SIMULATION DRIVEN OCCUPANT OPTIMIZATION, ROBUSTNESS & POSITIONING

Ravi Kodwani : Technical Director, Altair Engineering Inc
A Simulation-Centric Portfolio for Design, Data Analytics, Cloud and AI.
Broad Portfolio of Comprehensive Solutions

- Design, Modeling & Visualization
- Internet of Things
- Physics Simulation
- High Performance Cloud Computing
- Data Intelligence
- Altair Partner Alliance (APA)
HYPERWORKS: INTEGRATED CAE PLATFORM FOR SAFETY

- Component Meshing
  - HyperMesh
  - Connections
  - Morphing

- Model Building
  - Altair / FTSS Safety Tools
  - Comprehensive set of Humanetics and Altair Dummies
  - Barries and impactors

- Reliability / DOE / Optimization
  - HyperStudy
  - Airbag shape, Inflator characteristics, Sensors
  - timing DOE and Optimization for limiting occupant injuries

- Simulation
  - Robust, Scalable, Repeatable results
  - UP and FVM Airbags
  - Cut Methodology

- Results Visualization
  - HyperView / HyperGraph
  - Easy templates generation for quick reports
  - Autorun in batch mode after simulation

Dummy-Seat Positioning
Airbag, Seat belt Set-up
Airbag Folding pre-simulation tools
SIMULATION DRIVEN OCCUPANT OPTIMIZATION, ROBUSTNESS & POSITIONING

AGENDA

Occupant positioning in HyperMesh
  Seat Mechanism
  Dummy Positioner
  Seat Deformer
  Belt Routing
  Interlinked Environment

Occupant Safety post-processing

Robustness and Optimization using DOE and Optimization
EXEC SUMMARY
CRASH SOLVERS INTERFACES

- Generic Keywords Support Improvement & Support of New Solver Versions
- Total of 20 New Entities
- HyperMesh 2019 CRASH Interfaces
- Improved Parametrization Capabilities (LS-Dyna & PAM-CRASH)
- Solver Keywords based ID Manager
- Mass Calculation & Mass Summary Tool
- Penetration Check (RADIOSS & LS-Dyna) & Model Checker
HyperMesh offers following tools related to impact analysis:

- Pedestrian Impact Tool (Euro-NCAP, GTR, UN-R127)
- Instrumental Panel Impact Tool (FMVSS201 & ECE-R21)
CRASH & SAFETY – OCCUPANT SAFETY

• HyperMesh 2019 offers a **complete solution for occupant safety application** for RADIOSS & LS-Dyna solvers

• **New Tool added** to the occupant safety tools portfolio

• **Improvements in existing tools:**
  • Mechanism creation Lead Time reduction with new automated mechanism builder process
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CRASH & SAFETY – SEAT MECHANISM TOOL

• Tool available for RADIOSS and LS-Dyna Interfaces
• Interactive and automatic modification of the seat position
• Save multiple positions of the seat for the different load cases
• Mechanism information (bodies, joints, positions) are saved in the solver deck after the END keyword, using Primer MECHANISM syntax
CRASH & SAFETY – MECHANISM TOOL

- Automated mechanism creation process
- Mechanism creation time reduction from ~45min to ~5min
DUMMY POSITIONER

Dummy tree structure:
- Reads Primer & LS-Pre dummy tree
- Export dummy tree in Primer format

Dummy position can be saved:
- As a position
- As a dummy angle file

Move:
- One joint at a time
- Multiple joint with possibility to constraint certain degree of freedom
DUMMY POSITIONER

• Tool available for RADIOSS and LS-Dyna Interfaces
• Interactive and automatic modification of dummy limbs
• Save multiple positions of the dummy for the different load cases
• Dummy information (bodies, joints, positions) are saved in the solver deck after the END keyword

Saved positions for different crash regulations
DUMMY POSITIONER

• Multiple targets point positioning allows to position the ATD precisely and easily based on measurement made in tests
  • Input is X,Y,Z measurement from tests
  • Location of measurement corresponds to target modeled on ATD
  • With simple script & a few rules the process can be automated and run in batch
CRASH & SAFETY – DUMMY PRE-SIMULATION

- Important tool for occupant safety simulation process, allowing to simulate the deformation of the whole dummy using the **cable method**
- Automatic detection of the cable attachment nodes when those are not specified in the dummy metadata
- Automated export of the pre-simulation solver deck (LS-Dyna or RADIOSS)
DUMMY POSITIONER : PRE-SIMULATION

• Puppet method for pre-simulation and removing intersection after geometric positioning.
  • Simple process where the tool automatically computes the difference between the current position and the reference position
  • Export of pre-simulation input file to submit to solver
  • Read result file (h3d or dynain) and optionally take into account pre-stress
CRASH & SAFETY – SEAT MECHANISM + DUMMY

- Ability to link a dummy to a seat mechanism
  - Constraints can be used to fix the bodies of the dummy that should remain in position (hands/feet)
  - Dummy is automatically moved based on the motion of the seat

Initial seat+dummy position  Modification of seat position  New seat+dummy position
SEAT DEFORMER

• Provides a quick and efficient way to remove intersection between the ATD and the seat
• Optionally import initial stress (solid, shell, beam).
SEATBELT

- Allow the full modeling of a seatbelt system
- All LS-Dyna seatbelt modeling supported (mixed 1D-2D, mixed 2D seatbelt/shell,
- Automatic creation of slipring, retractor, pre-tensioner and attachments to the vehicle structure
- Automatic creation of contact
- Modeling of full shell meshed seatbelt
- Automatic seatbelt update upon dummy and seat motion
BELT ROUTING

- Interactive modification of belt path and belt ends orientation
- New belt object in HyperMesh with all parameters defining the belt (mesh size, mesh type, belt size,….) allowing direct and quick modification of belt model.

Thorax belt creation

Pelvis belt creation
SAFETY TOOLS

• Complete restraint system generation
  • Works in conjunction with the seat mechanism and dummy positioning tool to easily reroute the belt
SUMMARY

• Seat Mechanism
  • Reads and export mechanism in Primer format
  • Following joint type are available
    • Spherical
    • Revolute
    • Cylindrical
    • Slider
    • Double Slider
  • Mechanism can be checked for error
    • Nodes in multiple bodies
    • Redundant joint
    • Empty bodies
  • Multiple position can be saved
  • Dummy can be coupled to the seat
  • Automatic extraction of mechanism
SAFETY TOOLS

- Upcoming: Combining dummy pre-simulation & seat deformer
  - Combining these steps will allow to improve efficiency as well as accuracy. Seat foam deformation will be more realistic.
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  • Combining these steps will allow to improve efficiency as well as accuracy. Seat foam deformation will be more realistic.
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Occupant Safety post-processing

Robustness and Optimization using DOE and Optimization
HyperGraph Report Template
Occupant Reports with HyperGraph

**IARV Summary**

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**Legend**
- Good
- Acceptable
- Marginal
- Poor
## HYPERVIEW RESULTS TEMPLATE

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<th>C</th>
<th>D</th>
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<tr>
<td><strong>Peak Values</strong></td>
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<tr>
<td>12. Neck-(kN)</td>
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<tr>
<td>13. Chest(G)</td>
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</tr>
<tr>
<td>14. ChestDef(mm)</td>
<td>50.00</td>
<td>30.38</td>
<td>29.77</td>
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</tbody>
</table>

![Graphs showing data trends](image-url)
ALTAIR HYPERSTUDY

- Multi-Disciplinary **Design Exploration** and **Optimization** software for engineers
  - **Automates** processes for parametric study, optimization and robustness assessment
  - Uses **state-of-the-art** mathematical **methods** and data-mining
  - **Guides** the user to **gain insights** from the data collected
WITH HYPERSTUDY YOU CAN

- Investigate relationships
- Make predictions
- Identify best design
- Assess reliability

Design of Experiments
Fit
Optimization
Stochastic
HYPERSTUDY KEY DIFFERENTIATORS

**Usability**
Step-by-step process that guides the user
Features such as archive that improves usability

**Technology**
State-of-the-art methods for reliable and robust product design

**Data Mining**
Box plots, correlation matrices, linear effects, parallel-coordinate plots among many others

**HyperWorks Integration**
Seamless integration with HyperMorph and Solvers
Automatic process
HYPERSTUDY USER INTERFACE

Streamlined Process

Efficient algorithms

Rich Visualization

Increased Usability
AIRBAG SHAPE OPTIMIZATION WORKFLOW

Stable Load case

Model Optimization Ready

Parameterization: Example Airbag Properties

Parameterization: Morphing and shape creation

XREF to EREF Conversion

Tcl

Hyperstudy Setup on Linux server

Optimized Results

Hyperstudy Setup

Optimization Setup

Nominal Run

Hyperstudy

Linux Server

HPC

Run Optimization

Responses

Setup Optimization

Nominal Runs

Shape, a, b, c, d

Import variables

HM Model *.rad and includes

(a,b)

(c,d)
Example Load case

- Sled Test
- Airbag: Passenger Airbag
- Dummy: Hybrid III – 50th Percentile
- Design Variables:
  - Airbag Shape
  - Airbag tether lengths
  - Vent area
  - Vent timings
- Optimization Objective:
  - Minimize Head injuries (HIC)
- Constraints:
  - Volume
  - Other Injuries
BASE SIMULATION RESULTS

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A</td>
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<td>Peak Values</td>
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<td>CAE - Passenger</td>
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<td>Nij</td>
<td>0.8000</td>
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<td>11</td>
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<td>NecFz-(kN)</td>
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<td>ChestG(G)</td>
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<tr>
<td>14</td>
<td>ChestDef(mm)</td>
<td>50.00</td>
<td>29.77</td>
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</table>

Process Workflow

Back to Index
USER STEPS INVOLVED IN OPTIMIZATION

- Setup Hyperstudy on HPC Server (One time setup)
- Run tcl to create EREF and reference part from XREF geometry
- Parameterize Airbag properties and shape
- Setup Hyperstudy using a Hypermesh or parameterized tpl model
- Setup Responses
- Setup Optimization
- Results and post processing
SETUP HYPERSTUDY RESPONSES

Setup Responses

In the end, you should have a list of Responses defined as shown:

<table>
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<tr>
<th>Active</th>
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<th>Vname</th>
<th>Expression</th>
<th>Value</th>
<th>Comment</th>
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<td>Volume</td>
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<td>max(v_1)</td>
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</table>

(Optional: Shown just for example. Alternative to CSV file reading)
Step 14: Hit ‘Back’ from the Responses tab, and you will be taken to Evaluate tab of Nominal Run.

In the activity list on the right, uncheck everything except for Extract Responses step.

Click Evaluate Tasks, once it completes for all Nominal runs, you can check all the responses in Evaluation Data tab.
Step 19:
In Objective definition, Select Type as Minimize

Inside Apply On box, select appropriate Response, HIC 36 in this case.

Step 20:
Go to Constraints tab.
Click Add Constraint > Label the constraint appropriately > Hit OK
RESULTS AND POST PROCESSING

Setup Optimization Study

Step 3: Go to Evaluation Data tab.

All runs and their results will be listed in this tab.

One can right click on a variable or response and sort it by ascending or descending order as well.
RESULTS AND POST PROCESSING

Setup Optimization Study

Step 4: Go to Post Processing step.

In the Scatter 2D tab, select Correlation tab from bottom left.

In this chart, the number tell the intensity of relation between the design variables and responses corresponding to given row and column.

For example, -0.76 in first row 5th column corresponds to HIC36 and vent area. Select the cell and it will show the scatter chart for HIC36 and Vent area values from runs during optimization.

Negative value suggests that one entity will decrease in value while other increases.

Usually correlation values greater than 0.7 indicate significant relationship.
HYPERSTUDY RESULTS SAMPLE

Input variables and Response tables (Optimization / DoE)

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<th>Value 3</th>
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Pareto Charts (DoE)

Correlation Charts (DoE / Optimization)
## RESULTS AND POST PROCESSING

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**Process Workflow**

**Back to Index**
REAL LIFE PROJECT FOR HIGHLY NON-LINEAR PROBLEM...

Traditional Approach

Efficient Approach

Change accommodation
SUMMARY

• HYPERWORKS PROVIDES THE INTEGRATED SIMULATION SOLUTION FOR OCCUPANT SAFETY.

• NEW FEATURES FOR OCCUPANT SET-UP ARE CONTINUOUSLY ENHANCED FOR INTUITIVE, EASIER AND FASTER PRE-PROCESSING NEEDS.

• EASY TO CREATE GRAPHS AND TABLE TEMPLATES IN SYNC WITH ANIMATION POSTPROCESSING PROVIDES READY TO USE REPORTS WITH POSSIBILITY OF CUSTOMIZATION TO MEET YOUR SPECIAL NEEDS.

• HYPERWORKS DOE AND OPTIMIZATION TOOLS ARE INTEGRATED WITH PRE-POST-SOLVE TOOLS MAKE THE SET-UP AS ENGINEERS JOB RATHER THAN EXPERTS.