Downloaded from SAE International by William Neale, Monday, April 12, 2021

2021-01-0855 Published 06 Apr 2021

Calibrating Digital Imagery in Limited Time Conditions of Dawn, Dusk and Twilight

James Marr, William Neale, Steven Beier, Alireza Hashemian, and Nathan Mckelvey Kineticorp LLC

Citation: Marr, J., Neale, W., Beier, S., Hashemian, A. et al., "Calibrating Digital Imagery in Limited Time Conditions of Dawn, Dusk and Twilight," SAE Technical Paper 2021-01-0855, 2021, doi:10.4271/2021-01-0855.

Abstract

This paper presents a methodology for accurately representing dawn and dusk lighting conditions (twilight) through photographs and video recordings. Attempting to generate calibrated photographs and video during twilight conditions can be difficult, since the time available to capture the light changes rapidly over time. In contrast, during nighttime conditions, when the sun is no longer contributing light directly or indirectly through the sky dome, matching a specific time of night is not as relevant, as man-made lights are the dominate source of illumination. Thus, the initial setup, calibration and collection of calibrated video, when it is dark, is not under a time constraint, but during twilight conditions the time frame may be narrow. This paper applies existing methods for capturing calibrated footage at night but develops a method for adjusting the footage in the event matching an exact time during twilight is necessary. This method allows photographs and video that are captured either slightly earlier or later than desired to be accurately adjusted in post processing - thus removing the need to have footage captured at an exact time.

Introduction

Capturing video or photographs during twilight can be difficult if the image must be captured at a specific time in an area that has heavy traffic or is difficult to access. In some cases, more than one image must be captured at the same time from two different perspectives such as when capturing a video or photograph from a pedestrian's point of view and from a driver's point of view. In accident reconstruction industries, for instance, one challenge is capturing footage when the date available to do so differs from the date that the accident occurred. Collecting footage at the accident scene on the anniversary date may be helpful, but not always feasible. Another option, presented in this research, is to capture footage on a different day, but at a time adjusted so the sun or light from the sun is at a comparable time. Adjusting the time for the footage to be captured can enable an investigator to match the lighting conditions that existed at the time of the accident even when capturing footage on a different date. This is done by analyzing what the light level was at the time of the accident and determining when that same level of light will be on the day the investigator is at the scene [1, 2]. To determine what the light level, measured in lux, would be at the scene on a specific date and time, the latitude and longitude are entered with the corresponding date and time and a lux level calculated. With a target lux value calculated, any date of an inspection can be analyzed to determine at what time the same lux value will occur at that location. But even with the adjusted time correctly calculated, challenges may still remain if the light level is rapidly changing during sunrise, sunset or twilight hours. Additionally, if multiple views are needed at the same time, recording both views in the short time frame can pose another challenge. The research and methodology presented in this paper addresses these two challenges.

Background

Dawn and dusk each have three twilight phases that occur each day and night. Astronomical twilight, the earliest stage of dawn in the morning and last stage of dusk at night, occurs when the geometric center of the sun is 18 degrees below the horizon [3]. This phase will transition to nautical twilight when the geometric center of the sun reaches 12 degrees below the horizon. Civil twilight occurs when the geometric center of the sun is 6 degrees below the horizon and ends at sunrise. The same is true when transitioning from civil twilight to astronomical twilight in the evening. Simply put, twilight is the time of day between daylight and darkness. Light levels change rapidly during this time making it difficult to capture multiple vantage points or complex drive throughs at a scene. For example, if an accident scene is on a highway with entrance and exit ramps that are far apart, the time it takes to simply loop around can use up valuable time. Further, the time that these three phases of twilight start and stop differ throughout the course of the year, as the earth's rotation relative to the sun also changes. The location on earth also affects the time

Downloaded from SAE International by William Neale, Monday, April 12, 2021

these phases start and stop. For instance, at the equator, the time it takes to pass through astronomical, nautical and civil twilight during sunrise is shorter than at a location closer to the poles. What remains constant is the angle of the sun's position below the horizon for each phase.

Methodology and Procedure

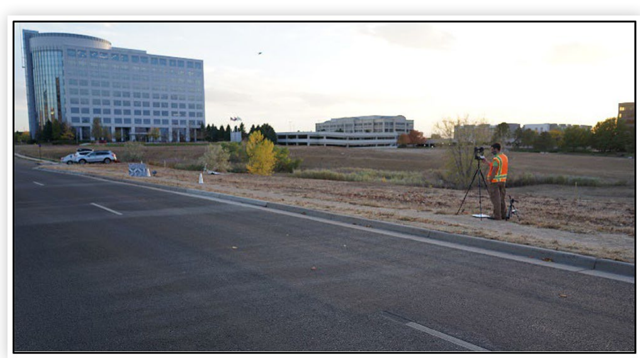
The purpose of this paper is to provide a method for reliably and accurately adjusting video and photographs that were captured during twilight, but not necessarily at the exact time intended. During twilight, when the sun is below the horizon, the light arriving at the earth's surface indirectly from the sky dome changes rapidly, requiring adjustments in the settings of the camera to keep up with changing light. When researching how much the light changes during twilight, and how the camera might need to be adjusted to stay calibrated, a pattern emerges that provides a method for adjusting the footage to appear correct for a different time that it was captured. A scenario where this type of adjustment might occur is as follows: an investigator uses accepted methodologies to capture a drive through video during twilight. However, the time the video was captured is 5 minutes too early or too late than the precise time intended. In this case, the video might appear slightly brighter or darker than it should be due to the rapid change in light during that 10-minute window. By calculating how much the light has changed during that 10-minute window and how the camera would have to be adjusted to remain in calibration, the difference in settings can be applied to the footage in post-processing. The post processed adjusted video is darkened or lightened according to the change in natural light so that it properly represents the lighting and visibility for the actual time that the run was intended.

From this research, it was determined that between sunset and civil twilight, the first of three twilight phases, there is approximately a 24-minute window that adjustments can be made to the captured footage and still maintain quality and clarity in the video. After civil twilight, the window of time for capturing footage increases, as the change in light is less drastic. Between civil twilight and nautical twilight, for instance, the change in the amount of light is so small that the window to adjust photographs increased to approximately 40 minutes. Further, between nautical twilight and astronomical twilight the amount of light and the camera settings were unchanged so that all the photographs taken in this time period looked the same. Looking at these time frames from a lighting perspective, photographs taken from sunset to civil twilight had a change in light from the sky dome that ranged from 374 lux at sunset to 1.41 lux at civil twilight. This represents a change of approximately 372 lux over the course of 32 minutes. From civil twilight to nautical twilight the lux values dropped from 1.41 lux to .09 lux, which represents a change of only 1.32 lux over 40 minutes. From nautical twilight to astronomical twilight, the lux measurements recorded during testing changed by only .01 lux, and the camera settings were the same throughout. During full daylight hours, the camera is designed to accommodate changes in daylight, and can be set to automatic settings for proper exposure. Similarly, in full nighttime conditions, lighting from the sky does not change and photographs and video can be taken at any point during full nighttime without adjusting for changes in light from the sky [4, 5, 6, 7, 8, 9].

To demonstrate this methodology, a series of photographs were taken before or after the target time and their exposure values changed in post-processing to match a photograph taken exactly at the target time. This testing was performed on a four-lane roadway in Greenwood Village, Colorado that included an open field and buildings in the distance. This location was chosen because it included a wide range of scene lighting, including streetlights and traffic signal lights. In each direction, north, south, west and east, the scenery was unique. To obtain photographs, the camera was calibrated to record a view representative of the lighting conditions following peer-reviewed and accepted calibration methodologies [10, 11]. This included using white cones, calibration luminance panels and calibration charts placed in view of the camera. *Figure 1* and *Figure 2* depict the testing setup including the area the photographs were taken, and the calibration charts, camera equipment and cones that were utilized.

Two calibration charts were placed 75 feet in front of the camera. One chart was 10 feet to the right of the 75-foot centerline and measured 2 feet wide by 10 feet tall and contained ten Landolt C's [10]. The second chart was placed directly along the 75-foot centerline and contained a contrast and spatial frequency panel that has been validated for calibrating nighttime imagery [11, 12]. This chart, measuring 3.3 feet wide by 2.6 feet tall, contains 24 circles with varying gradients of light to dark and varying size and visual frequency. An LED light panel was also used in the photographic calibration process [13]. Illuminance values were collected with a Konica Minolta T-10 Illuminance meter with NIST traceability and a factory reported accuracy of ±3%. *Figure 3* shows the general layout of the testing including the location of the illuminance meter, camera, cones and the nighttime photography calibration charts.

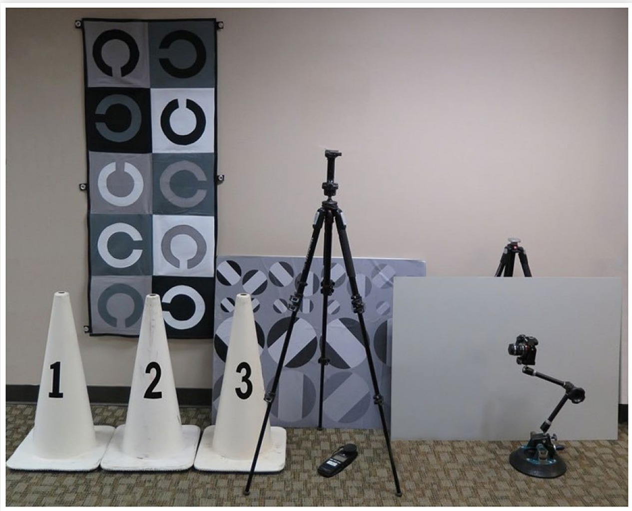
FIGURE 1 Photograph of testing equipment setup



© SAE International.

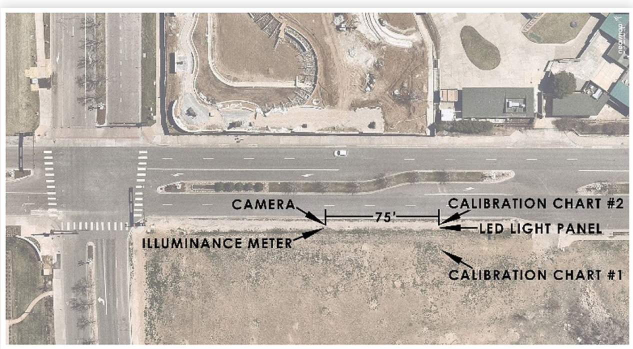
Downloaded from SAE International by William Neale, Monday, April 12, 2021

FIGURE 2 Equipment used in the testing



© SAE International.

FIGURE 3 Top-down diagram of the testing layout



© SAE International.

FIGURE 4 Camera setup in vehicle to capture driver's view

© SAE International.

FIGURE 5 Camera setup on GigaPan

© SAE International.

Setup, Documentation and Data Collection

Testing was performed on May 21, 2020. Measurements, photographs, and documentation were obtained beginning at Sunset (8:12pm) and continuing until the beginning of Astronomical twilight (10:04 pm). Documentation included illuminance values and photographs collected every 4 minutes. Imagery was captured both inside and outside a vehicle using two Sony A7S high-definition cameras. For imagery taken inside the vehicle, a camera was attached to a rigid suction cup camera rig mounted at a driver's eye height, which provided a driver's perspective with a clear view through the windshield. This view represented the view available to a driver at the testing scene. *Figure 4* is a photo of the in-car camera setup.

While photographs were taken at 4-minute intervals, video was taken from inside the vehicle at the onset of sunset, and the beginning of civil, nautical, and astronomical twilight. Additionally, video was taken halfway through each twilight period. These videos were taken every 16 minutes with the vehicle driving along a roadway that is oriented north to south. For imagery outside the vehicle, a Sony camera was equipped with a GigaPan [14] that was mounted to a tripod and remained stationary throughout the photographic documentation. The GigaPan communicates with the Sony camera through a USB cable and enables the camera to be oriented at predefined angles. In this case 4 positions were defined that included views looking north, south, west and east. These same predefined angles were used throughout the testing. *Figure 5* is a photograph of the GigaPan setup.

Outside the vehicle documentation consisted of taking four photographs at 4-minute intervals. Four photographs were taken each 4-mintue interval to capture a view North, South, East and West. Thus, a total of 116 photographs were taken over the 2-hour twilight time period and were later separated and organized into the three different twilight categories of astronomical, nautical and civil twilight times. *Figure 6* depicts a summary of the data collects, including the time of day and the twilight category the photographs were taken. *Figure 7* shows three examples of the photographs taken. These include a photo at sunset, halfway to the beginning of civil twilight and at civil twilight.

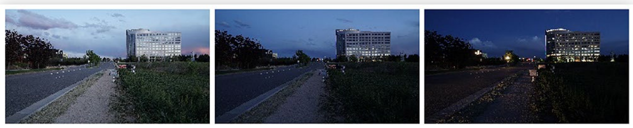
Downloaded from SAE International by William Neale, Monday, April 12, 2021

FIGURE 6 Time of day and twilight category photographs were taken.

Sunset	8:12	Civil Twilight	8:44	Nautical Twilight	9:24	Astronomical Twilight	10:04
	8:16		8:48		9:28		
	8:20		8:52		9:32		
	8:24		8:56		9:36		
	8:28		9:00		9:40		
	8:32		9:04		9:44		
	8:36		9:08		9:48		
	8:40		9:12		9:52		
			9:16		9:56		
			9:20		10:00	Nautical Twilight Next Day	4:29am

© SAE International.

FIGURE 7 Photographs taken at sunset *(left)* halfway to civil twilight *(center)* and at civil twilight *(right)*



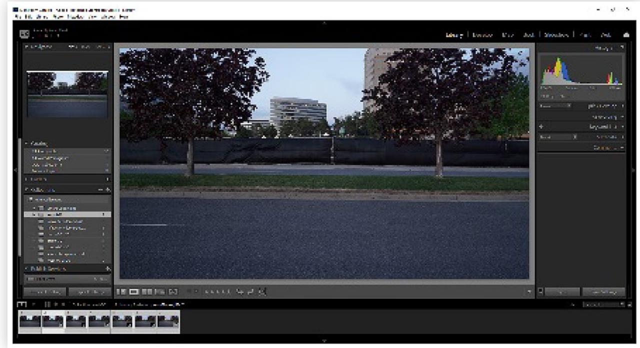
© SAE International.

Image Processing for Sunset to Civil Twilight

After all the photographs and videos were captured and organized, the photographs taken before or after a target time were imported in Adobe Lightroom Classic for adjustment. Lightroom is a post-processing software application that allows adjustments to be made to the exposure of the photographs. Adobe is a widely used software designer for digital image processing, though other software programs may be available for similar purposes if the program allows for post-processing exposure control. In this program, adjustment to the exposure of the photographs are made using an exposure slider which defaults at zero and can be moved in a positive or negative direction to give the photograph a lighter or darker appearance. The exposure slider values range from -5 to +5 and will become brighter as the exposure increases and darker as the exposure decreases. The temperature and tint of the white balance were also adjusted using sliders to adjust the overall color of the photographs. The temperature of the image will have more blue as the slider moves to the left and more yellow as the slider moves to the right. The tint will appear greener as the slider moves to the left and redder as the slider moves to the right. Figure 8 is a screenshot of Adobe Lightroom Classic.

The first set of adjustments were made to the photographs taken after the target time of 8:12pm which represented the onset of sunset. Photographs taken after 8:12pm were adjusted in Lightroom to match a target photograph that was taken at exactly 8:12pm. Adjustments were made until the quality of the adjusted photographs visually deteriorated and became too grainy or otherwise no longer representative of a high-quality image. Adjustments to the exposure were made in Lightroom starting with the first photo, taken at 8:16pm, until it matched the target photo taken at 8:12pm. In this instance, the exposure was adjusted to a value of +0.1. The temperature and tint adjustments were not necessary for the photograph taken at 8:16pm so those values remained unchanged. The next photograph taken at 8:20pm was also adjusted to match the photo taken at

FIGURE 8 Screenshot of Adobe Lightroom Classic



© SAE International.

TABLE 1 Temperature, tint, and exposure values in Lightroom.

Photograph Time Taken	Temperature	Tint	Exposure
8:16 PM	0	0	0.1
8:20 PM	5	-4	0.5
8:24 PM	8	-6	1.2
8:28 PM	14	-12	1.3
8:32 PM	20	-14	1.7
8:36 PM	28	-16	2.0

© SAE International.

FIGURE 9 Unadjusted south-facing photographs (top row) and adjusted photographs (bottom row)

© SAE International.

8:12pm. This process of adjusting the exposure of each photograph continued at 4-minute intervals up to the time frame of 8:36pm which would be the seventh photograph after sunset began. This time also corresponds to 8 minutes before the beginning of civil twilight. Photographs taken after this point in time could not be adjusted to match the target photograph of 8:12pm, since the deterioration in quality after the adjustment was too significant. Figure 9 depicts a series of calibrated and unadjusted photographs looking south taken from 8:12pm to 8:36pm (top row) and the series of photographs adjusted in Lightroom to match the 8:12pm target photograph (bottom row). Slight differences in cloud cover can be observed in the photographs, and the appearance of manmade lighting in the building is also apparent. However, neither the cloud cover nor the presence of interior building lights affected the visibility of the roadway and immediate surroundings from the location that the photograph was taken. *Appendix A* contains a single page of the same images represented larger.

Adjustments were made to the temperature, tint and exposure of the south-facing photographs taken from 8:16pm to 8:36pm and noted in Table 1. This table includes the temperature, tint, and exposure settings that were made in Lightroom. These same settings were applied to the photographs taken facing north, west and east and found to properly adjust the images to match the target photo.

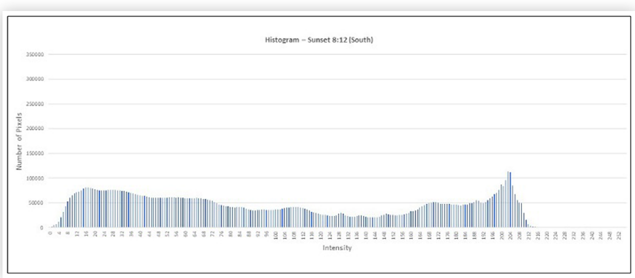
Downloaded from SAE International by William Neale, Monday, April 12, 2021

Photograph Comparison South Facing

The adjusted photographs were initially validated by visually comparing the adjusted photographs to the target photograph. This match is apparent in *Figure 9*, where all 7 of the adjusted photographs appear substantially similar to the target photograph taken at 8:12pm. To numerically validate that the exposure-adjusted photographs match the target photograph an additional analysis was performed. Histograms of each adjusted image were compared to the histogram of the original target photograph taken at 8:12pm. Lightroom can display the image histogram that gives the frequency distribution of the averaged intensity values of all of the pixels in the image. *Figure 10* is the histogram of the target photograph taken at 8:12pm. The horizontal axis represents the intensity values ranging from 0 to 255, and the vertical axis is the number of pixels. The intensity values are based on average intensity values of the Red, Green and Blue channels of an image with 0 representing black and 255 representing white, or full brightness. *Figure 11* shows the overlay of the histograms of the original target photograph from 8:12pm and the unadjusted photograph from 8:32pm. When comparing these histograms, it is clear that the pixel intensity distribution is not the same. The histogram of the image taken at 8:32pm is skewed to the right indicating a darker photograph, as there are more pixels in the image with lower intensity values. The photograph taken at 8:12pm is lighter and therefore has a more uniform histogram. This is depicted visually in *Figure 12* with the lighter, target photograph from 8:12pm on the left, and the unadjusted original photograph from 8:32pm on the right.

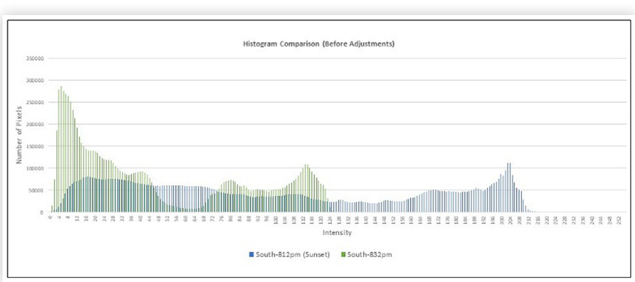
After adjustments were made in Lightroom to the photograph taken at 8:32pm, the histogram was again compared to

FIGURE 10 Histogram of the 8:12 pm south-facing photograph (target)



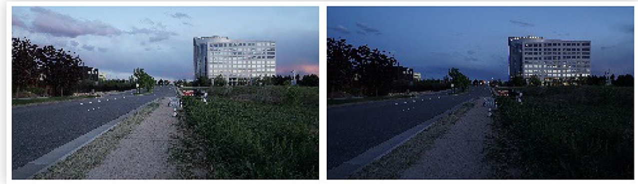
© SAE International.

FIGURE 11 Histogram of the 8:32pm south-facing photograph (to be adjusted) overlaid on the histogram of the 8:12pm photograph (target)



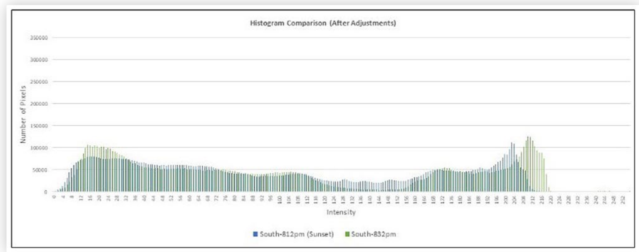
© SAE International.

FIGURE 12 South-facing photographs at 8:12pm, *(left)*, and at 8:32pm, *(right)*



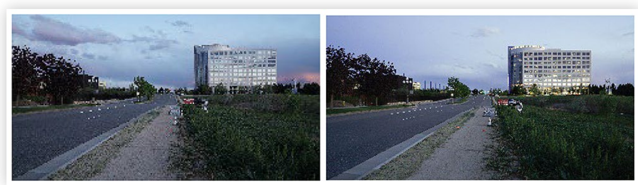
© SAE International.

FIGURE 13 Histogram of adjusted south-facing photograph taken at 8:32pm overlaid on the histogram of the target photograph histogram



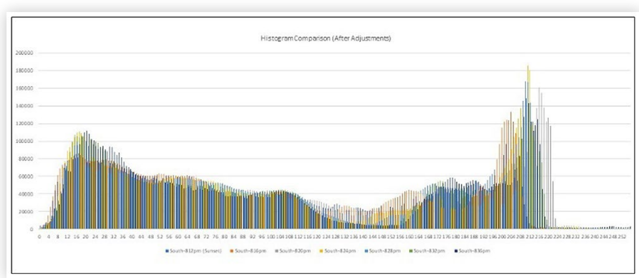
© SAE International.

FIGURE 14 Target south-facing photograph taken at 8:12pm, *(left)*, and adjusted photograph taken at 8:32pm, *(right)*



© SAE International.

FIGURE 15 Histogram of all adjusted photographs overlaid on the histogram of the reference photograph histogram



© SAE International.

the target photograph from 8:12pm. *Figure 13* shows the comparison of the two histograms, depicted as a more consistent pixel intensity distribution. As depicted, the adjusted image has a histogram that more closely matches the histogram of the target photograph. Visually, too, the resulting images are substantially similar, as depicted in *Figure 14*.

After the six photographs captured during this time interval were adjusted to match the target photograph, the histograms of all the adjusted images were compared to the histogram of the target photograph. *Figure 15* shows the

Downloaded from SAE International by William Neale, Monday, April 12, 2021

overlay of the histograms of all the adjusted photographs from the time period of 8:16pm to 8:32pm overlaid on top of the 8:12pm target photograph histogram.

Photograph Comparison East Facing

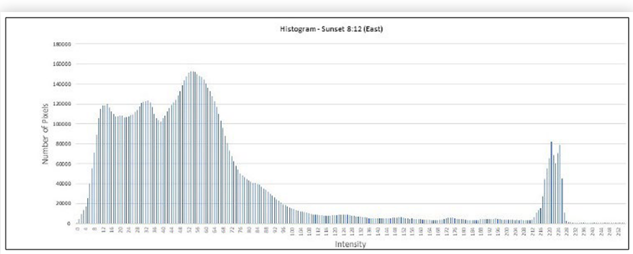
Additional validation was performed for the east-facing photographs. For these photographs, the same temperature, tint, and exposure values in *Table 1* were applied to each image and subsequently compared to the target photograph of the corresponding view. The top row of photographs in *Figure 16* depict the unadjusted photographs looking east taken at 4-minute intervals starting at 8:12pm and ending at 8:36pm. The bottom row of images are the adjusted photographs using the same temperature, tint, and exposure values used for the south-facing photographs. In this example the photographs were adjusted to match the target photograph taken at 8:12pm. *Appendix B* has this image enlarged for clarity.

Figure 17 is the histogram of the east-facing 8:12 pm target photograph and *Figure 18* are the histograms of the six Lightroom-adjusted east-facing photographs taken in the same time period from 8:12pm to 8:36pm using the same exposure values as used on the south-facing photographs.

FIGURE 16 Unadjusted east-facing photographs, *top*, and adjusted exposure photographs, *bottom*

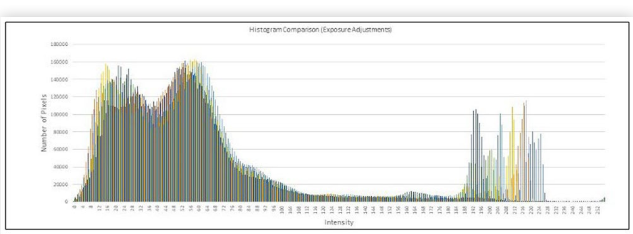
© SAE International.

FIGURE 17 Histogram of east-facing target photograph taken at 8:12pm, looking east.



© SAE International.

FIGURE 18 Histogram of east-facing adjusted photographs using the same exposure values in Lightroom



© SAE International.

The same validation process was performed on the photographs taken looking north and west over the same time period. The same temperature, tint, and exposure values used in *Table 1* were applied to each image and again compared to the target photograph taken at 8:12pm. The results of this process yielded the same substantially similar visual imagery and histograms.

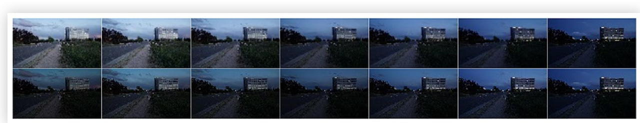
Image Processing for Civil Twilight to Sunset

In addition to adjusting the six photographs taken after 8:12pm to match the 8:12pm target photograph, this same process was performed in reverse. In reverse, a target photograph was taken at 8:36pm and photographs taken earlier than 8:36 were then adjusted to match it. In this series, the exposure was adjusted to make the earlier photographs, which were too light, darker to match the target photograph of 8:36pm. When the adjustments were made for this series of photographs the exposure slider was adjusted to the left, or negative direction. These adjustments also allowed for a 24-minute window of time before image quality was unacceptable. *Figure 19* shows the south-facing photographs taken at the scene (top) and the adjusted photographs on the bottom. The last photograph on the right in the top row is the 8:36pm target photograph.

Adjustments made to the temperature, tint and exposure of the photographs were noted so that the same values could be applied to photographs taken with the camera oriented to the north, west and east. *Table 2* shows the values of the temperature, tint and exposure entered in Lightroom for each adjusted photograph.

Again, to confirm that the exposure values for the south-facing photographs entered in Lightroom work on all of the images taken looking north, west and east in the time period from 8:12pm to 8:36pm, the same exposure values used in *Table 2* were applied to the photographs in Lightroom. The

FIGURE 19 Unadjusted south-facing photos, *(top)*, and adjusted exposure photographs, *(bottom)*



© SAE International.

TABLE 2 Temperature, tint, and exposure values in Lightroom.

Photograph Time Taken	Temperature	Tint	Exposure
8:32 PM	0	0	-0.4
8:28 PM	-7	-5	-1.0
8:24 PM	-14	-10	-1.2
8:20 PM	-20	-16	-2.0
8:16 PM	-25	-20	-2.5
8:12 PM	-30	-26	-2.8

© SAE International.

Downloaded from SAE International by William Neale, Monday, April 12, 2021

histograms were also overlaid, and it was determined that the same exposure values in *table 2* can be used on all the photographs in the 24-minute window looking north, west and east. In other words, the process for adjustment of photographs can work if the photograph is taken later and adjusted to appear earlier in time, or if taken earlier can be darkened to appear as if it were taken later in time.

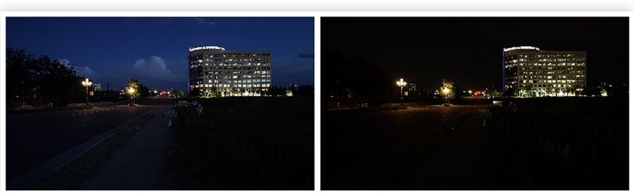
Image Processing for Civil to Nautical Twilight

The same Lightroom adjustment process was used for photographs taken from civil twilight, which began at 8:44pm, to nautical twilight, which began at 9:24pm. Because the light level drops more slowly after civil twilight begins, the adjustments to the photographs are not as dramatic. *Figure 20* shows a comparison of the photographs taken at 8:44pm and at 9:24pm. The light level at the beginning of civil twilight was 1.41 lux and dropped to .09 lux at the beginning of nautical twilight. The exposure time on the camera during civil twilight started at .8 seconds and ended at a 2-second exposure time. Because of this small amount of change in exposure all of the photographs taken during civil twilight were able to be adjusted in Lightroom to match any chosen target photograph taken during the civil twilight time period.

Image Processing for Nautical to Astronomical Twilight

Figure 21 shows a comparison of the photographs taken at the beginning of nautical twilight, which began at 9:24pm and the beginning of astronomical twilight, which began at 10:04pm. The light level at the beginning of nautical twilight was .09 lux and was .08 lux at the beginning of astronomical twilight. Because the amount of light remained effectively the same, the camera settings also remained the same throughout nautical twilight and therefore no adjustments were necessary for any of the images. In other words, there is no target image from nautical twilight to astronomical twilight because all of the photographs have the exact same camera settings.

FIGURE 20 Photographs taken at 8:44pm, *left*, and photograph taken at 9:24pm, *right*.



© SAE International.

FIGURE 21 Photographs taken at 9:24pm, *left*, and photograph taken at 10:04pm, *right*.

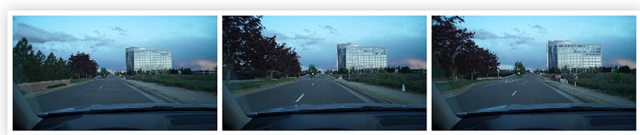
© SAE International.

Video Testing

The same adjustment process used in Lightroom for the photographs was applied to the frames of the video footage obtained during this testing from inside the vehicle. A series of still frames were exported from the video files to be imported into lightroom individually. Video drive-throughs occurred at sunset, civil twilight, nautical twilight and astronomical twilight. Drive-throughs were also taken at the midpoint in time of each twilight phase. *Figure 22* depicts three still frames from the video drive-through obtained during the sunset time frame. This view looks south.

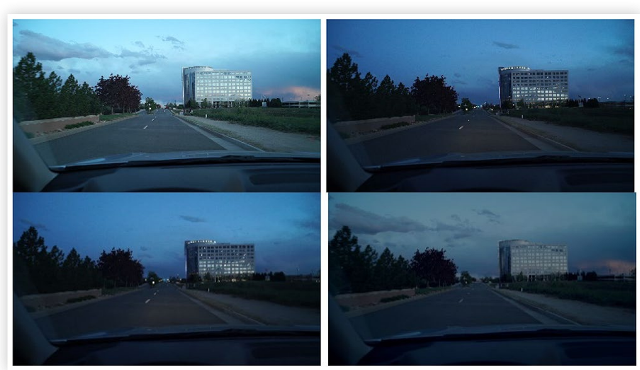
Frames were exported, and processed, from the drive-throughs at 8:12pm and at 8:28pm. These images were imported into Lightroom and a target image was chosen that corresponds to an image taken at a different time. For instance, the frames exported from the video drive through at 8:12pm were adjusted in Lightroom to match the target frame saved from the video taken at 8:28pm. *Figure 23* depicts a calibrated and unadjusted still frame from the drive through taken at 8:12pm and the drive through taken at 8:28pm (top row) and the still frame from 8:12pm adjusted in Lightroom to match the target still frame from the 8:28pm drive through (bottom row).

FIGURE 22 Still frames from video captured at sunset



© SAE International.

FIGURE 23 Unadjusted south-facing still frames (top row) and adjusted still frame (bottom row)



© SAE International.

Downloaded from SAE International by William Neale, Monday, April 12, 2021

Adjustments were made to the temperature, tint, and exposure to match the target image. *Table 3* shows the values of the temperature, tint and exposure entered in Lightroom for the frame saved from the video taken at 8:12pm to match the target frame saved from the 8:28pm video.

The histogram of the adjusted 8:12pm still frame was compared to the histogram of the target still frame taken at 8:28pm. *Figure 24* is the histogram of the target still frame saved from the video taken at 8:28pm. *Figure 25* shows the overlay of the histograms of the original target still frame from 8:28pm and the unadjusted still frame from 8:12pm. When comparing these histograms, it is again clear that the pixel intensity distribution is not the same. The histogram of the still frame from 8:28pm is skewed to the right indicating a darker image. The still frame from 8:12pm is lighter and therefore has a more uniform histogram. This is depicted visually in *Figure 26* with the darker, target still frame from 8:28pm on the right, and the unadjusted still frame from 8:12pm on the left.

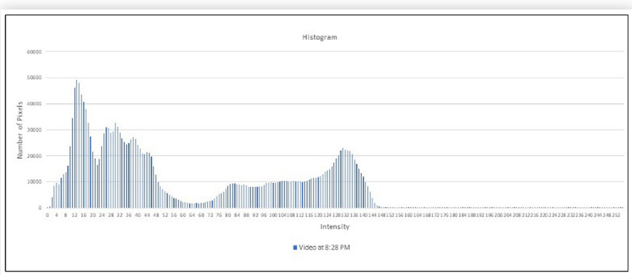
After adjustments were made to the still frame from 8:12pm, the histogram was again compared to the target still frame saved from the video taken at 8:28pm. *Figure 26* shows the comparison of the two histograms, depicted as a more consistent pixel intensity distribution. As depicted, the adjusted image has a histogram that more closely matches the histogram of the target still frame. The resulting images are substantially similar, as depicted in *Figure 27*.

TABLE 3 Temperature, tint, and exposure values in Lightroom.

Still Frame Time	Temperature	Tint	Exposure
8:12 PM	2	20	-1.4

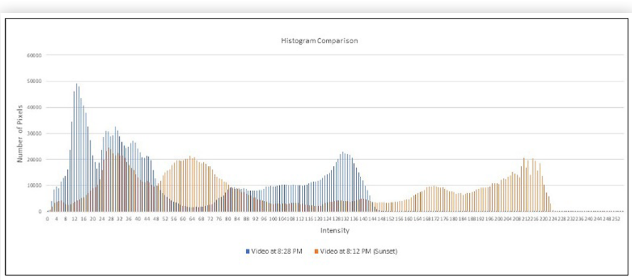
© SAE International.

FIGURE 24 Histogram of the 8:28 pm south-facing still frame (target)



© SAE International.

FIGURE 25 Histogram of the 8:12pm south-facing still frame (to be adjusted) overlaid on the histogram of the 8:28pm still frame (target)

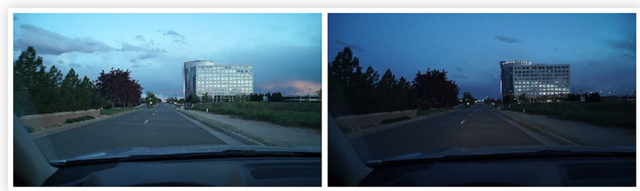


© SAE International.

As before with the photographs processed in reverse, the same steps were applied to the video frame taken at 8:28pm to match the target still frame taken at 8:12pm. *Figure 28* depicts the overlay comparison of the two histograms after adjustments were made to the still frame from the video taken at 8:28pm. *Figure 29* depicts visually the target still frame taken at 8:12pm on the left, and the adjusted video frame taken at 8:28pm on the right.

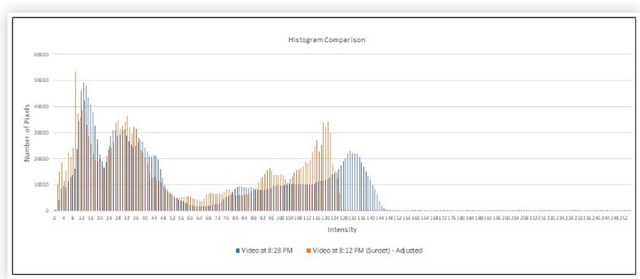
For the time frame starting at civil twilight and continuing to nautical twilight, the drive through scene was sufficiently dark that the headlamps of the vehicle were on. This caused the video to record a view where the roadway was illuminated by the headlamps. Attempts to adjust this footage to appear darker or lighter resulted in the illuminated roadway appearing too bright or too dark relative to the original footage. As a result, it was determined that footage taken during this time frame cannot be easily adjusted to match a target time that differs by more than a few minutes. For the time frame starting at nautical twilight and continuing to astronomical twilight, the camera settings did not need to change as the lighting differences in this time period were not discernible from inside the vehicle. These video runs all had the same camera settings and do not look any visually different.

FIGURE 26 South-facing still frame at 8:12pm, *(left)*, and at 8:28pm, *(right)*



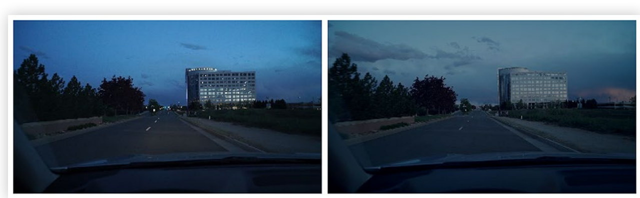
© SAE International.

FIGURE 26 Histogram of adjusted south-facing still frame taken at 8:12pm overlaid on the histogram of the target still frame histogram



© SAE International.

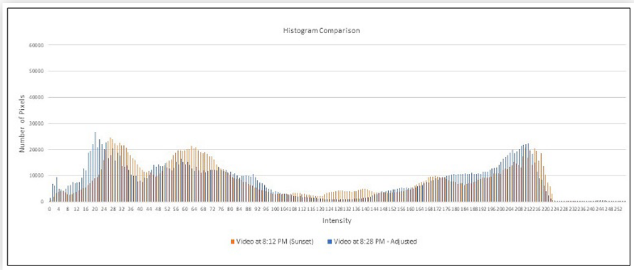
FIGURE 27 Adjusted still frame from video taken at 8:12pm, *left*, and still frame from video taken at 8:28pm, *right*.



© SAE International.

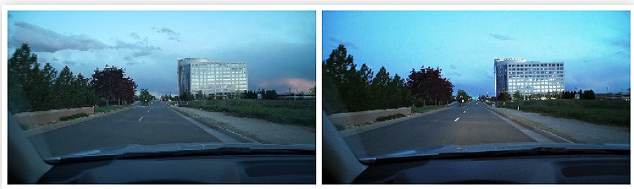
Downloaded from SAE International by William Neale, Monday, April 12, 2021

FIGURE 28 Histogram of adjusted south-facing still frame taken at 8:12pm overlaid on the histogram of the target still frame histogram



© SAE International.

FIGURE 29 Target still frame from video taken at 8:12pm, *left*, and adjusted still frame from video captured at 8:28pm, *right*.



© SAE International.

Discussion

Capturing accurate photographs during dawn and dusk lighting conditions can be challenging because the available light changes very quickly. This isn't a problem during night-time conditions, after the sun is sufficiently below the horizon and not contributing meaningful light to an area. During rapid lights changes, however, capturing footage from multiple perspectives can be difficult. This paper presents a method for adjusting photographs and video that were taken at a different time than the intended time. Through proper post-production adjustment to the exposure, tint and temperature, the photographs and video taken later or earlier can be represent lighting and visibility levels from the intended time. From sunset to civil twilight the adjustments are the most substantial, but from civil twilight to nautical twilight the adjustments are significantly less. From nautical twilight to astronomical twilight there is little discernible change in lighting and no change was required in the camera settings to account for the change in light. It is important to note that for this testing man-made lights such as streetlights, headlights and self-illuminated signage were not present in the direct foreground of the photographs. Adjustments may be necessary to account for man-made lights, as the ambient lighting decreases. This is due to the increased role that man-made lights play in providing light to an area in the immediate viewing area of the camera. As an example, when taking photographs of a pedestrian in a crosswalk, the overhead streetlights and illumination from the lights may appear over exaggerated in photographs when the exposure is increased or decreased. This effect can also work in reverse and needs to be considered.

References

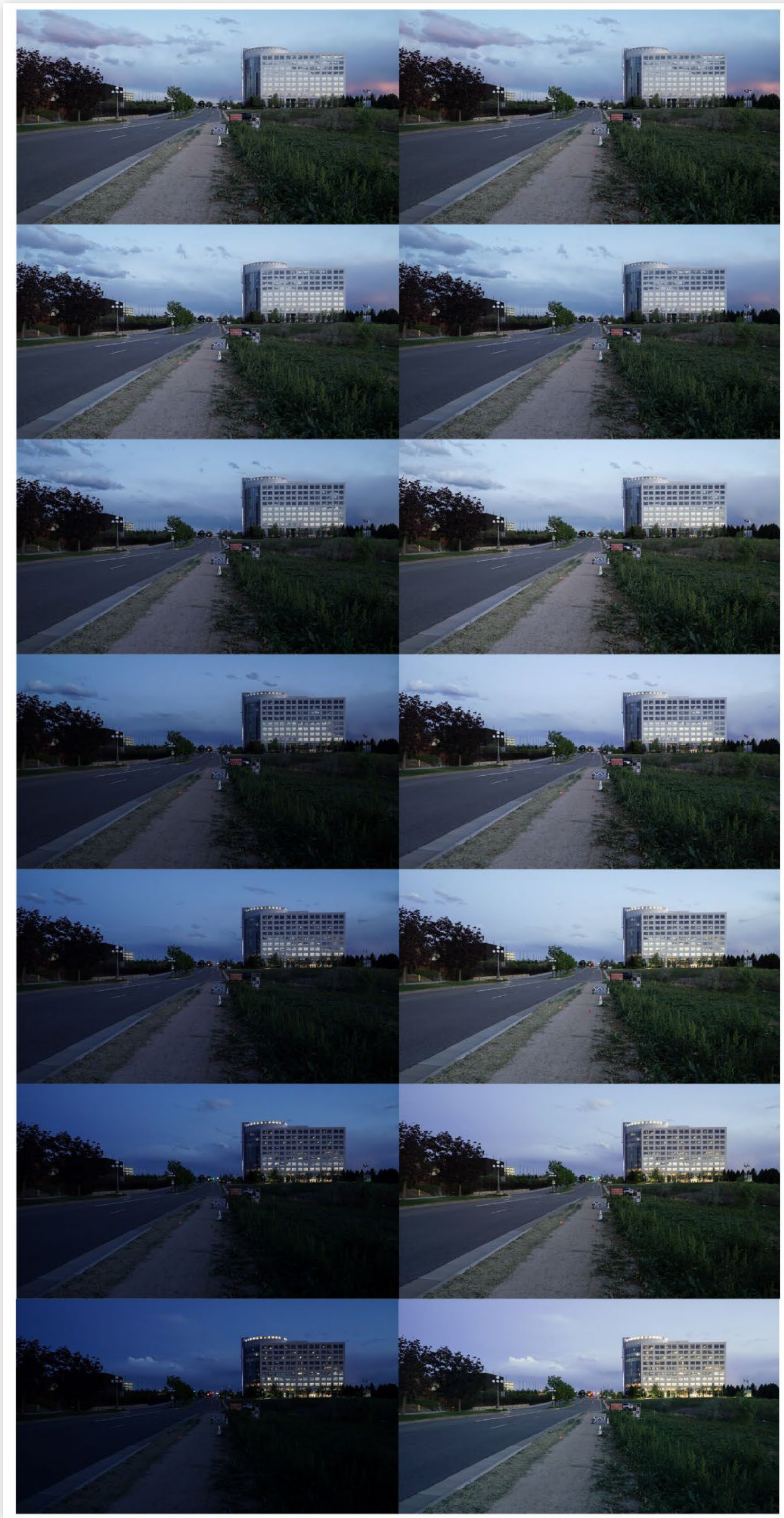
1. US Naval Observatory, "Computer Program for Sun and Moon Illuminance with Contingent Tables and Diagrams," Sun Moon.exe windows application, February 19, 1987, P.M. Janiczek and J.A. DeYoung.
2. Neale, W., Marr, J., McKelvey, N., and Kuzel, M., "Nighttime Visibility in Moonlight Conditions," SAE Technical Paper 2019-01-0141, 2019, doi:10.4271/2019-01-0141.
3. https://earthsky.org/
4. Neale, W., Marr, J., and Hessel, D., "Nighttime Videographic Projection Mapping to Generate Photo-Realistic Simulation Environments," SAE Technical Paper 2016-01-0415, 2016, doi:10.4271/2016-01-1415.
5. Neale, W., Marr, J., and Hessel, D., "3D Video Projection Mapping Photogrammetry of Physical Evidence through Video Tracking," SAE Technical Paper 2013-01-0788B-400, 2013.
6. Ayres, T.J., "Psychophysical Validation of Photographic Representations," Safety Engineering and Risk Analysis, SERA-Vol. 6, 1996.
7. Holohan, R., Billing, A., and Murray, S., "Nighttime Photography - Show It Like It Is," SAE Technical Paper 890730, 1989, doi:10.4271/890730.
8. Ayres, T.J., and Kubose, T., "Calibrating a Contrast-Sensitivity Test Chart for Validating Visual Representation," Proceedings of the Human Factors and Ergonomics Society, 59th Annual Meeting, 2015.
9. Ayres, T.J., and Kayfetz, P., "Calibrating Validation of Videographic Visibility Presentations," American Academy of Forensic Sciences, 67th Annual Meeting, Seattle Washington, 2010.
10. Muttart, J.W., "Driver's Responses in Emergency Situations," Crash Safety Solutions, Feb. 2017, p. 103.
11. Ayres, T.J., and Kubose, T., "Calibrating a Contrast-Sensitivity Test Chart for Validating Visual Representation," Proceedings of the Human Factors and Ergonomics Society, 59th Annual Meeting, 2015.
12. Ayres, T.J., and Kayfetz, P., "Calibrating Validation of Videographic Visibility Presentations," American Academy of Forensic Sciences, 67th Annual Meeting, Seattle Washington, 2010.
13. Neale, W., Marr, J., and Hessel, D., "Nighttime Videographic Projection Mapping to Generate Photo-Realistic Simulation Environments," SAE Technical Paper 2016-01-1415, 2016, doi:10.4271/2016-01-1415.
14. http://gigapan.com/

Contact Information

James Marr, B.A., B.S.
Kineticorp, LLC
(303) 733-1888
jmarr@kineticorp.com, www.kineticorp.com

Downloaded from SAE International by William Neale, Monday, April 12, 2021

Appendix A



© SAE International.

Downloaded from SAE International by William Neale, Monday, April 12, 2021

Appendix B

© SAE International.

© 2021 SAE International. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE International.

Positions and opinions advanced in this work are those of the author(s) and not necessarily those of SAE International. Responsibility for the content of the work lies solely with the author(s).

ISSN 0148-7191