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Performance Enhancement toward Developed Computer Vision Measurement Application for End Mill Cutting Tool

Chong Bin Hong[1], Rasidi Ibrahim[1*], Lee Neng Yung[2], Neexon Khoo[2]

[1]Faculty of Mechanical and Manufacturing Engineering,
University Tun Hussein Onn Malaysia (UTHM), Parit Raja, 86400, MALAYSIA

[2]HPMT Industries Sdn Bhd,
Jalan Sungai Kayu Ara 32/39, Taman Perindustrian Berjaya, 40460, Shah Alam, MALAYSIA

*Corresponding Author Designation

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Abstract: High mix low volume become mainstream trend recently among manufacturing due to the transform of consumption pattern especially during pandemic in order to maintain healthy cash flow. A rapid and flexible equipment especially in measurement required by quality control department of an end mill cutting tool manufacturer in order to enhance the productivity on daily output. Demand on design and develop a high degree of freedom computer vision measurement application is evident to overcome the tribulation of the department. In this research, a multi features developed computer vision measurement application will be the research object toward the performance during measurement and yet the enhancement will be carries out in order to increase the reliability of the measurement result output of the end mill cutting tool. The enhancements of the developed computer vision measurement application are mainly in program algorithm perspectives and the reliability of the measurement improved up to 80% in term of standard deviation or achieved below 1 micron repeatability for every measurement features. The root causes of unstable for the developed computer vision measurement application are concluded and recommendations are given in the end of this research.

Keywords: Image Processing, Computer Vision, OpenCV, Python

1. Introduction

Computer vision is a field that concerned with high-understanding on digital image or video by computers. The main principal of computer vision is to comprehend and reconstruct the nature scenes against on the result that capture by digital camera [1]. Computer vision get compliment recently among industries and research filed due to the more flexibility and sustainability compared to machine vision that has less degree of freedom in order to make change. In the other hand, computer vision considers

Corresponding author: rasidi@uthm.edu.my

much economic compare with other vision application due to computer vision able to function independently without much automated components[2].

By implemented computer vision in production line, the efficiency and productivity of production able to increase due to elimination of human inspection. This integration of hardware and software transform the conventional measurement, detection and checking method into a more efficient condition in term of cycle time and quality control. Computer vision provide higher quality in term of inspection, gauging, measurement and also assembly verification [3]. This able to ensure the products dispatched are within specification and increase the credibility of industry directly. Also, computer vision also provided higher flexibility to production which able to conduct few tasks simultaneously and extend more features to provide more degree of freedom compare to other vision method. Computer vision with low maintenance cost that able to replace few human inspectors that costly and it may sustain yet maintain the quality of output, thus it able to maximize the return of investment which valuable compared to human.

Different end profile able to perform different features to achieve desired geometry and appearance, for example ball shape end mill designed to shape the target object into certain radius or line form [4]. The requirement of geometry parameter and surface finishing of end mill cutting tool become higher as to achieve extreme precision, yet the finished product able to sustain and assembly perfectly. The manufacturer of end mill cutting tool become more challenges as the difficulty of process and product control had been increased. Therefore, the requirement on machines performance for both computer numerical control (CNC) and measurement equipment was also increased.

High demand and requirement in measurement equipment prompt the accuracy and reliability of the equipment become inevitable, yet reflected the significance of this study. Accuracy and repeatability below 1 micron become a target for a high performance measurement equipment in order to deliver quality products during production.

1.1 Problem Statement

A self-developed computer vision measurement application for end mill cutting tool [5] was introduced recently regarding rapid measurement toward few critical geometry parameters on end mill cutting tool which would directly affect the quality of the tool. The few geometry parameters such as outer diameter, runout, ballnose radius and corner radius were covered in the measurement application and it's concluded that the performance of the measurement was within 2 micron when compare with commercial unit, Zoller. However, this result was only concluded by averaging the repeatability of the measurement and the different of the single measurement result was up to 3 micron for certain measurement features. For vision measurement application especially in machine and computer vision, repeatability is more critical issue compare with accuracy since it is depend on the machine condition and method used [6]. In precision cutting tool manufacturing industry, different of 1 micron and below between each measurement machine was the market standard [7] as the requirement toward precision on geometry parameter of end mill cutting tool was getting higher. Therefore, enhancement toward the performance of the computer vision measurement application especially repeatability was necessary in order to provide a stable yet reliable measurement output.

1.2 Objective

The objective of this research study is to identify the factors that affect the performance during measurement process toward end mill cutting tool for every single covered parameter. Suggest and implement the solutions to the application, yet compare the measurement result before and after modification to ensure improvement in term of repeatability had presented. Targeted measurement

repeatability of the application is 1 micron and below among every repeat measurement result under similar condition.

2. Materials and Methods

2.1 Target research application

The self-developed computer vision measurement application for end mill cutting tool [5] is the targeted study machine in this research project. The measurement features that provided by this application were outer diameter, runout, ballnose radius and corner radius of end mill cutting tool. The targeted end mill cutting tool was placed on the v-block and undergo continuous rotation that drive by a DC motor. The targeted tool was exposed under the telecentric vision system in order to capture the backlight frame with sharp edges which contribute to the measurement result. The measurement result provided by the application was within 3-micron repeatability for all measurement features. Figure 1 shows the target research application in this study.

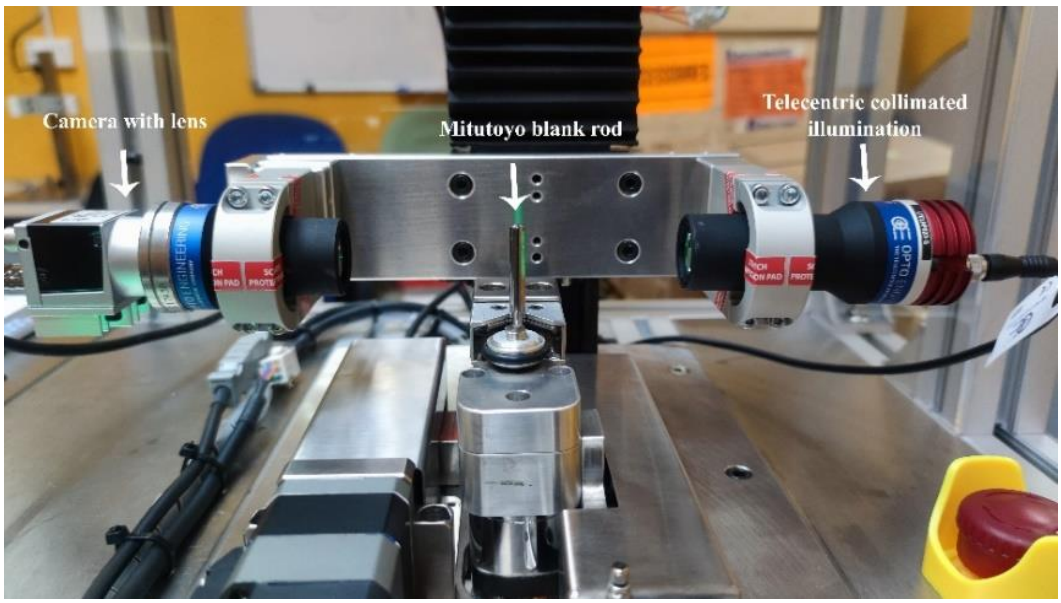

Figure 1: Target research application

2.2 Methods

Figure 2 below show the overall procedure flowchart of performance enhancement toward the developed computer vision measurement application for end mill cutting tool.

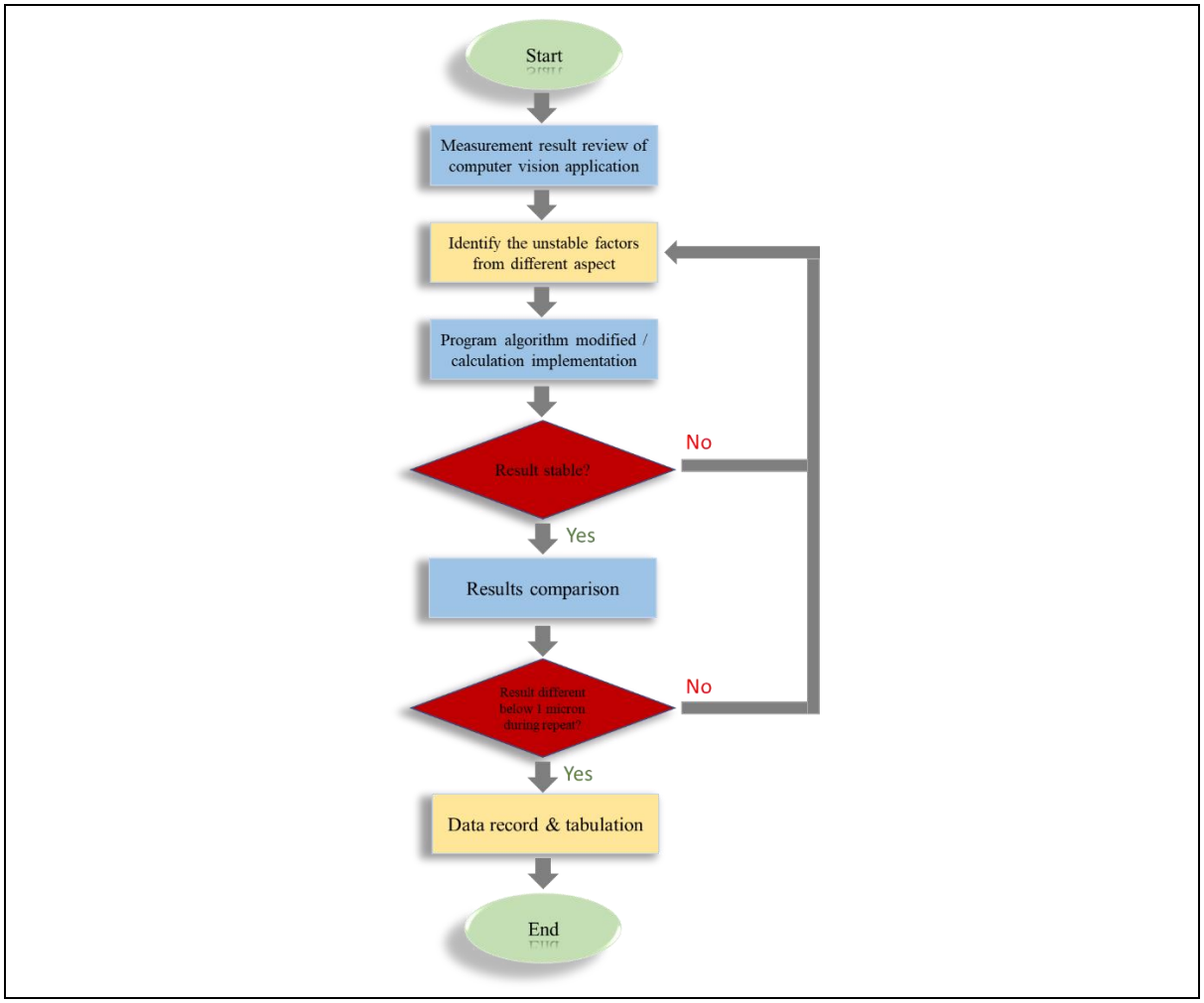

Figure 2: Overall procedure flowchart

All the elements involved in the targeted research application had been reviewed for every single features. Enhancement in term of program algorithm and measurement environment by calculated parameters had been introduced in order to achieve the repeatability as mentioned in research objective. Every adjustment made was under the same environment which was continuous repeated 3 times for a feature to obtain the average result value. The studied cutting diameter range covered was from 1mm to 8mm which was same coverage of the developed unit. The sample standard deviation had been calculated to identify the repeatability before and after adjustment to prove that the performance in term of repeatability of developed machine had improved.

For the targeted research application, the outer diameter feature was measured the edges of the end mill cutting tool at certain measuring height. Sub-pixel module had been introduced in this feature which was determine the sub-pixel value by pixel-intensity ratio method. This method limited by the maximum pixel intensity value which was 256 that unable to interpret the pixel further detail. Interpolation method had been introduced into this module to increase the resolution of sub pixel prediction. The interpolation process had been done on the edges of the end mill cutting tool in which the most distinct changes in term of pixel intensity had been choose. Quadratic interpolation between the most distinct changes pixel intensity and two adjacent pixels had been done in order to determine the edge coordinate in term of floating number, yet the outer diameter of the end mill cutting tool obtained in higher resolution.

Inconsistent in rotation speed of DC motor was the root cause that contributed the stability of repeatability toward the runout measurement result. The measurement environment become variance

when the end mill cutting tool rotated under different speed of DC motor. This effected the measurement toward runout of end mill cutting tool as the frames captured by vision system were lesser due to inversely proportional relationship between DC motor speed and total number of frame captures. A formula had been constructed in order to calculate the relative motor speed under different shank diameter in which it's provided controlled measurement environment for the application. The time consumed from one flute to another was defined and this standardize the measurement cycle time for a rotation even the shank diameter was variance.

Corner radius of an end mill cutting tool was essential in order provided constant cutting environment and smooth chip removal [8]. This significant parameter was determine by hyper least square fitting method [9] after the image had been stacked. Unfortunately, the result was inconsistent without some pre-process before that method in which some faults detection happened especially at the start and end point of the corner radius. Hence, normal vector that determined from sub-pixel module at image edges [10] was used as the indicator in order to determine the start and end point of the corner radius. The angle of the normal vector with respect to the global axis was calculated and tangent points of the corner radius were determined. The pixels between the detected tangent points were used as the input of hyper least square fitting module, yet more reliable measurement result had been obtained due to consistent of input parameters.

Meanwhile in ballnose radius measurement module, the stack image of the ballnose cutting tool was pre-processed by threshold method in order to exclude the blur noise at the edges. The edges presented "step" shape as it was affected the measurement result during hyper least square fitting. Hence, raw stack image as the input image and sub pixel module at edge [10] had been introduced in order to determine the edges coordinate in term of floating point instead of integer. By using floating edges coordinate as the input of hyper least square fitting to determine the radius of ballnose cutting tool, the accuracy of the measurement improved significantly which had better repeatability compare with previous method.

3. Results and Discussion

3.1 Measurement Result

Figure 2 shows the graph of the result standard deviation comparison between before and after adjustment as mentioned in section 2.2 for every single feature and percentage improved based of calculated sample standard deviation percentage.

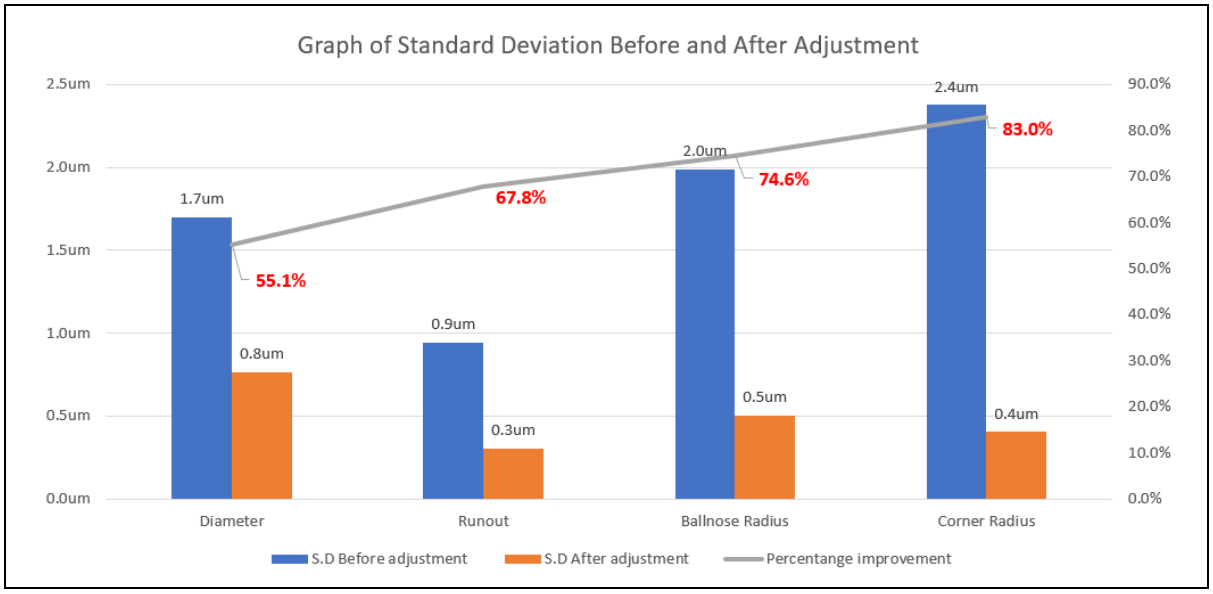

Figure 2: Graph of result standard deviation comparison and percentage improved

From Figure 2 above, it's evident shows that the improvement mentioned in previous sub section toward every single particular feature had effectively increase the repeatability of the application during measurement on end mill cutting tool. The calculated standard deviation before adjustment for diameter, runout, ballnose radius, and corner radius was 1.7, 0.9, 2.0, 2.4 micron respectively which consider ordinary performance. Therefore, adjustment had enhanced the performance to 0.8, 0.3, 0.5, and 0.4 micron respectively which below 1 micron repeatability. Although the graph only the average standard deviation for each measurement, but the difference between before and after adjustment was significant. The repeatability before and after adjustment had different up to 80%, also overall standard deviation after adjustment was below 1 micron which meet the market standard. This proven that the suspected factors that affected the performance in each feature were the root causes that provided unstable result toward the developed application. Hence, the primary objective of this research had accomplished by implemented improvement in term of programming algorithm modification and mathematical calculation.

4. Conclusion

The research objectives had been accomplished which the factors that affected the performance of the developed measurement unit had been identified for each measurement features, solutions had been suggested and implemented, also the repeatability of the developed units had achieved 1 micron and below. These achievements enhanced the performance of the developed measurement unit in term of repeatability which was the critical weakness especially for a precision measurement application. Therefore, the developed measurement unit after improvement was capable to compete with commercial unit in the market as its own more advantages in term of cycle time, accuracy, repeatability, investment cost, maintenance cost, and degree of freedom for additional of measurement features that promote its sustainability during implementation in production.

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