

INTISARI

Candi Brahma merupakan salah satu candi utama yang berada di kompleks Candi Prambanan yang telah diakui sebagai situs warisan dunia. Terletak di dekat zona sesar Opak, candi ini rentan terhadap kerusakan akibat gempa bumi, sehingga diperlukan pelestarian dan pemantauan untuk menjaga eksistensinya. Upaya pelestarian ini dilakukan dengan inventarisasi dan pendokumentasian digital melalui pemodelan 3D dengan tingkat kedetailan LoD 4. Selain pelestarian, terdapat permasalahan lain dalam hal aksesibilitas yang disebabkan oleh adanya pembatasan dari pihak pengelola untuk melihat Candi Brahma secara langsung. Oleh karena itu, model 3D Candi Brahma dibuat dalam bentuk *virtual reality* sebagai solusinya.

Pemodelan 3D tubuh Candi Brahma dilakukan menggunakan metode *primitive modeling* dari data *point clouds* hasil akuisisi alat *Terrestrial Laser Scanner* (TLS) pada tahun 2023. Sementara itu, panel relief, patung, dan ornamen arsitektur lainnya, dimodelkan dalam bentuk *mesh* menggunakan metode *Structure from Motion* (SfM) dari akuisisi data foto *Close Range Photogrammetry* (CRP). Pemodelan 3D tubuh candi dilakukan menggunakan *Software Revit*, sedangkan pemodelan 3D *mesh* direkonstruksi dengan *Software Agisoft Metashape*, *Blender*, dan *GIMP*. Hasil dari kedua model tersebut kemudian digabungkan untuk menghasilkan model 3D dari keseluruhan bangunan candi dan divisualisasikan melalui *Software Enscape*. Pada model 3D ini dilakukan penambahan atribut tentang Cerita Ramayana pada panel relief pagar langkan Candi Brahma. Hasil model 3D Candi Brahma kemudian diimplementasikan dengan teknologi *virtual reality* melalui *Software Steam*.

Hasil proyek akhir ini menunjukkan bahwa model 3D Candi Brahma, baik interior maupun eksterior, berhasil memenuhi standar spesifikasi LoD 4 dan telah teruji akurasi. Uji geometri RMSE diperoleh sebesar 0,010 m, yang menunjukkan bahwa nilai telah masuk ambang batas toleransi LoD 4 menurut standar *Open Geospatial Consortium* (OGC). Akan tetapi, uji geometri t-berpasangan diperoleh nilai t_{hitung} sebesar 5,460 yang berada di luar rentang interval kepercayaan 95% (t_{tabel} sebesar 2,045), yang menunjukkan bahwa hipotesis nol (H_0) ditolak. Hal ini berarti terdapat perbedaan ukuran yang signifikan antara model 3D dan objek di lapangan. Selain itu, pada model 3D panel relief pagar langkan Candi Brahma, telah dilengkapi atribut mengenai Cerita Ramayana yang berjumlah 27 panel relief. Kegiatan penelitian aplikatif ini juga menghasilkan model 3D Candi Brahma yang diimplementasikan dalam *virtual reality* berbasis VR-headset.

Kata kunci: Model 3D, Candi Brahma, *Virtual Reality*, *Point Clouds*, *Close Range Photogrammetry*

ABSTRACT

Brahma Temple is one of the main temples in the Prambanan Temple complex that has been recognized as a world cultural heritage. Located near the Opak fault zone, this temple is vulnerable to earthquake damage, so preservation and monitoring are needed to maintain its existence. This preservation effort is carried out with digital inventory and documentation through 3D modeling with LoD 4 level of detail. In addition to preservation, there are other problems in terms of accessibility caused by restrictions from the management to see Brahma Temple directly. Therefore, a 3D model of Brahma Temple is made in the form of virtual reality as a solution.

3D modeling of the body of Brahma Temple was conducted using the primitive modeling method from point clouds data acquired by the Terrestrial Laser Scanner (TLS) in 2023. Meanwhile, relief panels, statues, and other architectural ornaments were modeled in mesh from using the Structure from Motion (SfM) method from the acquisition of Close Range Photogrammetry (CRP) photo data. 3D modeling at the temple body was done using Revit software, while 3D mesh modeling was reconstructed using Agisoft Metashape, Blender, and GIMP software. The result of the two models were then combined to produce 3D model of the entire temple building and visualized through Enscape software. In this 3D model, attributes about the Ramayana Story were added to the relief panel of Brahma Temple balustrade. The result of the 3D model of Brahma Temple were then implemented with virtual reality technology through Steam software.

The result of this final project shows that the 3D model of Brahma Temple, both interior and exterior, successfully meets the LoD 4 specification standards and has been tested for accuracy. The RMSE geometry test was obtained at 1,010 m, which shows that the value has entered the LoD 4 tolerance threshold according to the Open Geospatial Consortium (OGC) standard. However, the geometry paired t-test obtained a t_{test} value of 5,460 which is outside the 95% confidence interval range (t_{table} of 2,045), indicating that the null hypothesis (H_0) is rejected. This means that there is a significant size difference between the 3D model and the object in the field. In addition, the 3D model of the Brahma Temple balustrade relief panel has been equipped with attributes about the Ramayana Story, totaling 27 relief panels. This applicative research activity also produces a 3D model of Brahma Temple that is implemented in VR headset-based virtual reality.

Keywords: 3D Model, Brahma Temple, Virtual Reality, Point Clouds, Close Range Photogrammetry