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ABSTRACT

Accident scene photographs contain important information that can be useful in determining how accidents happened. However, dimensions are difficult to gather from photographs. The size of an object in the photographs depends on how far away from the camera the object is located. An object in the background looks smaller and will measure smaller than the same size object in the foreground. This phenomenon is called perspective distortion.

Photogrammetry was introduced in the late 1800's as a tool to compensate for the perspective distortion and assist in gathering dimensions from photographs. One of the early techniques was to create a transparent miniature of a photograph and place the miniature in the view screen on the camera. The camera was then taken to the scene and matched to the correct position such that the image in the scene matched the image in the view screen. Today, using computer modeling software, a scene can be created in the computer model that matches the actual photograph. Using a technique called camera matching, the camera in the computer can be adjusted to match the photograph. Once properly matched, dimensions within the photograph can be gathered. This technique is useful in gathering dimensional data from crash scene photographs like the point of impact and the point of rest of crash vehicles. Once the crash scene dimensions are determined, the accident can be reconstructed using the principals of conservation of momentum and energy.

INTRODUCTION

In the late 1980's, a photogrammetric technique called the reverse projection method was introduced[1,2]. This method was based on re-establishing the original camera viewpoint by returning to the scene with a transparency placed in a camera's view screen and viewing the scene through the transparency. A Nikon F-3 camera with a detachable view prism was designed so that the transparency could be placed in the view screen. At the scene, one person would position the camera and adjust the focal length so that the transparency matched the scene. A second person would mark the position of the lost features such as the tire marks and positions of the vehicles. Once these features were determined, they would be surveyed to determine the necessary crash data. This method of reverse projection was tedious and time-consuming making it difficult to accomplish at scenes with heavy traffic. Due to the high cost of the camera, and the time/safety issues, this process was not often used.

A safer and more cost effective solution has arisen using computer modeling software. Instead of creating a transparency of the scene, the scene can be recreated using computer modeling software. A virtual camera can be created in the computer model. The scene photograph can be digitized and placed in the virtual camera's view port. In the computer model, the camera can be adjusted so that the modeled scene matches the background image. Once the camera is properly matched, the necessary dimensions can be identified and measured.

DISCUSSION

PROCEDURE

Below is an outline of the steps involved in gathering dimensions from photographs using the camera matching photogrammetric technique.

1. Create a digital model of the scene.
   - Gather dimensional data of known objects by either obtaining an aerial photograph of the scene or by performing a scene inspection.
   - Using scene data, create three-dimensional digital computer model of the accident scene.
2. Import scene photographs into the computer.
   - Digitize photographs.
   - Calibrate photographs as background images in the computer modeled scene.
3. Camera match the digital model to the background images.

- Create a camera in the computer model for the background image. A guideline for placement is to consider the height of the photographer. Place the camera approximately five feet five inches above the ground level. Start with a 50 mm lens. Based on the observed discrepancies between the perspective of the photograph and perspective of the computer scene, adjust the focal length and vanishing point of the camera accordingly. If the objects look stretched when matched to the photograph, increase the focal length and move the vanishing point away. If the objects look squished, decrease the focal length and bring the vanishing point closer.

4. Testing Accuracy of Camera Position
   - Measure other objects in the scene and compare their dimensions to the known dimensions of the objects.

CASE STUDY

To explain the process in greater detail, these authors created an accident scene and photographed the vehicles and the skid marks. The locations of the vehicles and skid marks were surveyed. Our objective was to determine the distances between the skid marks and vehicles using the camera matching photogrammetric technique and compare the results to the survey.

Figure 1 – Original Photograph

The first step was to gather dimensions from the scene so that a 3D model of the accident scene could be made. This can either be done by visiting the scene or, in this case, by gathering the data from an aerial photograph. The locations of the lane lines and curbs were measured and documented from the aerial. This information was used to create a three-dimensional model of the accident site in AutoCAD[3]. The data was then imported into a 3D-modeling program called 3DStudio Max[4].

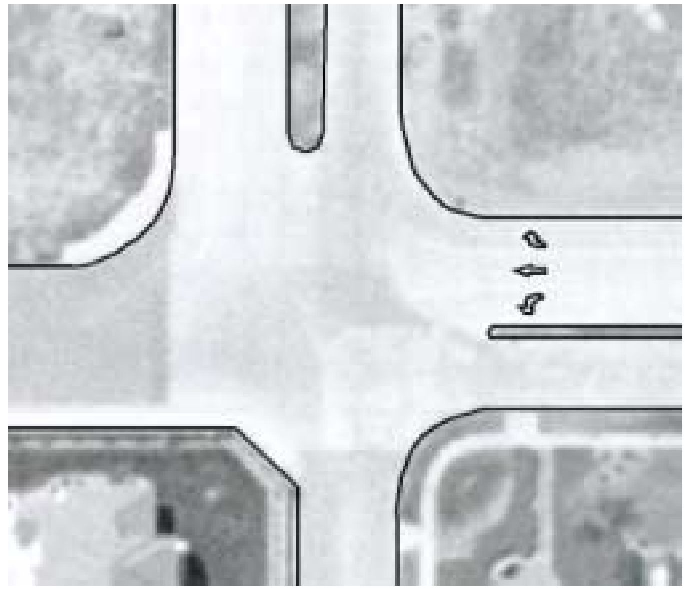

Figure 2 – CAD Model over Aerial Photo

A virtual camera was then placed in the computer modeled scene within 3DStudio. The original photograph was digitized and placed as the background in the camera view port. The camera was set at a height of five feet five inches off the roadway surface and the camera's focal length was set at 50mm. The camera's location was moved throughout the computer model while attempting to match the three-dimensional model to the photograph in the background.

As mentioned previously, there were three dimensions that the camera could be moved (x, y, z), however the z dimension was known relatively well because we had a good idea of the photographer's eye height. The camera could also be rotated about the x, y, and z-axis. The position and rotational values were relatively easy to adjust, however the camera's focal length was the most difficult parameter to adjust correctly. When selecting the virtual camera settings, it is recommended that a 50mm lens be selected initially. A 50mm lens most reasonably represents what the human eye sees. However, often times the camera used may have had a zoom lens. If you are able to contact the photographer to determine the setting, this could save you some time. Through trial and error, you will notice that as the camera's focal length is changed from 50mm to 28mm, objects in the scene become distorted. In this case, the lane stripes became shorter and did not match up with the lane stripes in the photograph in the background. As the focal length was changed from 50mm to 80mm, the lane lines became longer and still did not match up correctly. After modifying the focal length and adjusting the camera's position and rotation, the computer model eventually matched the photographic background. After some practice, this process became easier.

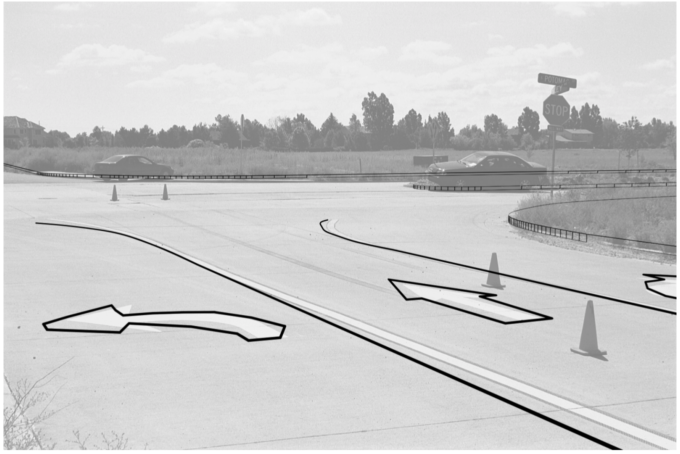

Figure 3 – CAD Model Matched to Photograph

The next step in the process was to import scaled models of the vehicles into the scene and to position the models so that they matched the photograph in the background.

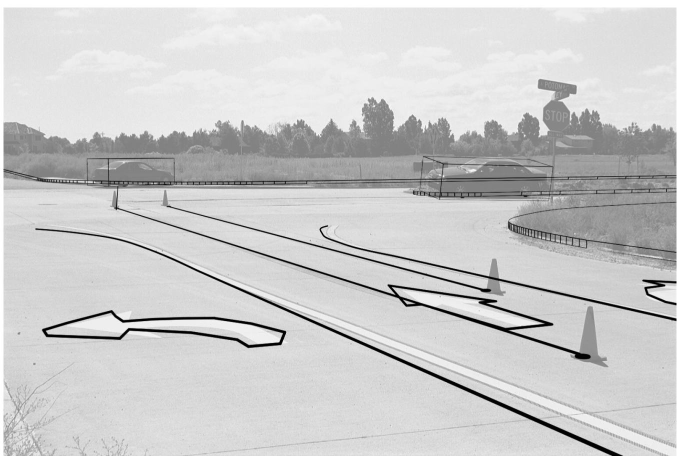

Figure 4 – CAD Model with Vehicles Added

Boxes with the same exterior dimensions (length, width and height) were used to represent the vehicles. The vehicles were positioned in their correct location at the points of rest. The tire marks were traced on the roadway so that they matched the photograph in the background. Once the vehicles and tire marks were recreated, the scene could be viewed from the top to determine distances.

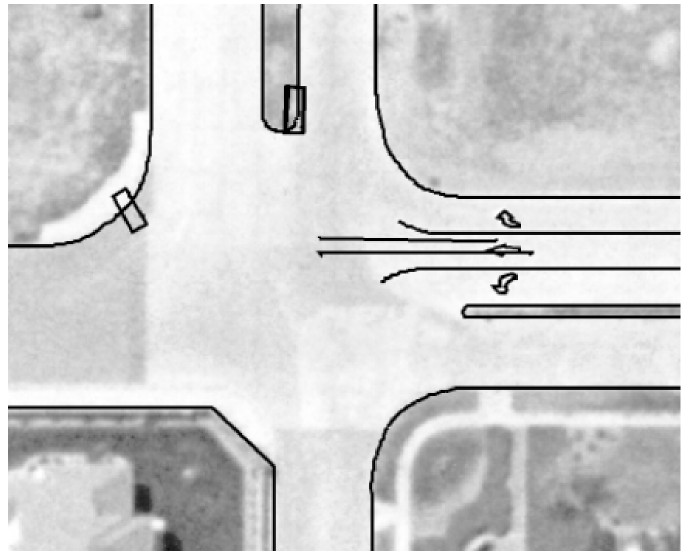

Figure 5 – Top View of CAD Model

In this case, we were interested in the length of the skid marks and the locations of the vehicles at the point of impact and rest. The photograph clearly showed the point of rest of the vehicles, and the point of impact was determined by making copies of the vehicles and placing them at the end of the tire marks. The red Honda was position so that its front tires lined up with the end of the skid marks. This was the red Honda's point of impact position. The black Audi was placed so that the damage to the right side matched the front of the red Honda. This was the black Audi's point of impact position.

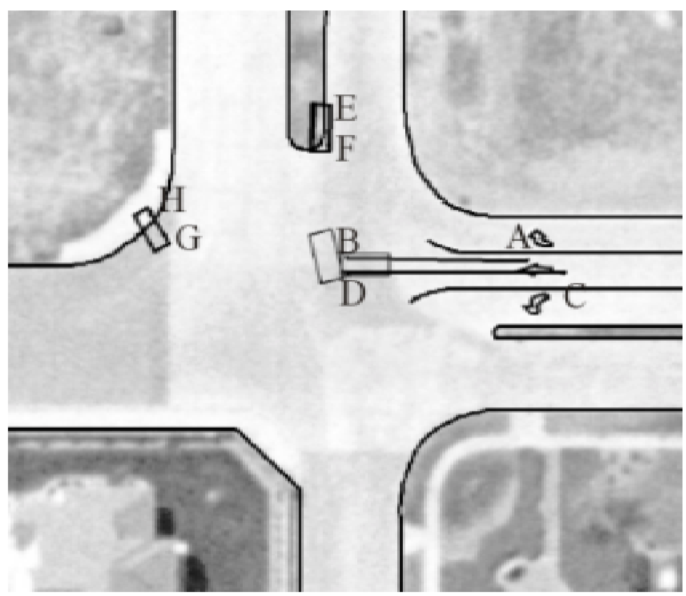

Figure 6 – Top View with Vehicles added at Point of Impact

In this case, we identified the start of the right skid mark as Pt. A and the end as Pt. B. We identified the start of the left skid mark as Pt. C and the end as Pt. D. The black Audi's left rear tire location was identified as Pt E and the front left tire was identified as Pt F. The red Honda's right rear tire was identified as Pt G, and the front right tire was identified as Pt H. A dimensional analysis was performed comparing the actual dimensions gathered in the field to the dimensions determined in the camera matching analysis. These authors found that the dimensions determined through the camera matching process were on average within 2.2% of the field dimensions.

Point ID	Field Dimension	Camera Matched Dimension	Percent Difference
A-B	59.76	61.56	3.01%
A-C	13.64	12.91	5.35%
A-D	60.12	61.42	2.16%
A-E	80.58	83.02	3.03%
A-F	77.08	78.47	1.80%
A-G	124.09	123.38	0.57%
A-H	128.32	128.96	0.50%
B-C	72.63	73.86	1.69%
B-D	5.13	5.42	5.65%
B-E	47.86	48.27	0.86%
B-F	39.54	39.35	0.48%
B-G	64.63	61.98	4.10%
B-H	69.51	68.11	2.01%
C-D	72.61	73.38	1.06%
C-E	93.83	95.49	1.77%
C-F	90.58	91.19	0.67%
C-G	137.17	135.82	0.98%
C-H	141.60	141.57	0.02%
D-E	52.86	53.72	1.63%
D-F	44.49	44.74	0.56%
D-G	65.35	63.14	3.38%
D-H	70.75	69.80	1.34%
E-F	8.74	9.14	4.58%
E-G	70.39	69.33	1.51%
E-H	69.43	69.16	0.39%
F-G	64.73	63.56	1.81%
F-H	64.67	64.81	0.22%
G-H	8.63	9.34	8.23%
Average			**2.12%**

CONCLUSION

Using this camera matching photogrammetric technique enables dimensions to be gathered from photographs quickly and safely using typical computer modeling software. The process provides a very descriptive and compelling visual record that can be used to gather important crash data. Based on the case study, the results are well within the levels of accuracy that make this process useful, although the accuracy depends on the ability of the user to accurately place the camera in the correct position with the correct focal length. This same limitation is inherent in the reverse projection method also.

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[3] AutoCAD 2000, Autodesk, San Rafael, California.

[4] 3DStudio Max, Discreet, a Division of Autodesk. San Rafael, California.

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