

Measurement of Bullet Hole Locations and Trajectories in Vehicles Using a Planar Projection Method

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ABSTRACT

Documenting the location of bullet holes and trajectories of bullets shot into vehicles typically requires creating a reference “box” around the vehicle against which locations and trajectory angles can be measured. The vehicle is “squared” by creating a rectangle around the vehicle with string and tripods. Locations of bullet holes and trajectory angles are measured relative to a coordinate system set up with the reference strings. Measurement of trajectory azimuth angles requires setting up and photographing directly above where the trajectory rod or string intersects the reference string [1]. The method presented in this paper is an alternative to setting up a string coordinate reference and allows for easier measurements of bullet hole locations and azimuth angles.

Materials and Methods

Trajectory analysis of a vehicle can be done at the scene, however it is usually preferable to transport it to a vehicle bay for examination. Before being moved, the vehicle must be adequately located within the scene by photographs, marking the tire locations, and possibly the use of surveying equipment or a 3D laser scanning device. All the normal documentation of the vehicle at the scene should be made prior to movement [1].

The equipment used in the presented method is shown in **Figure 1**.



Figure 1: 1- butcher paper, 2- laser trajectory kit, 3- plumb bob, 4- inclinometer, 5- electronic inclinometer, 6- laser plumb bob, 7- zero edge protractor, 8- duct tape, 9- card.

Squaring the vehicle using butcher paper

Butcher paper is commonly used in laboratories and has a straight edge (which can be checked by pulling a string along it). The straight edge of the paper can be used as a reference line, the same as a string reference line would be used. With the vehicle in a vehicle bay, or on a reasonably flat and level surface, a sheet of butcher paper is laid out on the floor along one side of the vehicle. A plumb bob can be used to align the straight edge of the paper parallel with the side of the vehicle. Typically the wheel base of the vehicle forms a rectangle and the paper edge can be placed along the tires (check that the measurement between left and right tires is the same for front



Figure 2: Butcher paper aligned parallel to vehicle side and taped down

and back axles and the front tires are straight). Paper can be positioned on both sides of the vehicle and square across front and back if there are trajectories in those directions. Once positioned, the paper is taped to the ground (**Figure 2**).

Documentation of reference points and bullet hole locations

With the paper in place, the location of bullet strikes and bullet holes on the outside of the vehicle as well as reference points such as front end, back end, door edges, pillar positions, window edges, open door angles, wheel wells and axles can all be projected vertically down to the paper with a plumb bob and marked. The height from the ground to bullet holes can also be recorded directly on the paper. Although a plumb bob on a string can be used, a self leveling laser plumb bob is a very precise tool for this purpose. The author used a



Figure 3: A dot is projected onto the paper and marked directly below a bullet hole.

Bosch GPL2 self leveling laser plumb bob (**Figure 3**) which will project a vertical laser line from surfaces that are up to 5 degrees off of level. The laser plumb bob can be performance checked using a normal plumb bob on a string. The plumb bob is hung from a door opening to the floor and when completely still, a mark is placed at the hang point and at the bob point on the floor. The laser plumb bob is then placed between the two points and the laser dots should align to both marks.

To mark the position of bullet holes or vehicle points of reference, the laser plumb bob is placed on the butcher paper such that the vertical laser beam is aligned with the bullet hole or point of reference and the laser dot projecting onto the paper

is marked (**Figure 3**). For curved vehicle bodies, a zero edge protractor or a rigid squared piece of card with a line drawn on it can be placed horizontally at the bullet hole to help align the laser. The distance between the plotted marks can easily be measured and noted directly on the paper (**Figure 7**).

Measurement of trajectory azimuth angles



Figure 4: 1- laser on trajectory rod inside the vehicle. 2- laser mounted on a tripod outside the vehicle.

This method can be used for measuring azimuth angles of trajectory rods in the outside body of the vehicle or trajectories from within the vehicle as might occur with shots into seats through an open door or window. **Figure 4** shows a laser trajectory rod placed in the center console within the vehicle projecting a beam (1) out through the open door, and a laser mounted on a tripod outside the vehicle with the beam (2) aligned with a hole in the weather stripping at the top rear corner of the passenger door and a bullet hole in the drivers' side door.

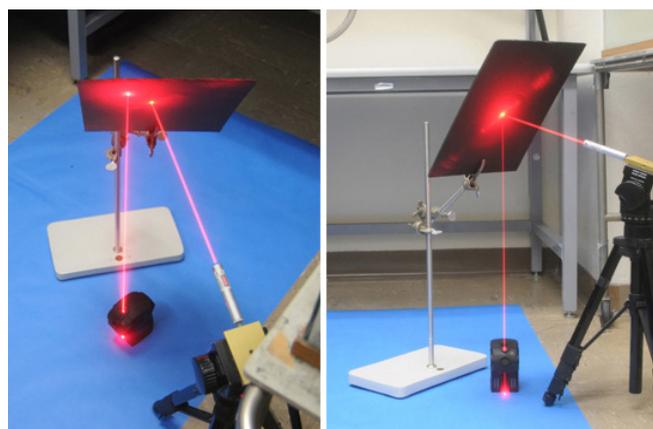


Figure 5: Lasers not aligned (left), Lasers correctly intersect when two laser dots project to a single point (right).

Once the trajectory lasers have been placed, two points along the laser line are projected vertically to the paper. The laser plumb bob is placed such that the vertical laser intersects the trajectory laser. In order to locate the point of intersection of the two lasers, a card is placed in the beam of the trajectory laser and then the plumb bob laser is positioned on the paper such that the two laser points coincide at the point of intersection. **Figure 5** shows that when the plumb bob laser is not aligned with the trajectory laser two dots are visible on the card. The plumb bob laser is correctly aligned with the trajectory laser when the two laser dots project to a single point. Note that by moving the card back and forth, the dots will separate and move together to a single point when aligned but the dots will never meet if the lasers are not aligned.

The first point projected onto the paper should be as near to

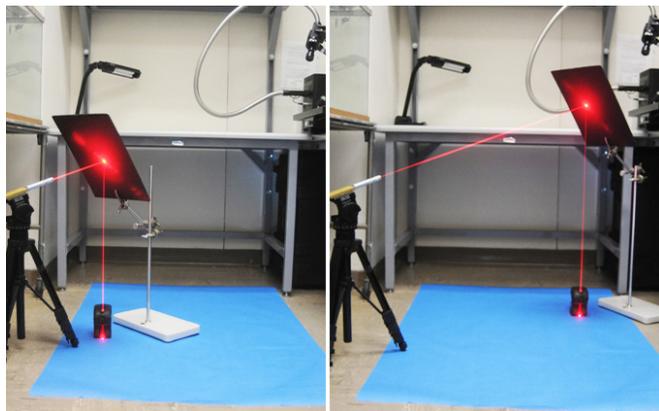


Figure 6: Plumb bob laser placed at two different points along the trajectory laser line. Marks are placed on the paper at both positions and a line is drawn between the two projected points and extrapolated to the straight edge of the paper.

the vehicle as possible (near the inner edge of the paper). The plumb bob laser is either aligned to the trajectory laser or the trajectory rod itself if it protrudes out the side of the vehicle. The near point is marked on the paper. The laser plumb bob is then moved some distance along the trajectory, still intersecting the trajectory laser and a second point is marked (**Figure 6**).

A line is drawn between the two projected points and extrapolated to the straight edge of the paper. This line represents the 3D trajectory line projected onto the 2D planar paper surface. The azimuth angle is easily measured between the plotted line and the straight edge of the paper with a protractor. This process can be repeated on the same paper for multiple trajectories. **Figure 7** shows typical annotation on the paper with bullet hole locations and plotted trajectories. Trajectory vertical angles are measured using an inclinometer.

The results may then be drawn in plan, elevation, front or back views and even in 3D using CAD software.

Conclusions

Setting up a reference coordinate system with string lines and tripods has certain disadvantages over the presented method. Firstly it is more time consuming to set up and may impede access to the vehicle once set up. Measuring azimuth angles with the string system requires taking photographs directly above the intersection of reference string and trajectory rod or string and may introduce potential parallax error. With the method presented here, once the paper is taped down it does not interfere with vehicle examination. The paper can be walked on, and the doors can be opened without interference. By precisely projecting trajectories onto the paper, the measurement of azimuth angles is easy and any possible parallax error is eliminated. The paper itself can be included as part of the scene notes and represents a 1:1 scale diagram with all measurements and angles. A disadvantage to this method is that it cannot be used on an uneven surface such as a slope greater than 5 degrees or rough dirt or gravel.

Acknowledgements

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References

- [1] Haag, L.C, *Shooting Incident Reconstruction*, Ch 9. Academic Press, San Francisco, 2006

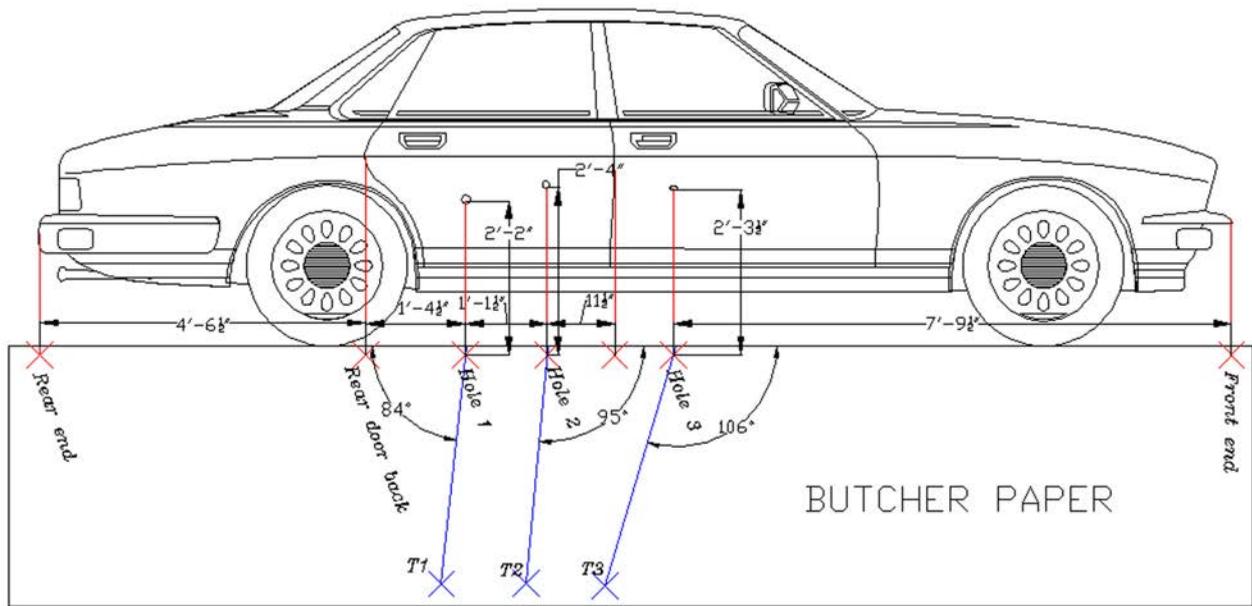


Figure 7: Diagram of bullet hole locations and trajectory (T1,2,3) azimuth angles plotted onto butcher paper.