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Focal Length Lens Effect at Non-Metric Camera for Three-Dimensional Models Result

Nur Alfan Wisnu Hardiatmojo [1]*, Martinus Edwin Tjahjadi[1], Fransisca Dwi Agustina[1]
[1] Institut Teknologi Nasional Malang, Bendungan Sigura-gura Street, Indonesia
*Corresponding author e-mail: nuralfanwisnu@gmail.com

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Abstract

Selections of non-metric cameras can be calculated properly starting from choosing the right camera sensor size and lens focal length to get better results. Differences in the choice of focal length in shooting can affect the resulting photo. The resulting photo may differ from how much of the object is captured and may suffer distortion due to different selections of the focal length. The purpose of this study is to show the magnitude of the effect of focal length variation in making a three-dimensional model based on the comparison of the results of the three-dimensional model visualization, the comparison of the results of geometric accuracy based on the independent checkpoint coordinate data, and the comparison of the distance results between retro targets. The results of this study indicate that a focal length of 70 mm has better results with the formation of the object completely resembling its original object compared to a focal length of 28 mm which is not good at forming a safety pillar on the bridge. The results of the RMSE value based on ICP coordinate data at a focal length of 70 mm are better with a value of 0.083 m compared to a focal length of 28 mm with a large value of 0.123 m. The results of the RMSE value based on the distance between retro targets at a focal length of 70 mm are better with a value of 0.003 m compared to a focal length of 28 mm with a large value of 0.004 m.

Keywords: close-range photogrammetric, focal length, non-metric camera, RMSE, three-dimensional models

1. Introduction

The camera is a very important instrument in the sector of photogrammetry. With a camera at the consumer level that has been many are used for three-dimensional modeling because the camera has a built-in lens called a kit lens. The type of kit lens you get is usually a zoom lens type with a different focal length range from each camera. A kit lens or zoom lens consists of an assembly of various lens elements to allow for a varied focal length range resulting from the lens system (Tjahjadi et al., 2019).

The use of non-metric cameras for three-dimensional modeling can be relied upon by considering the selection of the appropriate focal length. The focal length of the camera lens obtains the field of view or how many objects can be captured in the shot of the image. A short focal length is used when reducing the field of view, while a long focal length is used when zooming on the object for the close-up image (Kim, 2004). The use of a short focal length that produces a wide field of view and a wide depth of field, a short focal length will also give an inward distortion effect or pincushion distortion. While the use of a long focal length will result in a narrow field of view and a narrow depth of field, a long focal length will also give an outward distortion effect or barrel distortion (Dharsito, 2015).

On the side of the rapid improvement of three-dimensional modeling technology in various fields. these technological developments are practice in various methods, including data acquisition technology in the field of photogrammetric measurement. within the implementation of photogrammetric activities, especially in the manufacture of three-dimensional models, close-range photogrammetry methods can be used by utilizing non-metric cameras (Singh et al., 2013). With the accretion use of the non-metric camera for photogrammetric measurement, however, there are appear requirements to more perform measurements i.e. long distances for applications in construction engineering, deformation monitoring, and traffic accident reconstruction and as well as very short distances for applications such as digital documentation and three-dimensional visualization of cultural heritage objects via image-based approaches. Such measurements often require the use of long focal length lenses both to keep the high resolution of spatial and to optimize the precision of the angular measurement (Stamatopoulos & Fraser, 2011).

Close-range photogrammetry is a branch of science from photogrammetry using camera media located on the earth's surface which has provisions based on the distance between the camera and the object up to 300 meters (Wolf, DeWitt & Wilkinson, 2013). Three-dimensional modeling can be seen as a complete process that starts from data acquisition and ends with a three-dimensional virtual model displayed on a computer, three-dimensional and it can explain a more complete and general process for the object reconstruction process (Remondino & El-Hakim, 2006). Reconstruction of a three-dimensional model in an arbitrary coordinate system has the main goal of finding a way to produce a digital model of the object's surface that best matches the original (Tjahjadi, 2017).

This research was conducted to ascertain three-dimensional models quality using non-metric cameras with varying focal lengths to get more effective and efficient results by comparing the minimum and maximum focal lengths i.e. 28mm & 70mm.

2. Methods

2.1 Data

This research used four types of data acquired through field activities. Table 1 shows the details of the acquisition data used in this research.

Table 1. Data Requirement

No	Types of Data	Source
1	Photos with a Focal Length of 28mm	Data acquisition with non-metric camera
2	Photos with a Focal Length of 70mm	Data acquisition with non-metric camera
3	GCP-ICP	Data acquisition with geodetic GNSS
4	Distance Between Retro	Data acquisition with direct distance measurement with roll meter

2.2 Research Location

The research was focused on the results of the three-dimensional modeling bridge using a mirrorless camera with a focal length of 28 mm and 70 mm. Bridge object located in Pandansari Village, Ngantang District, Malang Regency, East Java Province. Geographically, the Selorejo Bridge is located at 7˚52'34,639" LS and 112˚21'16,625" BT. The research location can be seen in Figure 1, and the research object can be seen in Figure 2:

Figure 1. Research Location

Figure 2. Research Object

2.3 Data Photos Acquisition

Data acquisition in this research using the close-range photogrammetric method. Data photos were acquired using a mirrorless camera with full-frame sensor size 24MP resolution and minimum & maximum focal length. Multiple overlapping images taken from different perspectives, from the images produces measurements that can be used to create accurate three-dimensional models of objects (Yakar et al., 201). Determination of the coordinates of the used camera is not be required because the local futures of the object can be generated directly from the images. Photogrammetry techniques allow transforming images data of an object into a three-dimensional model by using pre-known parameters-digital camera (lens focal length, image size, and the number of image pixels and distortion factors) (El-Din Fawzy, 2019) and has other factors affecting the resulting accuracy i.e. the method of transformation into the referencing coordinate system, the amount and identical points distribution, the resolution of digital images, and the stability of the camera (Frastia, 2005).

The photo of the bridge object is taken using a close-range photogrammetry technique, the quality of the coordinate determination process can be improved by aiming at the object convergently from the camera to obtain more even results. With the convergent method or surround the object with a minimum overlap of about 60% of the photo from various sides of the photo and with the distance, conditional height, and camera settings such as iso, aperture, and shutter speed adjusted to the conditions in the field. This method is understood to enhance the measurement accuracy and enabled the maximum overlap between the image and flexible data acquisition. Due to the flexible data acquisition, the overall coverage of the object could be ensured. Another advantage of the convergent image acquisition geometry was the reduced image quantity due to the great overlap between the images (Ruotsala, 2016).

Close-range photogrammetry combines the acquisition of geometry and texture data of an object so that the accuracy in the reconstruction of a building is better. The accuracy in close-range photogrammetry can be influenced by several things, i.e., the base/height ratio, the number of photos, the number of control points, the number of points measured in the photo (tie points), ground sampling distance, and internal orientation parameters & external orientation parameters (Harintaka, 2012). To simplify and the increasing of software sophistication for data analysis are factors that have contributed to the improvements in efficiency and effectiveness. Photo processing is required to use artificial targets that are likely to be circular retro-reflective targets. Inconsiderate of the type of target, the aim is automatically to detect, recognize, identify and measure the point of interest (Shortis & Seager, 2014).

2.4 Data GCP-ICP and Distance Between Retro Acquisition

For high-accuracy data of the three-dimensional model requires measurements Ground Control Point (GCP) coordinates and for evaluation of three-dimensional model requires measurements Independent Check Point (ICP) coordinate & measurement of the distance between retro targets. The measurements of GCP and ICP was used a geodetic system to acquire with high accuracy. In the entire research object area, there are 4 GCPs and 19 ICPs with a pre-mark system. The measurement of the distance between retro targets was carried out directly on the retro that was placed at the bridge, the measurements of the distance between retro targets using a rolling meter measuring instrument were carried out five times and then the average value is calculated so that it can be used as a reference for actual size data in the field. The three-dimensional model was evaluated by comparing the visualization and ratio score Root Mean Square Error (RMSE) results between minimum & maximum focal length.

3. Result and Discussion

3.1 Three-Dimensional Model Visualization

The results of making three-dimensional models using three-dimensional modeling software from photo data obtained through shooting using mirrorless cameras with different focal lengths are two three-dimensional models. Using minimum focal length produces a total of 1983 photos and with maximum focal length produces a total of 3215 photos. The number of photos produced has a very significant difference because the greater the focal length, the narrower the field of view obtained. The following are the results of making a three-dimensional model with minimum and maximum focal length.

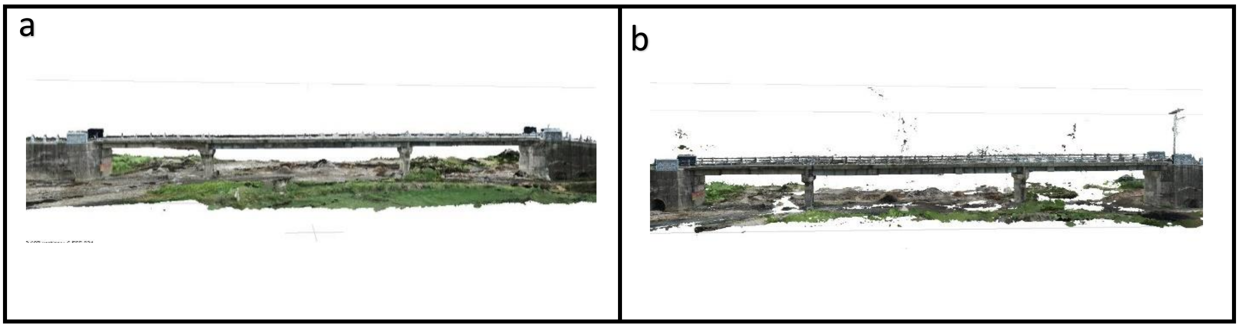

Figure. 3. (a) Overall visualization at minimum focal length and (b) Overall visualization at maximum focal length

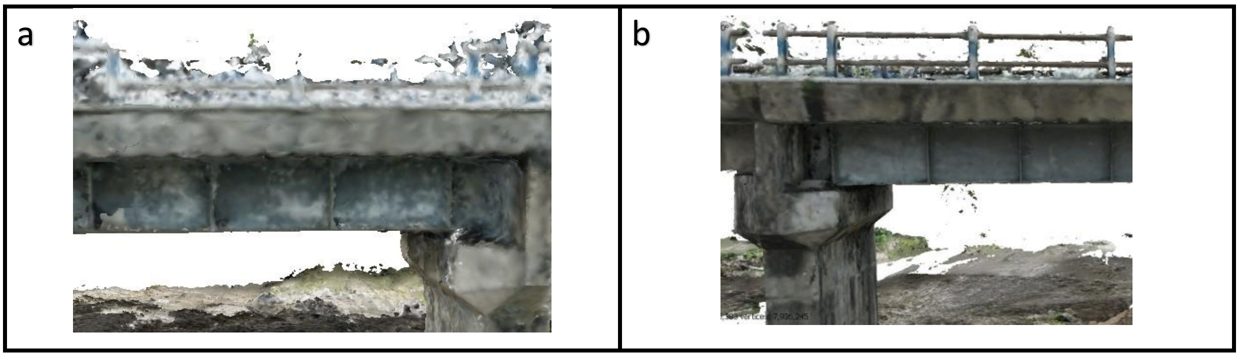

Figure. 4. (a) Side view of the bridge at minimum focal length and (b) Side view of the bridge at maximum focal length

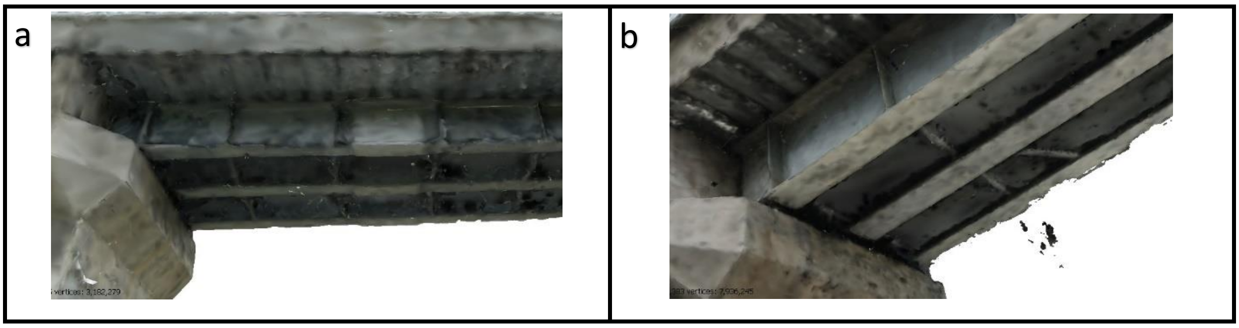

Figure. 5. Underside view of the bridge at minimum focal length and (b) Underside view of the bridge at maximum focal length

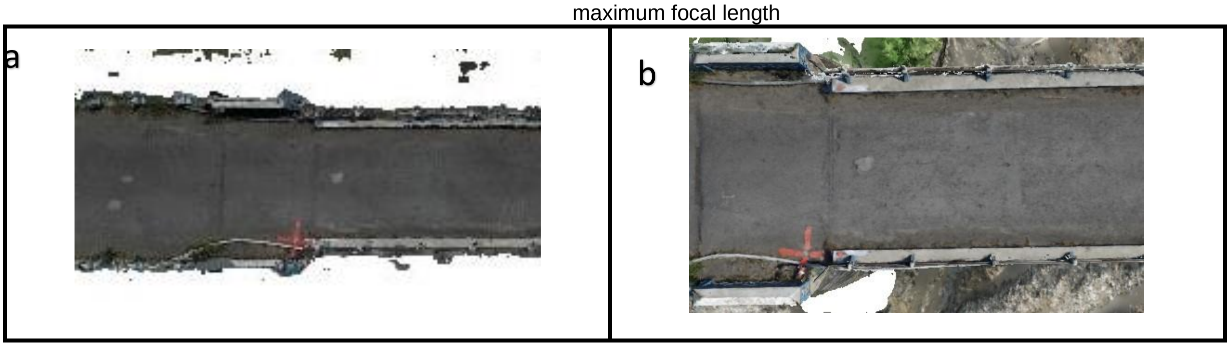

Figure. 6. Top side view of the bridge at minimum focal length and (b) Top side view of the bridge at maximum focal length

Overall, at minimum focal length, the tie points are 1,224,735 points. From the density of the tie points, it produces a visual form of a three-dimensional model that is structurally close to its original object, both from the side, top, and bottom of the bridge, while at maximum focal length, the overall tie points are 2,077,691 points. The density of the tie points, produces a visual form of a three-dimensional structural model that is close to the original object, both from the side, top, and bottom of the bridge. From the results of the three-dimensional model in figure 3, it can be seen that the two focal lengths can produce visualizations that already resemble the original object. At minimum focal length, it also forms other objects around the bridge such as streams, grass, and the surrounding conditions. At maximum focal length, it also forms other objects around the bridge, but the coverage area around the bridge is not as wide as that formed at the minimum focal length.

On the side of the bridge at minimum focal length, precisely on the top pillar of the bridge, the visuals produced are still not good because the pillars still cannot be separated properly and several pillars are not formed so that the pillars on the bridge are not very visible, but for the others such as concrete and the side of the bridge can be formed well (figure 4a). On the side of the bridge at maximum focal length, it can be formed well on all parts of the bridge object, both on the top pillars of the bridge, concrete, and on the side of the bridge, but on the top pillars of the bridge, there is still a little noise (figure 4b).

On the underside of the bridge at both focal lengths, it provides good visualization. At both focal lengths can form the structure of the bottom of the bridge to resemble the original object (figure 5).

On the top side of the bridge at both focal lengths, it is well-formed with a marked road structure that is all formed without any holes. Even though at minimum focal length, it is the same as on the side of the bridge, on the top side of the bridge, precisely on the safety pillar on the bridge, it has not been able to form properly according to the original object (figure 6a). At maximum focal length, the safety pillar on the bridge can be well-formed (figure 6b).

From figure 3 - 6 it can be seen that overall both the minimum and maximum focal lengths, can form a three-dimensional model visually like the original object. At maximum focal length, it can produce a better visualization of three-dimensional models compared to minimum focal length. It can be seen on the sides of the bridge, both north and south, which show quite different visualization results. On the side, the maximum focal length can display the safety pillars on the bridge, so that it can form a three-dimensional model according to the original object, while the minimum focal length is less successful in displaying the safety pillars on the bridge because in some parts of the bridge the safety pillars are less able to be formed. At the top and underside of the bridge, both focal lengths can produce an equally good visualization of the three-dimensional model.

The difference in the results of the visualization of the three-dimensional model can occur due to the difference in the field of view of the resulting photo. At minimum focal length, it has a wider field of view which causes the resulting photo not only to bridge objects but many other objects that enter into the resulting photo frame. At maximum focal length which has a narrower field of view, it produces a better visualization of the three-dimensional model because fewer other objects enter the resulting photo frame so that there is less noise in the photo.

3.2 RMSE Accuracy Based on ICP

Independent Check Point (ICP) in figure 7 is used to determine the accuracy of the geometry based on the RMSE values in the results of making a three-dimensional model based on direct measurements in the field using the Global Navigate Satellite System (GNSS). The RMSE value is obtained by comparing the ICP coordinates based on the calculation of the coordinate data in the field with the ICP coordinates in the three-dimensional model. The following tables show the results of calculating the RMSE value based on ICP coordinate data:

Figure 7. ICP Point Spread

Table 2. RMSE ICP Results at Minimum Focal Length

ICP	dx (m)	dy (m)	dx^2 (m)	dy^2 (m)	(dx^2 + dy^2)
ICP J1	0.012	-0.083	0.015	0.684	0.699
ICP J2	0.006	0.028	0.004	0.077	0.080
ICP J3	-0.076	-0.115	0.581	1.313	1.894
ICP J4	0.030	-0.026	0.088	0.066	0.153
ICP J5	0.014	-0.005	0.019	0.003	0.021
	:	:	:	:	
	:	:	:	:	
	:	:	:	:	
ICP J16	-0.008	0.093	0.001	0.863	0.863
ICP J17	-0.022	-0.048	0.050	0.230	0.280
ICP J18	0.166	0.003	2.767	0.001	2.768
ICP J20	0.062	0.030	0.390	0.088	0.477
		Total			27.24 m
		RMSE Score			0.123 m

Table 3. RMSE ICP Results at Maximum Focal Length

ICP	dx (m)	dy (m)	dx^2	dy^2	$(dx^2 + dy^2)$
ICP J1	-0.013	-0.096	0.018	0.930	0.948
ICP J2	-0.003	0.034	0.001	0.114	0.115
ICP J3	-0.007	-0.014	0.005	0.019	0.024
ICP J4	0.034	0.030	0.114	0.089	0.203
ICP J5	0.005	-0.001	0.002	0.0001	0.002
	:	:	:	:	
	:	:	:	:	
	:	:	:	:	
ICP J16	-0.007	-0.116	0.005	1.352	1.357
ICP J17	0.022	0.014	0.050	0.021	0.071
ICP J18	-0.003	-0.009	0.001	0.008	0.010
ICP J20	0.054	-0.003	0.291	0.001	0.292
		Total			1.246 m
		RMSE Score			0.083 m

Based on Tables 2 and 3, it can be seen that the three-dimensional model by taking photos using a minimum focal length has a geometric accuracy based on the RMSE value of 0.123 m, while the maximum focal length has a geometric accuracy of 0.083 m. From the table above, it is also known that the results of making a three-dimensional model by taking photos using maximum focal length are better than taking photos using minimum focal length based on the RMSE value of the ICP data. The difference in the accuracy of the two focal lengths is not that far apart, which is 0.040 m.

3.3 RMSE Accuracy Based on Distance Between Retro

The distance between retro targets is used to determine the RMSE values in the results of making a three-dimensional model based on direct distance measurements between retro targets using a rolling meter. The RMSE values are obtained by comparing the distance between retro which is measured directly in the field with the result of the distance between retro on the results of a three-dimensional model. The following tables show the results of calculating the RMSE values from the distance between retro targets:

Table 4. RMSE Retro Target Results at Minimum Focal Length

No	Retro	Distance Measurement (m)		Deviation
		Field Object	Model 3D	
1	1 to 2	0.754	0.752	0.002
2	1 to 3	0.759	0.758	0.001
3	2 to 4	0.749	0.754	-0.005
4	5 to 6	0.300	0.305	-0.005
5	5 to 7	0.590	0.592	-0.002
6	6 to 8	0.273	0.271	0.002
		RMSE Score		0.004

Table 5. RMSE Retro Target Results at Maximum Focal Length

No	Retro	Distance Measurement (m) Field Object	Distance Measurement (m) Model 3D	Deviation
1	1 to 2	0.754	0.753	0.001
2	1 to 3	0.759	0.757	0.002
3	2 to 4	0.745	0.750	-0.005
4	5 to 6	0.300	0.301	-0.001
5	5 to 7	0.590	0.593	-0.003
6	6 to 8	0.273	0.274	-0.001
		RMSE Score		0.003

Based on Tables 4 and 5, it can be seen that the three-dimensional model by taking photos using minimum focal length has a geometric accuracy based on the RMSE value of 0.004 m, while the maximum focal length has a geometric accuracy of 0.003 m. From the table above, it is also known that the results of making a three-dimensional model by taking photos using maximum focal length are better than taking photos using minimum focal length based on the RMSE value of the retro distance data. The difference in the accuracy of the two focal lengths is not that far apart, which is 0.001 m.

4. Conclusion

Based on the results of visualization, RMSE calculation based on ICP coordinates, and RMSE calculation based on the distance between retro targets, it can be seen that the use of the maximum focal length produces a better three-dimensional model. With the visualization results that are fully formed, including the safety pillars at the top of the bridge, which can be well-formed because it has a photo with a narrower field of view so that the pillar object can be focused properly which can produce a complete three-dimensional model that resembles the original object. The RMSE value based on ICP coordinate data, the maximum focal length also has a better RMSE value than the minimum focal length. At the RMSE value based on the distance between retro targets, the maximum focal length also has a better RMSE value than the minimum focal length.

The selection of the use of focal length when taking photos for the manufacture of three-dimensional models is quite influential on the results obtained. Based on the results of making a three-dimensional model using both focal lengths, the results of a three-dimensional model using maximum focal length have better results. These results can be seen from the visualization of a three-dimensional model that is more like the original object seen from the formation of a safety pillar on the bridge, the value of RMSE on ICP get a smaller result, and the value of RMSE on the distance between retro targets get smaller result too.

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