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Under the Hood of Implicit LS-DYNA

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Implicit in LS-DYNA v. 970

- LS-DYNA v. 970 has an extensive set of Implicit capabilities.
  - Implicit Time Simulation
    - static, dynamic, damping
  - Switching between Implicit and Explicit
    - automatic or user specified
  - Eigenanalysis
    - vibration or buckling
    - intermittent during an explicit or implicit simulation
  - Constraint and Attachment Mode Extraction
- Brad Maker gave several examples in his talk.

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Overview of Presentation

This presentation will give you an overview of

- How we implemented all of these implicit features.
- Integrated implicit with our flagship explicit code.
- Overview of our ongoing development of an MPP implicit capability.

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Implicit uses Explicit

- Explicit already performed many of the computations required for Implicit.
  - Force computations
    - From elements
    - From penalty constraints
  - Constraint application
  - Detection of contact
  - Output

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Reverse Communication

- We implemented Implicit using Reverse Communication
  - Called from Explicit
  - On return, Implicit sets flags to tell Explicit what to do next
    - Compute forces
    - Compute elemental stiffness matrices
    - Perform Contact analysis
    - Update history variables
    - Perform output
- Allows reuse of same contact, material, and element subroutines.

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Inside Implicit

Inside Implicit we can perform

- Linear Analysis
- Nonlinear Analysis
- Eigenanalysis
  - Newton or Quasi-Newton
  - Automatic time step selection
  - Static or Dynamic
  - Damping
  - Arc Length Methods
- Constraint and Attachment Mode Extraction

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Constrained Linear Algebra Problems

- All Implicit analyses need to solve

$$Ku = f$$

$$Subject\ \ to\ Cu = d$$

Or

$$K\Phi = M\Phi\Lambda$$

$$Subject\ \ to\ C\Phi = 0$$

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Setting up the Linear Algebra Problem

- Using the same data structures as explicit, Implicit computes the constraint matrix C and constraint right-hand-side d.
- Implicit uses explicit to compute elemental stiffness matrices, contact stiffness matrices, and forces.

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LCPACK

- We have implemented a powerful and efficient Linear Constraint Package (LCPACK)
  - Automatically determines dependent (slave) and independent (master) sets of variables from the constraint matrix.
  - Applies the constraints to form reduced linear algebra problems
  - Computes the dependent variables from the independent ones.

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Handling of Constraints in LS-DYNA

- We start with the full constraint matrix and perform an automatic partitioning of the dofs into the form

$$C_{D,D}u_D + C_{D,I}u_I = d$$

where $C_{D,D}$ is a full rank, square matrix that can be stably inverted.

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The Approach in LS-DYNA v. 970

- We factor $C_{D,D}$ using its special structure to yield

$$u_D + C_{D,D}^{-1} C_{D,I} u_I = C_{D,D}^{-1} d$$

or

$$u_D + \hat{C}_{D,I} u_I = \hat{d}$$

- This form allows for direct substitution to compute reduced linear algebra problems.

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Linear Algebra Infrastructure

- We have 3 different linear algebra equation solvers
  - MF (in-house multifrontal solver)
  - BCSLIB-EXT (multifrontal solver with extensive out-of-memory capabilities from Boeing)
  - Package of Iterative Methods
- BCSLIB-EXT, the industry standard block shift and invert Lanczos eigensolver from Boeing

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Serial and SMP

- Currently Implicit operates in serial and SMP modes.
- Next goal is to operate efficiently in MPP.

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MPP Implementation Plan

- Explicit alreadys operates in MPP so Implicit automatically gets MPP implementation of
  - Elemental force and stiffness computations
  - Contact
- We have a functioning MPP multifrontal solver DMF (MPP implementation of our in-house solver)
- We are developing and testing MPP implementation of LCPACK
- A parallel eigensolver (based on Lanczos technology from Boeing) is being developed.

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Conclusion

- LS-DYNA v. 970 has an extensive set of implicit analysis capabilities.
- Implicit can handle most of the modeling features provided by LS-DYNA.
- We are developing an MPP implementation of all of these capabilities.

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