

Speed Calculation from a Video Tape

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Introduction

Have you ever tried to encapsulate Newton's Laws of Motion or describe exactly what a coefficient of friction is to a jury (whether civil or criminal) and watched as their eyes glazed over? Or tried to detail the concepts behind the conservation of linear momentum to a judge who thinks sworn eyewitness testimony is much more reliable than actual physical evidence? Or attempted to explain to an attorney (Either side) that when a vehicle is in critical speed yaw that Sir Isaac Newton is now driving the car in question? They all begin to feel sorry for the defendant who now has all these mathematics aligned against him or her. We have all tried, sometimes in vain, to accomplish these things.

You may be interested in an often overlooked method for presenting a speed calculation that the Judge, the Jury and all the attorneys can actually comprehend and then, as a result, make a more informed decision in the case.

It is something that seems so simple, available and straightforward, but it is often disregarded.

Everyone calculates time and distance relationships in their head each day. Using this knowledge, if a crash case has provided a time and a distance, you can calculate an accurate and virtually indisputable speed.

All of us, even jurors, perform time and distance calculations every day. The Average Joe knows that it is 5 miles to the beer store, the speed limit is 30 MPH and the game starts at 2:00 pm. He must calculate, in his head, when he has to leave the house in order to get to the beer store, get his 6 pack of cool adult beverages and be able to return home in time for the start of the game.

So where are you going to get a known time and a known distance for an analysis of a car crash? Surprisingly, many crashes are caught on videotape. With the increasing use of in-car video taping systems in law enforcement vehicles, pursuits caught on tape by the media, Intelligent Traffic System cameras, intersection cameras and the widespread use of cameras by the public, a growing number of crashes are videotaped. In the instances when a radar-captured speed is displayed on the actual videotape, this procedure will verify the displayed speed and deflect any "radar inaccuracy/calibration" questions raised by the defense.

Police “Pursuit” Fatal Crash

Several years ago, I was directed to assist a District Attorney General’s Office in a crash reconstruction. The crash sequence itself was caught on videotape by an officer’s in-car camera. The officer had swerved into the path of a motorcyclist (sadly, another off-duty officer) and the resulting impact killed the motorcyclist. It was alleged that a pursuit of the motorcyclist was in progress.

This crash investigation was a train wreck from the beginning, with numerous conflicting statements by the officer driving the police car, conflict(s) of interest issues, lost video tapes, and witnesses who came forward only after false statements were issued to the new media, etc. The officer, driving the car, was charged with vehicular homicide for recklessly exercising deadly force on a misdemeanor. I was called upon, as an uninvolved law enforcement reconstructionist, to calculate a speed of both the patrol vehicle and the motorcycle.

A motorcycle was reported to have been traveling at a high speed behind the police officer with other officers attempting to overtake it. As the motorcycle came around a curve, he came upon the police car in front of him. The motorcycle came abreast of the patrol car, the police car driver swerved to his left impacting the motorcycle. The motorcycle’s direction was redirected and the driver vaulted off the motorcycle. The motorcyclist struck the guardrail, severing his arm at the shoulder and came to rest near the guardrail. The motorcycle also struck the guard rail and came to rest in the roadway.

Very little roadway evidence had been preserved; conflicting witness and officer statements were offered as evidence. The traditional reconstruction methods were not applicable. An accurate scaled diagram had been generated, but the most crucial piece of documentation had been ignored. That evidence was the videotape itself, which had disappeared, then partially reappeared, before I became involved. That being said, all interested parties agreed that the crash itself had been accurately captured on videotape.

There was no radar speed imported into the video. I would have been hesitant to use that speed anyway due to the controversy and jury questions that could have been generated by the defense regarding the accuracy of radar. There was a timer on the video, but I could not authenticate its accuracy, and I needed thousandths-of-a-second increments instead of hundredths-of-a-second displayed on the tape itself.

A speed estimate had been proffered by a defense expert that did not include the use of the videotape. What had been missed was that the video provided us with both a time and a distance. Using those two known values, easily obtained from the videotape, I felt I could calculate the speeds and then be able to articulate my conclusions to the jury in a manner that they could actually understand. It sounded simple, but I had never heard of anyone doing this, so I took it as a challenge.

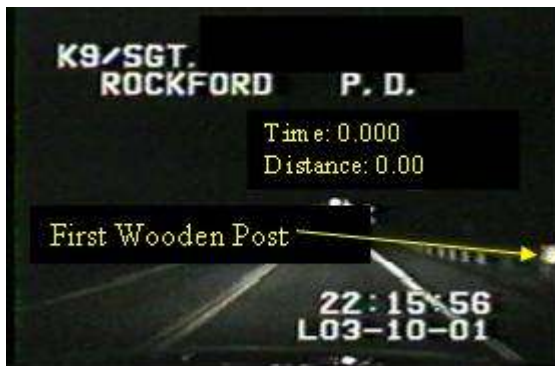
Time and Distance Analysis

After realizing that the usual reconstruction methods were not applicable in this case, I decided to “go to the videotape” that everyone had ignored as far as a reconstruction goes. I subsequently learned that a normal VHS video camera records at 29.97 frames per second, and from that I could determine my time value. In essence, a

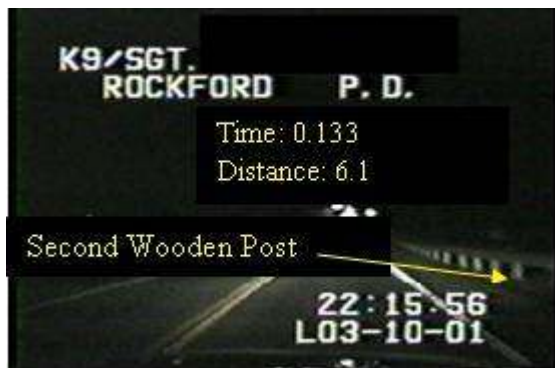
still picture is recorded every .0333 seconds. Those moving pictures are then played back at 29.97 frames (or pictures) per second and that set of moving pictures results in a playable videotape.

Using a Pro Video Editor and hijacking, by force, a crime scene expert from our Criminal Investigation Division, I was able to isolate the pertinent sections of the videotape and create an image sequence. I was able to save these images to a disk. I now had about 1,800 pictures (in jpeg format) of the crash sequence. I verified the 29.97 frames per second standard on the tape by counting the frames that had the time of "21:15:58" stamped on the camera timer and indeed there were exactly 29 frames with that exact time stamped on the frame. I had my time value, and now I needed a distance value.

I wanted to use a small distance so that I could estimate a very accurate speed of the patrol car just seconds prior to impact. If I could calculate an accurate speed of the patrol car, I could extrapolate that speed to arrive at the speed estimate of the overtaking motorcycle.

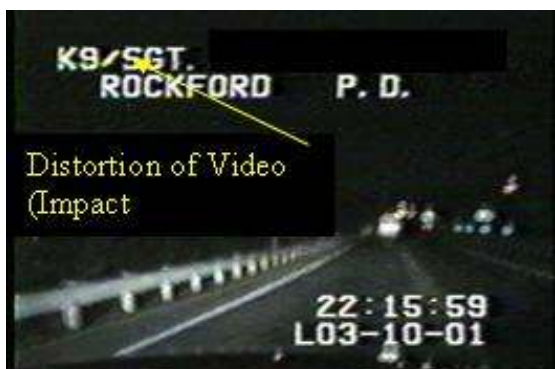


There was a guardrail that began just prior to the impact area. I measured from the first upright wooden post to the second upright wooden post while at the actual scene. The measurement was 6.1 feet and it took 0.133 seconds or 4 frames for the patrol car to travel through that distance.



An easy velocity calculation ($V=D/t$) and then velocity to speed conversion ($S=V/1.466$) found that the patrol car was traveling at 31.18 MPH just fractions of a second from impact.

I then calculated the speed of the motorcycle using a scaled diagram and the frames from the videotape.

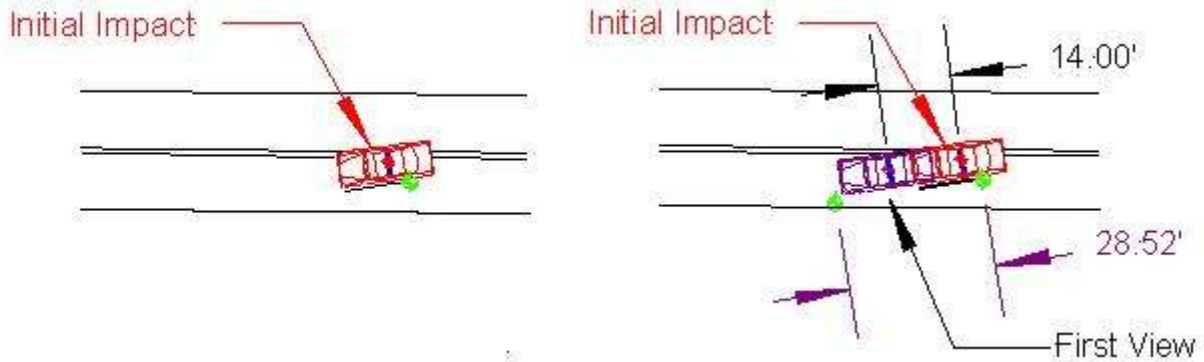


The exact impact of the motorcycle could be seen when the camera was distorted by the initial impact and I had the location of that impact from an offset tire skid from the motorcycle documented on the crash diagram. Several frames later, the motorcycle operator could be seen in a frame as he was ejected from the motorcycle and was vaulted forward. The speed loss was minimal as this was a same-direction sideswipe collision and the impact merely re-directed the trajectory of the motorcycle and the motorcyclist.

The offset tire mark, put down by the motorcycle, had been documented on the scene and the generated scale diagram which demonstrated the exact point that the skidding motorcycle struck the patrol car.

By using a scale diagram of this movement at the point of impact, I moved the patrol car forward at the calculated speed of 31.18 MPH (or 45.71 feet per second) and moved the motorcyclist's center of mass forward from its location at impact to the location at its first view during the same time frame. That distance was then measured on the diagram.

The motorcyclist moved about 28.52 feet in 10 frames (.332 seconds) with a resultant velocity of 85.90 feet per second or 58.60 MPH. The speed limit was 50 MPH. For the actual court exhibit, I ranged the distance the motorcyclist moved and arrived at a speed of between 58 and 68 MPH to account for a possible difference in perception of exactly where the motorcyclist's center of mass was in relation to the left front bumper of the patrol vehicle when he first came into view.



My calculated speeds were eventually accepted by the court *and* by the defense team that had already paid for its fatally flawed speed estimate that the defense originally offered. This defense expert actually tried to offer a conservation of linear momentum calculation on this sideswipe crash. This particular crash had no exchange of momentum. Neither the motorcycle nor the patrol vehicle attained a common velocity. This crash was an elastic crash, with great weight differences. The fact that the two centers of mass (Rider and Motorcycle) departed at differing angles in this crash was enough to rule out the use of a single departure angle conservation of linear momentum analysis.

This soon-to-be-un-subpoenaed “reconstructionist” arrived at a speed, on the part of the motorcyclist, of 132 MPH based solely on a conservation of linear momentum “calculation”. He also claimed he “animated the crash” even though the videotape was a pretty damn good animation. Needless to say, the defense did not use this “expert” at

trial. The “dark side” eventually called another expert to do a time and distance analysis using radio traffic that occurred about 4 minutes prior to the crash.

This second “expert” used a pursuing patrol officer’s radioed statements of his locations during the pursuit and the distance between these two radioed points as his time and distance data. Using these highly inaccurate times (Minutes) and distances (Rural blocks), he arrived at a speed estimate of the motorcycle at impact. It was found to be not very accurate. Using an officer’s declaration of his location “I am in the 6000 block of Elm Street” as an accurate location is unrealistic and inaccurate. Those of us, who have tried to find 6025 Elm Street, in the middle of the night, whilst going 80+ MPH (Trying to catch up to the action) know there is a big difference between 6001 Elm Street and 6099 Elm Street. Using these ephemeral locations and times (The time used was measured in minutes and the distance was a block) cannot result in accurate impact speeds estimated from four miles away from the area of impact.

Drag Racing Motorcycle Speeds Estimate

I was asked, several years ago, to assist the Chattanooga, Tennessee Police Department in the calculation of speeds of motorcycles drag racing. The CPD has an aggressive anti-drag racing program (HEAT), in which they develop information sources and use other means, to learn where and when future organ donors are going to be drag racing motorcycles and cars. The CPD Traffic Division then sets up a “sting” operation and videotapes the motorcyclists or sopped up vehicles in the act. When the CPD Traffic Division is sure they can ID the individual operators and they have captured the evidence, they swarm the gathering and make the arrests. The only problem they had in the first operation was the placement of the laser radar gun. They were secreted in an office building with stylishly thin windows and this lack of room did not allow the gun to get a “lock” on the motorcycles due to the high speeds through a tight distance. Again, we were able to isolate an image sequence from the videotape and save them to a disc.

Since we had an ability to arrive at a known time and a measurable distance, we were able to calculate the speeds.

In this case, the camera was stationary and the object we wished to evaluate was moving, contrasted to the previous case in which both the camera and the objects were moving.

We used two trees that were visible in the video and we then shot the area with our Total Station. We did this because we knew that the motorcycles moved through a greater distance than just the distance between the two trees due to the camera’s perspective issues. We now had a time (number of frames) and a distance estimate (distance adjusted for perspective) in order to calculate a speed of the motorcycle as it passed between the two trees.



Again a simple, and very easily demonstrable and explainable time and distance calculation arrived at a speed estimate for the motorcycle in question.



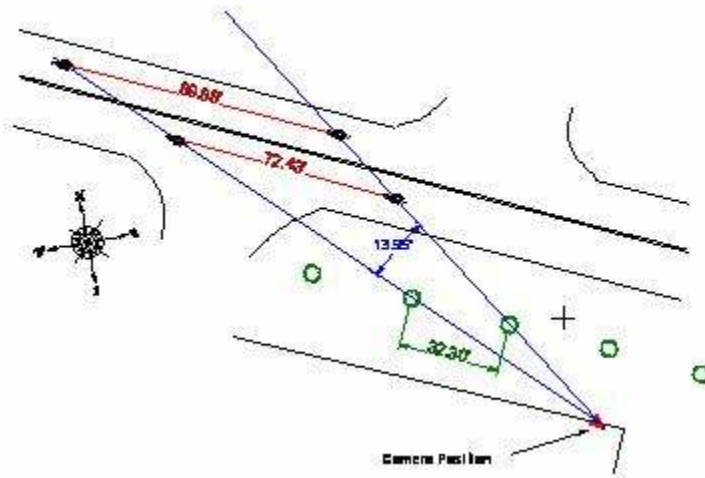
Speed Calculation

$$V = \frac{D}{t} \qquad S = \frac{V}{1.466}$$

$$V = \frac{72.43}{.350} \qquad S = \frac{206.94}{1.466}$$

$$V = 206.94 \text{ fps} \qquad S = 141.16 \text{ mph}$$

We then placed the frames in a Power Point presentation in preparation to accurately demonstrate, to a judge or jury, the exact speeds these motorcycles were traveling in order to gain a conviction for drag racing. Presented with this exhibit, along with the videotape, the defense found it considerably difficult to argue the fact that the motorcycles were not engaging in a contest of speed at speeds greater than 111 MPH over the posted limit of 30 MPH!



Helpful Hints

- If the camera is moving and the objects you are examining are stationary, no adjustment is required because as the camera moves through the field between the objects, the distance is the same. Use the same reference point and your distances will be correct.
- If the camera is stationary and the object is moving, adjustments for perspective must be made to arrive at an accurate distance through which the object moved.

- Any known distance, seen in the videotape, can be used such as crosswalk widths, length of painted lines, concrete islands, etc.
- Make sure that when converting the videotape and/or digital movie format to individual pictures, that they are outputted at 29.97 frames per second.
- Uses ranges for speeds to account for differing perception of where the object is related to the exact points used for start and end of distances. For instance, if you are using a tree as a starting point, are you measuring from the center or wither edge. As in the case of the drag racing motorcycles a motorcycle actually passed the tree being mid-frame. One frame the motorcycle is west of the tree and the next frame the motorcycle is east of the tree.
- These frames and diagrams can be very easily cut and pasted into a Power Point so that it can be entered into evidence as an exhibit.

Conclusion

Using inexpensive tools that most departments already have, a potent and easily understood reconstruction can be presented to a judge or a jury in a manner that anyone should be able to understand. A speed estimated from a simple time and distance calculation, over a few feet and fractions of seconds, is virtually indisputable in court.

About the Author: Sgt. Mark Kimsey is the Senior Crash Reconstructionist and supervisor of the Hamilton County, Tennessee, Sheriff's Office's Traffic Division. Sgt. Kimsey has been accredited by ACTAR (#1357). He is a member of numerous Crash Reconstruction Associations and is a Tennessee P.O.S.T. certified instructor in crash reconstruction. Sgt. Kimsey is certified as a crash reconstruction expert in the civil and criminal courts in Tennessee.