DATA ACQUISITION TECHNIQUES ON EXISTING HISTORICAL BUILDING BASED ON BUILDING INFORMATION MODELING (BIM) USING CLOSE-RANGE METHOD IN BALI

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ABSTRACT: The need for space is getting higher due to the increasing population growth thus it can expand its construction and the need for space for tourism which is functioned as a guest house and restaurant. Penglipuran Bali traditional village is designated as a tourism village that has historical buildings hence the transfer of functions of these needs is inevitable. In addition, currently, the need for BIM modeling and inventory digital data to provide designs (as-built drawings) for existing historic buildings requires a laser scanning device. It is very expensive and the process is rather long. 3D modeling of historic buildings requires precise data acquisition and processing to be of good quality. BIM can be created from laser scanning results or in the form of a point cloud. The next method offered uses a close-range method with a Digital Single-Lens Reflex (DSLR) that is integrated with an Unmanned Aerial Vehicle (Drone) in forming a 3D model. Every DSLR stand with Tripod has at least 9 photos with different heights and the sides are shifted about 20-25 cm to get 60% coverage. This method uses the concept of normal and convergent (15°) photos. The results of the point cloud integration of historical buildings can be used as a reference in BIM modeling with the addition of local wisdom semantic information and can also be used as a new method of data acquisition to implement 3D Cadastre in Indonesia while maintaining quality and low cost. Data acquisition has an RMSE of less than one centimeter (<1cm).

1. INTRODUCTION

1.1 Background

Increased population growth and tourism will require higher space and modern buildings and shift functions to tourist spaces such as guest-house, restaurants, and souvenir shops. It happened in the traditional village of Penglipuran. Penglipuran traditional village maintains a spatial layout based on tri hita karana, divided into three zones (Utama, Madya, Nista) called tri mandala and its ancestral assets, which are used as culture and indigenous knowledge (Suhari, 2020; Kasuma and Suprijanto, 2012). However, because of the need for space thus significant changes occur in the Madya and Nista zone. For information on the Utama zone, which contains objects that are purified or believed to be human relations with God, human relations occur in the Madya zone, and the Nista zone is for human connections with nature (Suhari, 2019; Kasuma and Suprijanto, 2012).

Traditional buildings that must exist in Penglipuran village are paon, sekenam, loji, and sanggah. It requires digital data to store images according to dimensions and scale to be used to reconstruct existing or damaged traditional buildings. A technological approach that can provide pictures and information related to measurements, scale, legal, customary law, and others is Building Information Modeling (BIM) (Suhari, 2020). BIM is a process for managing products and information to be provided to stakeholders (Hull and Ewart, 2020). In short, a model in 2D and 3D by providing information that is by need. To create Heritages BIM, it needs 3D laser scanning data (scan to BIM) to get points cloud is required (Baik et al., 2013; Baik, 2019). BIM can provide information on coordinates and customary laws so that conservation and reconstruction can be carried out (Arayici, 2008; Pocobelli et al., 2018; Logothestis et al., 2015).

The problem arises when the equipment to create a 3D model or scan to BIM is very expensive in buying and renting it. The approach in data acquisition is to use close-range photogrammetry and structure from motion methods to maintain excellent and accurate accuracy. Only with a DSLR camera, drone, and software to process the results of the photoshoot, the results of which will be in the form of a point cloud. It can be inexpensive and still maintain its accuracy with additional methods discussed in the next section. The modeling results are obtained with 6 mm or below 1 cm. using cheap equipment and fixed accuracy, it cannot use it for acceleration needs.

2. METHODS AND MATERIALS

2.1 Geodetic Control Networks Surveying

The measurement of the geodetic control network is needed to confirm the control point information that it will use for reference. Observations of these measurements are carried out at night from 8 pm to 11 pm (3 hours), the aim is to avoid crowds so as not to reduce the accuracy of the GNSS, and more and more satellites are received at night within 3 hours. Static and net methods are used to tie the points in the Penglipuran traditional village. Accuracy data received is 0.3 mm. Figure 1 explains the concept related to data collection with GNSS.

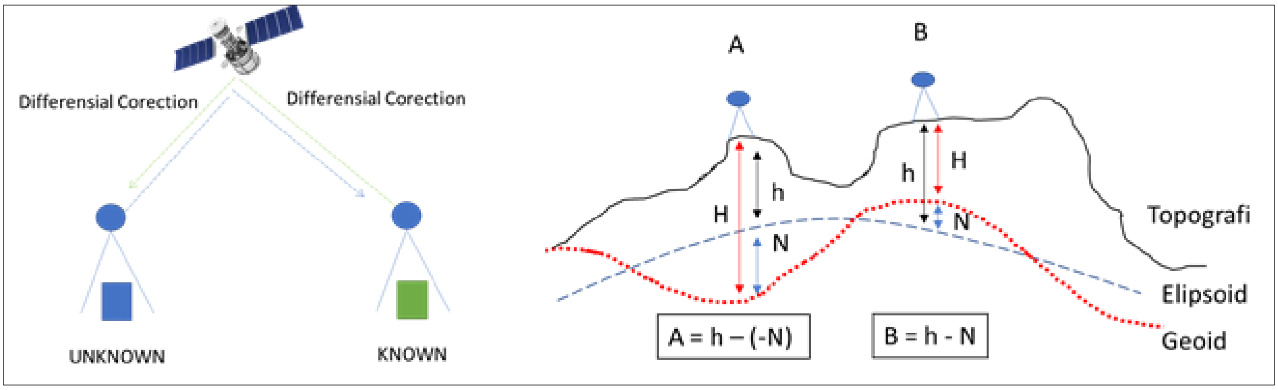


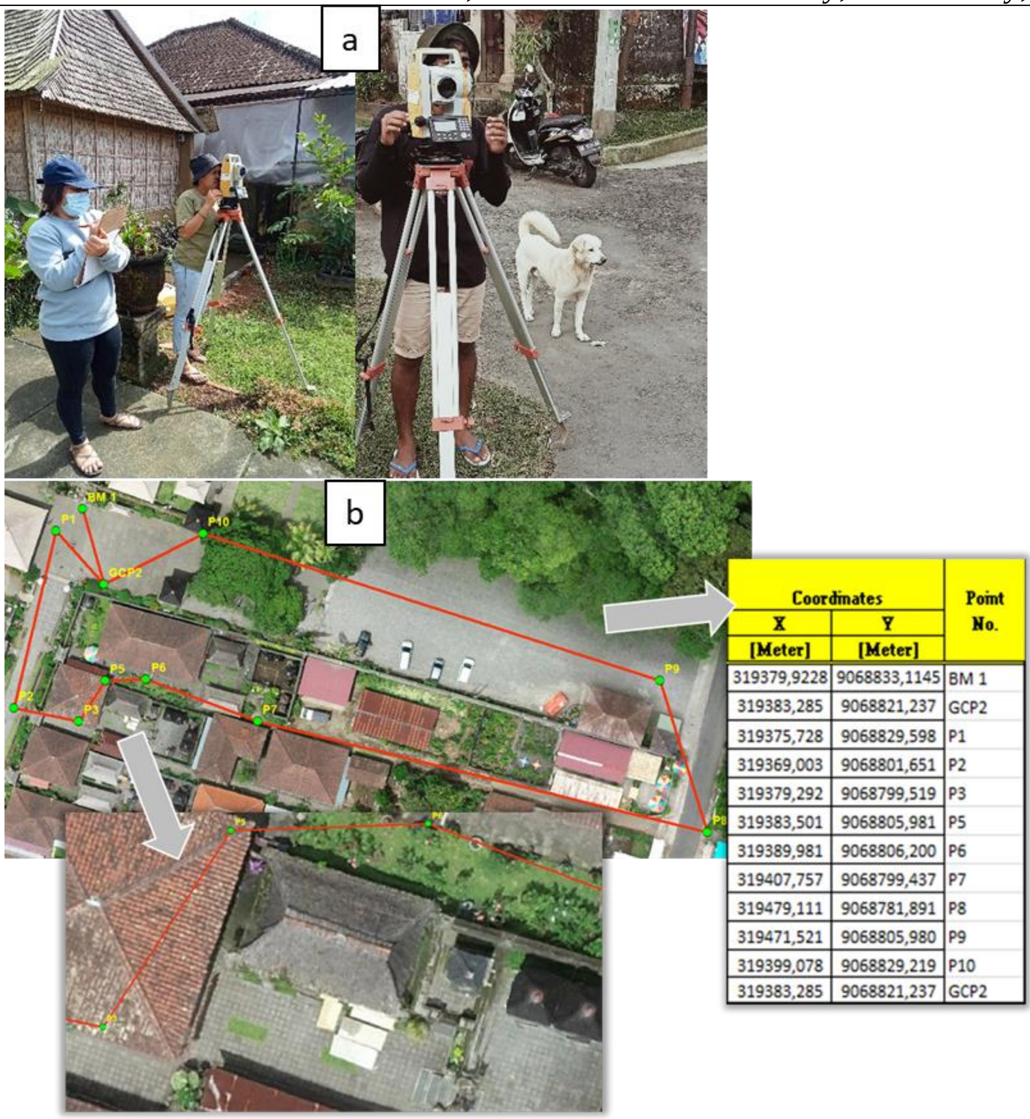
Figure 1. GNSS Correction, to get control point data, the height is corrected with geoid and get the orthometric height. (Author’s construction)

This situation in Penglipuran Village in carrying out GNSS observations, it carried out during the covid pandemic. Our team carried out GNSS measurements to create control points later as georeferences for 3D modeling with very high health protection. Figure 2 shows the installation of stakes in Penglipuran village.

Figure 2. Installation of stakes or control points and GNSS observations using the GNSS (Author’s documentation)

2.2 Horizontal and Vertical Control Framework

Measurement of the horizontal control network uses measuring equipment such as a total station with a perfectly closed traverse method. In contrast, the vertical control network uses a waterpass device or leveling with a double stand method to provide a height correction. In Figure 3, (a) shows the documentation of measurements made when taking horizontal measurements and (b) the results of correction and plotting of coordinates on a map that has been presented with data from drones or orthophotos.



Coordinates		Point No.
X [Meter]	Y [Meter]	
319379,9228	9068833,1145	BM 1
319383,285	9068821,237	GCP2
319375,728	9068829,598	P1
319369,003	9068801,651	P2
319379,292	9068799,519	P3
319383,501	9068805,981	P5
319389,981	9068806,200	P6
319407,757	9068799,437	P7
319479,111	9068781,891	P8
319471,521	9068805,980	P9
319399,078	9068829,219	P10
319383,285	9068821,237	GCP2

Figure 3. (a) Horizontal measurement documentation, (b) processing and plotting results

2.3 Structure from Motion (SFM) with Close Range Photogrammetry

Structure from Motion is a method for creating 3D models by overlapping and rotating objects. The structure of the motion photogrammetry (SfM) provides a hyper-three-dimensional scale (3D) landform model using overlapping images obtained from different perspectives with standard compact cameras (including smartphone cameras) and geographic reference information (Elter and Sofia, 2020). Low-cost photogrammetric method for high-resolution topographic reconstruction, ideally suited for research and low-budget applications in remote areas (Westoby et al., 2012). Using SFM can resolve the 3-D structures from a series of overlapping offset images (Figure 4).

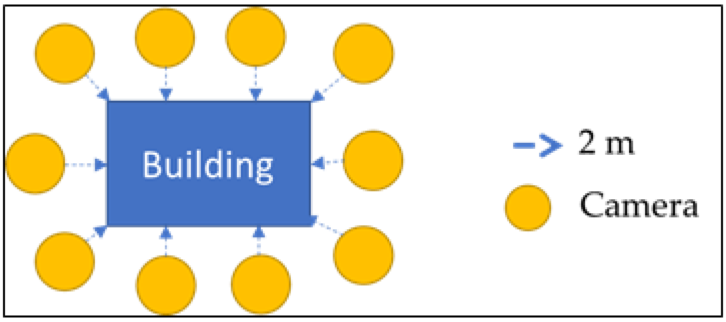


Figure 4. Structure from motion and close-range photogrammetry (Authors construction)

Close-range photogrammetry, mostly entirely digital, has become an accepted, powerful, and readily available technique for engineers and scientists who wish to utilize images to make accurate 3-D measurements of complex objects (Luhman et al., 2006). The CRP method uses standard and convergent techniques. Each standing with a tripod will produce nine images because every movement from top to bottom or conversely, there will be normal and convergent shooting from 15o-45o, with an approximate overlap of 60% of the body or tripod. At the same time, the technique for sideways shifting is about 20-25 cm from the width of the human body or surveyor, which is usually 40-50 cm in size (body from Asia). Figure 5 explains (a) the overlapping method and (b) the side-lap.

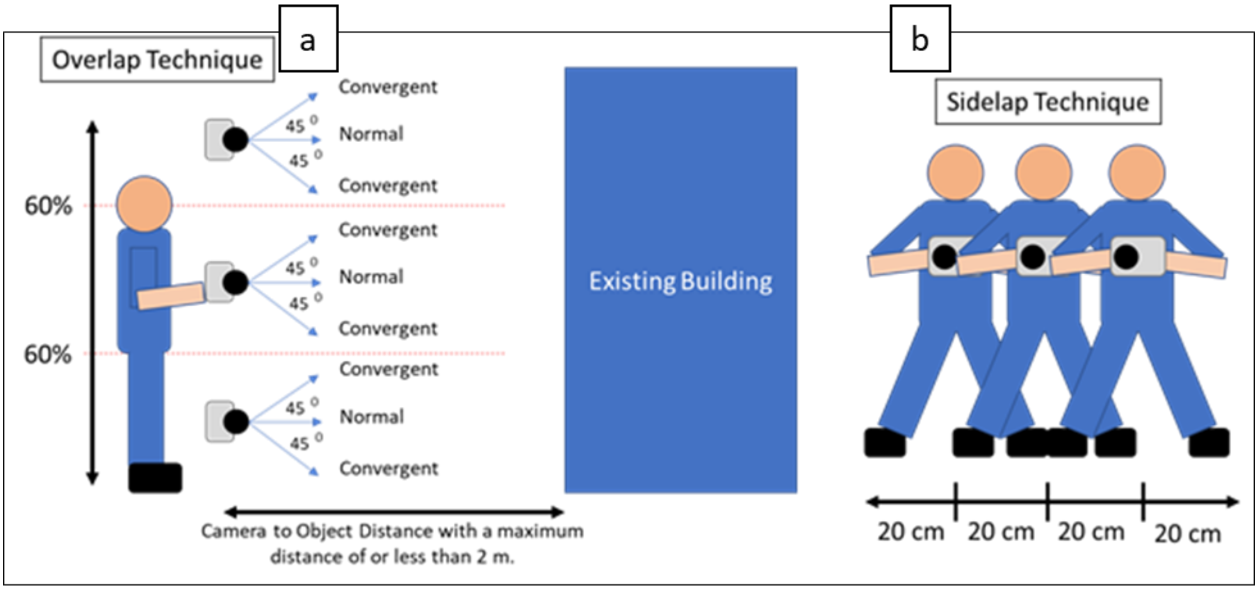


Figure 5. (a) An overlapping data acquisition technique by standing once nine images uses the standard and convergent method. At the same time, (b) is a side-lap data acquisition technique, where the shift is to the left or right, taking into account the distance.

3. RESULTS AND DISCUSSIONS

3.1 SFM and CRP for Existing Building

By adopting the structure from the motion method and close-range photogrammetry and adding the method discussed in section 2, and we call it SFM-CRP9, it can form 3D models with more accurate accuracy. Figure 6 shows the historical building modeling concept using the SFM-CRP9 method.

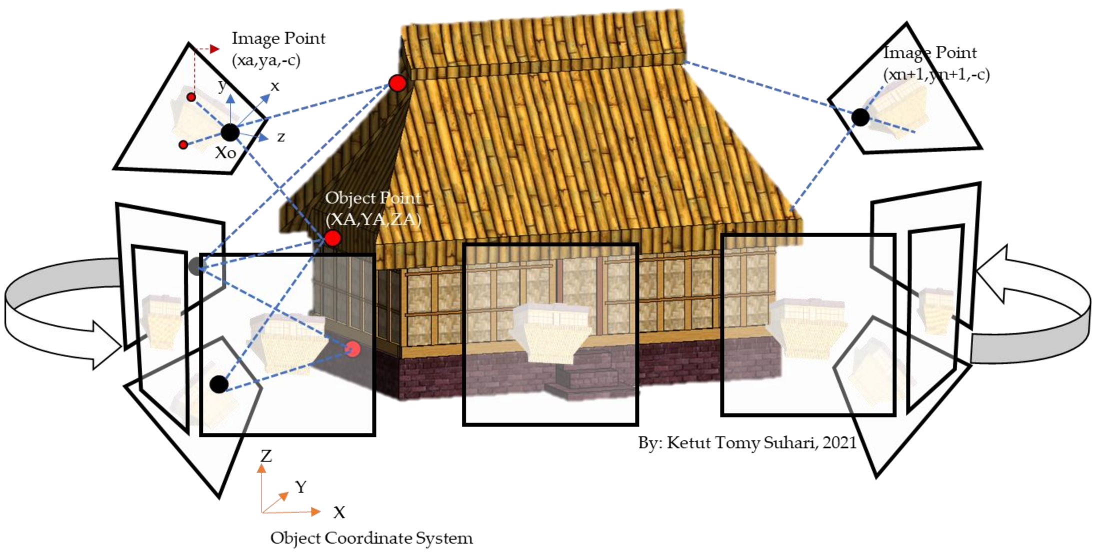


Figure 6. 3D modeling of historical buildings called Paon buildings in Penglipuran traditional village.

The results of photos taken on historic buildings such as paon, there are 841 images as table 1 below. One installation requires a lot of pictures to get the best results. In Figure 7, it missed nearly no information. The model was perfectly formed; however has not yet modeled the interior due to time constraints in processing, thus taking time for further research to settle attention to this.

Table 1. Information from the photoshoot of the historical building of Paon

Number of images	841
Flying altitude	2.22 m
Ground resolution	0.512 mm/pix
Coverage area	25 m²
Camera stations	841
Tie points	322,221
Projections	1,279,708
Reprojection error	3.03 pix

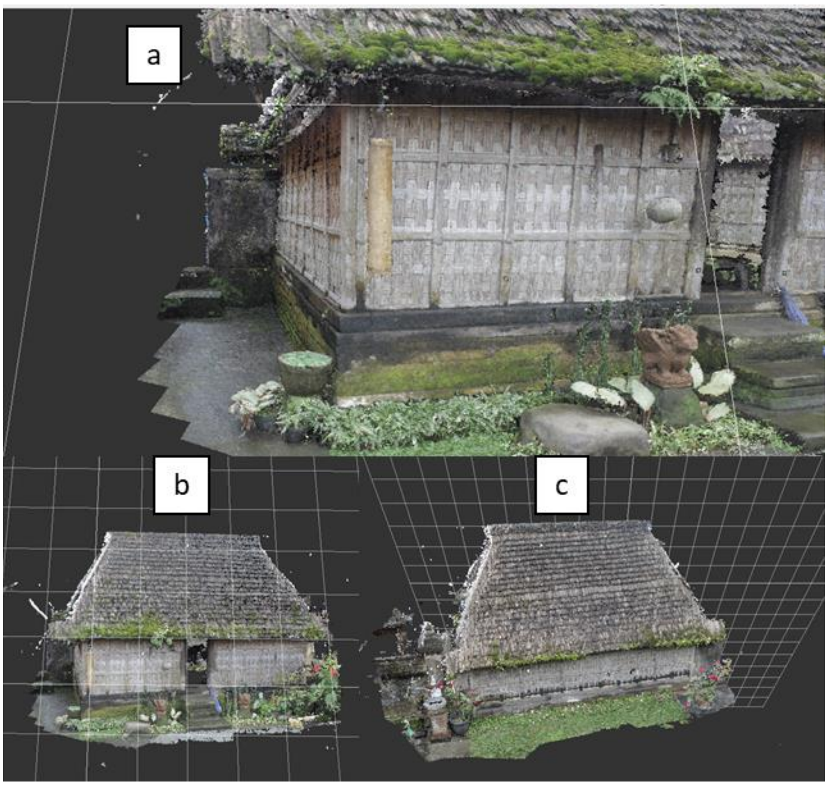


Figure 7. Point-cloud results using the SFM-CRP9 method, (a) front side view; (b) front view; (c) rear view of Paon building

3.2 Distance Validation

The results of the 3D model formed from the SFM-CRP9 method, validation is needed to trust the level of accuracy. However, the validation test is carried out only using the distance dimension. The distance in the field is obtained from the total station device. The following is the control point obtained from the total station measurement. The coordinates are entered at the retro point in the model formed by the Agisoft software (Figure 8) and modeled in Revit (Figure 9). The validation distance is 6.8 mm, as shown in table 2.

Figure 8. Provides fixed coordinate information to retro points

Table 2. Information on the accuracy of distance data in the field using the model

Label	Distance (m)		Eror (m)
	Model	Ground	
R1_R2	0.886719	0.891	-0.0042814
R1_R3	2.27461	2.285	-0.010389
R3_R5	0.655487	0.664	-0.0085134
R9_R10	0.961173	0.968	-0.00682734
R15_R16	0.678013	0.679	-0.000987384
R17_R18	0.613073	0.619	-0.00592708
Total			**0.00684905**

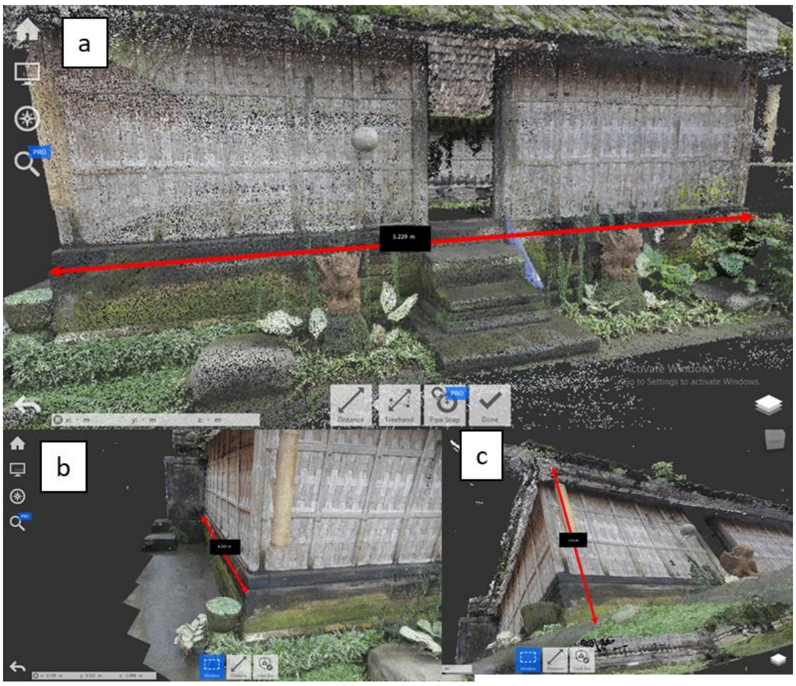


Figure 9. Point cloud results related to distance modeled in Revit software..

3.3 BIM constructions

The results of the data obtained can make the model an as-built drawing because, from these results, there are tiny errors in building construction and very accurate. In Figure 10, the effects of the depiction of DSLR data combined with Drone data are modeled into a BIM model. Making the model has LOD 3 information because it is modeled by the presence of a door and the shape of the roof. Implementing BIM requires industry foundation classes (IFC) language to interpret BIM (Figure 11). The aim is to facilitate work between professions such as geodesy, architecture, civil, and others. Discussing BIM further will be made in the following paper.

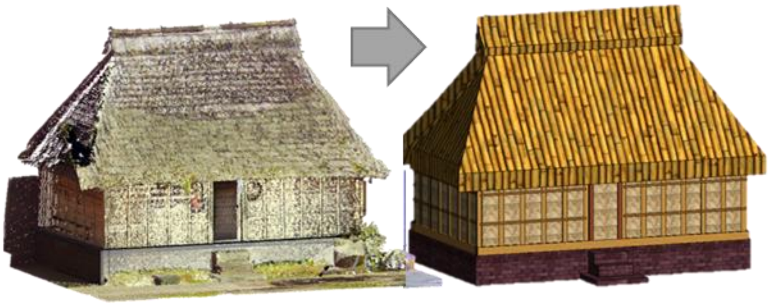


Figure 10. Scan to BIM (as built drawing)

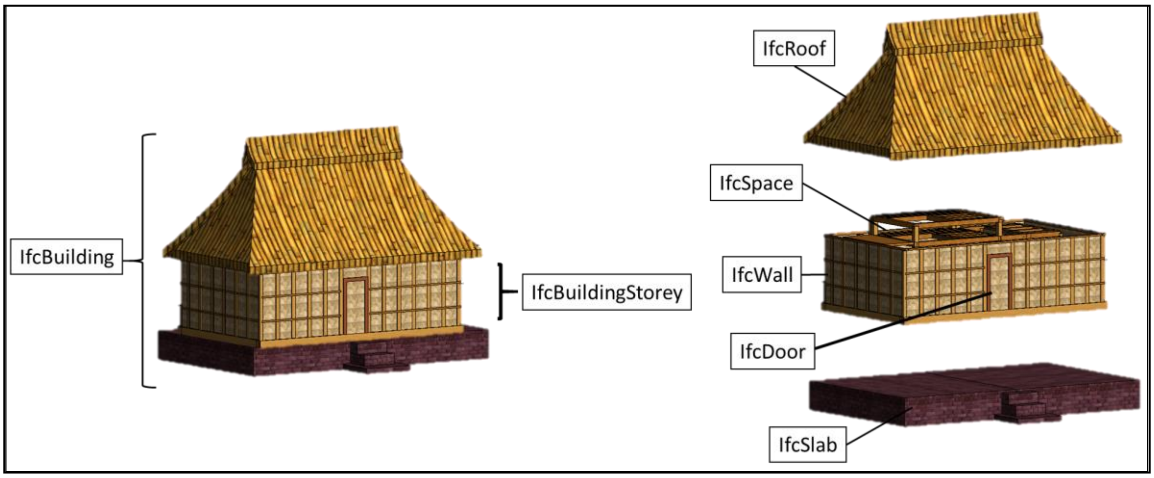


Figure 11. IFC for BIM

4. CONCLUSION AND FUTURE WORK

4.1 Conclusion

It uses technology for data acquisition and pre-existing methods, namely the SFM and CRP methods, to model objects in 3D. It requires overlapping images to obtain accurate data. We get nine photos in one stand by adopting some of these methods and adding them (SFM-CRP9). The goal is to model existing buildings accurately and conserve historical buildings to make it easier to reconstruct them someday. This method is very cheap to implement because it only uses digital cameras such as DSLRs and drones, unlike terrestrial laser scanning (TLS), but using this inexpensive method cannot speed up work. By applying this method, it can minimize errors and get an accuracy below 1cm. This new data acquisition method is part of acquisition data for implementing 3D Cadastre in Indonesia while maintaining quality and low cost.

4.2 Future work

For further research, the results of these points cloud are accurately used as a reference for making Heritages BIM property by parametric and can show and develop the algorithm.

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