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Digital Photogrammetry: It's role in Nation Building

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Abstract – ***The advent of technology has reawakening digital Photogrammetry since it a well-established techniques for acquiring dense 3D geometric information for real-world objects (phenomena) from stereoscopic image overlap and it has been shown to have extensive applications in a variety of fields. The aim of this work is to maps Faculty of Education, University of Lagos from four digital images acquired or captured by Trimble UX5 Aerial imaging Rover. The captured images were uploaded into Photomodeler UAS 2018 (Trial version) for processing using Multi-View Stereo (MVS) approach, thus produced dense 3D geometric information and textured to create a 3D model for the project site. The quality obtained from this research shows an average of 82% Photos coverage, minimum and maximum point marking residuals are 0.092 and 2.475 pixels respectively, minimum and maximum of point marking RMS residuals are 0.084 (pt292) and 2.208 pixels (pt384) respectively with an overall point marking RMS residuals of 0.825 pixels and minimum and maximum of point precisions in X, Y, Z are 0.00143m, 0.00139m, 0.00325m and 0.0226m, 0.0239m, 0.0162mrespectively with an overall RMS point precisions of 0.0185m were obtained. Also, minimum and maximum vector length of 0.00749m and 0.0329m respectively. The Digital image matching (DIM) software used in work, provide a wealth of additional details, which could not be managed easily using traditional digital photogrammetry. The Surveyors or Engineers can leveraged digital photogrammetry to produce initial survey and regular updates, to process the images into accurate 3D mesh models to facilitates decision-making or provide as-built documentation.***

Keywords: **CRP, Digital image, DIM, MVS, Point Clouds**

1. Introduction

Digital photogrammetry by UAV indeed opens various, new applications in the close-range aerial domain and introduces also a low-cost alternatives to the classical manned aerial photogrammetry (Colomina et al., 2008; Eisenbeiss, 2009). This development can be explained by the spreading of low-cost platforms combined with amateur or SRL digital cameras and GNSS/INS systems, necessary to navigate the UAV with high precision to the predefined acquisition points. The small size and the reduced pay-load of some UAV platforms limit the transportation of high quality IMU devices like those coupled to airborne cameras or LiDAR sensors used for mapping.

Digital image is a numeric representation, normally binary (0,1), of a two-dimensional image and it may be of vector or raster type (Wikipedia, 2018). Digital images is a very useful data set that can be obtained from aerial surveys, unmanned aerial vehicles (UAVs or drones), as well as ground-based mobile and static image capture using a variety of camera types, ranging from GoPro through to purpose-built air survey camera systems (Taylor, 2017) . Photogrammetry is the science, art, and technology of obtaining reliable information from photographs or images. Due to availability of digital camera today, Digital photogrammetry technique can be apply in various fields. This is simply a well-established technique for acquiring dense 3D geometric information for real-wold objects from stereoscopic digital image overlap and this can be classify into Aerial photogrammetry (AP) and Close-Range photogrammetry (CRP) (Geospatial Modeling & Visualization (GMV), 2018). The former is refers to the collection and processing of digital image captured from an aerial or orbital vehicle while the latter is refers to the collection of digital images or photographs from the ground or some lesser distance than traditional aerial photogrammetry (GMV, 2018). It is therefore becoming increasingly popular and accessible due to new, easy to use photogrammetry software and digital cameras. As a matter of facts, non-metric, off-the-shelf digital cameras can be used along with relatively cheap, or in some cases free, open-source photogrammetry software, to extract and process highly accurate and detailed 3D models of real-world objects or phenomena.

The algorithms use to extract and process highly accurate and detailed 3D models is term Digital Image matching. This technique according to Taylor (2017) did not arrive like a bolt from blue but has been around in the photogrammetric world for over two decades. It has been refined to generate photo meshes out of 3D point cloud. Therefore, it is now possible to produce 3D mesh models, point cloud data, digital surface models (DSMs) and true ortho images as data products (Taylor, 2017). Photogrammetric processing relies on identifiable features to be matched across sequences of digital images or multiples images.

2. Conceptual Framewok

UAV platforms are nowadays a valuable source of digital data for inspection, surveillance, mapping and 3D modelling issues. So, the research is anchored on digital photogrammetry which is describe as a well-established technique for acquiring dense 3D geometric information for real-wold objects or phenomena from stereoscopic digital image overlap captured by digital cameras on air or terrestrial platform. There are two main categories of digital photogrammetry and these are AP and CRP (GMV, 2018). The former is refers to the collection and processing of digital image captured from an aerial or orbital vehicle while the latter is refers to the collection of digital images or photographs from the ground or some lesser distance than traditional aerial photogrammetry (GMV, 2018).

This technique is used to process either Low altitude captured digital imagery (UAV, Kite, and Pole), Close-Range captured image (Terestial Digital cameras) or scan digital image (Historic Aerial Photogrammetry) and the processed data set are then use in extracting, building and exporting 3D surfaces and features. These processes are made possible as result of relatively cheap, or in some cases free, open-source photogrammetry software, to extract and process highly accurate and detailed 3D models of real-world objects or phenomena such as PhotoScan Pro, PhotoScan, PhotoModeler, Pix4D Mapper, among others. The work flow for digital photogrammetry is in figure 1.1.

Basically, Photogrammetric processing relies on identifiable features to be matched across sequences of images or multiples images to generate point clouds. A point cloud is a set of data points in some coordinate system. Simply, it is a collection of data points defined by a given coordinated system (Haughn Matthew, 2018 (whatIs.com)). Point clouds are used to create 3D meshes and other models used in 3D modelling for various fields including medical imaging, architecture, 3D printing, manufacturing, 3D gaming, and various virtual reality (VR) applications. According to Lemmens (2018), point clouds are soaring as the dominant source of geodata for creating 3D maps of cities, roads or other sites. Since the demand for detailed and up-to-date 3D maps is growing exponentially, point clouds are increasingly acquired using a variety of sensors. The major methods used are digital photogrammetry, exploiting dense image matching techniques, and various laser scanning platforms (Lemmens, 2018). Therefore, creating 3D maps from point clouds manually is time-consuming and costly and the objects that can be extracted from a mobile laser scanner point cloud significantly differ from those in a point cloud acquired from images recorded by a camera on board a UAS, for example. The type of point cloud, type of scene and use case dictate the classification method (Lemmens, 2018).

Airborne Lidar and photogrammetry are both viable methods for capturing point clouds for 3D modelling of man-made hard structures. Although both methods produce point clouds, the manner of capturing data differs in many ways, resulting in point clouds with differing characteristics (Schwind, 2018).

In addition, the wide availability of this data also triggered the revival of elevation data collection based on image matching. This trend is currently supported by the development of improved software tools which for example extend traditional stereo- to multi-image matching. According to Remondino et al. (2014), matching can be defined as the establishment of correspondences between various datasets (for example, images, maps and 3D shapes). In particular, image matching is concerned with the establishment of correspondences between two or more images (Schenk, 1999). In computer vision, image matching is often called the stereo correspondences problem (Szeliski, 2011; Sonka et al., 2014). Image matching requires the establishment of correspondences between primitives extracted from two or more images, along with the determination of the 3D coordinates of matched feature points via a collinearity or projective model. In image space, this process produces a depth map that assigns relative depths to each pixel of an image (Remondino et al., 2014). Thus,the corresponding outcome in object space is the 3D point cloud. For historical reasons, photogrammetric developments in the field of image matching were mainly related to aerial images and topographic mapping problems. The earliest matching algorithms were developed in the photogrammetry community in the 1950s (Hobrough, 1959; Williams, 1959). In the 1970s, the concepts of epipolar geometry and cross-correlation for image matching were introduced (Helava, 1978). With the advent of digital imaging, research was focused more on automated procedures to both replace manual operator intervention and achieve more powerful matching performance for single points (F€orstner, 1982; Ackermann, 1984; Gruen, 1985). In Gruen (1985) and Gruen and Baltsavias (1988), the multiphoto geometrical constraints (MPGC) concept was introduced. Subsequently, the matching procedure was also generalised to object space through the introduction of the concept of the "groundel" or "surfel" (Wrobel, 1987; Ebner and Heipke, 1988; Helava, 1988).

The aim of multi-view stereo is to reconstruct a complete 3D object model from a collection of images taken from known camera viewpoints and over the last few years, a number of high-quality algorithms have been developed and this technology is improving rapidly. So, Remondino et al. (2014), gave a critical review of four dense image-matching algorithms, available as open-source and commercial software, for the generation of dense point clouds and there are SURE, MicMac, PMVS, and PhotoScan.

3. Methodology

The flight and data acquisition is planned in the lab with dedicated software, starting from the area of interest (Faculty of Education, University of Lagos), the required ground sample distance (GSD) or footprint, and knowing the intrinsic parameters of the mounted digital camera. Thus fixing the image scale and camera focal length, the flying height is derived. Thereby, camera perspective centers ('waypoints') are computed fixing the longitudinal and transversal overlap of strips, while the presence of GNSS/INS onboard is usually exploited to guide the image acquisition. After which the Trimble UX5 was flown to acquire digital images in the Area of interest (Faculty of Education, University of Lagos) and four images from the acquired images were uploaded into PhotoModeler UAS 2018 for processing.

Therefore, Camera calibration and image orientation are two fundamental prerequisites for any metric reconstruction from digital images which are achieved by separating both tasks in two different steps as it is in PhotoModel UAS 2018. These tasks require the extraction of common features visible in as many images as possible and aerial digital photogrammetry is accomplished by exploiting automatic aerial triangulation (AAT) techniques. Procedures for the automated extraction of a consistent and redundant sets of tie points from markerless close-range (or UAV) images were carried in PhotoModeler.

Once a set of images has been oriented, the following steps in the 3D reconstruction and modeling process are surface measurement and feature extraction which starting from the known exterior orientation and camera calibration parameters, a scene is digitally reconstructed by means of automated dense image matching techniques or interactive methods for man- made features and vector information extraction using PhotoModel UAS 2018. Interactive approaches deliver sparse point clouds which need structuring and editing in order to create accurate 3D data (e.g. building models). This research uses an automated methods to produce a dense point cloud describing the surface of the surveyed scene (DSM), which has to be interpolated, maybe simplified and finally textured for photo-realistic visualization using a powerful image matching algorithm used in PhotoModeler UAS 2018. This process was able to extract dense 3D point clouds with a sufficient resolution to describe the object's surface and its discontinuities. Therefore the point density were adaptively tuned to preserve edges and, possibly, avoid too many points in flat areas. At the same time, a correct matching result was guaranteed and also in regions with poor textures.

Data collection & Equipment
Historic aerial photogrammetry scan to Digital,
or
Low Altitude Imagery e.g UAV,
or
Close-Range photogrammetry e.g terrestial cameras

↓

Data Processing for Scan to Digital Data processing are Estimates camera and Flight parameters, Build block file, Measure control points, Block Adjuctment, Data set in Leica Photogrammetry Suite (LPS)
or
Low Altitude Imagery (UAV, Kite, Pole)/ Close-Range Photogrammetry using Terrestial Digital Cameras processing are Pre-process images, Align Images, Measure control points, and Data set in Photogrammetry software like PhotoModeler, PhotoScan, etc

↓

Extracting, Building and Exporting 3D surface & Features
for
Scan to Digital Data: Measure breakline, Extract 3D surface Model (i.e Triangular irregular Network (TIN), Digital Elevation Model (DEM)), Extract 3D Features, Create Orthoimage in LPS
or
Low Altitude Imagery (UAV, Kite, Pole)/ Close-Range Photogrammetry using Terrestial Digital Cameras: Build 3D Geometry mesh, Build Texture, Export Orthoimage or Digital Elevation Model in Photogrammetry software

↓

Looking at the Data
Viewing and Basic Measurements: Proprietary Software like ArcGIS, RapidForm
or
Free Viewer: MeshLab for Meshes, ArcGIS Explorer for DEM or Orthoimages

Figure 1.1 Basic Digital Photogrammetry workflow

4. Samples of Dense Image-Matching Algorithms Developed

There are several evaluating photogrammetry software systems available for dense image matching and each of these systems uses different algorithms in dense image-matching in photogrammetry today. Five of these photogrammetry software systems will be discuss with respect to how image matching is carried out. These are PhotoModel, SURE, MicMac, PMVS, and PhotoScan.

Feature Software	**SURE**	**MicMac**	**PMVS**	**Photoscan**	**PhotoModeler**
Type of Photogrammetry	Various types of Sensors, +Aerial, Close-range, UAS (Mathias Rothermel & Konrad Wenzel)	high- resolution satellite images, large and complex terrestrial sequences or aerial blocks (Remondino et al., 2014)	Aerial, Close-range, UAS	Aerial, Close-range, UAS	Close-range, UAS
Vendor	nFrames (www.nframe.com)	Institute National de L'Information Geographique et Forestiere (IGN) (www.ign.fr)	GNU General Public License (GPL) (www.di.ens.fr)	Agisoft (www.agisoft.com)	Eos Systems - PhotoModeler
Uses	Cadaster, change detection, infrastructure planning,flood analysis,disaster relief, glacier melting, tourism and forestry (www.nframe.com)	Architecture, Archeology, Forestry, etc	It is use to reconstructs 3D structure of an object or a scene visible in the images thereby ignoring the non-rigid objects such as pedestrians in front of a building. (www.di.ens.fr/pmvs/pmvs1-1/index.html)	It is use to process digital images and thereby generates 3D spatial data to be used in GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales. (www.agisoft.com)	It is used for performing measurement and modeling in agriculture, archaeology,architecture, biology, engineering, film production, forensics, mining, stock pile volumes, etc. (PhotoModel UAS help, 2018).
Algorithms Features	It is a MVS technique (Haala and Rothermel, 2012; Rothermel et al., 2012) where a reference image is matched to a set of adjacent images using a semi-global matching (SGM) type of stereo algorithm (Hirschneuller, 2008) It uses a time- and memory-efficient SGM algorithm is applied to produce depth maps.	multi-resolution and multi-image method (Pierrot-Deseilligny and Paparoditis, 2006) which applies a coarse-to-fine extension of the maximum-flow image-matching algorithm presented in Roy and Cox (1998) The algorithm uses pyramidal processing by starting from a lower resolution, the matching results achieved in each pyramid level guide the matching at the next, higher resolution, level in order to improve the quality of the matching, up to the full resolution (Remondino et al., 2014). (http://www.MicMac.ign.fr)	It is a matching method (Furukawa and Ponce, 2010) that uses a multi-step approach that does not need any initial approximation of the surface (Remondino et al., 2014) Uses oriented and distortion-free images.	Automatically orient and match large datasets of images. the results obtained by Remondino et al. (2014) from the achievable 3D measurement results, the implemented image-matching algorithm seems to be a stereo SGM-like method that was used in it (http://www.agisoft.ru)	Creates accurate 3D models, and accurate 3D measurements from photographs taken and exported with photographic textures extracted from the original photographs. There are two methods to choose from when generating DSM's, these are MVS approach which is more automated and usually requires no parameter adjustment, no extents / trims, and no selection of photos to process while Paired Photos approach one generates a complete model by picking multiple pairs and then merging the point clouds. (PhotoModel UAS help, 2018).
Automatic modelling	Yes	Yes	Yes	Yes	Semi-automatic
Scalability	Yes, multiple images	Yes, multiple images	Yes, multiple images	Yes, multiple images	Yes, multiple images
License	Proprietary commercial product and a free version of it is available for research purposes.	A free, Open source solutions s	Open source solutions	Proprietary commercial product	Proprietary commercial product
Platform	Linux, Microsoft Windows	Ubuntu, Windows, Mac, Raspberry Pi	Linux, OS X, Mac,Microsoft Windows	Linux, OS X, Microsoft Windows	Microsoft Windows

5. Results and Analysis

The results obtained from this work shows that four digital images uploaded into PhotoModeler UAS 2018 were auto calibrated and all the images oriented (see fig 1). Also, it is reveal that the minimum and maximum Photo coverage are 52.8 and 82.3 percent respectively, thereby given an average Photo coverage of 82 percent (fig 1). It further shows that minimum and maximum point marking residuals of 0.092 and 2.475 pixels respectively (fig 1). Furthermore, it show that minimum and maximum point marking RMS residuals of 0.084 (pt 292) and 2.208 (pt 384) pixels respectively with an overall point marking RMS residuals of 0.825 pixels. The minimum and maximum of point precisions in X, Y, Z are 0.00143m, 0.00139m, 0.00325m and 0.0226m, 0.0239m, 0.0162m respectively with an overall RMS point precisions of 0.0185m were obtained. Also, minimum and maximum vector length of 0.00749m and 0.0329m respectively was given from this research work (fig 1).

Other statistical analysis that were obtained from this work are:

Figure 2 shows that the same photo quality were used in this research work, the graph in figure 3 show that there are more smartpoints generated from Photo 2-dsc00217 and least smartpoints from Photo 4-dsc00217, graph report (figure 4) reveal high photo connectivity between Photo 2-dsc00217 and Photo 3-dsc00217 than it is with any other pairs while the graph report for connectivity per Photo (figure 5a, b, c, d) show the connectivity of each photo with other three photos. Finally, Digital Surface Model and 3D Model are produced as in figures 6 and 7 respectively

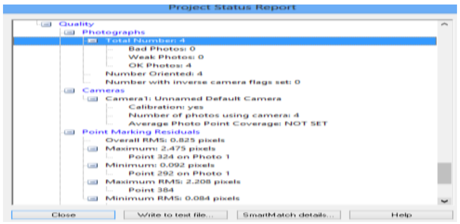

Figure 1a

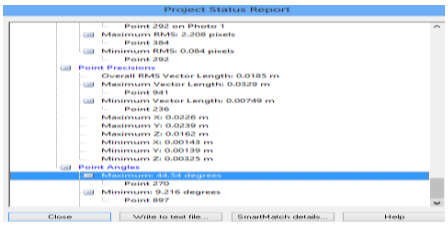

Figure 1b

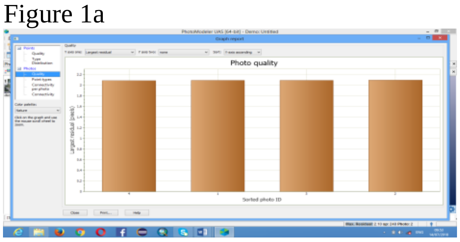

Figure 2

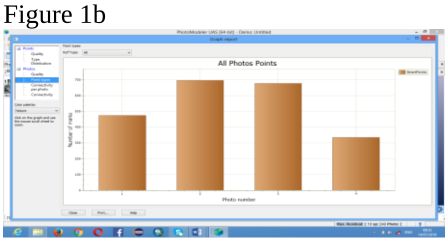

Figure 3

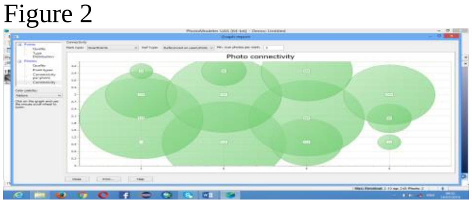

Figure 4

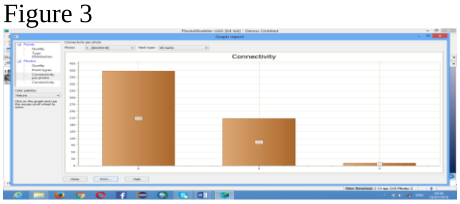

Figure 5a

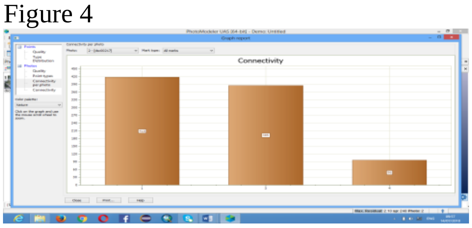

Figure 5b

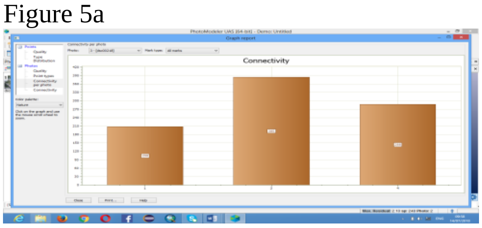

Figure 5c

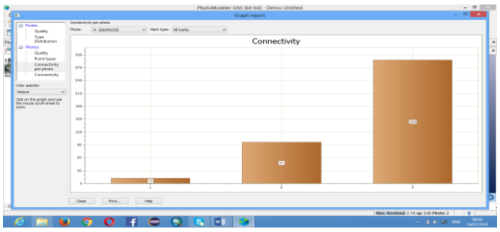

Figure 5d

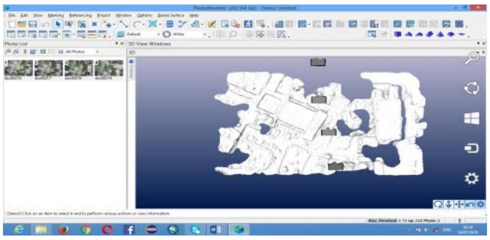

Figure 6a

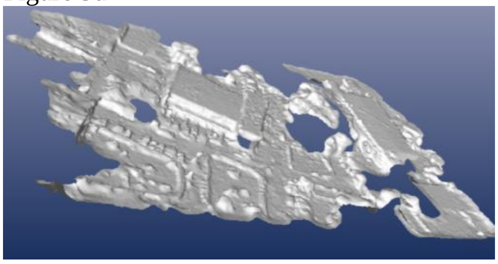

Figure 6b

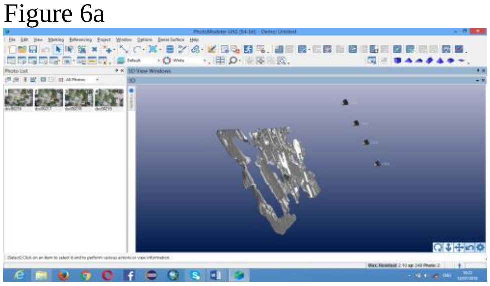

Figure 7a

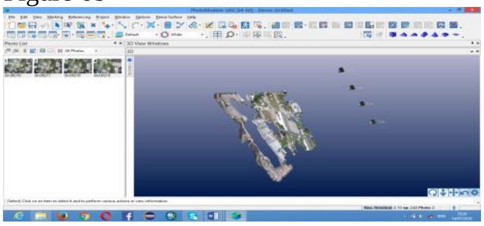

Figure 7b

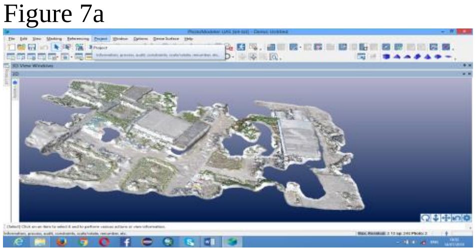

Figure 7c

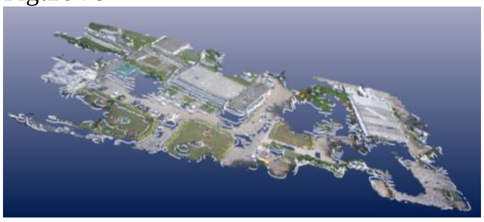

Figure 7d

Figure 7e

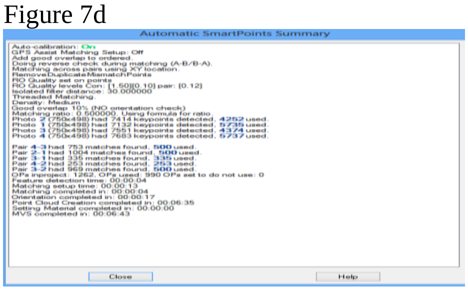

Figure 8

6. Summary and Recommendations

6.1 Summary

The results obtained from this work can be useful for geometric modeling purposes, for texture mapping on existing 3D data or for mosaic, map and drawing generation. If digital images acquire by UAS is compared to traditional airborne platforms, they decrease the operational costs and reduce the risk of access in harsh environments, still keeping high accuracy potential. Therefore, digital Photogrammetry by UAV platforms are nowadays a valuable source of digital data for inspection, surveillance, mapping and 3D modelling issues.

6.2 Recommendation

We recommend the following for any future work:

- The images should be collected with high forward overlaps, at least 80–90%.
- Future work has to be focused on develop tools for simplifying the flight planning when using nadiral images since the same task becomes much more complex in case of 3D objects requiring convergent images and, maybe, vertical strips.
- Despite the fact that automated image processing is already feasible with quite reliable and precise results, we also recommend that in the near future there should still be possible improvements.

For future work, we recommend that a licenced PhotoModeler UAS 2018 should be used since the accuracy obtained using trial version might has been distorted.

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