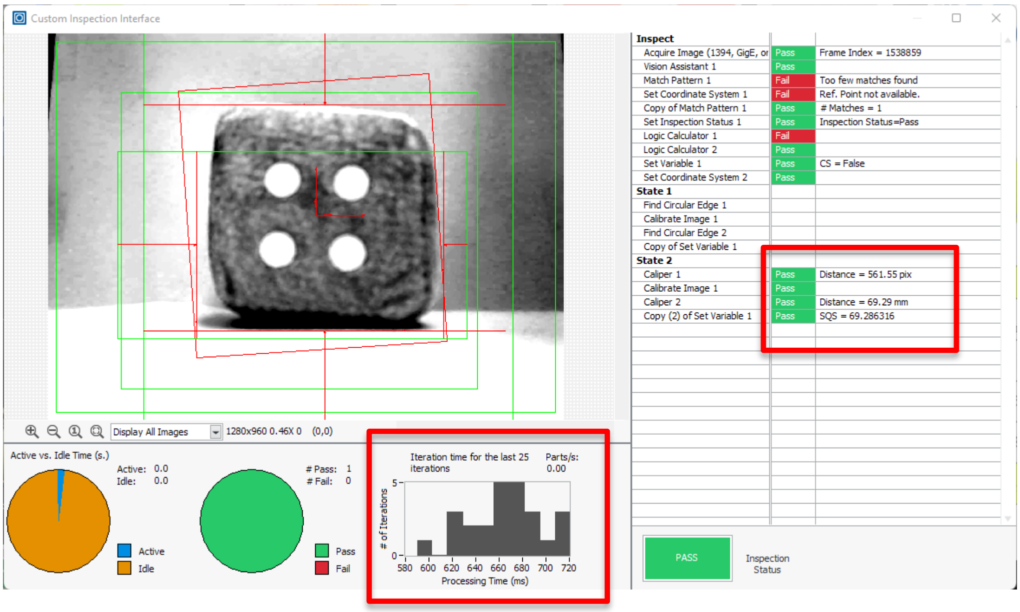

Fig. 9. Inspection result

The results shown from Table 2 show that the measurement process using VBAI runs smoothly and will get 99% accuracy for all shapes. The average speed obtained from each object is < 1 second. The accuracy results depend heavily on the image processing process, which is the key to the inspection process. Lighting is also the key to getting the correct dimensions. The most significant error was caused at different distances in placing the object to the camera from several experiments. Furthermore, the final result of this research is making object placement points to get a high level of accuracy.

5 Conclusion

This study proposes an automatic dimension measurement method using the NI Vision Builder Automated Inspection (NI-VBAI). Utilizing the AI system in this application has proven that it can be used for various purposes, one of which is measurement. From the results of the experiments that have been performed, it is concluded that NI-VBAI can be configured easily by adjusting several different forms of objects to measure without the need for data training processes like in other programming. This application is useful when the object being measured visually has several complex dimensions. Moreover, the time needed to take measurements and without training data will be shorter using NI-VBAI.

From several experiments, the most significant error percentage that makes up the error rate is the distance of the object placement point because NI-VBAI still uses visuals to analyze its size. Additionally, the difference in distance can affect the difference in the size of the original object. However, after calibration, a measurement percentage of 99% was obtained using the marked placement points.

This research has limitations in the aspect of the camera used, which is still cheap. The camera quality still needs more attention, especially the lighting system. In addition, an excellent light configuration is necessary to get maximum results. This research is limited to square and circular objects. Furthermore, it is necessary to experiment with more complex object shapes for dimensional measurements to see the level of accuracy obtained using NI-VBAI in future research.

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