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RECONSTRUCTION OF AN UNUSUAL ROAD TRAFFIC ACCIDENT USING COMPUTER SIMULATION

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ABSTRACT: In most of the cases of a road traffic accident reconstruction, the usage of traditional reconstruction methods represents the basic set of tools, but in an ever increasing number of cases, computer simulation is used for control the results or vice-versa. In some cases, traditional methods, based on linear momentum conservation, energy conservation and assessment of deformation of the vehicles or experimental results of crash tests are not suitable because of the highly unusual character of the collision. The paper deals with one case of this type in which the pedestrian was cut in two parts by the hitting car.

KEYWORDS: road accident reconstruction, computer simulation, pedestrian

INTRODUCTION

Road accident reconstruction is a very complex task in almost every case. In most of the cases of road traffic accident reconstruction, the usage of traditional reconstruction methods represents the basic set of tools. Until about the late 1970s accident analysis were carried out using the conservation of the linear momentum and the angular momentum. The law of conservation of energy was only used on a small scale for calculations. In the decade of the 1980s and 1990s, the spectrum of the methods used for reconstruction began to broaden.

At the beginning of the 1990s, the first complex reconstruction computer programs were developed. Today, in most of the cases, the traditional reconstruction and the methods based on simulation are used in parallel in order to reduce the level of uncertainty of the analysis. Nevertheless, in some cases, traditional methods, based on linear momentum conservation, energy conservation and assessment of deformation of the vehicles or experimental results of crash tests are not usable because of the highly unusual character of the collision.

A SHORT DESCRIPTION OF THE COLLISION

A Peugeot 307 having two passengers on the front seats run on a rural two lanes road during night and hit a 30 years old pedestrian who was highly alcohol intoxicated (with a BAC of 2.55‰). As a result of the collision, a complete severance of the body of the pedestrian occurs. The upper half of the body was found in the car, in front of the right front seat, because the windshield was broken and penetrated by the head and the upper part of the body (in reality the upper part probably landed on the body of the passenger who seated on the right front seat of the car), while the lower half was found on the road, at a distance of about 55 meters from the back of the place where the Peugeot stopped after the collision.

There were neither skid marks nor yaw marks on the road, only some blood stains, where the lower part of the body landed on the road and skidded until its stop. There were no signs found which could define the point of impact (POI) and the Peugeot was stopped using normal braking which did not produced any tire mark. The possible short tire marks created at the POI were not discovered by the investigators.

SOME PRELIMINARY DISCUSSIONS

It is quite clear that classic reconstruction methods are not usable in this case. As we do not have any tire mark on the road, we cannot determine the speed of the hitting car based on the energy dissipated in the post-collision braking until stop because we do not know what was the amount of deceleration created by the driver through the brakes.

As the body of the pedestrian was completely transected, the traditional models of determining the hitting speed of the car based on the distance of throwing of the body of the pedestrian are not applicable. Modeling the movement of the upper part of the body is out of the question as we do not know where the POI was. In this case, the author decided to try to use the road accident simulation program called Virtual CRASH in order to reconstruct what had happened.

First of all we have to try to clear up what was the mechanism of collision and how the body transection occurs. The pedestrian body was tearing apart in two parts, being transected at the level of the second and third vertebrae. The height of the pedestrian before the accident was approximately 1.78 m and its mass was about 67 kg.

The initial scenario of the author (based on the results of the investigation at the scene of the accident and analysis of the damage of the vehicle and the autopsy of the victim) was that the body of the pedestrian was cut by the upper part of the surface where the windshield was originally glued at the car body (which also could be defined as the front of the roof of the car). As we can see in Figure 1, the head of the pedestrian hit the windshield in its right upper part but with an unusually high force. As a result, the windshield was not only broken, but also even penetrated by the body of the pedestrian. There was even some damage on the roof.



Figure 1. Photos of the front of the car (left) and of the part which produced the severance of the body of the pedestrian (the latter marked with red line in the photo on the right)

Because of the fact that the pedestrian was hit under its center of gravity and because of the shape of the front of the car, the legs of the pedestrian were flipped up. The two distinct movements of the extremities of the body of the pedestrian resulted at a certain moment in a position in which the body of the pedestrian was grosso modo in a vertical position but with his head downward and his legs up. The transection was produced by the part which is marked with a red ellipse in the right photo in Figure 1. The front part of the roof functioned as a horizontal cutting edge having a high absolute speed and even a high relative speed compared to the speed of the body in the Ox direction (i.e. the longitudinal moving direction of the car).

In principle, the fact that the highly alcohol intoxicated pedestrian was hit on a rural road in a place where there were neither pedestrian crossing, nor street lighting, was equivalent to a clear responsibility of the pedestrian: the victim was in a place where it was forbidden to be for him, he has dark cloths and no active or passive light sources.

On the other hand, all the evidence which were found at the accident scene lead the investigators to the idea that the Peugeot was probably speeding on the road where the posted speed limit was 90 km/h. So it was very important even from judicial point of view to have a good estimation of the hitting speed.

Based on the relatively few data in the literature on similar cases, it was clear that the hitting speed have to be above 90 - 110 km/h. In the case described by Lerer and Volpe (1992) the minimum hitting speed was 112 km/h. Nadjem et al. (1996) studied 10 different cases of total pedestrian transections concluding that the hitting speed were in the interval of 80 - 100 km/h (50 - 62 mph). Rupp (1992) estimated the hitting speed in its case at around 100 km/h.

SOME COMMENTS AND THE RESULTS OF THE SIMULATION

In Virtual Crash, the body of a pedestrian is modeled by a system called multibody, formed by 14 pieces (ellipsoids) which are connected to each other. In the version 2.2, the links which connect these parts cannot be broken. In version 3, which is under development, transections will be modeled. So, the simulation cannot model the whole process of the pedestrian - car collision, only from the moment of the impact with the car, until the moment when the front of the roof cut the body of the pedestrian. Actually, the criterion based on which we could choose the right speed was, that the body of the pedestrian have to be in the right position at the right moment, i.e. when the body could be cut by the front of the roof.

There is another source of uncertainty of speed estimate, related to the way in which the windshield of a car is modeled in the 3D model in Virtual Crash. In principle, in the 3D model of a motor vehicle, the windshield is a surface which is transparent and it is totally penetrable from one side (normally from the inside of the car) and it is completely impenetrable from the other side

(normally from the outside of the car). As in our case the pedestrian not only broke the windshield, but even penetrated it, it was important to change the 3D model by changing the direction of the normal vector of the surface of the windshield (actually the value was changed from 1 to -1).

As a result, the surface of the windshield became perfectly penetrable from the outside (i.e. with zero mechanical resistance) and impenetrable from the inside (i.e. with infinite mechanical resistance, but this is irrelevant in this case). This means that from the point of view of the body of the pedestrian, the car has no windshield or has a windshield made of paper (with virtually zero mechanical resistance).

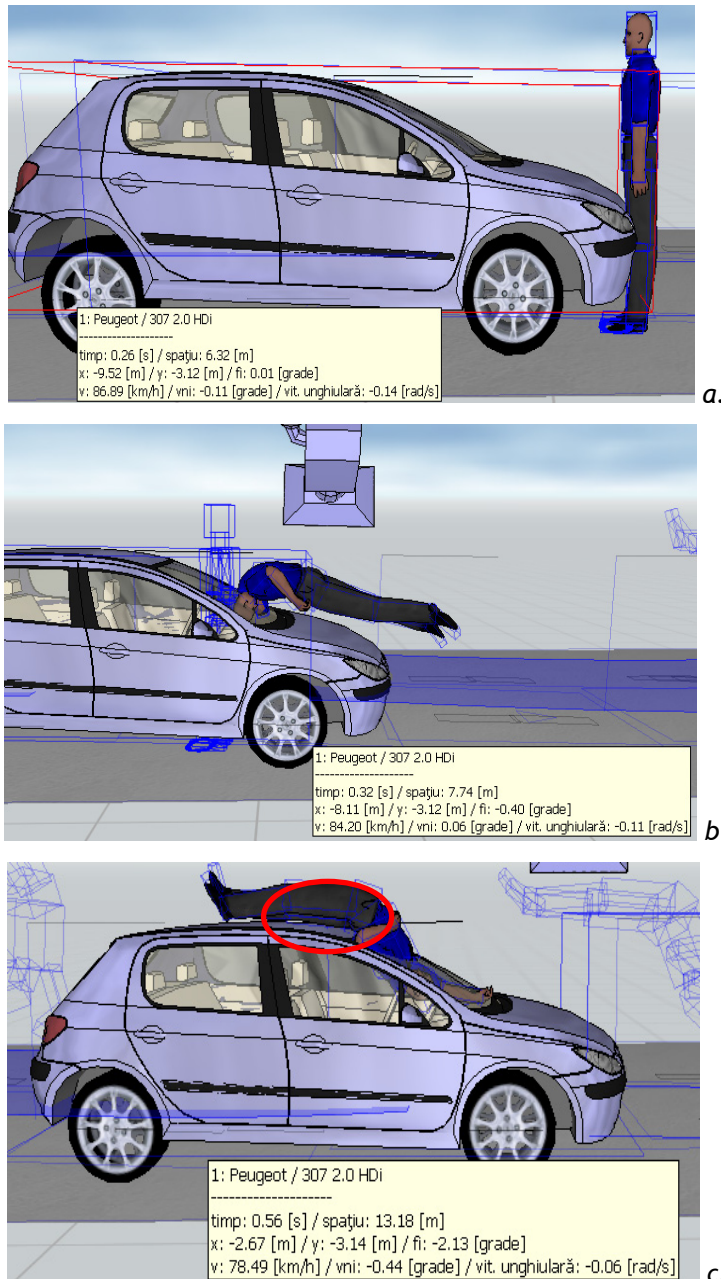


Figure 2. Characteristic moments of the simulation for a hitting speed of 87 km/h. a. the moment of the first contact; b. the position where the head have the first contact with the windshield; c. the position of the body when the transection could occur

In all of the presented cases, the location of the contact of the head with the windshield did not match the real location of the damage and cannot explain the penetration of the upper body through the upper right corner of the windshield. These could be considered as extra proofs for the fact that the hitting speed is none of the above mentioned. Finally, the hitting speed which corresponds best from every point of view was around 132 km/h.

As a result, the breaking and penetration of the windshield in the simulation do not needed extra kinetic energy and do not change the trajectory of the body at all. In reality, the breaking of the windshield and its penetration dissipated a certain part of the kinetic energy of the body of the pedestrian and changes somehow the trajectory on which parts of the multibody system were moving. Based on rationale thinking, we could estimate with high level of confidence that these facts mean a higher value of hitting speed, needed for the transection compared to that in the simulation.

The methodology which was used by the author could be best described as a step by step simulation at different hitting speeds and a continuous comparison with the possible real position of the pedestrian at the moment of the transection.

In Figure 2, we could observe that at a speed of around 87 km/h, neither the position where the head of the pedestrian hits the windshield, nor the position of the body do not correspond to the reality of the damage of the car and the transection of the body.

In Figure 3 on the left one could observe that at hitting speed of around 106 km/h, the body would have been cut well under the level where the real transection occurs. In Figure 3 on the right, at a hitting speed of 106 km/h, one could see a position in which the transection probably could not occur.

In Figure 4 on the left, it is clear that at a hitting speed of 122 km/h, the transection could result in a beheading of the pedestrian while in the captured image on the right, at hitting speed of 141 km/h, the severance could have occur well above the real transection surface.

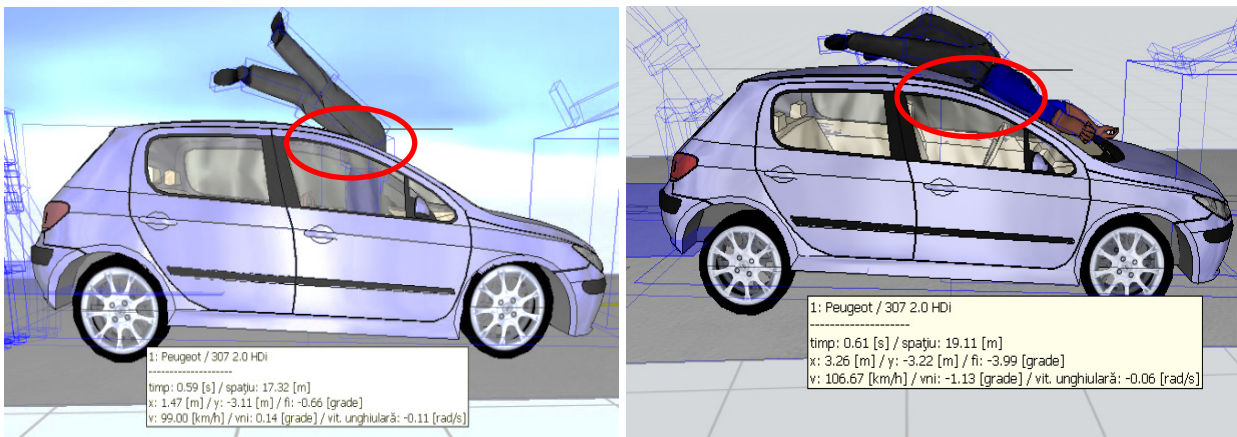


Figure 3. The position at the moment of the possible severance of the body for different hitting speeds. Left: for 106 km/h. Right: for 119 km/h.

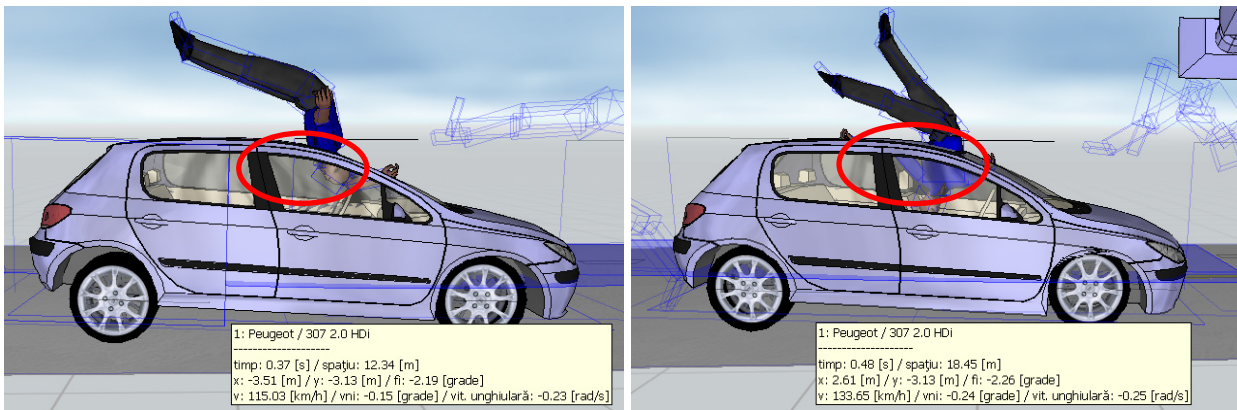


Figure 4. The position at the moment of the possible severance of the body for other different hitting speeds. Left: for 122 km/h. Right: for 141 km/h.

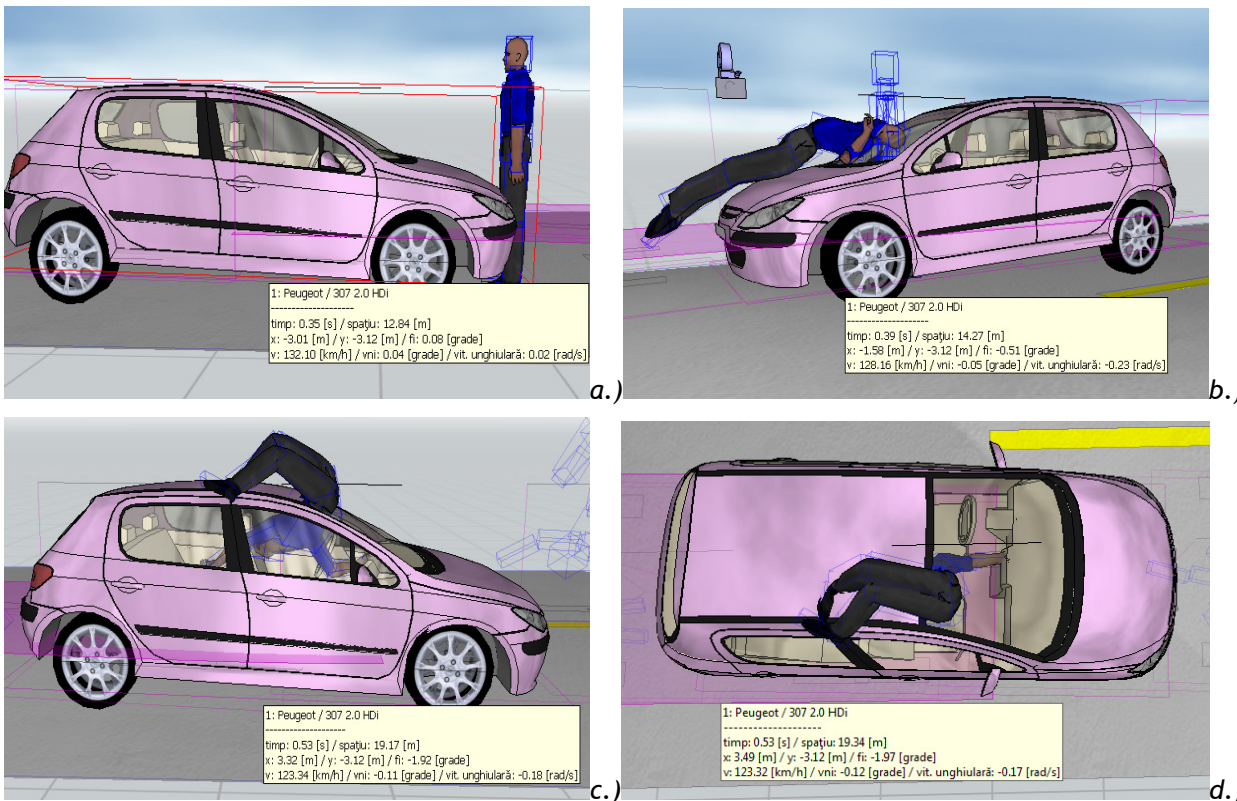


Figure 5. Characteristic moments of the simulation for a hitting speed of 132.1 km/h. a.) the moment of the first contact. b.) the position where the head have the first contact with the windshield. c.) and d.) the position of the body when the transection could occur.

In Figure 5 some characteristic images of the simulation for the hitting speed of 132.1 km/h are presented. In image b, it is observable that the place where the head of the pedestrian hit the windshield corresponds very well with the way the windshield was broke and penetrated (see Figure 1 left). Moreover, in the images noted with c and d, it is clear that at this speed, the transection could result in a severance which is very similar to the real case, either from the point of view of the trauma of the victim or the point of view of the damage of the windshield and the part of the front of the roof which cut the body.

In Figure 6 one could see that at the moment when the head of the pedestrian hit the windshield ($t = 0.39$ s), both the acceleration of the hip and of the torso were very high, nearly 1000 m/s^2 for the first and almost 500 . In the same diagram it is observable that at the moment when the transection began to occur ($t = 0.5$ s), the accelerations of the hip and of the torso were very different, i.e. 200 m/s^2 for the first and around -50 m/s^2 for the latter. These conditions could be strong enough for a complete transection of the body.

Virtual CRASH license: Dr. Ing. GÖNCZI Attila, expert tehnic auto judiciar

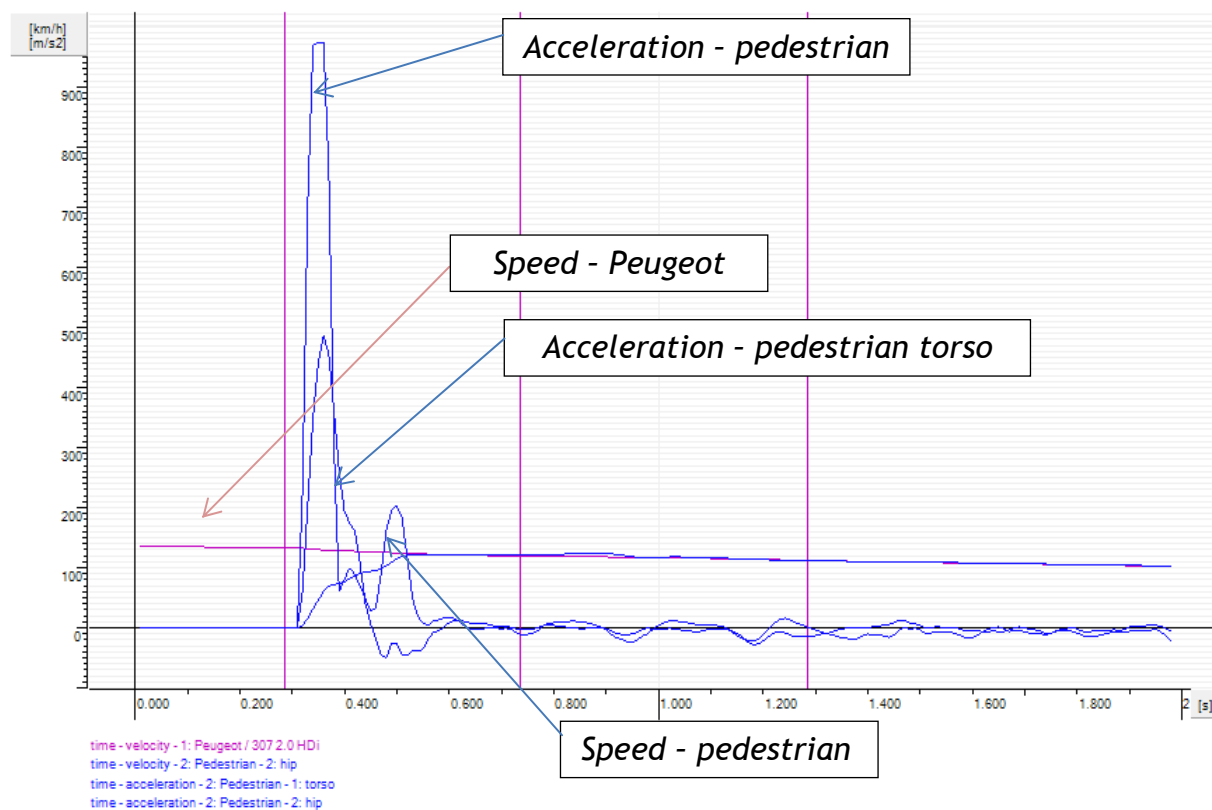


Figure 6. Diagrams of the speed and the acceleration as a function of time for different elements

Finally it is important to add that the place where the contact points between the legs of the pedestrian (which are bone fracture points on the legs of the victim in the same time) and the front bumper were at a height of around 20 cm respectively 38 - 41 cm from the ground. As the bumper in static position is at 30 respectively 50 cm from the ground, it is clear that the Peugeot was braked before the impact with the pedestrian. As a consequence, the initial speed of the car was even higher than the hitting speed, with at least 2 - 3 km/h.

CONCLUSIONS

There are some road accidents in which the application of the traditional accident reconstruction methods are not usable. One of them is when a complete transaction of the pedestrian hit by a car occurs.

The paper presented a method based on computer simulation using Virtual CRASH 2.2 and a "trial and error" approach of the method of comparison of the car damages and the victim's trauma with the ones appeared in the simulation. Using this approach, a minimum hitting speed with a high level of probability was determined.

In the given case, the Peugeot hit the pedestrian at a speed of minimum 132.1 km/h on a road where the stated speed limit was 90 km/h. Furthermore, it is extremely probable that the Peugeot was braked at the moment of the impact, which means that he minimum speed before the beginning of reaction of the driver, i.e. the braking, was at least 134 km/h. As a consequence, an absolute speeding could be considered as demonstrated. If we are taking into account the fact that the accident occurred during the night, the speed was definitely inappropriate to the traffic conditions.

From judicial point of view, these conclusions resulted in a certain responsibility of the driver, even if the pedestrian was heavily drunk and stayed on the road almost in the middle of the right lane at the moment he was hit.

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