Accuracy Test Use of Technology DSLR Camera and Drone for Bridge Deformation

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***Abstract*— The bridge is a building structure that serves as a means of road transportation to connect one place to another. In general, bridges that have been used need to be monitored to be able to the condition of determining bridge. It should be noted that in observing bridge deformation, accurate acquisition technology is needed. In the field of photogrammetry, currently, there is a technology that can be used for monitoring bridge deformation with non-metric cameras, this is DSLR cameras and drones. The technology used in monitoring deformation has different levels of sensitivity (accuracy) in detecting deformation. In this study, each of these technologies has a different sensitivity level, so it is necessary to test the accuracy of the use of the technology used for studying deformation. The sensitivity level of the technology used is very influential in detecting the smallest possible changes or deformations [12]. The test was carried out by photogrammetric using close-range photogrammetric techniques on technology DSLR cameras and drones. The process of technology accuracy test for bridge deformation uses the bundle adjustment method. Based on the results of the accuracy test using a technology DSLR camera and drones for bridge deformation, the RMSE values generated on DSLR cameras for components X, Y, and Z are 0.056 mm, 0.080 mm, and 0.060 mm, while on drone cameras for components X, Y, and Z are 0.44 mm, 0.43 mm, and 0.24 mm. So it can be concluded that the results of the comparison of the accuracy test use of technology DSLR camera are more accurate than drone technology. The technology non-metric camera, this as DSLRs and drones, can be used for studies on bridge deformation that are capable of producing RMSE values below 1 mm or achieving an accuracy of up to a fraction of a millimeter.**

Keywords—bridge, deformation, drone, DSLR camera, RMSE

I. INTRODUCTION

Bridges that have passed the load test and have been used still have to be monitored continuously for a certain period time to be able to determine the condition of the bridge structure [8]. In addition, other things that can affect the condition of the bridge are natural disasters. One of the consequences of natural disasters is damage to infrastructure in a construction structure. So to minimize this impact, it is necessary to take anticipatory steps, namely monitoring the deformation of the bridge. The technology used in monitoring deformation has different levels of sensitivity (accuracy) in detecting deformation. The sensitivity level of the technology used is very influential in detecting the smallest possible changes or deformations [12]. It should be noted that in observing deformation, accurate data acquisition technology is needed. With the principle of photogrammetry, DSLR cameras can measure objects from various shooting angles easily and quickly without requiring direct contact with the object being measured [7], and with certain software, the coordinate value of the observed deformation target point can be calculated for further analysis. [11. In drone technology, the DJI Phantom 4 Pro also has the advantage of being equipped with a 1" CMOS sensor which can allow the drone to record images in high frequencies and with less noise [3].

Utilization of technology in the field of photogrammetry using DSLR camera technology and the DJI Phantom 4 pro drone which can later be used as a bridge deformation study. The results of this study will be able to produce accuracy tests on DSLR cameras and DJI Phantom 4 pro drones which are an effective and efficient alternative technology for data acquisition for monitoring bridge deformation by obtaining maximum accuracy results below 1 millimeters.

II. METHODS

Bridge deformation is a change that can occur on a bridge in shape, dimensions, and position [9]. The stages of this deformation are shown in Figure 1 [12]. In the figure, there are three stages of deformation as described by [8], namely:

1. Elastic Deformation

   Elastic deformation is the process where the changes occurring in the bridge are not permanent and can return to their original position or shape. This stage occurs when the stress applied to the bridge is less than the strength of the bridge structure.

2. Ductile Deformation

   Ductile deformation is the condition where the elastic limit has been exceeded, resulting in changes to the bridge structure that cannot return to its original shape. This stage occurs when the stress applied to the bridge exceeds the capability and strength of the bridge structure.

3. Fracture

   Fracture is the stage where the elastic limit and ductile deformation have been exceeded. This stage occurs due to the continuous application of stress when the bridge structure is already in the ductile deformation stage, resulting in permanent damage to the bridge structure.

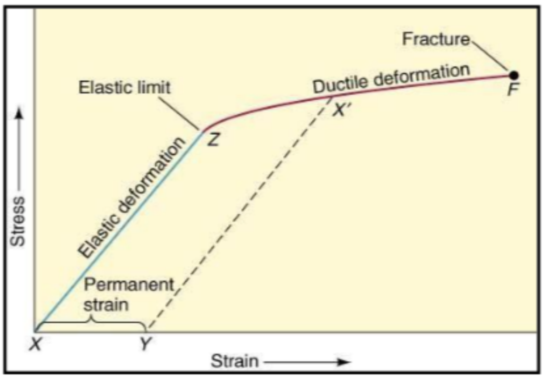


FIGURE 1. DEFORMATION STAGES

In the technique of taking data in close-range photogrammetry, the quality in the process of determining coordinates can be better with the method of taking pictures of objects in a convergent manner to get a more interconnected photo. This technique take has an advantage, especially if the object being observed is difficult to achieve. [6]. The principle of solving near-range photogrammetry is to apply the principle of the equation of collinearity conditions. Collinearity is defined as a condition where the photo shoot point, object point, and photo object are in the same straight line [2].

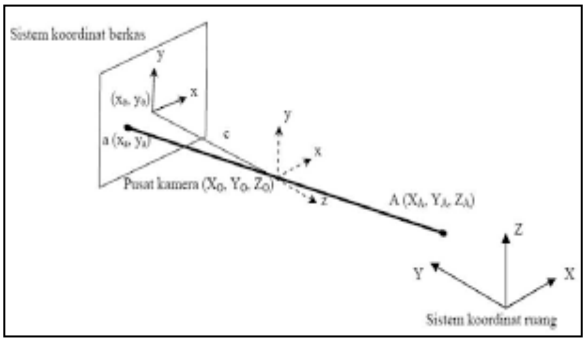


FIGURE 2. COLINIERITY CONDITIONS

Close-range photogrammetry is used when the position of the object being photographed is less than 100 meters (330 feet) and the camera position is close to the object [7]. Close-range photogrammetry techniques are useful in the following conditions: first, when the object to be measured is inaccessible or difficult to access; second, when the object is very small, especially microscopic (very small); third, data acquisition using photography can be done easily and quickly. Also state that close-range photogrammetry can measure objects without direct physical contact with relatively low operational costs [4].

The steps are carried out by making a measurement net taken from target points scattered around the measurement object. Considering that the position of the point above the earth's surface experiences a shift, then all points are assumed to be deformed, so they do not have a stable reference datum (free network adjustment). The monitoring point/target was shot using a DSLR camera and carried out by following the Standard Operating Procedure (SOP) for shooting deformation based on photogrammetric rules. These include the sensitivity (accuracy) of the measurement system and the shooting pattern.

The process of restitution of photogrammetric coordinates, namely the coordinates of a three-dimensional cartesian system (X, Y, Z) on a local datum is the main value generated in the system. The important steps in the process of processing photo data to obtain 3-dimensional coordinates can be seen in Figure 2. The description of the flow chart is explained as follows:

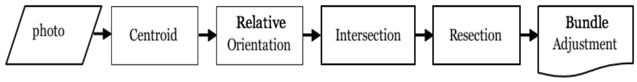


FIGURE 2. The process of restitution of photogrammetric coordinates

The sensitivity (accuracy) of the measurement system is very influential in detecting the minimum amount of deformation. The system accuracy indicator is formulated as follows [5].

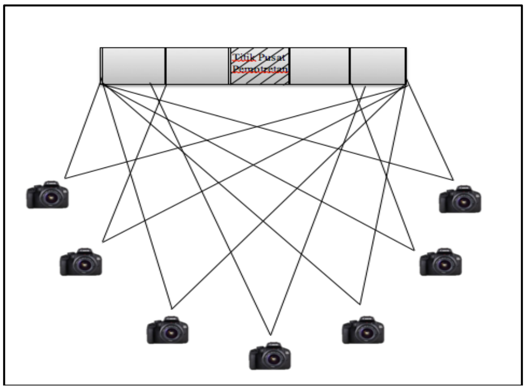
$$\overline{\sigma_c} = \frac{q}{\sqrt{k}} S_\sigma \quad (1)$$

where: c is the accuracy (RMS) of the magnitude of the shift to be observed; S is the shooting scale factor, namely the ratio between the shooting distance and the focal length of the camera at the time of the shooting; k is the number of shots for each camera position; is the accuracy of the photo coordinate measurement for the points whose position will be measured; and q is a constant which is generally 0.7 [5] for convergent shooting patterns.

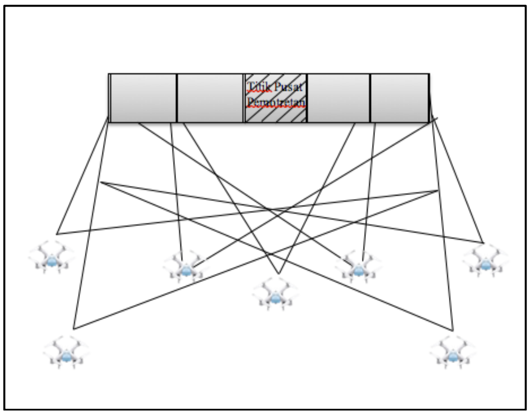
From Equation 1, it can be seen that the smaller the minimum shift observed, the more shots must be taken, the shooting distance must be closer, and the accuracy of the photo coordinate measurement must be as accurate as possible. The shooting pattern converging or converging towards the object being photographed can result in better coordinate accuracy [7].

III. RESULTS AND DISCUSSION

Data collection by measuring aerial photos using DSLR cameras and DJI Phantom 4 Pro drones. Shooting is done with a range of 2 x shooting (epoch) which will be used as a deformation shift test. DSLR technology bridge object shooting, a shooting technique that is carried out convergently with the camera in a horizontal position, then rotated to the left at 90°, and to the right at 90° (roll diversity). An illustration of the image can be seen in Figure 3 (a). DJI Phantom 4 Pro drone bridge object shooting: A convergent shooting technique with the camera in a horizontal position, then rotated at 90° left and at 90° right (roll diversity). An illustration of the image can be seen in Figure 3 (b).



(a)



(b)

FIGURE 3. (A) CONVERGENT SHOOTING TECHNIQUE USING A DSLR CAMERA, (B) CONVERGENT SHOOTING TECHNIQUE USING A DRONE

The data processing uses the close range photogrammetry method and the bundle adjustment method (multi photos). Then test the RMSE value / accuracy on the measurement data on DSLR cameras and drones.

Based on the results of photogrammetric measurements using the close-range photogrammetric method using DSLR camera technology and drones for bridge deformation studies, can be seen in table 1 and table 2. It can be seen in tables 1 and 2, namely, by taking measurements at 315 target points coordinates X, Y, and Z units of millimeters produce standard deviation values of Sx = 0.44 mm, Sy = 0.43 mm, and Sz 0.24 mm. While in table 2 the results of measurements using a DSLR camera by taking measurements at 315 target points of coordinates X, Y, and Z, units of millimeters produce standard deviation values of Sx = 0.056 mm, Sy = 0.080 mm, and Sz 0.060 mm.

TABLE 1. ACCURACY TEST USE OF TECHNOLOGY DRONE FOR BRIDGE DEFORMATION

TABEL KOORDINAT DRONE						
No. Titik	Koordinat			Standar Deviasi		
	X (mm)	Y (mm)	Z (mm)	Sx (mm)	Sy (mm)	Sz (mm)
1	7407,618	-24252,953	550,234	0,307	0,359	0,376
2	7695,346	-24171,421	548,613	0,159	0,225	0,271
3	7994,595	-24090,051	545,689	0,169	0,201	0,196
4	8286,462	-24009,075	542,860	0,228	0,247	0,157
5	8611,695	-23920,035	536,526	0,273	0,235	0,142
……	……	……	……	……	……	……
313	794,140	1582,494	714,635	0,193	0,204	0,118
314	937,438	1583,347	716,271	0,415	0,581	0,211
315	1072,062	1585,704	716,568	0,455	0,608	0,211
RMSE				**0,444**	**0,434**	**0,241**

TABLE 2. ACCURACY TEST USE OF TECHNOLOGY DSLR CAMERA FOR BRIDGE DEFORMATION

TABEL KOORDINAT KAMERA DSLR						
No. Titik	Koordinat			Standar Deviasi		
	X (mm)	Y (mm)	Z (mm)	Sx (mm)	Sy (mm)	Sz (mm)
1	915,528	8557,063	-372,386	0,035	0,062	0,055
2	705,144	8707,452	-407,714	0,035	0,057	0,054
3	488,801	8864,419	-445,917	0,037	0,056	0,053
4	276,507	9016,562	-482,579	0,039	0,054	0,052
5	40,862	9186,327	-526,613	0,042	0,053	0,053
……	……	……	……	……	……	……
313	-424,436	8249,116	874,492	0,05	0,046	0,033
314	-56,122	8053,76	943,631	0,052	0,048	0,035
315	291,097	7873,18	1003,413	0,057	0,061	0,039
RMSE				**0,056**	**0,08**	**0,06**

CONCLUSION

The conclusion of the measurement results using a DSLR camera is that it can produce a value of accuracy and standard of accuracy that is smaller and more accurate than using a drone camera. Both technologies can be used as alternative technology for bridge deformation studies to monitor the shift in the position of the bridge structure to achieving an accuracy of up to a fraction of a millimeter.

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