McHenry

Accident Reconstruction

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Refinement in the Simulation of Structural Interactions During Collisions

The interactions between the structures of colliding vehicles that are simulated by the original SMAC and the EDSMAC computer programs are limited to compressive forces and simple Coulomb friction. In many real-world collisions, the actual interactions are much more complex. They frequently include tensile forces and/or momentary interlocking of the structures. In those cases where acceptable matches of the positions and orientations at rest cannot be achieved with the original SMAC and/or the EDSMAC program and, further, where there are no obvious obstacles and/or topographical features that have significantly affected the vehicle motions, it becomes obvious that the simulated vehicle interactions are overly simplified. The SNAG routine of the m-smac computer program provides a capability for achieving higher fidelity matches of the positions and headings at rest while maintaining the principles of conservation of linear and angular momentum.

The SNAG routine incorporates impulsive linear and angular constraints that momentarily resist relative motions of the two vehicles while continuing to conserve both the linear and the angular momentum of the two-vehicle system during the collision. By this means, it is possible to simultaneously refine the matches of the positions and headings of both vehicles at their rest positions with a series of iterative adjustments of the impulsive constraints. The rationale of the analytical approach is the concept that inappropriate inputs for the impulsive constraints cannot achieve acceptable responses of both vehicles.

The moment constraint is applied in the form of equal and opposite couples that resist relative rotations of the two vehicles (i.e., it is independent of the locations of application on the two vehicles). The linear constraint also produces moments (generally unequal) on the two vehicles by virtue of the fact that it resists relative movement between specific points on Vehicles #1 and #2. The selected point on Vehicle #1 is specified in the SNAG inputs and the corresponding point on Vehicle #2 is defined as that which coincides at the start of SNAG. Thus, the effective resistance moments on the two vehicles are determined by the algebraic sum of those produced by the moment and the linear constraints.

In applications of m-smac, a best effort reconstruction without SNAG should first be attempted. If the achieved matches of the positions and headings at rest of the two vehicles are not acceptable and there are no obvious obstacles and/or terrain features that have affected the motions of one or both vehicles, application of the SNAG routine should be considered.

In an application of SNAG, a linear constraint resisting relative motions should first be applied, starting in the range of 500 to I 000 LB-SEC. The location of the linear constraint on vehicle #1 should correspond to either a major structural component, such as a wheel, or to a damage area that may have generated tensile forces. The objective of the constraint is to modify the rotational (i.e., yaw) responses of the vehicles to more closely match the headings of the two vehicles at rest. If excessive relative rotation occurs, the moment constraint should also be applied by means of a series of iterative adjustments of the SNAG inputs, the overall match of rest position evidence can generally be improved.

Care must be exercised in selecting the magnitudes of inputs for the constraints and for the corresponding null bands in SNAG to avoid oscillatory behavior. The time-history outputs should be carefully checked for oscillations prior to accepting the results.

It can be demonstrated, by setting the tire/terrain friction coefficient to 0.001, that the SNAG routine does not change the linear or angular momentum of the two-vehicle system during the collision, including the time of application of the constraints that resist relative motions. Thus, improvements in the overall match of the rest position evidence over that achieved with original SMAC and/or EDSMAC, can generally be obtained without any compromise of the validity of the reconstruction technique.

Snag Option

Inputs are in the form of impulsive linear and angular constraints that resist relative motions of the two vehicles. They are modeled as reaction constraints that act only to resist relative motions. The ***m-smac*** program conserves both the linear and the angular momentum of the two-body system in the absence of external (i.e., tire/pavement) forces. Thus, any interacting forces and/or moments that are applied to resist relative motions and, thereby, to improve the predicted position and heading at rest of Vehicle #1 will also affect the corresponding position and heading at rest of Vehicle #2. The analytical approach to input selection consists of iterative adjustments to achieve acceptable matches of the positions and headings at rest of both vehicles. The rationale is the concept that inappropriate inputs can not achieve acceptable responses of both vehicles.

Note that fields 3 and 4 of card 18 permit the input of viscous damping of the linear constraint for the case of long duration linear constraints where oscillations may occur.

The linear constraint aspect of Snag is input as the maximum impulse (Fdt) that can resist relative motion:

The average snag force (F) acts for a finite duration (dt), and the impulse therefore is equal to Fdt

The maximum speed-change that can be associated with the Impulse can be approximated from the equation:

$$\mathbf{m\Delta V = Fdt}$$

For example:

1000 lb-sec impulse acting on a 3000 lb. vehicle imparts a speed-change (ΔV) of approximately 7.3 MPH.

ΔV = Fdt/m = (500 lb-sec)/((3000 lb.)/386.4 in/sec^2)= 128.8 inches/sec

500 lb-sec impulse acting on a 3000 lb. Vehicle imparts a Speed change (ΔV) of approximately 3.7 MPH.

ΔV = Fdt/m = (1000 lb-sec)/((3000 lb.)/386.4 in/sec^2)=64.4 inches/sec

Specification of the duration of the snag impulse should include consideration of the type of vehicle interaction which is being simulated.

1. If the additional vehicle interaction occurs only during the normal period of a typical collision interaction, then its duration should be less than approximately 0.05 seconds. A finite time is required for the vehicles to interact to the point where an impulsive constraint/snag occurs, so the total duration of the collision and snag should be typically less than approximately 0.15 seconds.
2. If the actual impulsive/snag interaction acts to completely prevent the vehicles from separating then the duration may exceed that of a typical collision duration

Generally, a starting point for snag impulses which are supplemental to collision crush forces ranges from 100–1500 lb-sec. The starting range for snag impulses which are used to supplement narrow overlap impacts may be larger (e.g., see **Reference 76**). The ultimate test of the duration and force associated with a snag is that it results in acceptable responses in both vehicle trajectories.

The moment constraint aspect of Snag (Card 18, Field 1 & 2) is input as the maximum angular impulse (Fhdt) that can resist relative rotations:

$$mk^2 \Delta \dot{\psi} = Fhdt$$

$$\Delta \dot{\psi} = \frac{Fhdt}{mk^2} Rad / \sec$$

For example:

A 2000 lb-ft-sec angular impulse acting on a vehicle with a moment of inertia of 20,000 lb-sec^2-in imparts an angular velocity change of 1.20 rad/sec (68.8 deg/sec)

The impulse of the linear constraint may be approximated by the product of the entries in Fields 6, 7 and 2 of Card 16:

$$(AKSP)\ (DELPSM)\ (TSWIND) \cong \text{LB-SEC}$$

The impulse of the moment constraint may be calculated from the product of the entries in Card 18, Field 1 and Card 16, Field 2:

$$\frac{(TCON)(TSWIND)}{12.} = LB - FT - SEC$$

The moment constraint is applied in the form of equal and opposite *couples* that resist relative rotations of the two vehicles (i.e., it is independent of the locations of application on the vehicles). Note that the linear constraint (the SNAG as specified on card 16) resists relative motion and produces moments on the two vehicles that are dependent upon the locations of the points of application of the linear constraints. It follows that the simulation of a specific resultant resistance to relative motion requires a different value of the moment constraint for each location of the linear constraint.

The program outputs of m-smac now include an auxiliary output of the effective linear and angular impulses that act during an application of cards 16 and 18. The output includes a breakdown of the various contributions of the snag impulses and a calculation of the resulting Delta-V produced by the snag.

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Summary of Snag Impulses:
                                       Veh#1        Veh#2
   Resultant Impulse Linear    =        952.         950.   Lb-sec
                     Angular   =       -322.       -3239.   Lb-Ft-Sec
   Impulse due to Linear Components:
             Snag Force        =        948.         948.   Lb-Sec
             Friction          =        -69.         -69.   Lb-Sec
             Damping           =          0.           0.   Lb-Sec
   Impulse due to Angular Components:
             Snag Force        =       2457.       -6018.   Lb-Ft-sec
             Moment Constraint =      -2779.        2779.   Lb-Ft-Sec


   snag DeltaV       X         =        -6.4         -0.7   MPH
                     Y         =         2.1          4.5   MPH
                     Resultant =         6.7          4.5   MPH
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