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Simulation of mirror surfaces for virtual estimation of visibility lines for 3D motor vehicle collision reconstruction

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ABSTRACT

3D reconstructions of motor vehicle collisions are used to identify the causes of these events and to identify potential violations of traffic regulations. Thus far, the reconstruction of mirrors has been a problem since they are often based on approximations or inaccurate data. Our aim with this paper was to confirm that structured light scans of a mirror improve the accuracy of simulating the field of view of mirrors.

We analyzed the performances of virtual mirror surfaces based on structured light scans using real mirror surfaces and their reflections as references. We used an *ATOS GOM III* scanner to scan the mirrors and processed the 3D data using *Geomagic Wrap*. For scene reconstruction and to generate virtual images, we used *3ds Max*. We compared the simulated virtual images and photographs of real scenes using *Adobe Photoshop*.

Our results showed that we achieved clear and even mirror results and that the mirrors behaved as expected. The greatest measured deviation between an original photo and the corresponding virtual image was 20 pixels in the transverse direction for an image width of 4256 pixels.

We discussed the influences of data processing and alignment of the 3D models on the results. The study was limited to a distance of 1.6 m, and the method was not able to simulate an interior mirror.

In conclusion, structured light scans of mirror surfaces can be used to simulate virtual mirror surfaces with regard to 3D motor vehicle collision reconstruction.

1. Introduction

Reconstructions of motor vehicle collisions are used to identify the causes of these events and to identify potential violations of traffic regulations [1]. This allows for a proper legal evaluation of an incident. The movements of the vehicles and pedestrians involved, their speeds and the temporal reconstruction of parallel motion sequences can offer information regarding the causes of collisions [1]. The possibility of preventing an event is another important factor related to motor vehicle collision reconstruction. Visibility and, therefore, the recognition of potential danger by a vehicle driver play important roles in collisions related to a change in direction at crossings, junctions or roundabouts. Looking through the front and side windows is often not sufficient, which is why vehicle mirrors are also required.

In Switzerland, in addition to securing physical evidence, three-dimensional (3D) documentation of accident scenes is required [2]. Different 3D scanning techniques are used, such as laser scanning or structured light scanning [3]. The resulting data can be used later to generate 3D reconstructions and visualizations of events [4,5]. This allows answering forensically relevant questions in a court of law. Possible factors related to traffic accidents may include the following: number of impacts, sequence of events, and the speed and direction of motion of the parties involved. In most cases, the position of impact is the main focus of interest [6]. Buck et al. showed a case where the question “Accident or homicide?” was answered using the 3D data of the scene, the car and the deceased [7].

The field of view (FOV) of a driver through the front and side windows of a vehicle can also be visualized in 3D. This can be used to demonstrate the visibility, or lack thereof, of other road users. In many traffic-related reconstructions, the FOV is essential to judge the situation. Vehicle mirrors are therefore a centerpiece of reconstruction. Most passenger cars have at least three different

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mirrors: one interior rearview mirror and one wing mirror on each side of the vehicle. Trucks and vans often have more than three mirrors. Mirrors in vehicles are used to increase the FOV and reduce blind spots. In addition to flat mirrors, which achieve undistorted reflections, convex and aspheric mirrors are used, which offer greater FOVs [8].

Way and Reed presented a method for physically measuring the field of view of drivers in rearview mirrors [9]. They "[. . .] combine the computerized analysis methods with measurement of actual driver eye and mirror location to obtain accurate measurements of mirror FOV" [9]. Ball et al. showed another "method for determining and presenting driver visibility" [10]. They took the relevant vehicle and marked the FOV of the driver outside the car. This measured area was than imported into a 3D model. Using the markers, it was possible for them to use the top view of the scene and visualize the driver's FOV and detect what was visible and invisible to the driver.

These reconstruction methods are resource- and time-intensive. Changes in the positions of drivers influence the FOV and are difficult to take into account. Although Ball et al. already worked with the 3D data of vehicles, they did not exploit the full potential of 3D reconstruction and visualization techniques, as they only used 2D plans to show the FOVs of drivers. Furthermore, the reconstructed virtual mirror in Ball et al. had a flat mirror surface, in contrast to real mirrors, which often have a convex mirror surface [10].

The results mentioned above show that the virtual reconstruction of vehicle mirrors as flat, reflective surfaces or the use of inaccurate approximations of the convexity is not sufficient.

We hypothesize that by combining the surface scanning of vehicle mirrors with raytracing algorithms, the accuracy of simulation of the FOVs of mirrors, particularly convex mirrors, can be improved.

2. Methods

We designed this study to analyze the performances of virtual mirror surfaces based on structured light scans, using real mirror surfaces and their reflections as references. For this purpose, photographs of a setup, including the vehicle mirror surfaces, and images of a virtual scene of the same setup were generated. Six different vehicle mirrors from passenger cars (three), trucks (two) and a van (one) with different sizes and characteristics were selected randomly based on availability (Fig. 1).

The camera view in the virtual scene was generated in 3ds Max based on the rectified original photograph and 3D scan data of the setup. For the purpose of image rectification, an additional colored laser scan of each setup was carried out. As calibrated 50 mm lenses are not a standard, image rectification is part of the standard workflow within 3D reconstructions in Zurich.

For a comparison of the real and virtual mirror views, a defined, black-and-white checkered pattern with a size of 826 × 584 mm (square size 48.6 mm) was created. In the setup, a table was positioned in front of a wall, and the pattern was affixed to the table.

2.1. Data acquisition

For each mirror, the following procedure was implemented:

1. Positioning the mirror on the table in a secure position (to prevent shaking during data acquisition, Fig. 2).
2. Take three photographs from different, arbitrary positions around the table to obtain different angles on the mirror surface; thus, the black-and-white checkered pattern had to be visible in the mirror as well as on the table in front of the mirror.
3. Perform laser scanning of the setup, including the texture for image rectification.
4. Apply a matting agent to the mirror to enable a structured light scan of the mirror surface.
5. Scan the setup using the structured light scanner.

For the scanning procedures, a ZF 5010C laser scanner (Zoller + Fröhlich GmbH, Wangen im Allgäu, Germany) and an ATOS GOM III scanner (GOM mbH, Braunschweig, Germany) the sensor configuration 400 MV 700 which has a measuring volume of 700 × 530 × 530 mm (length, width, height) was used. The photographs were taken using a Nikon D700 camera (Nikon Cooperation, Tokyo, Japan) with a Nikon FX 24–84 mm 1:3.5–4.5 G lens. The positions of the photographs were not measured and different for each mirror.

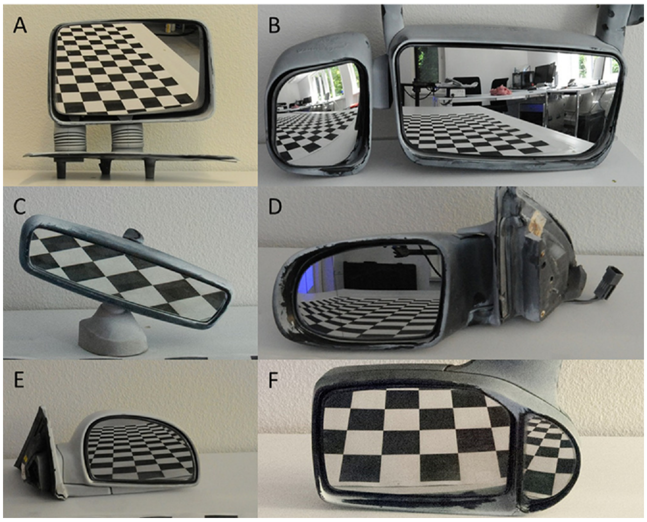

Fig 1. Mirror selection.
The figure shows the different mirrors used for the test series. They include a van left exterior mirror (A) a truck right exterior mirror (B) a passenger car interior mirror (C) a passenger car left exterior mirror (D) a passenger car right exterior mirror (E) and a truck exterior mirror (F).

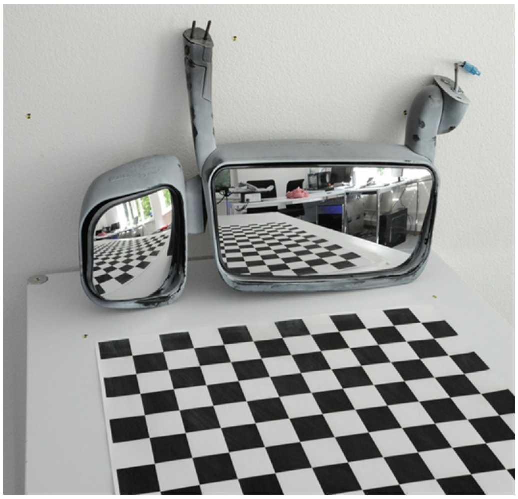

Fig. 2. Setup.
Each mirror was positioned on a table with a black-and-white checkered pattern in front a wall. For comparison, it was necessary that a sufficient amount of the pattern was visible in the mirrored surface.