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Design of IoT-Based Manufacturing Quality Control Systems with Exponentially Weighted Moving Average Chart

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Abstract

Quality control is needed for each manufacturing industry, so that product quality remains stable. Product variation is one of the factors that can reduce product quality, so quality control is needed. Control chart is one of the tools in statistical quality control that can be used to detect changes in product variations. One of the control charts that has a high sensitivity to the average shift is Exponentially Weighted Moving Average (EWMA) control chart. But in its implementation, the company still uses a manual process, starting from the process of data collection, data entry, to data processing into a control chart. Manual process can cause data collection errors and delays in quality decision. For EWMA control chart, the complicated calculation contributes additional difficulties for quality control implementation. The Internet of Things (IoT) is a concept that combines a device with other devices using internet connectivity, so that the distribution of data and information flow becomes faster and more accurate. Based on the IoT concept, a quality control design system is proposed that integrates data retrieval, data processing, control chart computation, and data display so that it can improve speed and accuracy in the process of making EWMA control chart. Based on testing, this system has been able to improve the accuracy of data retrieval and processing, speed up the process of making control charts, and integrate data collection, recording, and processing activities.

Keywords: statistical process control, internet of things, exponentially weighted moving average, digital caliper, web-based system.

1. Introduction

Product variation is a state when one product is not identical with another. Variations are caused by differences in treatment during the production process such as the condition of the equipment used or the way the operator processes the product. Large variations indicate that the quality of the product is low, because the product does not meet the standards desired by the enterprise. This causes the enterprise needs quality control to reduce these variations. Control chart is one of the tools in statistical process control to detect if the variations is out of control, so that corrective action can be taken to stabilize the process (Mitra, 2008).

There are several control charts, one of which is the Exponentially Weighted Moving Average (EWMA) control chart. The EWMA control chart is used to see variations based on the average shift in a production process. The EWMA control chart is used to analyze products that have variable data characteristics. The process of creating an EWMA control chart is different from other control charts. The EWMA control chart does not ignore data that has been previously plotted, so the latest data will always be influenced by previous data. This causes the EWMA control chart to have a higher sensitivity than other control charts in detecting average shifts (Montgomery, 2009).

The implementation of the monitoring process using the control chart is carried out through several processes such as measurement of product dimensions, recording, data entry, calculation, and making a control chart. Commonly in most mid-small companies the process is done manually. Starting from product measurement, product size recording, product data entry, to making control charts. Manually processing takes a long time and can cause delays in taking action. In addition, the chance of an error in data entry is quite high. Data entry errors can result in decreased accuracy of data processing on the control chart. So that it causes errors of action in quality control efforts (Ćwikła, 2013)

One way to overcome this is to utilize the concept of the Internet of Things (IoT) in the process of making a control chart. The concept of IoT can help the process of taking data, recording data, and processing control chart data. IoT helps integrate these activities more quickly and efficiently by using the internet network. In general, IoT is defined as a global network infrastructure where physical and virtual attributes in manufacturing systems are seamlessly integrated into the information network (Xu et al., 2014). According to Lee (2015), IoT is recognized as one of the most important fields of future technology and receives wide attention from various industries. IoT is an internet-based system that can connect other entities. The concept is that IoT can send and access data in real-time, thus speeding up the process of information dissemination. IoT in the manufacturing industry is used for various purposes, such as monitoring the state of the machine, taking data from sensors so as to assist companies in carrying out quality control (Mishra et al., 2018). Examples of uses such as using sensors to monitor product quality results. The sensor accepts data criteria on the product (size or color), after which the data is sent to the operator via the internet network. The data is received by the operator into computer software, so the operator can take action based on the data obtained.

Based on these problems, this research was conducted to designing a quality control system with a system that can integrate the measurement process, data entry, data calculation, and appearance of an IoT-based control chart with an output in the form of an EWMA control chart. System testing is carried out on Small Scale Manufacturing Laboratory (SSML) which is a manufacturing company. The resulting product has a critical value on the dimensions (variables) of the product. SSML still applies quality control in a conventional process. The process of archiving data size and data entry is still done manually by operators at SSML.

2. Exponentially weighted moving average control Chart

The EWMA control chart is able to detect if there is a cause of variability in the production floor. The cause of variability is detected through a shift in the average occurring in a process. That is because the EWMA control chart takes into account previous observation data, so that small shifts can be detected. The EWMA control chart is defined as follows:

$$Zi = \lambda x_i + (1-\lambda) Z_{i-1}, \quad (1)$$

$$UCL = \mu_o + L\sigma \sqrt{\frac{\lambda}{(2-\lambda)}(1-(1-\lambda)^{2i})} \quad (2)$$

$$LCL = \mu_o - L\sigma \sqrt{\frac{\lambda}{(2-\lambda)}(1-(1-\lambda)^{2i})} \quad (3)$$

In equations (1) Zi is EWMA value, where the x_i is the observation value and λ is the smoothing value, the value ranges from $0 < \lambda \leq 1$. (2 and 3) UCL is upper control limit and LCL is lower control limit, μ_o is the target value or observation mean, σ is the standard deviation, and L is the width of the control limits (Montgomery, 2009). The examples of EWMA control chart charts can be seen in Figure 1.

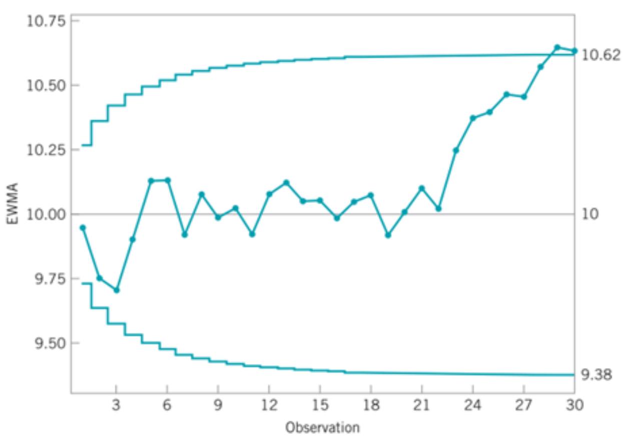

Fig. 1: Examples of EWMA Control Chart

3. Basic Concept of The System

The system design will be described in the form of architecture diagrams, information systems, and data flow diagrams. The system design is as follows.

3.1 Architecture Diagrams

Computer architecture can be seen in Figure 2. The scheme of the tool designed is divided into three parts, namely client tier, logic tier, and database tier. Client tier shows how the system interacts directly with user and operator. Object measurement is using digital caliper Mitutoyo. Microcontroller is used to take the record data from digital caliper, and sending the measurement data to web application. Application tier shows applications that are on the system. The application will process measurement data received from the microcontroller. Tier database is a place to store measurement data. Measurement data is stored in a database so that the data is more organized and efficient if you want to use the data.

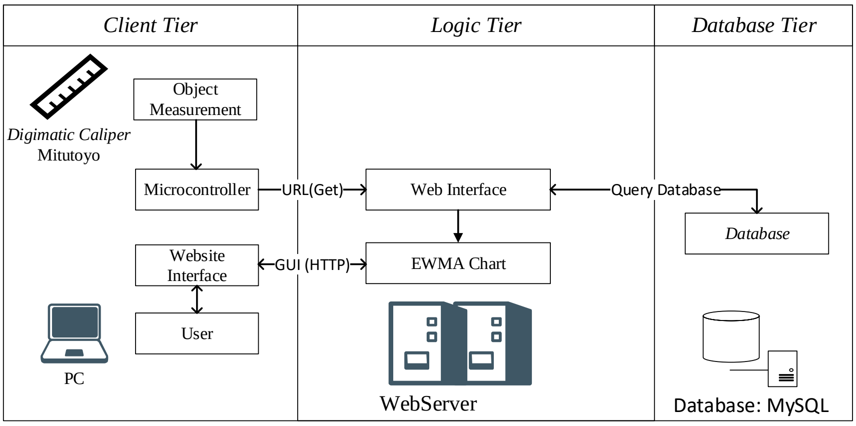

Fig. 2: Architecture Diagram

3.2 Information Systems Flow

The flow of information systems is used as a description of the flow of logic that occurs in a system. The information system is depicted in a visual form in the form of a chart containing symbols. There are several entities that interact with the system, including measuring devices, microcontrollers, websites, users, and operators. The design of information system flow can be seen in Figure 3.

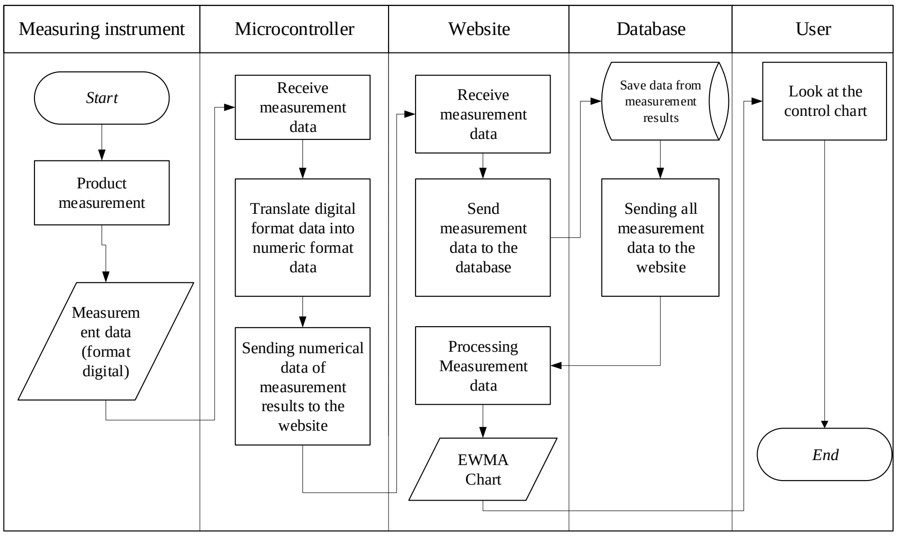

Fig. 3: Information Systems Flow

3.3 Data Flow Design

Data flow in the quality control system design is described in the form of Data Flow Diagrams (DFD). DFD has several diagrams, namely Context Diagrams, DFD level 1, and DFD level 2. Context diagrams are used as a preliminary description of the system before the DFD is described. Context diagrams illustrate how the system interacts with external entities. Context Diagrams can be seen in Figure 4.

DFD on this system contains two external entities, has five processes, and one data store. Entities in this system are operators and users. The processes contained in the system are data translation, data transmission, data processing, and data display. Data storage performed by the system is the measurement of numerical data from measurement results. DFD level 1 in the design of this quality control system can be seen in Figure 5. There is a more detailed description of the data flow from DFD level 1, namely DFD level 2. DFD level 2 in the design of this quality control system can be seen in Figure 6.

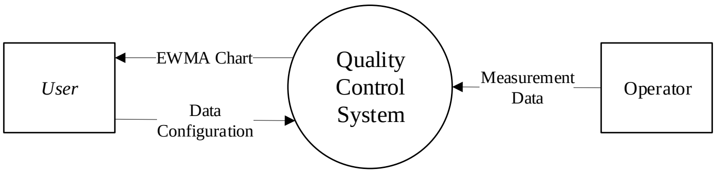

Fig. 4: Context Diagrams

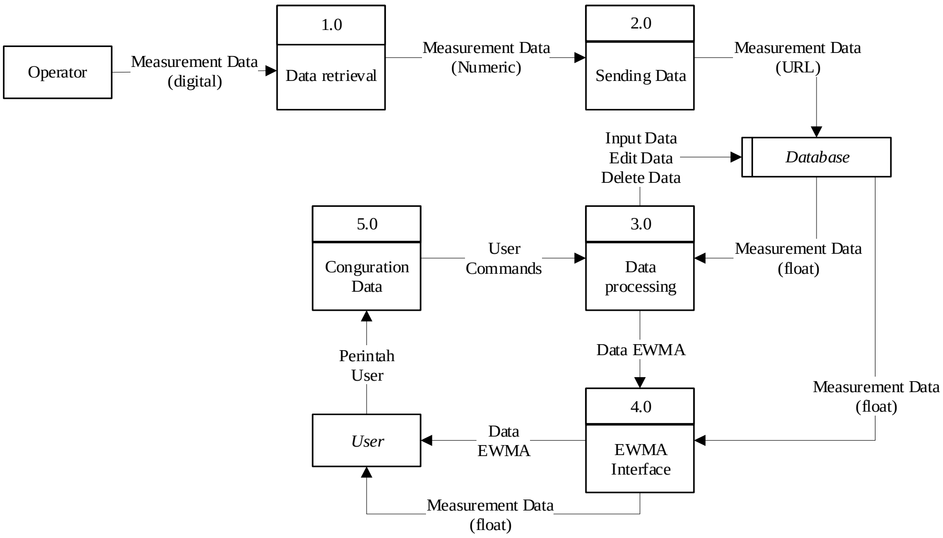

Fig. 5: DFD Level 1

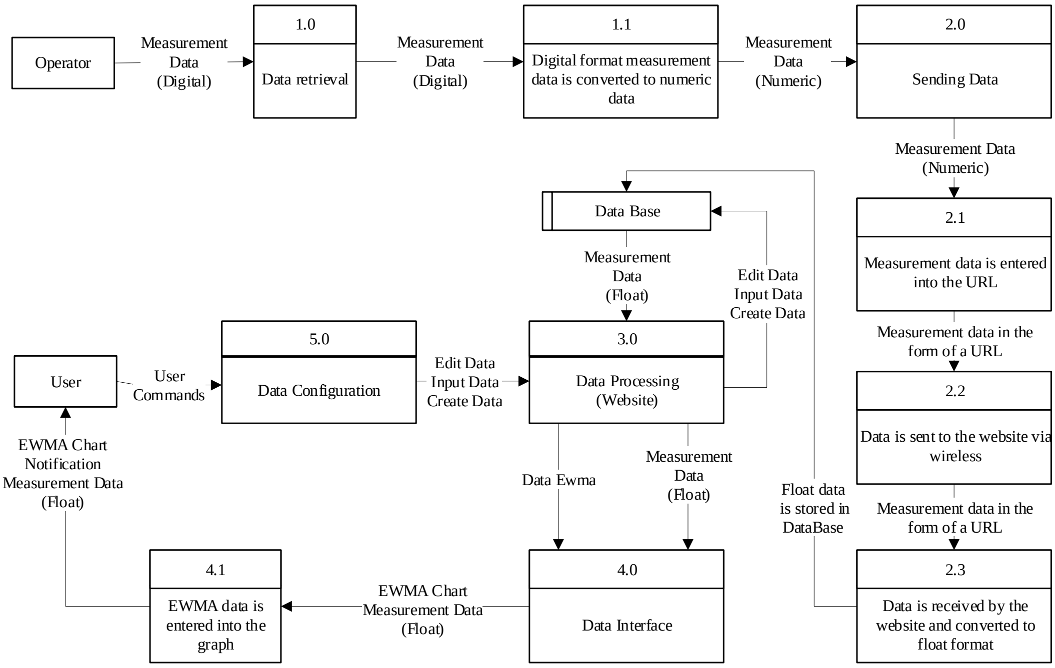

Fig. 6: DFD Level 2

4. System Prototype and Testing

The prototype system in this paper has been made and the system will be tested. The appearance of EWMA control chart in the website system can be seen in Figure 7. System testing is performed using measurement data on the Front Cover sub-product in Small Scale Manufacturing Laboratory and the output will be an EWMA control chart of the observed production system. Testing is done by taking 25 subgroup data, each of which contains 1 sample. Based on Figure 7 that there is data out of control, so the company needs to take corrective action on the production system. The results of EWMA control chart data processing from the system are in accordance with the results of data processing in the Minitab application, so it can be said that the accuracy of data processing on this system has been accurate.

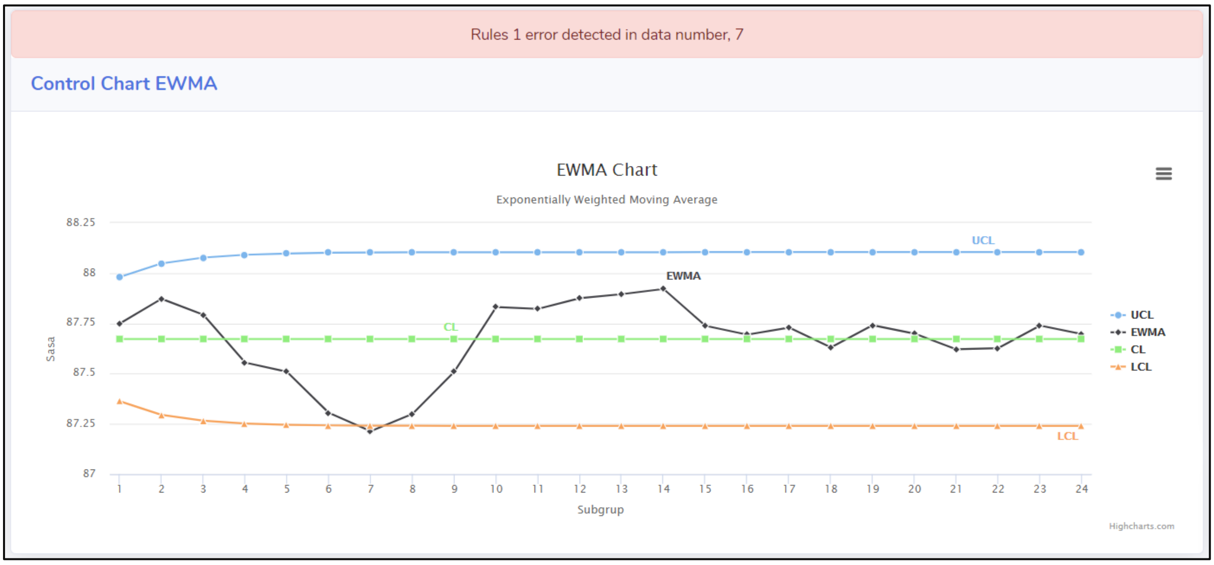

Fig. 7: EWMA Control Chart on System

After that, a comparison is made between the quality control process manually and the process using the system. This is to see whether the system can minimize time and improve data accuracy. The comparison between system and manually process can be seen in Table 2.

Table 2: Comparison between System and Manually of Measurement Data and Recording Speed

Measurement Data			Process Time		
No	**Measurement Manually (mm)**	**Measurement Using Proposed System (mm)**	**No**	**Process Time Manually (seconds)**	**Process Time Using Proposed System (seconds)**
1	87.93	87.93	1	192.1	4.53
2	88.16	88.16	2	196.8	5
3	87.61	87.61	3	196.72	5.2
4	87	87	4	197.18	4.6
5	87.4	87.4	5	200.15	5.33
6	86.83	86.83	6	201.75	4.2
7	87	87	7	197.13	4.75
8	87.5	87.5	8	199.24	4.79
9	88	88	9	197.54	5.02
10	88.58	88.58	10	199.41	5
11	87.8	87.8	11	193.12	4.92
12	88	88	12	195.11	5.74
13	87.94	87.94	13	200.68	5.35
14	87.98	87.98	14	218.14	5.6
15	87.31	87.31	15	214.12	4.45
16	87.59	87.59	16	201.67	4.8

Table 2: Comparison between System and Manually of Measurement Data and Process Time (Continued)

Measurement Data			Process Time		
No	**Measurement Manually (mm)**	**Measurement Using Proposed System (mm)**	**No**	**Process Time Manually (seconds)**	**Process Time Using Proposed System (seconds)**
17	87.81	87.81	17	208.48	5.12
18	87.4	87.4	18	210.7	4.63
19	88	88	19	208.88	3.21
20	87.6	87.6	20	220.51	4.25
21	87.44	87.44	21	232.07	5.22
22	87.64	87.64	22	230.4	4.62
23	88	88	23	217.1	5.74
24	87.68	87.6	24	215.41	3.37
25	87.17	87.17	25	232.83	4.13
Average				207.09	4.78

Based on Table 2 above, the time required in the measurement process, recording data to the database, and processing the EWMA control chart data with a manual process is 207.09 seconds. The time needed to carry out the process of measuring, recording data to the database, and processing the EWMA control chart data by the system is an average of 4.78 seconds for each measurement. Based on Table 2 above, it is shown that from 25 measurements, the measurement data results in the system are in accordance with the measurement data manually. This indicates that the accuracy of the data obtained from the measuring instrument is very good.

5. Conclusion

Based on the system that has been designed, the accuracy of the data obtained is accurate both for data collection and data processing. The system can reduce the possibility of errors in data collection, recording, and processing. Based on system testing, the time needed for the measurement, taking, and processing to become an EWMA control chart is only 4.78 seconds, compared to 207.09 seconds using manual process. This system has minimized the time needed to carry out EWMA-chart process control activities, making it easier and faster for the quality control section to detect out-of-control condition due to the shifting of process variations. The proposed system integrates process control activities, including: data measurement activities, data entry, data processing, and computational result display.

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