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Determination of Irrigation Water Surface Flow Velocity Using Video Analysis with Tracker Application and Linear Regression

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Abstract: Advances in computer technology and software allow for more practical and accurate measurements. This study aims to measure the velocity of irrigation water surface flow using video analysis with Tracker application and linear regression in Microsoft Excel. Video data was recorded in the irrigation canal of Bendhung Lepen, Yogyakarta, using bamboo leaves as test objects. The analysis process involved tracking the motion of the object in the video and calculating the velocity based on the slope of the displacement versus time graph. The results showed that the velocity of water surface flow was (8.39 ± 0.05) cm/s from Tracker analysis and (8.39 ± 0.04) cm/s from Excel linear regression, with a correlation coefficient of 0.9985 and a coefficient of determination of 0.9971. The method used proves the reliability and efficiency of a technology-based approach to water velocity measurement.
***Keywords**: water surface flow velocity; video analysis; Tracker; linear regression*

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Introduction

Irrigation is one of the important aspects of agriculture that serves to ensure the continuity of water supply to crops. Irrigation is one of the important factors in farming activities in a broad sense. Irrigation is a form of human effort to irrigate agricultural land (Dairi, 2021). The existence of irrigation not only supports plant growth, but also plays a role in maintaining the stability of food production and preventing crop failure due to lack of water supply. Irrigation efficiency can affect agricultural land productivity, especially in the face of climate change challenges that cause erratic rainfall patterns.

The speed of water flow in irrigation canals plays a crucial role in organizing efficient water distribution (Rusmayadi et al., 2023). It determines how quickly water reaches a particular area and ensures that all crops receive an adequate water supply. Water flow velocity management is essential to avoid water wastage, reduce the risk of soil erosion, and minimize the occurrence of excessive waterlogging (Wijayanto et al., 2021). One way to

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monitor and measure surface flow velocity of irrigation water is through the use of technology that enables more accurate and efficient measurement.

Water flow velocity is measured with physical tools such as floats or more complex flow velocity measuring instruments (Bunganaen et al., 2017; Noviandani et al., 2020). This method has been widely used in daily practice by both farmers and hydrologists. However, this method often faces challenges such as the long time and amount of cost involved. In addition, the determination of flow velocity can also be done by experimental methods using sand as an indicator to track water flow (Han et al., 2020).

Advances in computer technology and software allow for more practical and accurate measurements that offer more efficient and accurate solutions. The use of video allows the recording of object information in the form of image pixels, and through modeling the relationship between the visual characteristics of the object and its pixel values, the position of the object can be estimated continuously by the video tracker (Maggio & Cavallaro, 2011). One of the tools that can be used for video tracking is the Tracker application. The Tracker application is a video analysis software that allows users to track the motion of objects in video, measure position, and convert visual data into numerical information useful for physics analysis, including velocity calculations (Claessens, 2017). Tracker also enables the measurement of physical quantities based on video material, processing the received data and comparing it with mathematical models (Chernetckiy et al., 2021). In this context, Tracker can be used to analyze the motion of objects floating on the surface of irrigation water to calculate the velocity of water surface flow. This opens up opportunities to improve irrigation efficiency and ensure even water availability in agricultural areas.

The technology can analyze water flow movement and provide a more efficient alternative to traditional methods (Wu et al., 2019). In addition, the application of video analysis to measure water flow velocity in rivers shows great potential in utilizing this technology in various water management contexts (Chen et al., 2024; Yuan et al., 2024). Linear regression analysis can also be used for magnitude determination and prediction with the correlation coefficient and coefficient of determination showing the relationship between variables and the error rate of the data obtained (Jesiani et al., 2019).

This research offers the novelty of applying video analysis using the Tracker application in the context of measuring irrigation water surface flow velocity. In addition, using linear regression to analyze the data obtained will provide a more in-depth quantitative approach. Therefore, this research aims to develop a new method of determining irrigation water surface flow velocity using video analysis with Tracker application and linear regression approach with Microsoft Excel to provide a deeper understanding of irrigation water surface flow dynamics.

Method

This research was conducted in the irrigation channel of Bendhung Lepen Tourism area located in Giwangan, Umbulharjo, Yogyakarta. Video data was recorded on 7 December 2024 at 07.00 WIB using an iPhone 11 camera placed at a certain height to obtain an optimal viewing angle of the water surface.

Figure 1. Research diagram

Figure 1 shows the diagram of the research conducted. The test object was a bamboo leaf allowed to float on the water surface. The recording process was carried out for 10 seconds.

The resulting video was then analyzed using the Tracker application. The first step was to import the video into the Tracker application, followed by calibration of the coordinate system using a reference object of known size in the video. The movement of the object on the water surface is tracked frame-by-frame to obtain position data as a function of time. The velocity of the object is calculated based on the change in position against time using the analysis feature in the Tracker application.

Linear regression analysis was performed with Microsoft Excel using data from the Tracker application. Linear regression is expressed by

$$y = ax + b \tag{1}$$

where *α* is the slope coefficient of the line that shows the average change in *y* for each change in *x* and *b* is the intercept or the point where the regression line intersects the *y*-axis at *x* = 0. The deviation of the data from the predicted value of the regression is indicated by the standard deviation of the residuals expressed by

$$s_{\hat{y}} = \sqrt{\frac{\Sigma\left(y_i - \hat{y}_i\right)^2}{N-2}} \tag{2}$$

where *y* is the actual observed value (original data), $\hat{y}_i$ is the predicted value (the result of the regression line), *N* is the number of observational data and *N*-2 is the degree of freedom for linear regression (Montgomery et al., 2021).

$$s_a = s_{\hat{y}} \sqrt{\frac{N}{N\Sigma x^2 - (\Sigma x)^2}} \tag{3}$$

Equation 3 calculates the standard deviation of parameter *α* in linear regression with *x* as the independent variable (Montgomery et al., 2021). Velocity is the displacement travelled in an interval of time (Giancoli, 2005).

$$s = vt \tag{4}$$

The research data is in the form of displacement as the *y*-axis and time as the *x*-axis so that the slope parameter represents velocity. The uncertainty of velocity (s_v) depends directly on the standard deviation of the parameter *α* (s_a) so it is expressed by

$$s_v = \sqrt{\left(\frac{\partial v}{\partial a} s_a\right)^2} = \sqrt{\left(s_a\right)^2} = s_a \tag{5}$$

with the velocity value and its uncertainty based on linear regression analysis expressed by $v \pm s_v$.

The strength of the relationship between variables *x* and *y* can be measured using the value of the correlation coefficient. The correlation coefficient (*r*) ranges from $-1 \le r \le 1$. If the correlation coefficient has a value of -1 or 1, it can be said that the relationship between variables is perfect where the events in variable *y* can be explained by variable *x* without any error. The smaller the correlation coefficient value, the greater the error for making predictions (Kurniawan & Yuniarto, 2016). The coefficient of determination (R^2) has a value ranging from

0 to 1. The value must be greater than 0 and less than 1. It cannot be equal to either limit. The closer the value is to 1, the stronger the linear relationship between variables x and y (Kutner et al., 2005). Thus, the method used to explain the effect of the variable has merit (Ndruru et al., 2014).

Results and Discussion

In this study, the measurement of water surface flow velocity was carried out through the integration of video-based motion tracking technology using the Tracker application and with linear regression-assisted mathematical analysis through Microsoft Excel, including slope, intercept, and correlation and determination coefficients, which are indicators of accuracy and reliability in determining water surface flow velocity. Combining these two methods produces precise quantitative data while ensuring the validity of the research results through consistency between the values obtained from each method. This approach demonstrates the reliability of modern technology in improving measurement accuracy and efficiency.

The Tracker application analyze the motion of objects floating on the water surface by recording data on object displacement in centimeters and time in seconds. The analysis results are presented in the form of a motion tracking graph, which provides visual information about the object's displacement pattern over time.

Video of the movement of objects on the water surface was analyzed using the Tracker application. The displacement data obtained is expressed in cm and the time interval is in seconds. Based on the analysis, the results of the motion tracking graph plot on Tracker are shown in Figure 2.

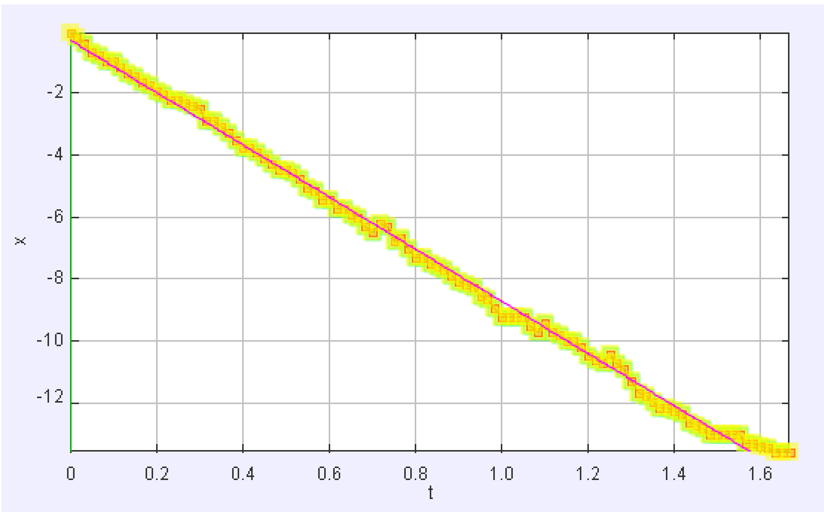

Figure 2. Motion graph of the object in the Tracker application

The analysis results provide an overview of the motion tracking graph with a negative slope. This negative slope occurs because the analyzed video is moving toward the left, which physically indicates a negative velocity vector direction. The results of the calculations performed on the Tracker application are shown in Figure 3.

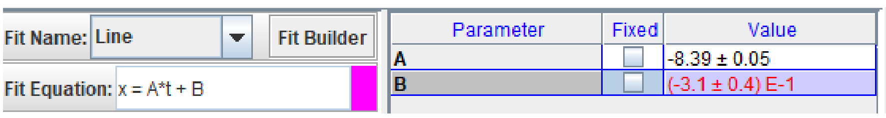

Figure 3. Analysis results in the Tracker application

However, in accordance with the physics convention in this study, the velocity value is still expressed as positive. From the analysis conducted through the Tracker application, the value of parameter A or velocity is obtained as (8.39 ± 0.05) cm/s while the resulting parameter B value is 0.31. These results provide initial confidence that the video tracking method with Tracker can capture motion with good accuracy.

Linear regression analysis conducted using Microsoft Excel software provides results that support and reinforce the findings from the Tracker application. Based on the analysis conducted with Microsoft Excel, the results of the graph plot shown in Figure 4.

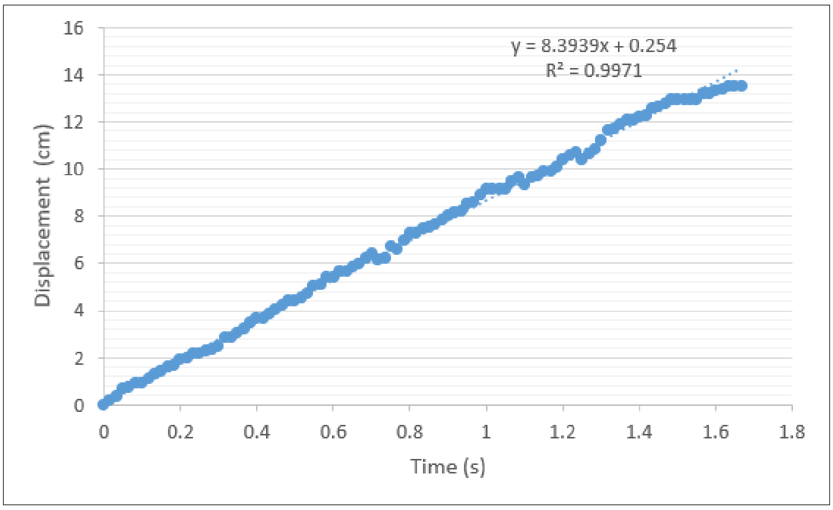

Figure 4. Graph of analysis results in Microsoft Excel

The slope value obtained from Microsoft Excel is 8.3939 and the intercept value is recorded at 0.254. In addition, the results of this analysis also show a correlation coefficient of 0.9985 and a coefficient of determination of 0.9971. Both of these values indicate a very strong relationship between the variables analyzed, as well as a very small error rate. The standard deviation value of the speed used as the uncertainty value shows a value of 0.04. Based on the results of these analyses, the velocity value obtained is (8.39 ± 0.04) cm/s which is consistent with the results from the Tracker application.

The alignment of results between the Tracker application and Microsoft Excel in this study confirms the reliability of the analytical method used. The consistent results between these two tools show that a technology-based approach can produce accurate data in surface water flow velocity analysis. The Tracker application enables high-fidelity video-based motion analysis. In a study by Setiawati & Radiyono (2017), the Tracker application was used to analyze the relationship between terminal velocity and viscosity of a liquid, producing accurate and consistent data. This shows that the Tracker application effectively measures motion parameters in fluids.

In addition, Microsoft Excel has been widely used in data analysis and mathematical modeling. Hidayati & Supardan (2012) utilized Excel to predict fluid flow distribution. This study showed that Excel can be used to model fluid velocity profiles with sufficient accuracy. The application of linear regression in this analysis plays an important role in identifying the relationship between the observed variables. Linear regression allows researchers to model and predict the relationship between independent and dependent variables, thus improving the accuracy and reliability of the analysis results. Research by Ardhi et al. (2023) showed that the linear regression method was used to calibrate water flow sensors and resulted in a significant increase in water flow measurement accuracy.

The integration of the Tracker application, Microsoft Excel, and linear regression analysis provides a comprehensive and effective method for analyzing water surface flow velocity. This approach improves measurement accuracy and simplifies the data analysis process. Thus, making this approach a reliable and efficient solution for hydrodynamics research.

Conclusion

This research successfully developed a practical method to determine the velocity of irrigation water surface flow using video analysis with the Tracker application supported by linear regression analysis with Microsoft Excel. The results showed that the water surface flow velocity was (8.39 ± 0.05) cm/s analyzed with Tracker application and (8.39 ± 0.04) cm/s analyzed with linear regression analysis using Microsoft Excel. These results prove that a technology-based approach can be relied upon to obtain precise results in the measurement of water surface flow velocity.

For future research, it is recommended to be applied in hydrological studies that require efficient and practical measurement of water flow velocity. In addition, this method can be used to test on various river conditions with different flow characteristics. The use of a more sophisticated camera is also recommended to improve the quality of video capture. The obstacle found is the difficulty in taking videos with the appropriate angle.

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