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Data Article

Registered Relief Depth (RRD) borobudur dataset for single-frame depth prediction on one-side artifacts

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A R T I C L E I N F O

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A B S T R A C T

Single-frame depth prediction is an efficient 3D reconstruction method for one-side artifacts. However, for this purpose, ground truth images, where the pixels are associated with the actual depth, are needed. The small number of publicly accessible datasets is an issue with the restoration of cultural heritage objects. In addition, relief data with irregular characteristics due to nature and human treatment, such as decolorization caused by moss and chemical reaction is still not available. We therefore created a dataset of Borobudur temple reliefs registered with their depth for data availability to solve these problems. This data collection consists of 4608×3456 (4K) resolution and profound RGB frames and we call this dataset the Registered Relief Depth (RRD) Borobudur Dataset. The RGB images have been taken using

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an Olympus EM10 II Camera with a 14 mm f/3.5 lens and the depth images were obtained directly using an ASUS XTION scanner, acquired on the temple's reliefs at 15000–25000 lux day time. The registration process of RGB data and depth information was manually performed via control points and was directly supervised by the archaeologist. Apart of enriching the data availability, this dataset can become an opportunity for International researchers to understand more about Indonesian Cultural Heritages.

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Specifications Table

Subject	Computer Science Application
Specific subject area	Registered Depth Relief Image and Depth Prediction
Type of data	RGB 24-bit relief images at 4608 × 3456 (4k) resolution Grayscale Depth Image data
How data were acquired	The RGB images were taken by Olympus EM10 II camera with a 14 mm f/3.5 lens and taken from a distance of two meters from the front of the relief. Depth data was obtained from the primary data mesh model obtained from scanning using an ASUS XTION scanner. The registration process of RGB and depth image was achieved using control points in MATLAB program and an estimated linear transform supervised by archaeologists.
Data format	.jpg for RGB and .png for the depth data .ply for secondary mesh 3D model
Parameters for data collection	Relief images were taken from a two-meter distance in front of the reliefs. For the primary data mesh model, an ASUS XTION scanner at a distance of 1 meter from the relief was used. Both processes were done during the day with a cloudy lux capacity of 15000–25000, not exposed to direct sunlight and at the relief that can be reached by humans.
Description of data collection	RGB images. The relief images were taken from a two-meter distance in front of the reliefs in 4608 × 3456 (4k) resolution. Mesh model. The data mesh model is taken using ASUS XTION scanner, scanned on the surface at the optimum distance of 1 meter. The depth image is created with multi-depth images with resolution 640 × 480. The data is saved in .ply format. Registered depth data. From the mesh data, 1920 × 1080 resolution depth images are obtained using one perspective derivation from the mesh's frontal view. After that, the RGB and depth data registration was done manually by estimating a projective transformation from control points. The registration is needed to normalize all the images, including resolution, capturing distance, and different perspectives. The relief data has been taken on floor one and two since restoration is still being maintained on floor three. After registration, the depth image resolution becomes 4608 × 3456 (4k).
Data source location	Borobudur Temple: Jl. Badrawati, Kw. Candi Borobudur, Borobudur, Kec. Borobudur, Magelang, Jawa Tengah, Indonesia. Location on map: -7.607841891331872, 110.20391222994367.
Data accessibility	*Registered RGB and Depth:* https://simpan.ugm.ac.id/s/9EU8gMckNx7k037 Mesh models: https://simpan.ugm.ac.id/s/TanB8sjZvyBqReS *If there any further question, you can send an email to* aharjoko@ugm.ac.id or aufaclav@ugm.ac.id to req*uest the dataset.*

Value of the Data

- RRD Borobudur Dataset is a one-side cultural heritage artifacts data for single-frame depth prediction, showing the original state of the reliefs at the temple and all acquisition processes are supervised directly by the archaeologists.
- Researchers who are interested in single-frame depth prediction on one-sided cultural heritage artifacts in real outdoor conditions may use this RRD data. It can also be integrated with data sets of other sources to obtain a more general data source in the training phase.
- Presented data can be used as a basis for archaeologists to make depth predictions, visualization, and digital conservation to convert it into the 2.5 D model for vast numbers of reliefs in an efficient way.
- This data can be used for researchers that want to make a depth prediction for other artifacts that have similar relief characteristics.
- This data can also be used to segment content from the relief based on the available depth and challenges available in the RGB data.
- The presented data can be further analyzed to solve a specific condition problem in the real artifact, such as the diversity of material colors or chemical reaction on the relief surface.
- This data can become an opportunity for International researchers to understand more about Indonesian Cultural Heritages.

1. Data Description

Registered Relief Depth (RRD) Borobudur Dataset consists of two registered sets of images with RGB image 4k resolution and Grayscale depth Image 24 bit. Based on Frisky et al. work [1], the quality result of 3D model from single image is preferred to be used for Indonesian archaeologist's field work because of its efficiency. The RRD Borobudur Temple dataset contains a total of 30 Borobudur reliefs from three different floors in the temple. This number makes this dataset the first single image depth prediction dataset on cultural heritage applications with a moderate number of data, higher than publicly available data [2,3]. On the RRD Borobudur Dataset, we scanned all reliefs from the first and second level of the temple. Fig. 1 shows the example of Borobudur relief data with their corresponding depth information. Most Borobudur relief sizes are close to square, and in this dataset, a 4608×3456 (4k) resolution is used to capture the reliefs.

Fig. 1. Data examples of RRD temple dataset. Column (a) shows the RGB images, and column (b) shows the ground truth.

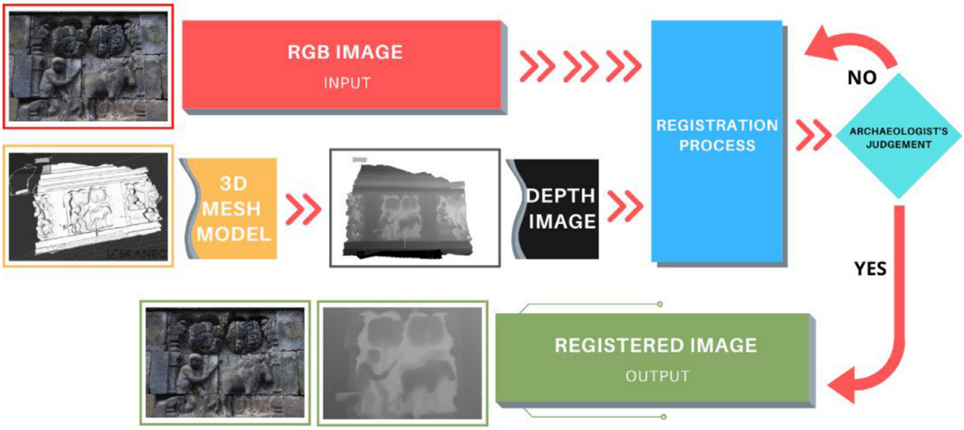

Fig. 2. The whole process of data acquisition.

2. Experimental Design, Materials and Methods

In general, the whole process used to create this dataset is shown in Fig. 2. First, we took RGB relief images using a camera Olympus OMD II with a fixed configuration of lens 14 mm with a focal length of f/3.5. The images are taken from 2 meters distance during the day with a light intensity of 15000–25000 lux and not exposed to direct sunlight. The 2 meters is chosen because with this distance can capture the optimal size of the relief. Further distance makes unneeded side part is also captured, and closer range makes the relief is cropped.

The second task is to obtain the mesh's depth image from the direct scan to the relief. The direct scan is carried out using an ASUS XTION scanner from 1 meter from the object, and the results are saved in the ply file format. A further distance of more than 1 meter can cause the relief's undetected surface, and closer range makes the detail degraded. Then to get depth data, we performed the following steps in MeshLab [4]:

1. Open the .ply data in Meshlab
2. Adjust the position 90 degrees from the surface, a frontal position from the relief
3. Render -> Shaders -> Depthmap.gdp
4. Save the obtained depth map into a depth image

The optimal working distance of the two capturing devices, camera and ASUS XTION, are different, as well as the output resolution. These differences will be regularized using the registration process. The registration process was done using control points in Matlab using projective transform with local approximation methods [5]. The registration process using Matlab can be seen in Fig. 3. Due to the colors and contours variation and the complex shape, archaeological supervision was needed to determine the boundaries of the shape.

After all registration processes were completed, we performed verification experiments with one pair of data set (RGB and depth) images and an additional RGB image in order to estimate the accuracy of these processes. Hence, we have prepared three images: two RGB images from different points of view, I_1 and I_2 and a depth image d registered. Then a three-way transformation was performed to get the transformation T_i. First, we registered d with I_1 to get transformations matrix T_1, registered I1 to I2 and obtained T_2, and registered I_2 to d to get T_3. Finally, we get the final transformation matrix $T_i = T_3 \cdot T_2 \cdot T_1$. The obtained transformation matrix T_i is then applied to d to obtain $\hat{d}$ and find the error between these two depths. Based on our experiment, we get 0.912 RMSE in millimeters, which demonstrates that our registration process error is relatively small and the data is reliable as ground truth.

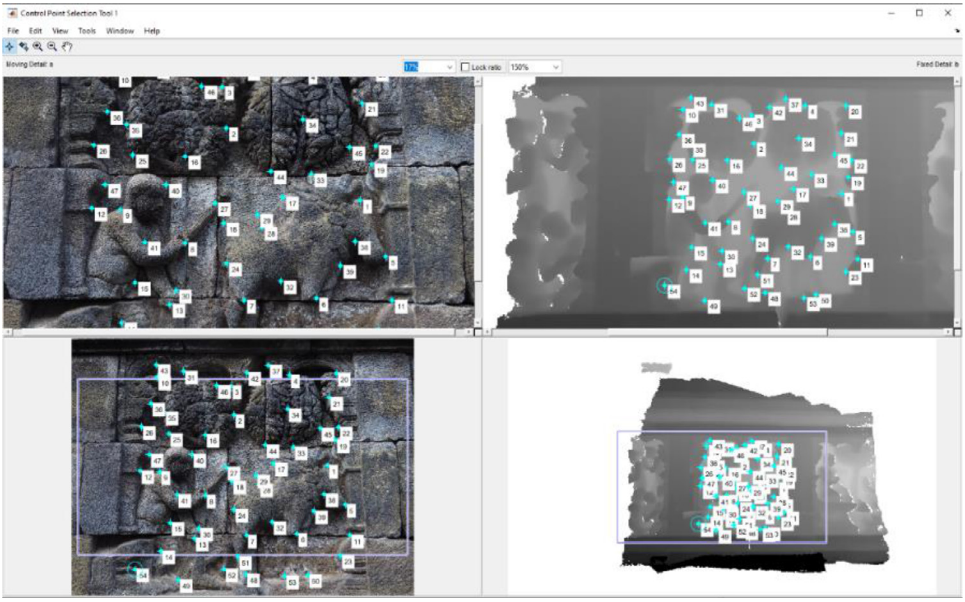

Fig. 3. Registration process using control points in MATLAB.

CRediT Author Statement

Aufaclav Zatu Kusuma Frisky: Conceptualization, Methodology, Software, Writing – original draft, Investigation, Formal analysis; **Agus Harjoko:** Supervision, Data curtion, Writing – review & editing, Funding acquisition, Resources; **Lukman Awaludin:** Software, Investigation; **Andi Dharmawan:** Data curtion, Funding acquisition; **Nia Gella Augoestien:** Project administration, Visualization; **Ika Candradewi:** Investigation, Software; **Roghib Muhammad Hujja:** Project administration, Visualization; **Andi Putranto:** Supervision, Investigation, Validation; **Tri Hartono:** Data curtion, Resources; **Yudi Suhartono:** Data curtion, Resources, Validation; **Sebastian Zambanini:** Methodology, Writing – review & editing; **Robert Sablatnig:** Supervision, Conceptualization, Resources.

Declaration of Competing Interest

The authors declare that we have no known competing financial interests or personal relationships that could have influenced the work reported in this article.

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