

Experiences with LS-DYNA Implicit MPP

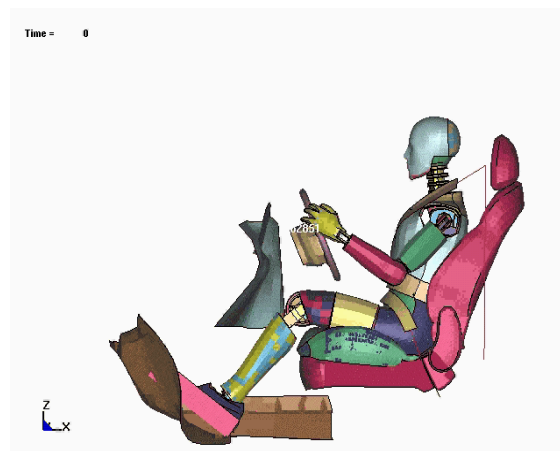
Cleve Ashcraft, Roger Grimes and Bradley Maker
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LS-DYNA

- Finite Element Analysis package
 - Explicit
 - Designed for small time steps and major deformation (think crashes)
 - One of the few commercially available packages which is MPP
 - Customers want MPP Implicit

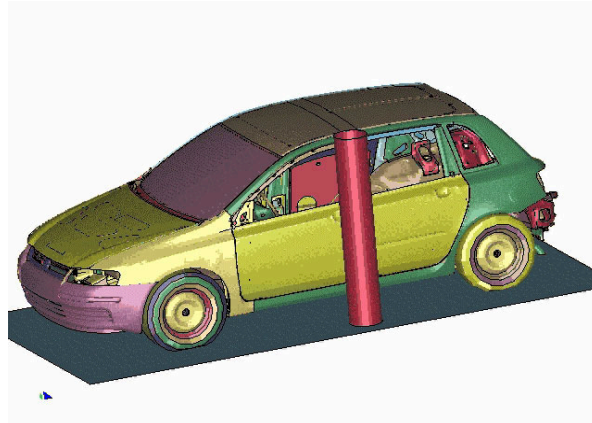
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Crash Dummy with Air Bag



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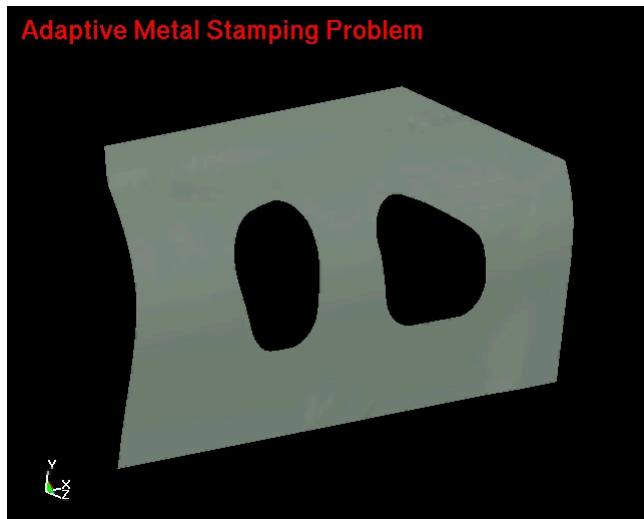
Side Impact



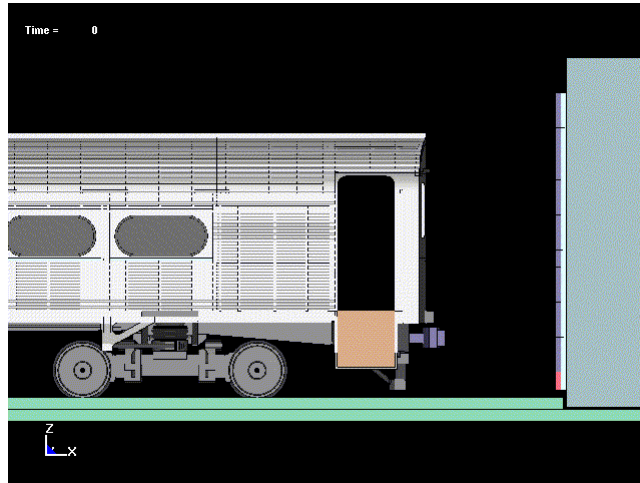
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Metal Forming

Adaptive Metal Stamping Problem

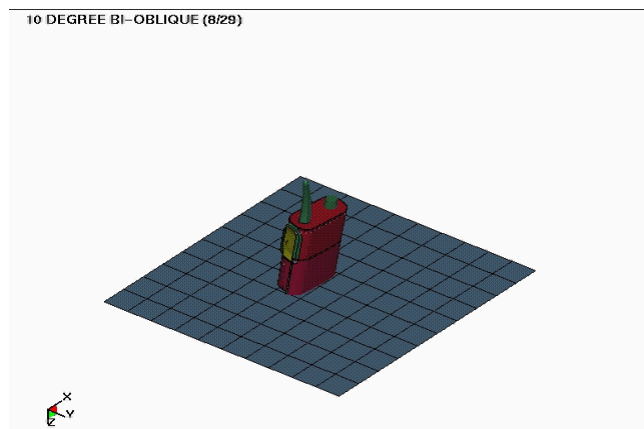


Train Crash



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Cell Phone Drop Test



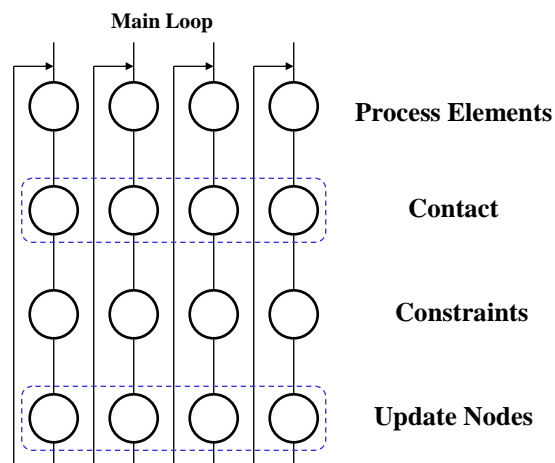
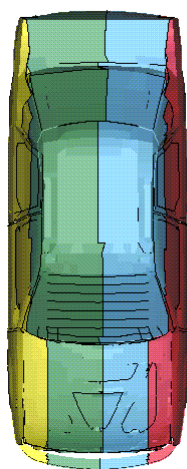
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The Vision

- LSTC wants to provide a single package that allows users to perform all of their analyses.
 - Implicit computations must be integrated with explicit
 - Linear analyses (useful for debugging large models) must be integrated as well.

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Explicit MPP Parallelism



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Problem Partitioning

- Explicit partitions the problem into subproblems executing on each processor
 - Strict partitioning of elements
 - Nodes may be on more than one processor
 - Load balance for explicit is bad for parallel linear algebra

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Implicit Computations

- At LSTC we have been developing an integrated package that allows us to switch between implicit and explicit computations in the same simulation.
- We have also added many linear analyses
 - Linear Static
 - Vibration
 - Buckling

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Implicit Uses Explicit

- Implicit uses already existing explicit computations for
 - Element matrix computations
 - Force
 - Stiffness
 - Contact

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Towards MPP

- Explicit is already available in MPP
 - Achieves linear speed up
 - In production at many sites using up to 256 processors.
- We started our efforts to make an MPP version of LS-DYNA Implicit
 - Already have a distributed memory parallel linear equation solver based on multifrontal
 - Developing, based on Boeing's Lanczos software and our linear equation solver, a parallel eigensolver.

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So what's so hard?

- Everything else!
- We need to solve

$$Ku = P$$

$$\text{Subject to } Cu = f$$

- Contributions for K, C, P, and f are distributed.
- Contact can change the distribution!

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Matrix Assembly and Constraints

1. Assemble C
2. Find full rank set of dependent variables, C_{DD}
3. Invert C_{DD} and form $u_D + \hat{C}_{DI} * u_I = \hat{f}$
4. Assemble K and partition into $\begin{bmatrix} K_{DD} & K_{DI} \\ K_{DI}^T & K_{II} \end{bmatrix}$
5. Substitute to form $\hat{K}_{II} * u_I = \hat{P}_I$

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Our biggest problem

- Matrix assembly and constraint application in a distributed memory parallel environment where problem partitioning can change.
- We are now in the final stages of debugging and testing of this capability.

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Current State of Affairs

- All of the software for MPP Implicit Nonlinear is integrated into current development version of LS-DYNA (v. 971)
 - Works on most nonlinear problems in four different computer environments.
- Linear Equation Solver working well.
- Parallel Eigensolver in testing mode

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Linear Equation Solver

- CPU times for problem with 1.32M rows

# Proc	Factor	Solve
1	4712	83.2
2	2515	47.2
4	1380	37.3
8	697	17.7
16	428	13.1
32	277	5.9

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Contact in MPP

- We are currently integrating MPP contact algorithms with MPP Implicit.
- All large models of interest to LSTC and our customers need contact
 - Spotwelds (which hold cars together) are modeled with Tied Contact
 - Crash and metal forming need contact

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No results yet

Come to Dearborn May 2-4 for our Users Meeting.
We will have results or one of the following will be true about the MPP Implicit Team

- a) We will be tarred and feathered;
- b) We will be in the pillory so our boss, distributors, and customers can throw rotten vegetables at us; or
- c) Our hides will be on display

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