C3 Weakness in the Numerical Models Used in Accident Reconstruction Programs

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After attending this presentation, attendees will understand the limitations of using computer programs in accident reconstruction.

This presentation will impact the forensic community and/or humanity by identifying the limitation of the computer programs allowing the forensic community to understand when the results provided are significant and when they have little value.

In the last several years, there has been an increasing usage of equations from various programs, like CRASH (Calspan Reconstruction of Accident Speeds on the Highway) and SMAC (Simulation Medel of Automobile Collisions), their derivatives, and other programs to determine pre impact and post impact velocities of vehicles. The use of equations from various programs, without regard for the underlying simplifying assumptions and checking routines, leads to errors and inaccuracies.

The underlying physics of accident reconstruction has been analyzed and compared to the assumption used in several programs. The first area addressed were those based on CRASH. The analysis was performed by comparing the simplifying assumptions in the programs to the actual values expected in collisions. Additionally the simplifying assumptions were checked for internal consistency. One area of particular concern was if the program violated a simplifying assumption required in the derivation of the equations necessary to develop the program. As an example, if the underlying equations used a simplifying assumption of homogeneity and then the program instructed the user to input values that established the surface was not homogeneous, this was identified as a potential problem. Finally, the computer-generated results of tests were compared with the actual speeds of the vehicles to determine if the program was accurate

A fundamental principle of mathematics is that for every unknown in a problem, a separate, independent equation must exist in order to arrive at a unique solution. In accident reconstruction the common unknowns of interest include: the mass of Vehicle 1, the mass of Vehicle 2, the initial speed of Vehicle 1, the initial speed of Vehicle 2, the final speed of Vehicle 1, the final speed of Vehicle 2, the approach angle of Vehicle 1, the approach angle of Vehicle 2, the departure angle of Vehicle 1 and the departure angle of Vehicle 2.

Less common, although often-critical variables include, tire forces, friction, steer angles, stiffness values, slope, surface material, and tire design.

In order to resolve the problem, equations are often solved simultaneously. Common fundamental equations used are conservation of linear momentum, conservation of angular momentum, conservation of energy, the principle of restitution, Newton's Laws of Motion, and the basic equations of motion. As the complexity of the problem increases, more equations are required to achieve a unique solution. As the number of variables and equations increase, the use of computers becomes more beneficial. This, in turn, explains the proliferation of programs available.

Even the use of computers does not relieve the investigator of the basic need of a separate equation for each variable. Compounding the problem is the use of quadratics, in some of the equations, since quadratics usually do not have a unique solution. For this reason, it is common to use simplifying assumptions and secondary equations such as those postulated in the work of Campbell or McHenry. Often these secondary equations are based on the same or additional assumptions.

As a result of the analysis it was determined that the numerical models used to predict the impact speed of vehicles have several limitations. The underlying simplifying assumptions used to derive the equations of the CRASH model in particular were found to have numerous problems. Among the critical assumptions identified in the derivation of the algorithm were several that were immediately violated by the program. These assumptions included that the vehicles act like a mass with a spring, the spring constant is constant, only plastic deformation occurs, the spring constants for both vehicles are equal, crush is symmetrical on both vehicles, the crush distance equals the acceleration distance and the system acts like a simple harmonic oscillator. Occasionally some of these assumptions are met, but it is rare that all are met and it is common that none are met. Typically, the program requires the operator to violate most, if not all of these assumptions.

In addition to the primary part of the program, the crush coefficients used are derived by a separate approach that uses many of the above assumptions and actually adds additional ones including the assumption that the vehicles are homogenous both vertically and horizontally.

The full-scale crash test run to validate the model actually showed that the results had no statistical significance. In some cases the program returns impossible answers. In other cases, the error associated with CRASH predictions has been observed to exceed 100%.

The use of CRASH, and its derivative programs, to reconstruct automobile collisions is valid only under certain conditions. The results obtained have limited statistically value. Anytime the programs are used, the assumptions should be checked for validity and how well the assumptions are met by the facts of the collision.

The approach used in this analysis has application in evaluating the reliability of any program used in accident reconstruction.

Computer Model, Accident Reconstruction, Crash

