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Development of descriptive analysis module within a cloud-based quality analyser: case study in a guitar industry

Razita Raihanah[1], *Fahmi* Arif[2,*], and *Said* Muhammad Baisa[3]

[1,2,3]Department of Industrial Engineering, Institut Teknologi Nasional Bandung, Indonesia

Abstract. Along with the revolution of the manufacturing world, companies face a new challenge to continuously improving their production processes to meet the escalating demand for high-quality goods in a fiercely competitive market. The previous concept of Cloud-Based Quality Analyzer (CQA) can be used as a real-time monitoring software that provides information of the on-going process. This concept can be implemented as an effort to achieve high quality manufacturing. This study aimed to develop the descriptive analysis module to realise the concept of CQA and evaluate its ability in realising online quality monitoring process. By employing the waterfall methodology, this study developed and implemented the descriptive analysis module in the CQA environment. The module was implemented in a case study in guitar manufacturing. The result showed that this module worked perfectly in displaying the multivariate process control chart and successfully gave the warning when some processes were in out-of- control state. Furthermore, the user acceptance test also showed a positive response from the users. The descriptive analysis module was believed able to enhance the quality of manufacturing process while reducing the dependencies to the human quality engineers. However, more case studies in various industries were required to evaluate the benefit of implementing this module.

1 Introduction

The evolution of manufacturing through digitalization and automation aims to enhance productivity and efficiency within factories. A system known as Cyber Physical System (CPS) involves interconnected computer systems that interact with the physical world via sensors and actuators [1]. This technology facilitates information distribution and automated control, representing a key feature of Industry 4.0 in manufacturing [2]. A study by [3] emphasises that as Industry 4.0 progresses, quality analysis processes must shift toward data-centric methods. Their study reveals that many quality engineers rely on intuition or qualitative judgement when making decisions, influencing the efficacy of quality inspection processes [4]. Therefore, the advancement of Industry 4.0 necessitates a

* Corresponding author: fahmi.arif@itenas.ac.id

more data-oriented approach to enhance the management and enhancement of product quality.

In most manufacturing companies, the primary challenge in enhancing quality lies in constraints related to time and cost [5]. Many companies persist in using traditional systems within their quality processes, leading to prolonged durations for quality analysis and control. Certain quality analysis software, exemplified by the work of [6], has been developed. Nevertheless, the development of this software was challenging and demanded substantial effort.

Cloud-based quality analyser (CQA) was introduced by [2] to serve as a quality analysis system, examining process parameters and generating output in the form of reports, warnings, control charts, and predictive models. This system swiftly conducts data-based quality analysis without necessitating the involvement of a human quality engineer. Its principal objective is to replace the role of a quality engineer, ensuring a more consistent and expedited analysis process. Broadly, this system comprises two analytical functions: descriptive and predictive analysis. However, being in a conceptual framework, its efficacy in analysing manufacturing process quality remains unverified. This study aimed to implement the descriptive analysis module and assess its performance through a case study focused on guitar manufacturing.

2 Methodology

In developing the descriptive analysis module for CQA, this study adopts the waterfall methodology that consists of analysis, design, implementation, testing and maintenance [7]. The initial stage includes thorough collection of requirements from stakeholders to define the software's functionalities and features. The fundamental requirements include:

1. Enabling visual report presentation through a multivariate control chart.
2. Supporting file uploads in CSV format.
3. Providing downloadable analysis outcomes in PDF form.

This phase also involves designing the use case diagram depicted in Fig. 1 below.

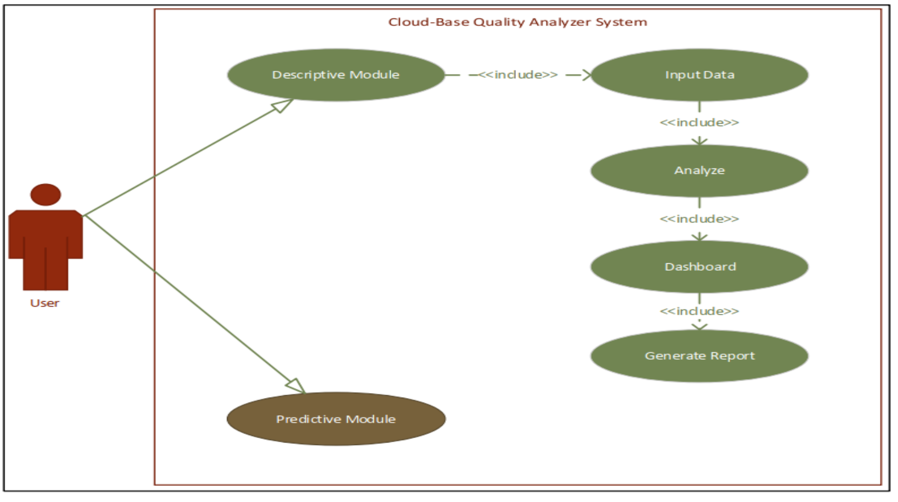

Fig. 1. Use case diagram for CQA's descriptive analysis module.

After the requirement and use case diagram is determined, a comprehensive system design phase begins. This involves creating a detailed architecture, database schema, and outlining the software's overall structure. As this study uses the Django framework, this phase involves setting up models, views, and URL patterns. With the design in place, the process of writing code in Python is started. The code is written to create the application's logic, views, templates, and integrate the defined functionalities. In this phase of development, the primary application logic, namely the Hotelling's T2 algorithm, is implemented. This algorithm enables the system to generate a multivariate control chart and signal an alert when it detects an out-of-control condition.

After finishing each stage, thorough testing is conducted to verify that the system aligns with the designated requirements. This encompasses unit, integration, and system testing. Django provides its testing framework enabling automated testing of various elements. Additionally, the testing phase involves executing the user acceptance test to gauge user perceptions of the system's performance.

3 Result and Discussion

3.1 Functionality of the descriptive analysis module

Following the development phase, CQA's descriptive analysis module becomes operational for monitoring the manufacturing process. To assess the module, a case study is conducted within guitar manufacturing. The analysis starts by uploading a CSV file containing data on the guitar manufacturing process. A specialised page, illustrated in Fig.2, was tailored explicitly for this purpose.

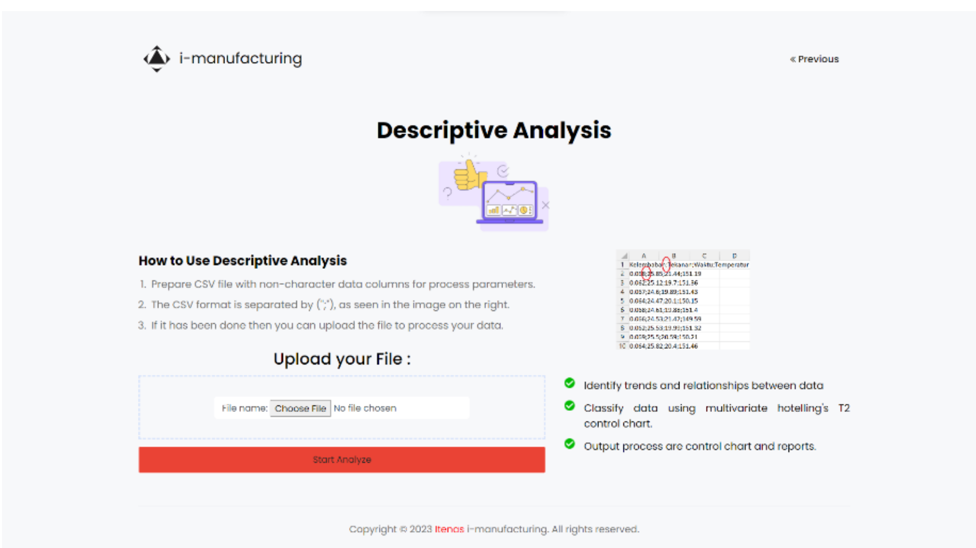

Fig. 2. The homepage for the descriptive analysis module.

The dataset comprises 803 products, each associated with 4 process parameters indicating the conditions during their manufacturing. These parameters encompass humidity, pressure, duration, and temperature of the process. This leads to the visualisation of a control chart, accompanied by alerts displayed upon detecting an out-of-control condition. The outcome of the analysis is depicted in Figure 3.

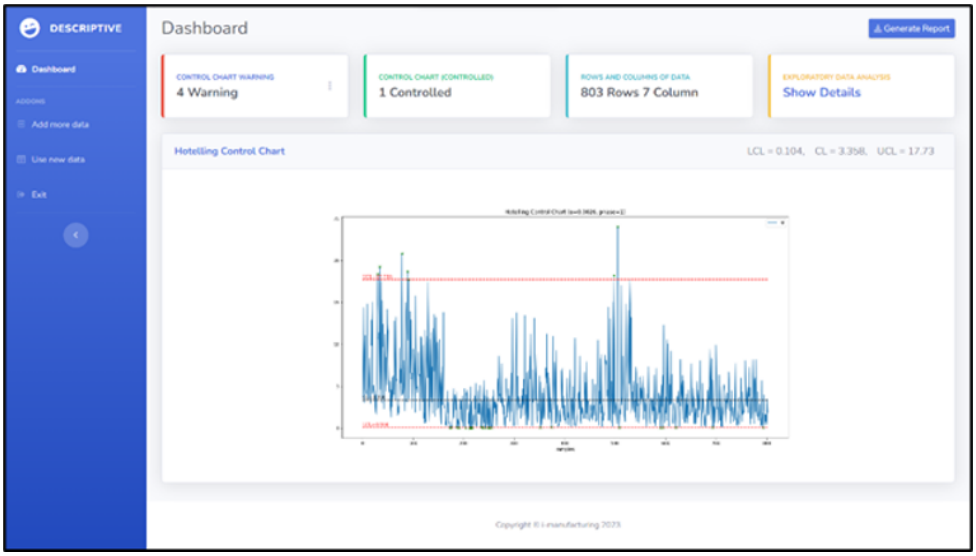

Fig. 3. Descriptive analysis result.

The analysis result shows that 29 products were manufactured under conditions exceeding the outer limits, leading to 4 warnings indicating an out-of-control situation for some products. Further detailed information can be accessed by opting to display details, as depicted in Figures 4 and 5.

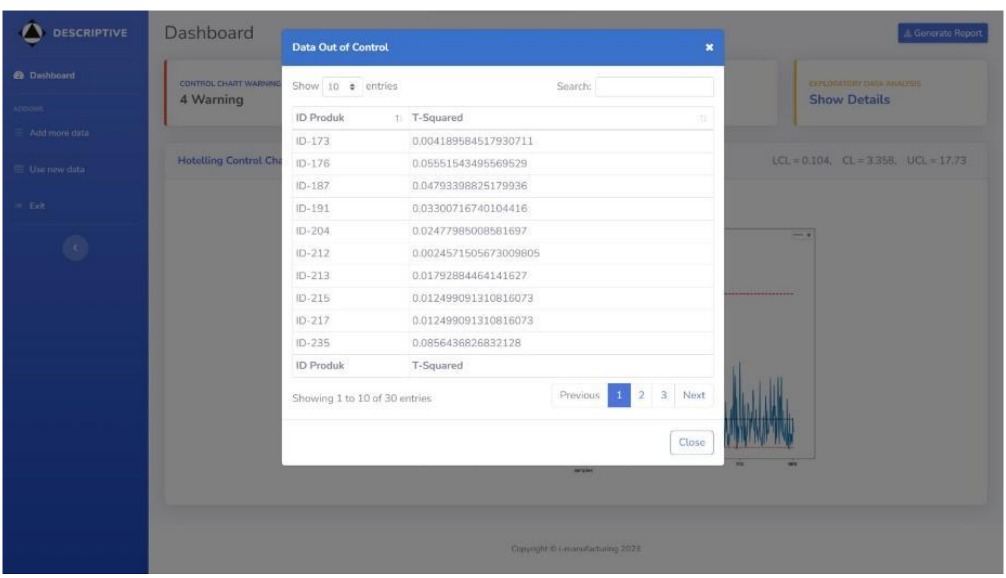

Fig. 4. Detail out-of-control data display.

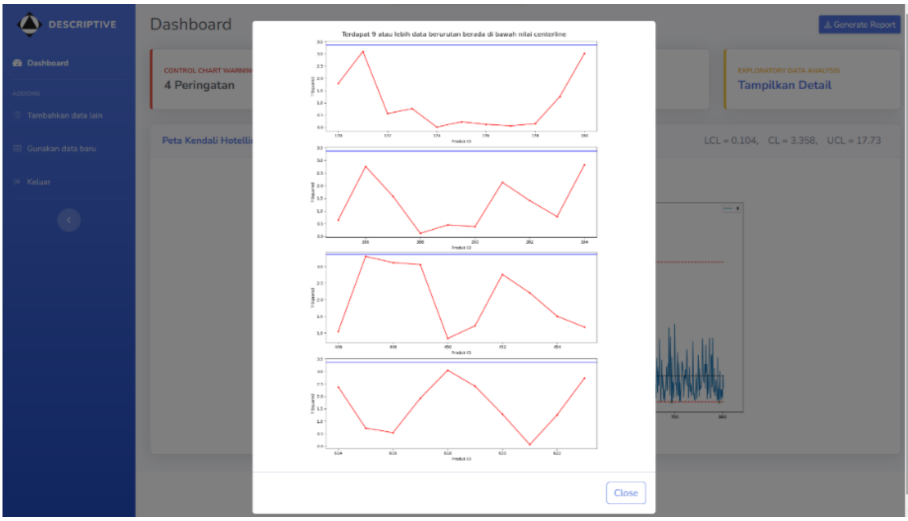

Fig. 5. Detail warning chart display

To confirm these findings, a manual analysis was carried out using Microsoft Excel, and the outcomes were cross-referenced. Both analyses yielded identical results, affirming the proper functionality of the descriptive analysis module.

3.2 User acceptance

User acceptance testing assesses five usability aspects: learnability, efficiency, memorability, errors, and satisfaction [8]. A questionnaire employing a four-point Likert scale is devised for this evaluation. Two quality engineers from a guitar company participate as respondents for this test. The result shown in Table 1.

Table 1. User acceptance test result.

No	Question	Score
1	The program can be operated without the need to be given a hint/instruction	2,50
2	The main functions of the program can be understood quickly	2,00
3	The navigation system in the program is intuitive and easy to follow	3,00
4	The descriptive analysis process is completed in a short time	3.50
5	No delay in loading when using the program	2.00
6	Only a few steps are required to perform descriptive analysis	4.00
7	Program usage procedures can be remembered without having to relearn	2,00
8	Only a few errors occur when using the program	3,50
9	Errors that occur do not reduce the effectiveness of the program	3,00
10	Errors are manageable and do not significantly disrupt the process	3,00
11	The program can help to achieve high productivity	3,50
12	Program is convenient to use	4,00
13	Only minimum effort is required to operate the program	3,00

Table 1 displays the comprehensive outcome of the user acceptance test. Learnability was assessed through questions 1-3, efficiency through questions 4-6, memorability through question 7, errors through questions 8-10, and satisfaction through questions 11-13. The findings indicate an overall score of 2.5 for learnability, 3.17 for efficiency, 2.00 for memorability, 3.17 for errors, and 3.5 for satisfaction.

Based on the resulting score, users found the system moderately easy to learn and efficient, scoring 2.5 and 3.17 out of 4, respectively. However, memorability scored lower, indicating potential challenges in recalling the system's functions. On a positive note, users observed few errors, suggesting a relatively stable system. The high satisfaction score of 3.5 out of 4 indicates overall contentment with the system's performance and features. Overall, while there are areas for improvement, the system generally meets users' needs and leaves them satisfied with its functionality.

4 Conclusion

This study explores the development and assessment of a descriptive analysis module within the CQA, aiming to enhance manufacturing efficiency and quality through digitalization. The module, designed using the waterfall methodology, underwent rigorous phases from requirement gathering to testing, aiming to enable multivariate control chart visualisation, CSV file uploads, and PDF output generation. Through a case study focused on guitar manufacturing, the system successfully processed a dataset of 803 products, identifying 29 products produced under conditions beyond acceptable limits, triggering alerts for potential out-of-control situations. Manual analysis validation using Microsoft Excel corroborated the system's accurate functionality.

Furthermore, user acceptance testing provided valuable insights into the system's usability. The assessment revealed moderate ease in learning and high efficiency in operation, supported by minimal errors and high user satisfaction. However, challenges in memorability hint at potential difficulties in recalling system functions. Despite areas for improvement, the system generally meets user needs, showcasing stability and overall satisfaction with its functionality.

In essence, the developed descriptive analysis module within CQA demonstrates promising potential for enhancing manufacturing quality control. Its success in processing real-world manufacturing data and garnering positive feedback from user acceptance testing sets a strong foundation for further refinement and application in Industry 4.0 manufacturing environments, emphasising the significance of data-centric approaches in quality analysis processes.

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