SMAC 2003
The Automatic Iteration of SMAC

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SMAC2003
The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
- Research Approach
- Results
- Discussion and Conclusions
- Future Plans
The Automatic Iteration of SMAC

What is SMAC?

- Simulation Model of Automobile Collisions
- Similar to performing a mathematical full-scale test
- Created in response to need for more accurate reconstructions and uniform interpretation of evidence
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- What is SMAC?
  - SMAC Includes:
    - Trajectory Model
    - Tires forces modeled pre-impact, during impact, post impact
    - Conservation of Linear and Angular Momentum throughout the simulated event
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What is SMAC?

- SMAC Includes:
  - Collision Model
  - Finite duration of the impact
  - Tire forces fully active during collision
What is SMAC?

- The inclusion of both Trajectory & Collision Models in SMAC reduces sensitivity to any limitations of either technique.
- SMAC includes provisions for multiple impact, sustained contacts, and provides generality.
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The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
  - Reduces or eliminates the need to manually iterate
  - Provides testing and refinement of evidence match.
  - Allows sensitivity testing of input variables
  - Includes unlimited objective iterations
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- What is SMAC?
- Why Automatically Iterate SMAC?
  - Saves time!
    - Time required for “best match” limited only by processor speed
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The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
  - Jones, SAE 750894
    - “To make SMAC ‘user-orientated’ so that users can operate with ease”
    - Found that it is “insufficient to iterate on rest positions alone”
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- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
  - Moffatt and Byrd, 1980 (DOT-HS-8-01820)
    - Iterated impact speeds, steering & braking
    - Limited by computer costs and capabilities
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- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
  - CRASH-97 – 1997, (SAE 970949)
    - Used automatic iteration of SMAC for motions between separation and rest to refine separation speeds
    - Did not include collision simulation due to computational time considerations
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- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
- Research Approach

- With advent of gigahertz Pentium machines, iteration of complete SMAC including collision feasible
- This project an extension of our prior work on CRASH-97 (SAE 970949)
Research Approach:

- Create a “function” which provides a measure of the correlation of a SMAC reconstruction with measured evidence
- Choose or create a function minimization routine to guide iterations of SMAC to minimize the “function”
Correlation factor function

- What are important measures in any accident reconstruction?
  - Trajectory measurements
  - Damage measurements
Trajectory Measurements
Use Measured Scene Evidence

- Directions of travel
- Approx POI
- POR
- Tire tracks and characteristics
- Skidding? Tracking?
SMAC Correlation Function

- **Trajectory measurements**
  - The approximate positions and orientations of the vehicles at impact
  - The measured positions and orientations of the vehicles at rest
  - Distance POI to POR for each vehicle
  - Azimuth angle POI to POR for each vehicle
  - Direction of the System Momentum
Damage Measurements:
Use Vehicle Damage Evidence

Measure and Define Damage per:

Collision Deformation Classification (SAE J224 MAR80)

Equidistant Crush Measurement (SAE J2433)

Tumbas & Smith (SAE 880072) Damage Measurement Protocol
SMAC Correlation Function

- **Damage measurements:**
  - Damage width
  - Damage depth
  - Damage area
  - Centroid of the damage region
  - Clock direction of the approximate PDOP
SMAC Correlation Factor
Damage
ITERATION PROCEDURE

- Collision responses highly nonlinear
  - Any function minimization technique must handle step discontinuities
  - Restarts to insure a global v local minimum

- Weighting factors to establish priorities
  - Initially to grossly match evidence
  - Secondarily to assist in refinement of match

- Auxiliary calculations and checks
  - To help guide the iteration procedure
ITERATION PROCEDURE

Starting Values for ITERATION

- Original intent was simply for improvement
- CRASH-type interface and information
  - CRASH original intent as SMAC preprocessor
- Information required:
  - Impact positions and headings.
  - Rest positions and headings.
  - Wheel steer and drag
  - Vehicle type and specifications
  - Damage measurements.
ITERATION PROCEDURE

- For Initial development and testing of SMACITER
  - Used SMAC generated reconstructions based on the RICSAC tests

- Final testing of SMACITER
  - Used ‘raw’ reported test results and other high confidence reconstructions to test convergence ability of SMACITER
ITERATION PROCEDURE

- Variables iterated
  - Initial Speeds and Positions
  - Steering and Braking
    - Minor adjustments of steering and braking within ranges of uncertainty during iteration
  - Sideslip and Angular Velocity Options
    - Provide ability to address control losses preceding impact
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RICSAC Test#4

VEHICLES:
NO. 1 — 1974 FORD TORINO
NO. 2 — 1974 FORD PINTO

VEHICLE #2 — TIRE SCUFFS
LEFT REAR
LEFT FRONT
RIGHT FRONT

VEHICLE #1 — TIRE SCUFFS
LEFT FRONT SCUFF
LEFT REAR SCUFF

VEHICLE #1 — RIGHT FRONT SCUFF

Scale (m)
RICSAC Test#4
1st Pass with CRASH results: 31.9 MPH
RICSAC Test#4 SMACITETER Final Results, 38.3 MPH
Correlation “Score” is a summation of the deviations from a perfect evidence match.
VEHICLES:
NO. 1 — 1974 CHEVROLET CHEVELLE
NO. 2 — 1974 CHEVROLET CHEVELLE
RICSAC Test#8
Impact Speeds 20.8 MPH, 20.8 MPH
RICSAC Test#8, SMAC RUN with CRASH

Speeds 19.5 MPH, 24.5 MPH

Click on Picture for Animation
Results with CRASH speeds
RICSAC Test#8, SMACITER Start with
CRASH Speeds 19.5 MPH, 24.5 MPH
RICSAC Test#8, SMACITER RESULTS
20.9 MPH, 20.8 MPH

Click on Picture for Animation
Summary of SMACITER Results
Vehicle#2
Start
24.5 MPH
V
RESULT
20.8 MPH

Vehicle#1
Start
19.5 MPH
V
RESULT
20.9 MPH

Click on Picture for Animation
SMACITER Test
with High Confidence Reconstruction
SMACITER Test
with High Confidence Reconstruction
SMAC 1\textsuperscript{st} Pass

Click on Picture for Animation
SMACITER Test
with High Confidence Reconstruction
Final Result

Click on Picture for Animation

-6.912
Side-Slap Contact
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Discussion and Conclusions
Impact Speed Correlation

Impact Velocity Absolute Error Percentage (%)  
SMACITER vs RICSAC Test Results and High Confidence Reconstructions
ΔV Correlation

Impact Speed Change (DELTA-V) Absolute Error Percentage (%)
SMACITER vs RICSAC Test Results and High Confidence Reconstructions
Discussion and Conclusions

- SMACITER is a tool to aid and assist an accident investigation
- Feasibility of the automatic iteration of SMAC has been demonstrated
  - This research represents the 1st validation of SMAC without using Impact Speed as input
- SMACITER converges towards evidence match
  - Yields impact velocities within ±12%
  - Yields ΔV’s within ±8%
Discussion and Conclusions

- CRASH serves its original purpose as a pre-processor for SMAC
- A correlation factor or “score” is a desirable means of ranking the achieved match of evidence and thereby the quality and reliability of the reconstruction
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FUTURE PLANS

- Additional refinements of SMACITER
- Complete comparison of SMACITER with all available full-scale tests
- Further evaluation of a correlation factor or “score” as a potential measure of reconstruction accuracy
- Implementation of Restitution enhancements per SAE 970960
- 3D components – merging of 2 HVOSM vehicles with refined SMAC
End of Presentation

Thank you!