World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 3.419

CRASHED VEHICLE PROFILE CREATION BASED ON DIGITAL CLOSE-RANGE PHOTOGRAMMETRY

Valeria Ersilia Oniga*[1], Ana-Maria Loghin[2] and Daniela Corina Păun[3]

[1]Lecturer, Ph. D Eng., "Gheorghe Asachi" Technical University of Iași, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Department of Terrestrial Measurements and Cadastre, Romania.

[2]Ph.D. Student, Eng., "Gheorghe Asachi" Technical University of Iași, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Romania.

[3]Ph.D. Student, Eng., Faculty of Geodesy, Technical University of Civil Engineering Bucharest, Romania.

Article Received on 12/05/2016 Article Revised on 02/06/2016 Article Accepted on 23/06/2016

***Corresponding Author**
Dr. Valeria Ersilia Oniga
Lecturer, Ph.D Eng., "Gheorghe Asachi" Technical University of Iași, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Department of Terrestrial Measurements and Cadastre, Romania.

ABSTRACT

For many years, close-range photogrammetry has been dealing with the extraction of high accuracy information from images, representing one of the most attractive and provocative researching domain. The data acquisition process is performed without any direct contact with the studied object, in a very short time, thus close-range photogrammetry has applications in areas such as: preservation of cultural heritage, soil erosion, buildings 3D modelling and vehicle measurements in damaged-based accident reconstruction. In order to determine the correct amount of the material damage caused by the traffic accident, insurance companies need accurate quantitative information regarding the damage sustained by the crashed vehicle. So, in this paper, the crashed vehicle profile was created by digital close-range photogrammetry, using the digital images acquired with a digital camera. In order to obtain the results, first the digital camera was calibrated using a 2D target, then the vehicle involved in a crash accident was modelled in 3D based on digital images. Finally, using the Hausdorff distance, the distorted vehicle 3D model was compared with the 3D model of the same type of vehicle undistorted, thus resulting the deformations of the crashed vehicle. Both vehicles 3D models were obtained by digital close-range photogrammetry, using artificial targets placed on the vehicles bodies and the "PhotoModeler Scanner" software. The differences between the two models were highlighted using a color palette, offering at the same time a global comparison.

KEYWORDS: close-range photogrammetry, vehicle profile reconstruction, 3D model.

1. INTRODUCTION

In last decades, the development of road transport together with the increasing number of vehicles led to a continuous attention concerning traffic security. The street traffic is composed by four principal elements: human, vehicle, road and the rule of road. A road-traffic accident is an unexpected event that occurs on a travelling road when a vehicle collides with another vehicle, animal, stationary obstruction or trees, due to the disregard of the rule of road. Traffic collisions may lead in injury, death or property damage.

Road accidents occur as a result of one, or more than one of the following factors: human factors, vehicle factors, road and environmental factors. Driving faster or slower than the flow of traffic – which may or may not accord with the posted speed limit – has robustly been demonstrated to increase the likelihood and severity of crashes (Ohakwe, Iwueze, Chikezie, 2011).

The impact of car crash injuries on public health is substantial everywhere in the world and is increasing (Murray, Lopez, 1997). Road traffic accidents are consistently in the top ten causes of deaths world-wide. In order to reduce the number of fatalities caused by traffic collision, better knowledge and understanding of the sequence of events prior to and during a traffic accident, Accident Reconstruction, is required. So, it is important to obtain detailed quantitative information about the damage sustained by the crashed vehicles (Coyle F., 2008).

Over the past four decades, close-range photogrammetry has known remarkable developments, including the evolution from manual to automatic image orientation and also from manual feature point measurement to automatic generation of dense 3D point clouds (Fraser C., 2015). Photogrammetry involves the use of multiple two-dimensional photographs to create a three-dimensional representation of an object. Initial applications of close-range photogrammetry in accident reconstruction often involved scene documentation, but more recently, they are used to quantify the vehicle dimensions and crush damage (Randles B., Jones B., Welcher J., Szabo T., Elliott D., MacAdams C., 2010).

With the ever wider adoption of spatial information analysis, there has been an increasing awareness of the importance of 3D data acquisition systems to support traffic accident reconstruction and forensic analysis. In an application such as accident reconstruction, GIS and CAD systems have limited utility without the underlying data (Fraser, 2006).

Over recent years, total stations and even laser scanners have been employed for incident scene dimensioning. These technologies are producing more accurate and in the case of laser scanners, more comprehensive 3D models, but data acquisition at the scene is slow compared to the photogrammetric approach. Moreover, total stations and laser scanners are relatively expensive and complex for local police and traffic agencies to use. Digital close-range photogrammetry displays many attributes which make it a well suited technology for the provision of the necessary 3D measurement data. It has a major advantage concerning the data acquisition speed and is an easy-to-use, accurate and reliable measurement tool that incorporates a reasonable degree of process automation. The scene can be recorded in a very short time and imagery provides a permanent archival record that will support further measurement after the accident (Fraser, Cronk, Hanley, 2008). These data, taken *in situ*, are the basis to perform the necessary calculations, basically the energy analysis of the road accident, for the corresponding expert reports and the reconstruction of the accident itself, especially in those accidents with important damages and consequences (Morales A., Gonzalez-Aguilera D., Gutiérrez M. A., López A.I., 2015).

The principal purpose of this article is to create a crashed vehicle profile by means of close-range photogrammetry techniques, in order to determine the correct amount of the material damage caused by a traffic accident, or which parts of the vehicle body were affected by the crash, as insurance companies need accurate quantitative information regarding the damage sustained by the crashed vehicle.

2. MATERIALS, EQUIPMENTS AND METHODS

Traffic security and fluency is a complex system that depends on several parameters, as they are shown in the following figure.

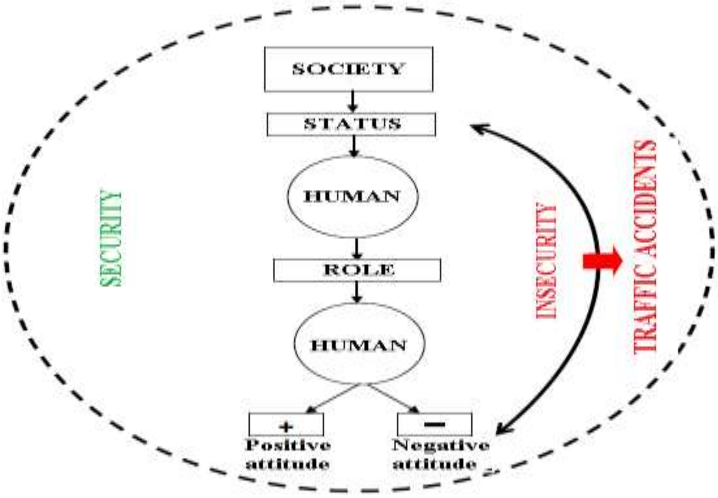
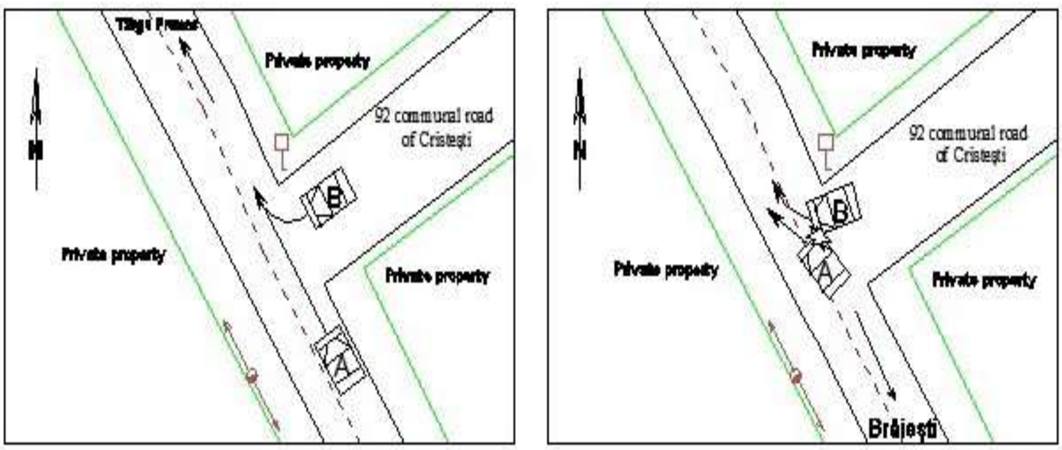


Fig 1: Traffic security and fluency.

2.1 PRESENTATION OF THE TRAFFIC ACCIDENT

Concerning the conditions of the traffic accident, there are analyzed the exact location and time of the occurred event, the speed and movement direction, the state of the road and meteorological conditions, the technical condition of the vehicles, the caused damage after the incident and also victim injuries.

The traffic accident that represents the case study of this paper, occurred on 280A county road, in Brăești locality, Iași county, Romania, on 25th of May 2013 at 10:30 in the morning. The first vehicle involved in the accident was travelling from Brăești locality to Târgu Frumos city on the priority road, with a speed of 50 km/hour (Fig. 2). At the intersection with the 92 communal road of Cristești, was hit in the right-frontal side by the vehicle that makes the object of this study, a „Dacia Logan" car (Fig. 3), that didn't took into account the ensurance conditions when executing the right turn. The weather and road conditions were good and fortunately there were no victim injuries.



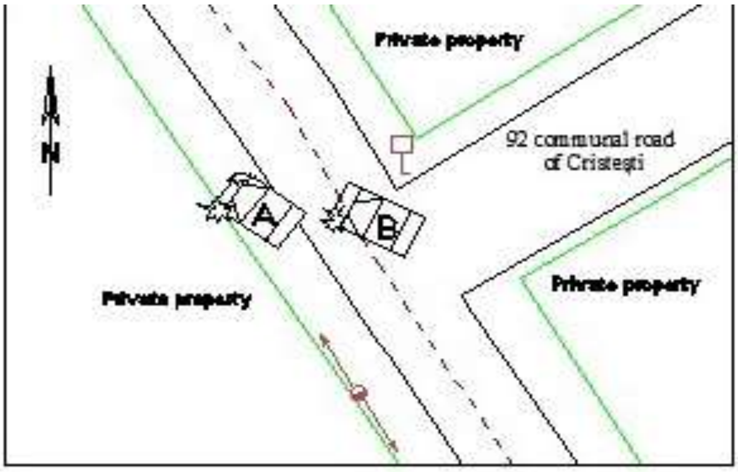


Fig 2: CAD drawings illustrating the accident scene reconstruction.

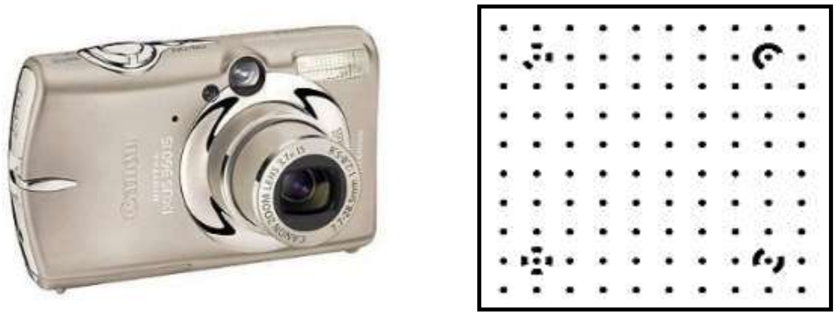
Fig 3: Perspective view of the crashed "Dacia Logan" vehicle.

2.2. EQUIPMENTS

In order to graphically reconstruct the accident scene, measurements were carried out at the crash site with a GNSS South S82T with all its components and also with a total station Leica TC 110A with included accessories.

The images were taken with a Canon IXUS 960 IS digital compact photo camera, having 12.1 Mega pixel resolution (Fig. 4a). In this paper, it was used the minimum focal length of 8mm, the digital images having the resolution of 1600 x 1200 pixels.

In order to determine the intrinsic parameters of the used camera, an automated calibration process was made, using a 2D calibration target provided by "PhotoModeler" software, consisting in a grid with 10 rows and 10 columns, totalizing a number of 100 points, having 4 control points (Fig. 4b).



(a) **(b)**

Fig 4: (a) Canon IXUS 960 IS digital camera.

(b) 2D calibration grid

2.3 MATERIALS FOR DATA PROCESSING

The vehicle involved in the crash accident was modeled in 3D based on digital images, using artificial targets placed on the vehicles bodies and the "PhotoModeler Scanner 6" software. This photogrammetric software is developed by Eos Systems Inc. Company from Vancouver, Canada and is used in metric information extraction from photographs taken with an ordinary digital camera, allowing camera calibration process, 3D model generation and data information exporting in different formats.

In order to determine the deformations of the crashed vehicle, the 3D model of the deformed vehicle was compared to the 3D model of the same type of vehicle undistorted, using the "CloudCompare" software. This software allows 3D point cloud editing and processing algorithms, like: registration, resampling, statistic computation, segmentation.

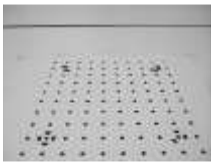
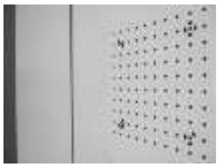
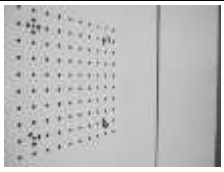
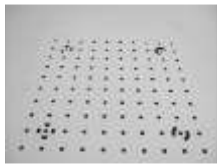
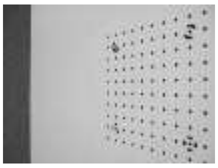
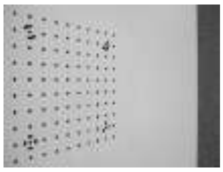
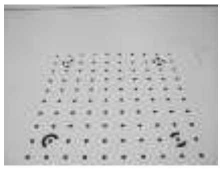
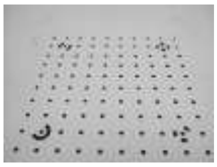
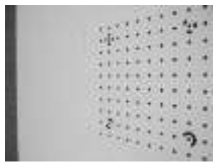
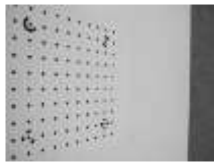
3. RESULTS AND DISCUSSION

3.1 CAMERA CALIBRATION

A previous important step in 3D model generation is represented by the camera calibration process, that has as result the intrinsic parameters of the camera, or the interior orientation parameters: the focal length, the coordinates of the principal point in pixels and also the coefficients for radial and tangential distortions (Loghin, Oniga, 2014).

This 2D calibration grid was printed on a A4 sheet of paper and then attached to a planar surface, preferably with un uniform texture and color, this fact leading to a reduced time of interior calibration parameter calculation. There were taken 12 images of the 2D calibration target, using 3 different positions of the camera, as it can be seen in the following table.

Table 1: Calibration image capturing.

Series	Digital camera position			
				
				
				

The twelve calibration images were imported into "PhotoModeler Scanner" software and the Camera calibration project was processed. Finally, the intrinsic parameters of the Canon Digital IXUS 960 IS camera were obtained, as can be seen in Table 2.

Table 2: The Canon Digital IXUS 960 IS digital camera intrinsic parameters.

Focal length	**f [mm]**	**u_0 [pixels]**	**v_0 [pixels]**	**k_1 [mm]**	**k_2 [mm]**	**p_1 [mm]**	**p_2 [mm]**
f = 8 mm	7.9230	1261.055	879.545	$2.559 \cdot 10^{-3}$	$-1.880 \cdot 10^{-5}$	$6.169 \cdot 10^{-5}$	$-9.405 \cdot 10^{-6}$

3.2 THE 3D MODEL GENERATION OF THE VEHICLE

In order to generate the 3D model of the crashed vehicle, there was used a number of eight images taken with the same CANON IXUS 960 IS digital camera. These photographs were taken around the car, from different angles, with the interest object central located, having an overlap of about 25% to 60% (Fig. 5). As mentioned, the studied object has to be central located in the image, due to distortions that are higher in the margins. Also, in order to determine the 3D position of a detail point, this must be identified in a minimum of three photos. An important condition to be mentioned, is that each single photo of the "PhotoModeler Scanner" project must have six common detail points with the other ones.

(a) (b)

(c)

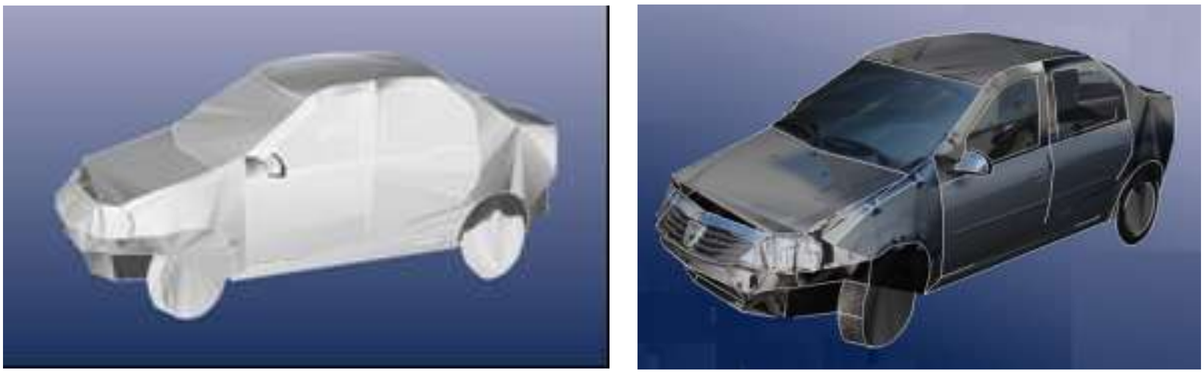
Fig 5: Photo acquisition of the crashed Dacia Logan vehicle.

(a) left- side view; (b) frontal view; (c) right- frontal side view

The images were then imported into the “PhotoModeler Scaner” software and the manually match common features method was used. The detail points and lines together with the artificial targets placed on the vehicle body, were identified and correlated, using the “Reference Mode” software’s function (Fig. 6).

Fig 6: Points correlation between images.

After the correlation process, the entire project was processed and the three-dimensional coordinates of 370 characteristic points of the crashed vehicle were calculated based on a number of eight digital images, as well as the exterior orientation parameters for each camera position. Using points, lines and curves, the 3D model of the crashed vehicle was obtained. As the 3D model was created in a local coordinate system at an arbitrary scale, the scaling process was necesary. So, a reference distance was measured, namely the distance between the central points of the car wheels from the same side of the vehicle. The final 3D model can be visualized with the created surfaces or in a textured mode, using the software's high-quality option (Fig. 7).



(a) **(b)**

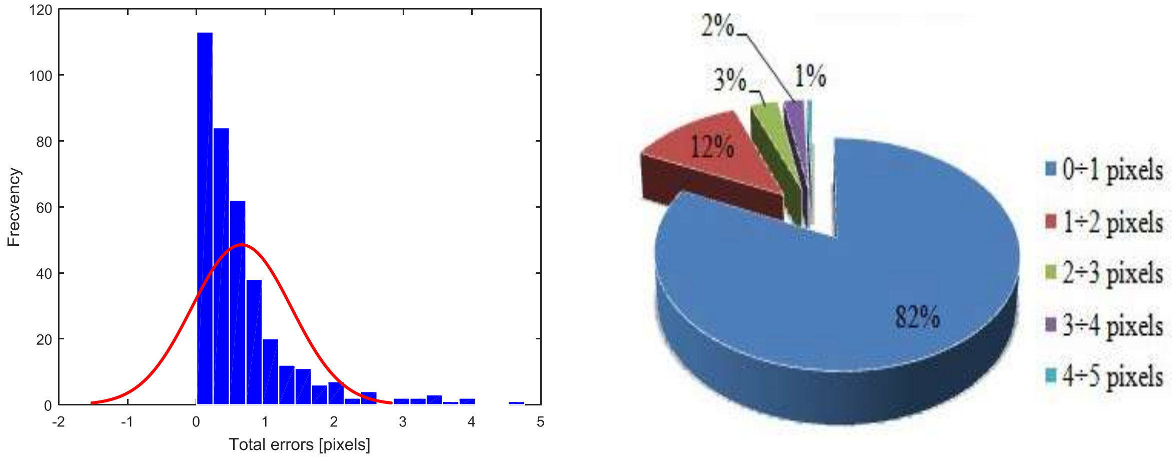
Fig 7: The 3D model of the Dacia Logan crashed vehicle, created in "PhotoModeler Scanner" software (a) with surfaces and (b) with textures.

In order to obtain the 3D model of the undistorted "Dacia Logan" vehicle, the same processing steps as in the case of the crached vehicle were followed.

3.3 QUALITY ASSESSMENT OF THE CRASHED VEHICLE 3D MODEL

For this case study, all the image coordinate errors were less than 5 pixels, tolerance suggested by "PhotoModeler Scanner". The overall residual of the project was 1.62 pixels, less than the recommended of 5 pixels.

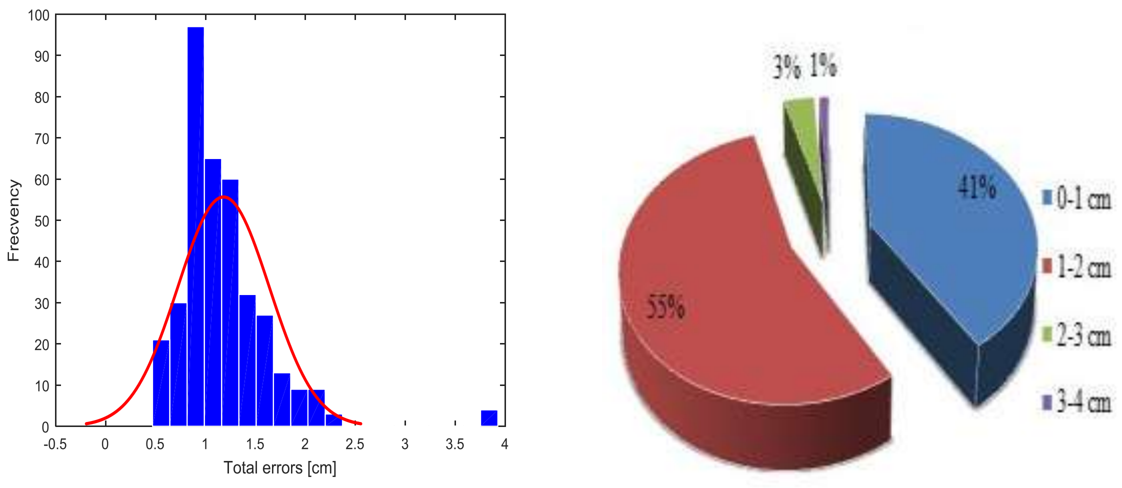
First, were calculated the errors distribution histogram of the detail points coordinates, measured in image coordinate system (Fig. 8 a), showing that the errors are in range of 0.002 pixels ÷ 4.761 pixels and the percentage of error repartition of the detail points image coordinates (Fig. 8 b).



(a) **(b)**

Fig 8: (a) The total errors distribution histogram and (b) the percentage of error repartition of the measured detail points image coordinates.

Second, the total errors for determining the crached vehicle detail points coordinates in world units were calculated. From the total error distribution histogram of the detail points coordinates (Fig. 9 a), it can be seen that the errors ranges between 0.5 cm and 3.9 cm (Oniga V. E., 2014). It was also realised the percentage of errors repartition of the detail points world coordinates, with an interval of 1 cm, that can be seen in Fig. 9 b.



(a) **(b)**

Fig 9: (a) The total errors distribution histogram and (b) the error repartition of the measured detail points coordinates in world units.

The angles between the projection rays range between $9^0.7322 \div 89^0.7464$ with an average angle of $45^0.0013$ and the percentage of angles repartition, with an interval of 20^0 (Fig. 10), shows that a large percentage of points coordinates were calculated using values between $50^0 \div 70^0$.

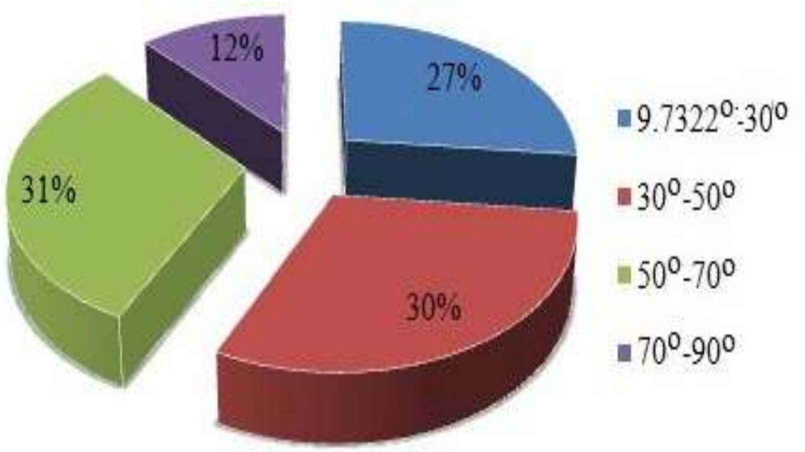
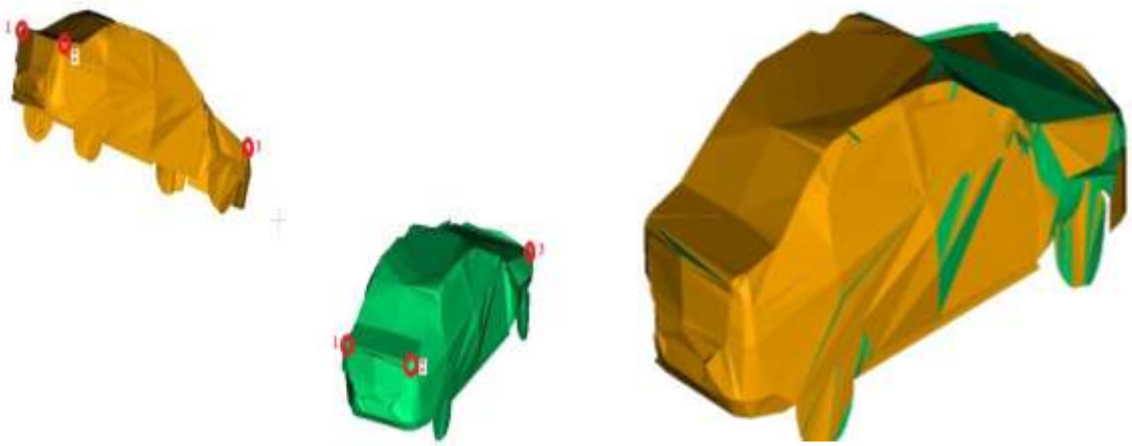


Fig 10: The percentage repartition of the angles between the projection rays.

3.4 COMPARATIVE ANALYSIS OF THE TWO GENERATED 3D MODELS

In order to determine the degree of damage of the crached "Dacia Logan" vehicle, its 3D model was compared with the 3D model of the same type of vehicle undistorted, considered as reference model, using the Hausdorff distance implemented into "CloudCompare" software. In a first phase, the two 3D models were imported into "CloudCompare" software. In a second step, the two 3D models were aligned using three manually selected corresponding points, as it can be seen in the Fig. 11.



(a) **(b)**

Fig 11: "CloudCompare" visualisations.

(a) the two 3D models in their own coordinate system and (b) the aligned 3D models

In the last step, the Haussdorf distance between the two 3D models was computed, using the *"Compute cloud to mesh distance"* function of the software, resulting the 3D model of the crashed vehicle with the deformations, as it can be seen in the Fig. 12.

The calculated Haussdorf distances between the two models, considered as deformation of the crashed vehicle, were highlighted using a colour palette, offering at the same time a global overview of the demages caused by the crash. So, analyzing the color palette, it can be made a short analysis over the deformations of the crached vehicle body: if the distances are null, then there is no deformation in the respective area; if they are positive, then the positive deformations appear and the components of the body car were distorted outwards and finally, if the differences are negative, the deformations are also negative in that area, fact that means that part of the car's body are missing or are inward distorted.

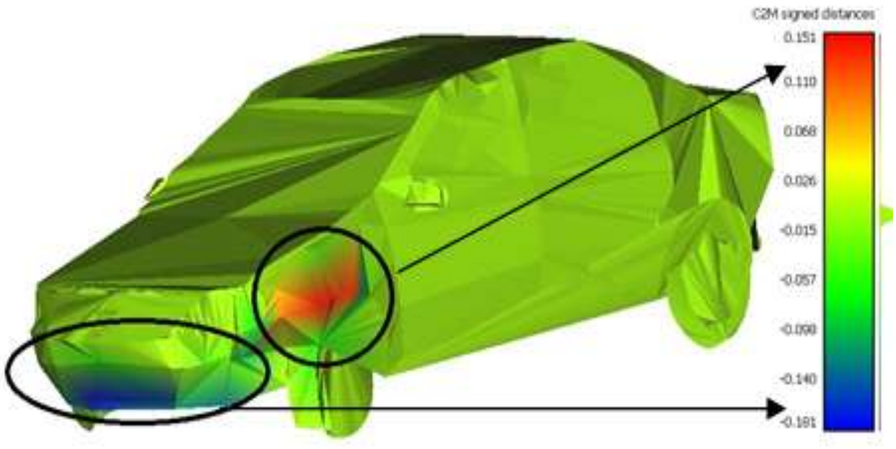


Fig 12: The 3D model of the crashed vehicle with the deformations.

From the resulted 3D model it can be seen that in the frontal part there are blue colored triangles, showing that negative distances with values of around 18 cm were calculated, which means that the bumper is missing. Also, on the left-side, there are red colored triangles, showing that positive distances with values of around 15 cm were calculated, the left guard being outwards distorted, as can also be seen in Fig. 5 b..

In order to determine the deformation percentage, the volumes for the two corresponding 3D models were computed using the "I-Site Studio" software. First, the "Spherical triangulation" function was used to create the body car surfaces, both damaged and undamaged based on the measured characteristic points and second, the volumes were computed for the closed mesh surfaces. The results show a volume of 4.41 m^3 for the undamaged model, respective a value of 4.03 m^3 for the damaged one.

The difference is of 0.38 m^3 representing a percentage of 8.64%, if the original model is considered to have 100%. It can be concluded that the vehicle involved in the traffic accident was damaged in a percentage of 8.64%.

4. CONCLUSIONS

This study shows the importance and use of digital close-range photogrammetry in vehicle modelling and measurements in damaged-based accident reconstruction, as one of the key problems of the insurance companies when evaluating the material damages caused by a trafic accident, includes the accurate knowledge of the vehicle body deformations and the degree of car damages.

So, the crashed vehicle profile was created using the “PhotoModeler Scanner” software and the digital images acquired with a CANON IXUS 960 IS digital camera which was previously calibrated. By comparing the crashed vehicle 3D model with the 3D model of the same type of vehicle undistorted, considered as reference model, using the Hausdorff distance, the deformation values were calculated and highlighted using a colour palette. Analyzing the color palette, a short analysis over the deformations of the crashed vehicle body can be made in order to see which parts of the vehicle body were affected by the crash.
By calculating the volumes for the closed mesh surfaces, representing the damaged, respectively undamaged vehicle profile, the correct amount of the material damage caused by a traffic accident can be determined.

The 3D reconstruction of the crashed vehicle profile can be made using digital close-range photogrammetry with high accuracy, in a very fast way and at a smaller price in comparison to other technologies.

5. REFERENCES

1. Coyle F. “Digital close-range Photogrammetry in motor vehicle accident reconstruction”, Doctoral thesis, Dublin Institute of Technology., 2008.
2. Fraser C., 2006, “Accident reconstruction via digital close-range Photogrammetry”, American Society of Photogrammetry and Remote Sensing, Annual Conference proceedings, Reno, Nevada, May 2006; 1-5, 121-128.
3. Fraser C. “Advances in Close-range Photogrammetry”, Presentation to 55th Photogrammetric Week, Stuttgard, September 2015; 7- 11: 257- 268

4. Fraser C., Cronk S., Hanley H. “Close-range Photogrammetry in traffic incident management”, The International Archieves of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B5., Beijing 2008; 125-128.
5. Loghin A. Oniga V. E. “The influence of camera calibration parameters on 3D buildings model creation”, Rev CAD, University “1 Decembrie 1919” of Alba Iulia, 2014; 16: 178- 185.
6. Morales A., Gonzalez-Aguilera D., Gutiérrez M. A., López A. I. “Energy Analysis of Road Accidents Based on Close-Range Photogrammetry”, Remote Sensing, 2015; 7: 15161-15178.
7. Murray C, Lopez A. ”Alternative projections of mortality and disability by cause 1990–2020: Global Burden of Disease Study”, Lancet., 1997; 349: 1498–1504.
8. Ohakwe J., Iwueze I.S., Chikezie, D. C. “Analysis of Road Traffic Accidents in Nigeria: A case study of Obinze/ Nekede/ Iheagwa Road in Imo State, outheastern, Nigeria”, Malaysia, Asian Journal of Applied Sciences, 2011; 4(2): 166-175
9. Oniga V. E. “Buildings 3D modelling by classical and digital photogrammetry”, ISBN 978-606-687-119-8, Tehnopress, Iasi, Romania., 2014.
10. Randles B., Jones B., Welcher J., Szabo T., Elliott D., MacAdams C. “The Accuracy of Photogrammetry vs. Hands-on Measurement Techniques used in Accident Reconstruction”, Society of Automotive Engineers, International, USA, 2010; 65-76.