Development of Direct Time Study Technology for Advanced Work Measurement

Euis N.S. Yuliani, Muhammad Kholil, Ajeng Y. Setianingrum, and Adik S. Wardoyo

***Abstract*—In a working system, standard time is a parameter to measure or analyze the performance of workers, also used to improve flow process efficiency and determination of production targets. Standard time is obtained by work measurement. Work measurement is the evaluation of the time required to complete a job using the stopwatch and other methods. It enables the organization to promote productivity and measure direct time study. However, there are several challenges associated with its implementation such as the continuous analysis of workers from start to finish by an observer. This leads to the inability of the observer to carry out other activities, workers tend to work inadequately under supervision, and limited timeframe. These challenges led to the development of a technology that measures work takes more measurements and produces accurate and real-time cycles without the presence of observers. Therefore, the purpose of this research is to develop a technology with the ability to automatically measure work directly using the vision sensor technology. The designed equipment measures the movement of workers based on color, which is converted into work time, and further processed into standard time using an application program. The results of this study are vision sensor technology, which is an integration of hardware (Pixy CMUcam5 and Arduino Uno Rev 3 components with AT Mega 328P) and application programs (Visual Studio 2015 programming). Furthermore, based on usability testing, the results have shown that parameters were able to function accurately and in real-time, and based on the mean of standard time, it is seen that the difference in measurement of time using technology and stopwatch is only 7.8%.**

***Index Terms*—work measurement, direct time study, vision sensor technology.**

I. Introduction

WORK measurement is a concept that was applied to evaluate and determine the time it takes to complete a job [1]. The working measurement method consists of direct time study, predetermined motion systems, standard data and work samples [1]. This research, therefore, examines work measurement using the direct time study method which was implemented by analyzing the working time, with an output known as “Standard Time” [1].

A conventional direct time study uses a stopwatch as its measurement tool. The stages of the process include the performance of cycle measurement by observing the work progresses and measuring the time required for its completion. This was followed by the continuous measurement of the amount of data. After the collection of cycle time data, it was then processed to generate the standard time. According to research, it takes approximately one day to analyze work which was not influenced by workers or machines unproductivity [2].

The effectiveness of work measurement with a direct time study makes this method popularly used by many cross-field research [3-13]. Although this process produces more benefits, unfortunately, there are some challenges associated with it as follows:

1) Measurement of work with direct time study requires more than one data cycle time, to adjust the amount of data needed, therefore, the observer takes a longer time to collect data. This was shown from the results of interviews with practitioners working in one of the manufacturing companies which stated that the measurement of work with this method takes approximately 3 to 4 hours for 3 days.
2) The observer needs to monitor the worker continuously until the amount of data required was obtained.
3) There is a tendency for people to work improperly when they are supervised and unable to complete their work [2].
4) Matters relating to precision when starting and ending the measurement of time, especially in the movement of short elements with variations possible due to lack of uniformity in starting and ending the measurement of time because the movement was not properly captured by the observer.
5) The non-uniformity of an observer's competence with others over the ability to measure time [2] and [6].

From the above-listed challenges, there is a need to design technology capable of carrying out work measurements using a tool-based direct time study method.

The vision sensor technology is a tool capable of measuring direct working time automatically. It was well developed and widely used in many organizations. The research conducted by [14] utilizes this technique to build equipment capable of separating Lego based on color. Similarly, [15] research utilizing the vision sensor technology in building smart home systems. It was used to detect movements occurring in the observed system [15].

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E.N.S.Y, M.K., Authors are with the Industrial Engineering Department, Faculty of Engineering, Mercu Buana University, Jakarta, Indonesia.
(e-mail: nina.yuliani@mercubuana.ac.id; m.kholil@mercubuana.ac.id).
A.Y.S., Authors is with the Industrial Engineering Department, Gajah Tunggal Polytechnic, Tangerang, Indonesia. (e-mail: hakutamanana@yahoo.com).
A.S.W., Authors is with the Electrical Engineering Department, Gajah Tunggal Polytechnic, Tangerang, Indonesia. (e-mail: adiksusilowardoyo@gmail.com).

Based on the problems described, the purpose of this research, therefore, is to develop a technology capable of carrying out work measurements automatically by utilizing the vision sensor technology. This new technology was designed to measure workers' movement, which was converted into work time and further processed into standard time using an application program.

II. System Design

A. *Defining Functional Parameters of Technology*

Based on the observations and literature studies carried out, the determined functional parameters for the technology to be designed are as follows:

1. It has the ability to measure time repeatedly due to the rigorous collection of data that forms cycles.
2. The technology automatically measures work time in real-time, with low human intervention.
3. It has the ability to measure work time without disrupting workers' concentration and without the presence of an observer.
4. It measures precision in seconds.
5. It works stably and automatically defines when measurements are started and ended.
6. It integrates data collection and processing properly and accurately.

B. *The Stages of Technology Design and Application Program*

Flowchart the stages of technology design and application program are shown in Fig. 1.

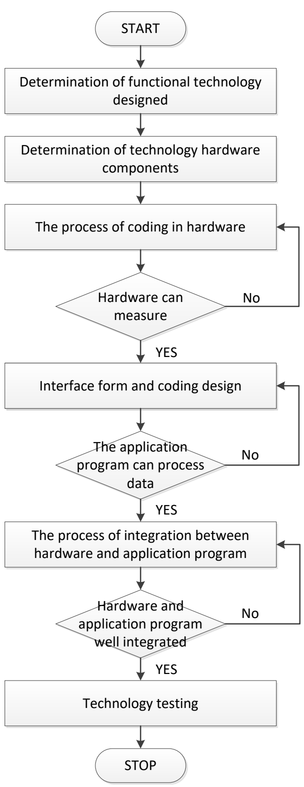


Fig. 1. Flowchart the stages of technology design and application program.

The components used in vision sensor technology are:

1. Pixy CMUcam5 (shown in Fig. 2)
   This is a vision sensor that functions to capture the movements of workers' hands observed through color detection [17]. This was continued to Arduino and translated into coordinates, with lighting used to read movements.

Fig. 2. Pixy CMUcam5.

2. Flash lightning LED camera DSLR studio emergency LD-160 (shown in Fig. 3).
   This instrument has the ability to provide good lighting on Pixy CMUcam5 without interrupting workers' sensation glare.

Fig. 3. Flash lighting LED camera.

3. Logitech C930E series webcams (shown in Fig. 4).
   The Logitech C930E webcam series is equipment used to record workers' hand movements to compare conventional work measurements using a stopwatch and designed equipment.

Fig. 4. Webcam.

4. Arduino Uno Rev 3 with AT Mega 328P [16-18] (shown in Fig. 5).
   Data collected through Pixy CMUcam5 was forwarded to Arduino Uno Rev 3 with AT Mega 328P in the form of coordinates. These coordinates are processed by the software to form a start-ending timer.

Fig. 5. Arduino uno.

5. Laptop (shown in Fig. 6).
   Pixy CMUcam5 - Arduino Uno Rev 3 with AT Mega 328P - Logitech C930E series webcams are integrated with laptop to form a system.

Fig. 6. Laptop.

C. *System Integration Technology*

The block diagram of the system integration technology is shown in Fig. 7.

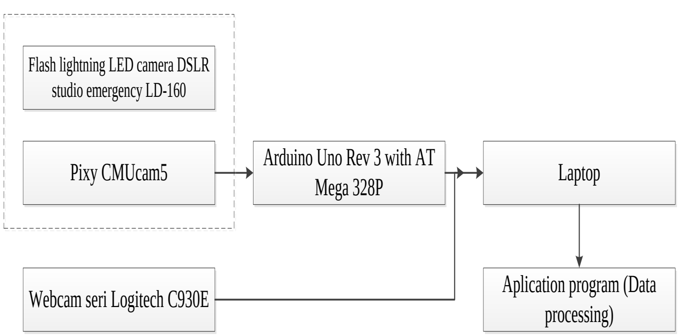


Fig. 7. Flowchart system integration technology.

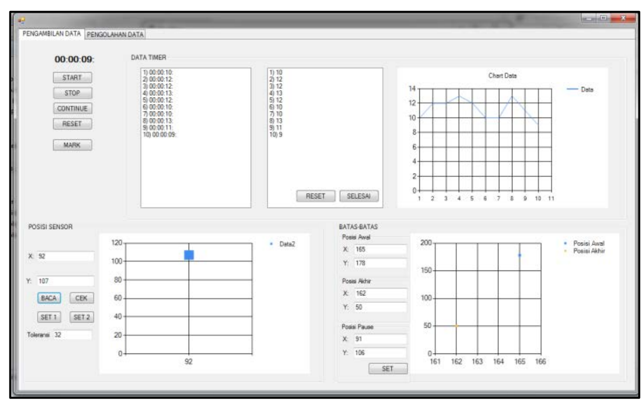
The technology to be designed consists of hardware components involving Pixy CMUcam5 which was integrated with Arduino Uno Rev 3, AT Mega 328P, Logitech C930E series webcams, and application programs using the Visual Studio 2015 programming language. Logitech C930E series webcams are used to record motion videos in the work cycle, while Pixy CMUcam5 detects human movements by sensing colors and produces output in the form of coordinates. Arduino Uno Rev 3 with AT Mega 328P measures and convert coordinates at the start and end of time. The measured cycle time was stored for further processing.

After the hardware component determination stage, the Pixy CMUcam5 and Arduino Uno Rev 3 components with AT Mega 328P are coded to carry out instructions using the Visual Studio 2015 programming language. This was preceded by the initial testing stage to determine whether the hardware components are able to execute the action as instructed. The next stage is the design of application programs used to process the output generated from the technology.

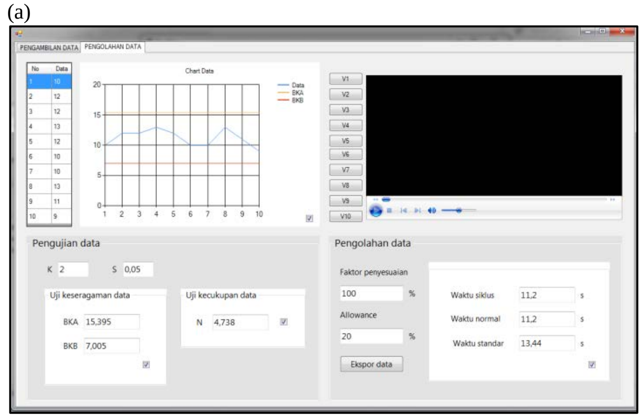
The design phase was conducted in several steps as follows: 1) Testing the uniformity of the data with a control chart, which is built on application programs using a 3-sigma basis. 2) Data within control limits were processed into standard time to follow a standardized formula. The output of the application program was exported into a report in Microsoft Excel format.

The next stage is the process of integration between hardware and application programs. This was carried out to ensure the data was collected and processed uniformly. Therefore, the user tends to immediately obtain output in the form of standard time from the observed work process. After the successful integration of the process, the design phase was completed.

The application program interface was shown in Fig. 8.



(a)



(b)

Fig. 8. Application program interface (a), (b).

The finished product vision sensor technology is shown in Fig. 9.

Fig. 9. Vision sensor technology.

Fig. 10 and 11 shows the assembly set-up of technology.

Fig. 10. Vision sensor technology installed on the table.

Fig. 11. Integrated vision sensor technology with laptop.

III. Results and Discussion

The final stage of the design stage is testing the equipment designed. Equipment testing was carried out in the form of experiments on the work of the equipment designed. Tests carried out with the aim to see the ability of equipment in carrying out its functions. This test will be carried out by simulating the work of sorting and arranging eggs. Measurements were made on the performance of the equipment designed not on the performance of the participants involved in the experiment.

A. *Usability Testing of Technology and Application Program*

Usability testing of the technology was carried out on the performance designed in functionality based on predetermined parameters, as follows:

1. Ability to measure repeatedly
2. Automatic measurement with low human intervention
3. Measurement without the observer's presence
4. The precision of measuring instruments in seconds
5. Automatic definition when starting and ending measurements
6. Integration between data collection and processing
7. The technology produces accurate and real-time data

These parameters are further translated as a technology testing category which includes the following:

1. Determination of start-stop coordinates
   This test was used to measure the defining parameters automatically when starting and ending a measurement.
2. Measurement of time per cycle repeatedly
   It was used to measure the parameters of the ability repeatedly.
3. Time measurement was automatically conducted continuously with the reading of coordinates to measure automatic measurement parameters with low human intervention.
4. Recording time measurement data automatically without the presence of the observer.
5. Transferring collected data to the application program automatically without the presence of an observer.
6. It was also used to process data in application programs.
7. Presenting output in Microsoft Excel format.
   This test was used to measure the parameters of integration between data collection and processing.
8. It also measured the precision parameters of the measuring instrument in units of seconds.

The results of the usability testing technology were shown in Table I.

TABLE I
THE RESULTS OF THE USABILITY TESTING TECHNOLOGY

No	Testing	Success/Failed
1	Determination of start-stop coordinates	Success
2	Measurement of time per cycle repeatedly	Success
3	Automatic time measurement repeatedly with coordinate readings	Success
4	Recording time measurement data automatically	Success
5	Transferring collected data to the application program automatically	Success
6	Data processing in the application program	Success
7	Measured data in seconds	Success
8	Presenting output in Microsoft Excel format	Success

B. *Assessment Performance of Vision Sensor Technology*

Performance evaluation of technology will be done by comparing standard time based on application program technology and stopwatch.

Performance 1: Standard time processed using an application program **has the same value as** a manual calculation.
<u>Standard Time (Application Program)</u>

The results of the observed time, normal time and standard time (application program) were shown in Table II.

TABLE II
OBSERVED TIME, NORMAL TIME, AND STANDARD TIME PROCESSED USING APPLICATION PROGRAM

	DATA (in seconds)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	10	8	8	10	10	16	12	10	10	10
	13	10	11	11	13	13	10	11	14	9
	14	10	9	8	13	14	10	9	13	14
	13	10	10	12	13	13	10	8	11	12
	13	12	12	12	13	13	11	9	12	13
	13	9	11	10	13	13	9	11	14	10
	13	12	14	12	13	13	10	12	12	10
	13	13	10	10	13	13	10	10	13	12
	11	13	8	10	11	12	15	12	13	10
	15	11	9	11	15	13	8	10	13	13
T_{obs}	12.8	10.8	10.2	10.6	12.7	13.3	10.5	10.2	12.5	11.3
T_n	12.8	10.8	10.2	10.6	12.7	13.3	10.5	10.2	12.5	11.3
T_{std}	15.4	13.0	12.2	12.7	15.2	16.0	12.6	12.2	15.0	13.6

Standard Time (Manual Calculation) [1]

Observed Time (T_{obs})

$$T_{obs}=\frac{\sum x_i}{n} \tag{1}$$

$$=\frac{10+13+14+13+13+13+13+13+11+15}{10}=12.8\text{ s}$$

Normal Time (T_n)

PR = Performance Rating = 100%

$$T_n=T_{obs}(PR) \tag{2}$$

$$=12.8\times1=12.8\text{ s}$$

Standard Time (T_{std})

A_{pfd} = Allowance = 20%

$$T_{std}=T_n\left(1+A_{pfd}\right) \tag{3}$$

$$=12.8\times(1+0.20)=15.36\text{ s}$$

The results of the observed time, normal time and standard time (manual calculation) were shown in Table III.

TABLE III
OBSERVED TIME, NORMAL TIME AND STANDARD TIME PROCESSED USING MANUAL CALCULATION

	DATA (in seconds)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	10	8	8	10	10	16	12	10	10	10
	13	10	11	11	13	13	10	11	14	9
	14	10	9	8	13	14	10	9	13	14
	13	10	10	12	13	13	10	8	11	12
	13	12	12	12	13	13	11	9	12	13
	13	9	11	10	13	13	9	11	14	10
	13	12	14	12	13	13	10	12	12	10
	13	13	10	10	13	13	10	10	13	12
	11	13	8	10	11	12	15	12	13	10
	15	11	9	11	15	13	8	10	13	13
T_{obs}	12.8	10.8	10.2	10.6	12.7	13.3	10.5	10.2	12.5	11.3
T_n	12.8	10.8	10.2	10.6	12.7	13.3	10.5	10.2	12.5	11.3
T_{std}	15.4	13.0	12.2	12.7	15.2	16.0	12.6	12.2	15.0	13.6

Performance 2: The standard time processed from data collected through application program technology **has a value that is not much different from** the standard time processed from data collected through a stopwatch.

The results of the observed time, normal time and standard time (collected by technology) were shown in Table IV.

TABLE IV
OBSERVED TIME, NORMAL TIME AND STANDARD TIME PROCESSED USING DATA COLLECTED THROUGH TECHNOLOGY

	DATA (in seconds)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
T_{obs}	12.8	10.8	10.2	10.6	12.7	13.3	10.5	10.2	12.5	11.3
T_n	12.8	10.8	10.2	10.6	12.7	13.3	10.5	10.2	12.5	11.3
T_{std}	15.4	13.0	12.2	12.7	15.2	16.0	12.6	12.2	15.0	13.6
Mean			13.8							
Std. deviation			1.4							

The standard time processed from data collected through technology, the mean is 13.8 seconds and the standard deviation is 1.4 (13.8±1.4).

The results of the observed time, normal time and standard time (collected by stopwatch) were shown in Table V.

TABLE V
OBSERVED TIME, NORMAL TIME AND STANDARD TIME PROCESSED USING DATA COLLECTED THROUGH STOPWATCH

	DATA (in seconds)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
T_{obs}	14.3	13.6	11.5	11.6	13.6	12.1	11.1	12.1	12.4	11.6
T_n	14.3	13.6	11.5	11.6	13.6	12.1	11.1	12.1	12.4	11.6
T_{std}	17.2	16.3	13.8	13.9	16.3	14.5	13.3	14.5	14.9	13.9
Mean			14.9							
Std. deviation			1.3							

The standard time processed from data collected through stopwatch, the mean is 14.9 seconds and the standard deviation is 1.3 (14.9±1.3).

Comparison standard time between technology and stopwatch were shown in Table VI.

TABLE VI
COMPARISON STANDARD TIME BETWEEN TECHNOLOGY AND STOPWATCH

	Technology	**Stopwatch**	**Difference**	
Mean	13.8	14.9	1.	7.8%
Standard Deviation	1.4	1.3	1s	

By comparing the mean of the standard time, it is seen that there is only a difference of 7.8%.

IV. CONCLUSION

The design and development of vision sensor technology were successfully made and tested for usability. The results indicate the designed has been able to perform its functions adequately following the parameters initially defined. However, the following needs to be considered when using the equipment, this equipment is quite sensitive to light, therefore, users need to ensure the color markers used are good, not smooth and shiny to achieve an optimal process. Adjust the position of the sensor reading area to capture all areas of the worker's movement. Ensure there are clear differences between the "start" and "stop" coordinates without overlapping. Ensure the color markers used to analyze the "start-stop" coordinates are in the sensor reading area, to avoid a "pause" condition, which disrupts the equipment while recording.

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Euis Nina Saparina Yuliani is a graduation student with major in Industrial Engineering. She is a lecturer and researcher in field of industrial engineering. She is currently studying about productivity system, ergonomics, product design, occupational health and safety, and interaction human-technology.

Muhammad Kholil is a graduation student with major in Industrial Engineering. He is a lecturer and researcher in field of industrial engineering. He is currently studying about lean and green manufacturing and productivity system.

Ajeng Yeni Setianingrum is a graduation student with major in Industrial Engineering. She is a lecturer and researcher in field of engineering. She is currently studying about productivity system and interaction human-technology.

Adik Susilo Wardoyo is an undergraduate student from Mercu Buana University, located in Jakarta, Indonesia. His major is Electrical Engineering. His field of research is control and automation.