11-1-2011

A 3-D Lighting and Shadow Analysis of the JFK Zapruder Film (Frame 317)

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Abstract

Claims of a broader conspiracy behind U.S. President John F. Kennedy's assassination have persisted for the past nearly five decades. The Zapruder film is considered to be the most complete recording of JFK's assassination. Many have claimed that this 8mm film was manipulated to conceal evidence of a second shooter, which would invalidate the claim that a lone gunman, Lee Harvey Oswald, was responsible for JFK's assassination. Here we consider the viability of one specific claim of postproduction tampering in the Zapruder film.

1. Introduction

United States President John F. Kennedy was assassinated on November 22nd, 1963 while his procession was driving through Dealey Plaza in Dallas, Texas. Shortly afterwards, Lee Harvey Oswald was arrested and charged with the crime. Because he was killed before his trial, and the conclusions of the Warren Commission[1] have been challenged, many questions surrounding the assassination remained unanswered. Since this time, numerous theories have circulated suggesting that Oswald acted as part of a larger criminal conspiracy involving a variety of government, international, or criminal groups.

Abraham Zapruder captured the most complete documentation of the events of November 22nd with his Bell & Howell 8mm roll film camera. After

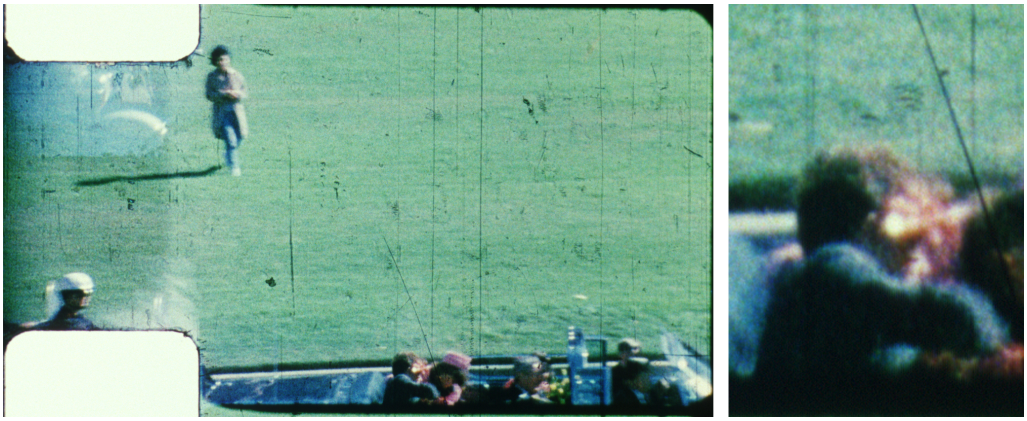

Figure 1: Frame 317 of the Zapruder film (left), and a magnified view of JFK – the authenticity of the shadow on the back of JFK's head has been called into question.

its public release in 1975, challenges to the authenticity of the Zapruder film began to surface (e.g., [2, 3, 4, 5, 6]). The Zapruder film has been analyzed for evidence to support alternate theories of who and how many people were involved in the assassination. For example, it has been argued that on frame 317 (and neighboring frames) what appears to be a shadow on the back of JFK's head, Figure 1, is the result of tampering, purportedly to conceal evidence of a shot exiting through the rear of JFK's head. This shot could only have come from a second shooter, as Oswald was positioned behind JFK.

Here I describe a 3-D photo forensic examination that allows for a geometric analysis of the lighting and shadows in frame 317 to determine if the shadow on the back of JFK's head is consistent with the scene geometry and illumination.

2. 3-D Model

We digitally recreate portions of the scene depicted in frame 317 of the Zapruder film, Figure 1. This requires the construction of a 3-D model of JFK's head and body, the geometry of the street on which JFK's car was traveling (Elm St.), and the position of the sun.

2.1. JFK

In [10], the authors describe a 3-D morphable model for the analysis and synthesis of human faces. The model was derived by collecting a large set of

Figure 2: Profile and frontal views of JFK. See also Figure 3.

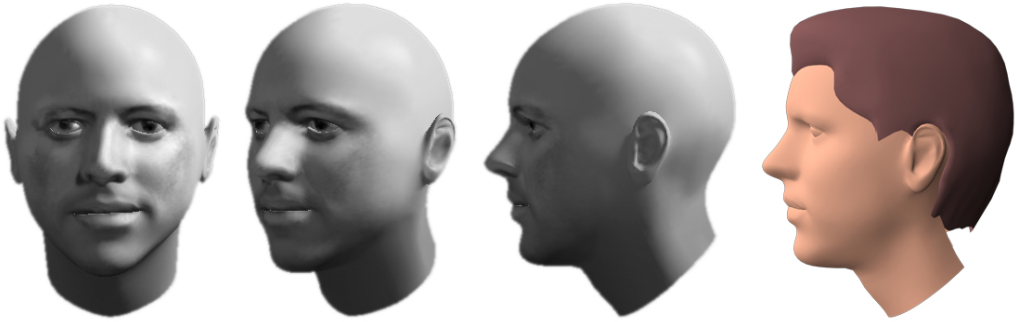

Figure 3: Shown from left to right are three views of the estimated 3-D model of JFK, and the 3-D model with skin color and hair. See also Figure 2.

3-D laser scanned faces and projecting them into a lower-dimensional linear subspace. New faces (geometry, texture/color, and expressions) are modeled as linear combinations of the resulting low-parameter linear basis. The model parameters can be estimated from a paired profile(s) and frontal image.

Shown in Figure 2 are left and right profile and frontal views of JFK. These photographs provide the input for constructing a 3-D model from a commercially available implementation of techniques similar to those described in [10] (FaceGen, *Singular Inversions*). Three views of the resulting estimated 3-D model show a good agreement with the original photos, Figure 3. Also shown in the right-most panel of Figure 3 is the estimated 3-D model with the addition of skin tone and a generic wig, added to better model the shape of JFK's head.

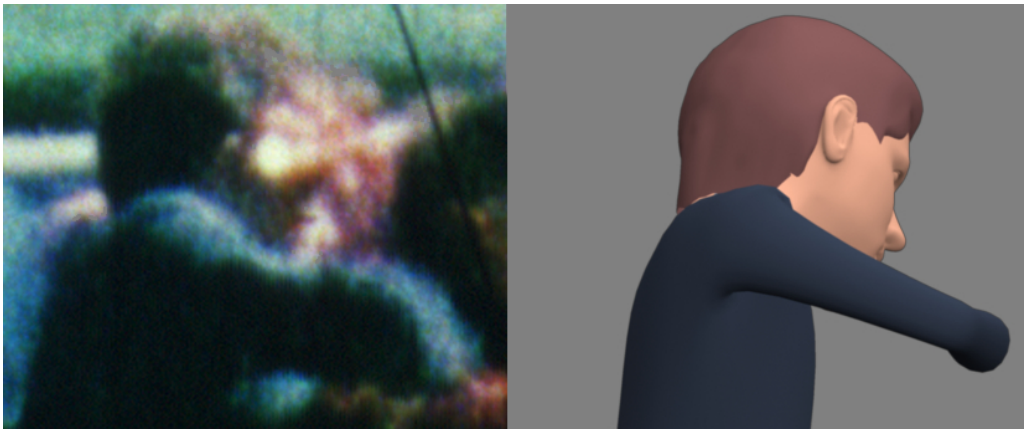

Figure 4: Shown on the left is JFK in frame 317 and shown on the right is our 3-D model (illuminated with only ambient lighting).

This 3-D head model was combined with a generic[1] articulated 3-D body[2], and rendered in the 3-D modeling software Maya (*Autodesk*). Shown in Figure 4 is a rendering of the combined 3-D head and body, positioned to be consistent with JFK's body/head pose in frame 317.

2.2. Elm Street

At the time of his assassination, JFK's car was traveling on Elm St. in Dealey Plaza, Figure 5 (top panel). We are interested in analyzing lighting and shadows, and therefore need to know the angle between people and objects in the scene and the sun. As such, it is important to determine if, and by how much, Elm St. is angled relative to the horizontal plane.

Shown in Figure 5 (bottom panel) is a digital elevation map (DEM) obtained from airborne LiDAR (Light Detection and Ranging), courtesy of the National Geospatial Intelligence Agency. The color coding corresponds elevation with red denoting the highest elevation and blue the lowest elevation. The long straight portion of Elm St. is 50 meters in length, and the difference in elevation across this distance is 2.75 meters, yielding an angle of 3.2°. That is, JFK's car was pitched 3.2° downward as it was traveling along Elm

[1] A more detailed body was not constructed (e.g., [11]), because we were primarily interested in the shadow on the head, for which a generic body sufficed.

[2] Alfred 1.2.0: www.creativecrash.com/maya/downloads/character-rigs/c/alfred

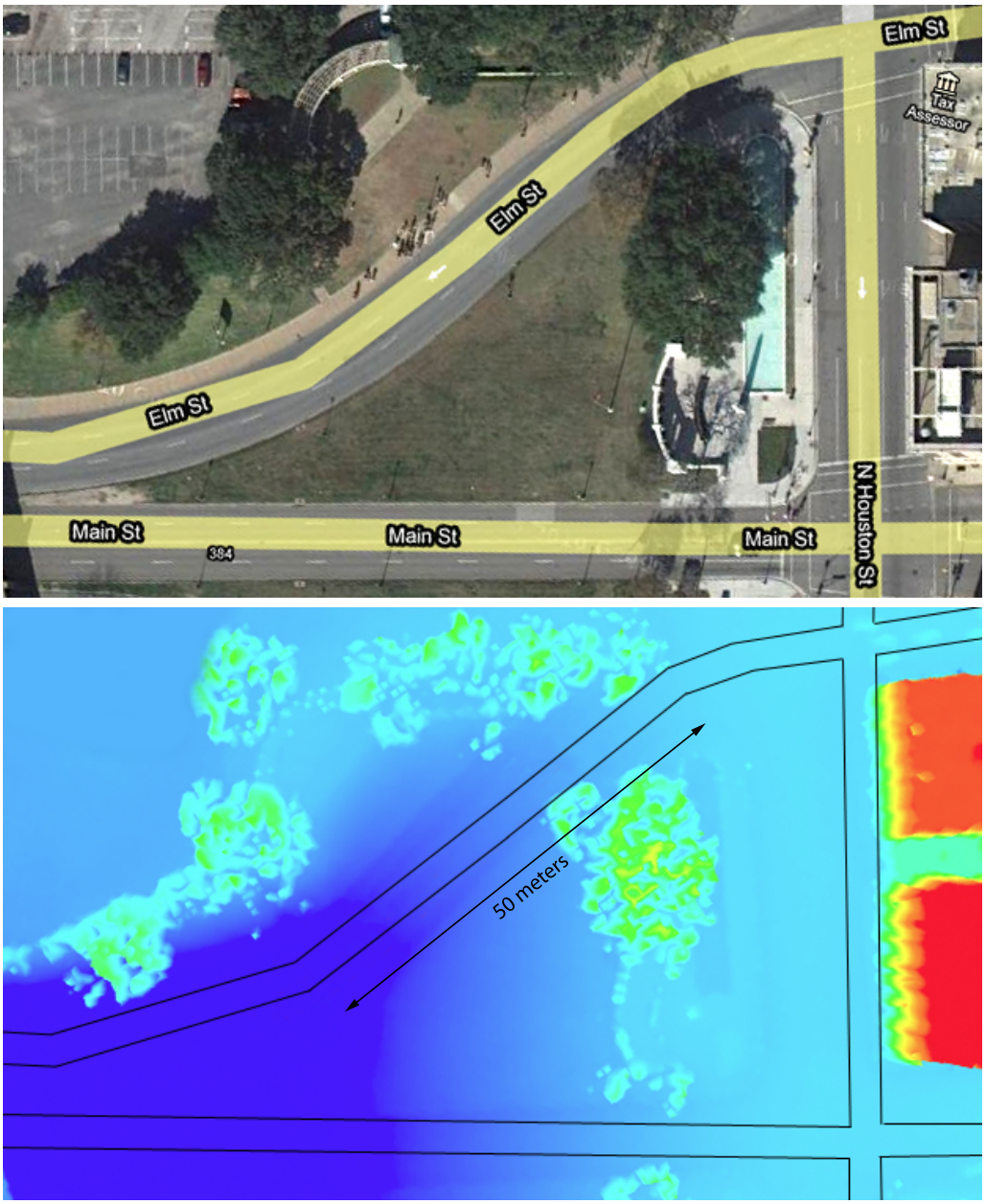

Figure 5: An aerial map of Dealey Plaza (top), and a digital elevation map (DEM) of this area (bottom). The color coding corresponds elevation with red denoting the highest elevation and blue the lowest elevation.

St. As such, the road was modeled as a planar surface angled by this amount relative to horizontal.

2.3. Light

JFK was assassinated on November 22nd, 1963 at 18:30 (UTC) in Dealey Plaza. It is an easy matter to determine the relative position of the light at this time and place. Specifically, the location of Dealey plaza is given by 32° 46′ 43″ N and 96° 48′ 30″ W. According to the National Oceanic and Atmospheric Administration solar calculator, the sun's position (specified as azimuth and elevation[3]) at this location and date was 181.91° 37°, respectively.

2.4. Summary

We now have at our disposal a 3-D model of JFK's head and body, a 3-D model of Elm St., and the 3-D position of the sun at the time of JFK's assassination. These models were combined using the 3-D modeling software Maya. A virtual camera was positioned where Abraham Zapruder was standing with his 8mm movie camera. The pedestrian on the grass and the police officer's helmet were modeled with simple geometric primitives in order to validate the estimated 3-D sun position and 3-D scene geometry. The next section describes a lighting and shadow analysis from this 3-D model.

3. 3-D Analysis

Shown in Figure 6 is the 3-D rendering of the models described in the previous section. The top and bottom panels show the rendered image superimposed (with different opacities) on top of the original frame. This was done in order to see the details of the rendering as well as the relative alignment with the original photo. First, note that the length and angle of the cast shadow of the pedestrian onto the ground is the same as in the original photo. This shows that the 3-D model of the ground plane and sun position are correct. Notice also that the lighting gradient on the police officer's helmet is consistent with the original photo.

Shown in Figure 7 is a magnified view of JFK. This 3-D rendering reveals, as with the original photo, a shadow on the back of JFK's head. In addition,

[3]Azimuth is measured clockwise from true north to a point on the horizon directly below the sun. Elevation is measured vertically from this point to the position of the sun.

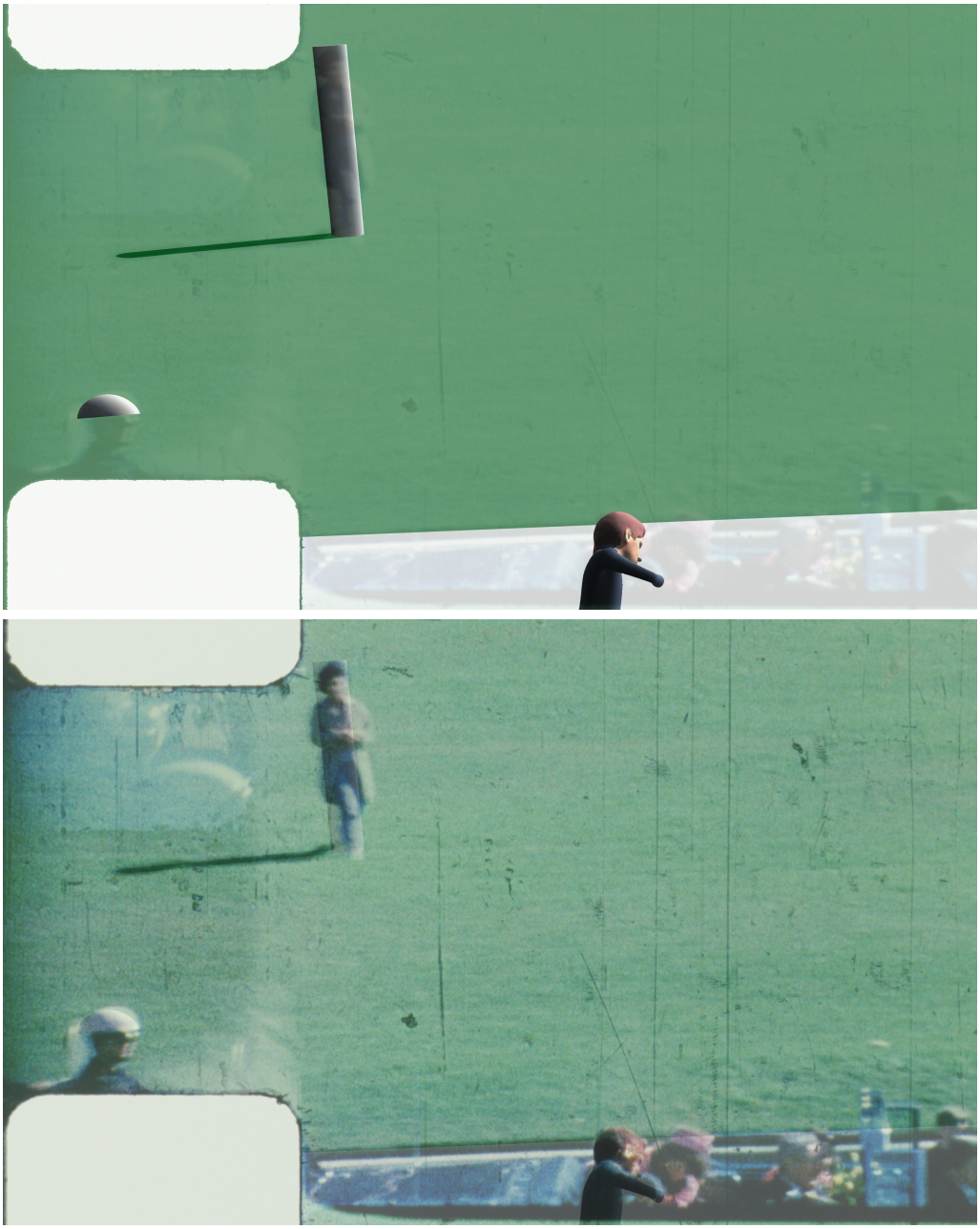

Figure 6: The rendered 3-D scene superimposed on top of the original frame 317 (Figure 1) with 80% and 20% opacity. See also Figure 7.

Figure 7: The original and 3-D rendering of JFK on frame 317. Note the consistency in the shadows on his head and body. See also Figure 6.

the lighting gradients on his shoulder and arm are consistent with the original photo. The slight differences in the precise shape of the shadow on the back of the head are due to differences in the underlying 3-D shape of the hair, which are difficult to precisely model.

We note that the original photo clearly shows a shadow on JFK's right cheek which is not reproduced in our 3-D reconstruction. This shadow is due to the damage inflicted to JFK's right temple which is casting a shadow onto his face.

The lighting and shadows in frame 317 of the Zapruder film are consistent with the 3-D geometry of the scene and sun position. It has been argued that the darkening on the back of JFK's head is not a shadow. Such claims are not supported by this 3-D photo analysis.

4. Discussion

We have described a 3-D photo forensic analysis of the historic, and at times controversial, Zapruder film. This analysis focuses specifically on frame 317, and the shadow on the back of JFK's head. This analysis shows that the shadow, which some have argued is the result of manipulation, is consistent with the 3-D geometry of the scene and position of the sun. While this does not, of course, prove that the 8mm original film has not been altered, it does prove that the shadow is physically plausible.

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