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ARCHITECTURAL PHOTOGRAMMETRY: A LOW-COST IMAGE ACQUISITION METHOD IN DOCUMENTING BUILT ENVIRONMENT

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ABSTRACT: Architectural photogrammetry, as a digital survey method requires photographic images produced by using a precision camera. This method, particularly the close-range photogrammetry, has been more effectively used than other techniques such as laser scanning. This paper aims to show that the close-range photogrammetry is a practical way and low-cost image acquisition in architectural projects. By applying a sequential two-step process method, capturing images in the field and using photogrammetry software has conducted to generate from the point cloud to the architectural model. This model shows a high level of accuracy detail from a part of the *Sewu Temple* Indonesia, where this research has conducted. Thus, this research concludes that using architectural photogrammetry is to obtain accuracy detail of architecture object in complex nature and as a low cost and effective methods.

Keywords: Architectural Photogrammetry, Photographic Image, Acquisition, Software

1. INTRODUCTION

Photogrammetry is known as a digital image processing method in orthoimages and image mosaics. Photogrammetry has mostly used in the field of archaeology [1]. However, today's photogrammetry has widely recognized as an alternative low-cost solution in image processing [2] compared to the laser scanning method [3]. Photogrammetry has applied in various disciplines [4] such as geoscience [5], structural engineering [6], zooarchaeology [7], heritage documentation [8] [9], archaeology [10], buildings inspection [11] and architectural representation [12].

There are groups of kinds in photogrammetry. One of them is known as close-range photogrammetry (CRP). The CRP has adopted from the aerial photogrammetry. This adaptation has aimed to fit with a specific field such as architecture [13]. The adoption of this CRP gives a new possibility in the digital image processing by using less equipment. At least, CRP requires a camera, personal computer and scale bar to obtain a 3D image [14]. The application of CRP in architecture is a non-intrusive technique in documenting and producing a 3D model. Conventionally, the documenting and 3D image have collected from 2D technics such as sketch and mechanical drawing following up to vector and massing software.

In contrast, the photogrammetry sequentially generates serial images to points cloud that can conduct in fast and accurate detail of the 3D object. As digitally formed, a virtual model of CRP represents existing built forms and possibly used to design and reconstruct the built form. Therefore, photogrammetry becomes an effective tool and a low-cost method [15]. Photogrammetry is not to change an architect's role, but a means in helping to present the architecture [16].

2. THEORETICAL BACKGROUND

Photogrammetry has developed in various ways and technologies. Architectural photogrammetry can generate a 3D model by a combination of methods, namely laser-scanning, aerial photogrammetry, close-range photogrammetry, computer modelling, traditional lines drawings, and physical model building [17]. In particular, in the image acquisition process, architectural photogrammetry can also combine different cameras or lenses by taking at least two rays of satisfactory intersection angle of images (Fig. 1) [18] with various devices such as DSLR and the Unmanned Aerial Vehicle (UAV) [19].

Using photogrammetry will push forward and expand architectural methods in the documenting-built environment. As a digital form of technology, the photogrammetry offers more flexibility to manage images and essential measurement for architectural analysis and documentation methodologies [20]. The photogrammetry can generate a geometric of a precise model and architectural representation in limited time [21] and makes the process of survey short, free of danger and mistakes [22] [23]. The photogrammetry also opens to develop and combine with other BIM software [24]. Therefore, the architectural photogrammetry is not going to replace conventional method in image acquisition. Instead, it helps architect in their works and the cheapest, practical and suitable technique for the 3D digitization and documentation.

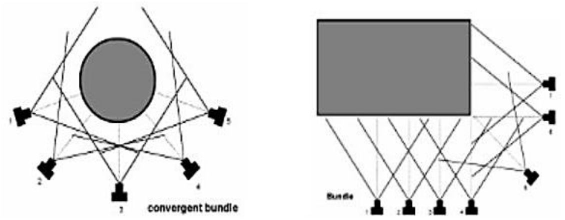

Fig. 1 The configuration of the camera for image acquisition

3. RESEARCH METHODOLOGY

The method in photogrammetry has organized in sequential steps. In this paper, close-range photogrammetry has conducted in a two-step process. The first step is capturing photographic images from various angles by using a DSLR camera and drone. This step is called the fieldwork phase applied to collect quality and geometric information of the images such as position, size, contrast, filtering and shape. This first step has much more relied on the skill of the person who has operated the devices [18].

The second step is to arranged the images by applying photogrammetry software to generate dense cloud and texture data. The software is automatically interpreting the semantic information of the image [25]. This computational phase is sequentially run in the software's workflow to obtain 3D images at the end of the process.

The architectural site of this research was on the *Sewu Temple* in Central Java, Indonesia. It has focused on one of the hundreds of stupas. It has used a Canon DSLR D-60 with an EF 50 mm f/1.4 USM lens with a tripod in acquisition images. The UAV used was a DJI Phantom 4 quadcopter drone equipped with a camera 35 mm lens. In the cloud images processes, this research has used an Agisoft Metashape Professional 64-bit software. A comparison of the device has also used Leica RTC360 3D Laser Scanner with a tripod to produce a similar result.

4. RESULT AND DISCUSSION

The field operator must understand several technical parameters. The most basic setting is multi-image restitution of a block of overlapping images and collinearity equations [26]. The block images must be arranged in between 60% to 80% overlaid on each image. This block means that the degree of overlapping is correlating to effects on detail obtained. In this research, the overlap is not only applied on the block images, but also between the blocks. It means that two-block images are generated horizontally and vertically in direction using two devices; DSLR camera and drone (Fig. 2).


Fig. 2 The overlapping of the block images by Using DSLR and Drone

Another fundamental parameter is image distortion that is caused by reasons such as operator position, lenses-used, amount of light, the angel of the device, and assistive devices (Fig. 3). Therefore, in practical ways, the number of technical images captured are significant not only to reduce the distortion [27] [28] but also to contribute to generating the density of the points cloud [29].


Fig. 3 Acquiring Overlapped Images Using DSLR Camera

As using a metric device, DSLR camera with metric attributes is an ideal tool to produce technical images. However, it is necessary to set lenses-used to ensure consistency of the focal length. Therefore, the metric camera calibration [30] [31] needs to control while collecting images. In practical ways, using prime lenses or fixed lenses can avoid this control.

Slightly different on a drone, as having a non-metrical camera, it is necessary to use a drone with a high-quality camera to ensure the image quality produced [24]. A drone is a useful device to acquire fast and accurate images that cannot be captured on certain positions by DSLR camera such as at a high-level place, large area, delicate angels [32] [33]. In practical ways, besides numbers and overlapping images, it is also necessary for a drone operator to have a proper flight plan in avoiding an images overabundance (Fig. 4).

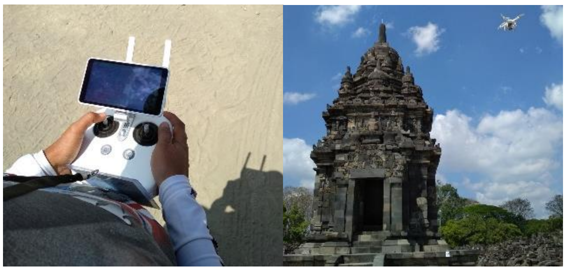

Fig. 4 Using Drone's Camera in Acquiring Image Mosaics

All images that cameras have acquired then are generated by photogrammetry software. There are several alternatives software which can process the image. The software is available for commercial and open-source options based on computer skills and requirements [34].

This generating process is following the workflow. The workflow starts with aligning images. In this first phase, the interface software shows a position and orientation of images and builds a sparse a point cloud model. From here, this earliest model displays two groups of arranged images on the main windows, and sources images on the bottom pane (Fig. 5).

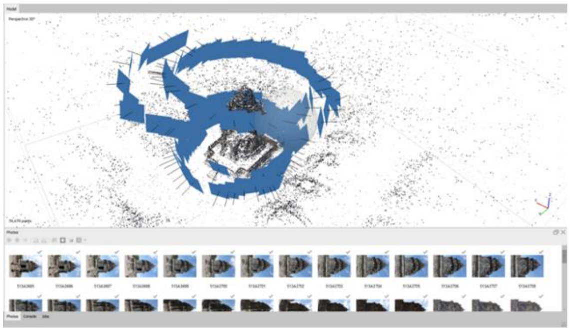

Fig. 5 Aligning Images in Photogrammetry Software

The next phases are sequentially building dense point cloud and building mesh (3D polygonal model) (Fig. 6).

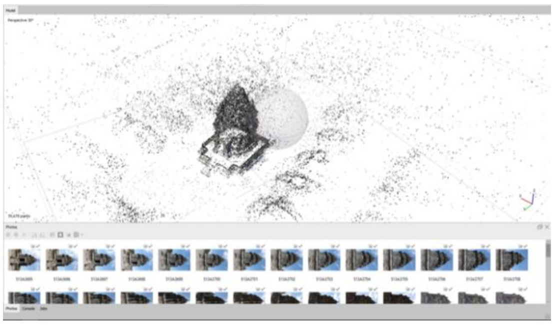

Fig. 6 Generating a Point Cloud Model

The process has continued to build texture, build a tiled model, build a digital elevation model (DEM), and build ortho-mosaic (Fig. 7).

In every phase, the photogrammetry software shows the preferences dialogue command before continuing the processing, giving a chance to correct or adjust during the process. The last phase in the photogrammetry software is exporting the result and making the 3D model available to other software such as BIM platform [35] [36] [37].

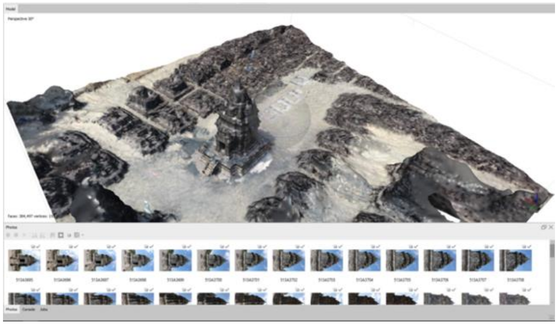

Fig. 7 Creating the Ortho-mosaic Images

From the whole process, this close-range photogrammetry (CRP) shows more advantageous than conventional methods (Fig. 8). CRP can be conducted in limited time to obtain a 3D model [22] [38]. The photogrammetry process can also be accurately recovered regardless of the size of the object [39].

Fig. 8 The Result of Point Cloud 3D Model

As a comparison of the result, this research has also used a laser scanner device on the same research object (Fig. 9 left). The laser scanner can produce a significant volume of points cloud (Fig. 9 right) and generates very great detail in fast and precision both on an object and large area [19]. For this reason, the laser scanner still the best device in documenting field data until today. However, as a part of its advantage, this device's price is still high, and for maintaining and routines, calibration makes laser scanner less practical and economical. Therefore, it is necessary to provide a low-cost alternative method and practice using close-range photogrammetry.

Fig. 9 Using Laser Scanner Device (left) and Point Cloud Model (right)

5. CONCLUSION

The close-range photogrammetry (CRP) overs architecture efficiency in the time process and gave alternative and valuable method in obtaining a complete exterior of an architectural model. From this paper, a combination of DSLR camera, drone and the photogrammetry software shows the 3D architectural model produced can be generated from a natural setting into a high technical accuracy detail.

However, due to less familiarity with the software workflow, the photogrammetry becomes less used in the practice of obtaining information in architectural objects. The software also requires mastery of more advanced software to process further architectural models that have produced to be compatible with other fields.

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