Unique Linear Solver Needs of the Los Alamos Radiation Transport Team

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8 / 28 / 96
Outline

- **DANTE**
  - Problem Characteristics
  - Matrix Characteristics
  - Matrix Storage
  - Current Solution

- **Augustus / Spartan**
  - Problem Characteristics
  - Matrix Characteristics
  - Discretization
  - Current Solution

- Overall Needs of Radiation Transport
DANTE
Problem Characteristics

- Radiation Transport ($S_N$, $SP_N$, $P_N$)

- 1–D, 2–D, 3–D Cartesian

- Arbitrary Finite Element (Hexahedra, Tetrahedra, etc.)

- Unstructured Mesh — Node-Based

- Variables: Intensity for every point, angle and energy group (energy groups always decouple)
DANTE
Matrix Characteristics

- Size (rows): $S_N$ & $SP_N$: $n_{nodes}$;
  $P_N$: $n_{nodes} \times F(n_{angles})$

- Absolute size (rows): 10,000 – 1,000,000

- Sparse ($\approx$ 10 non-zeroes per row)

- Actual number of non-zeroes per row unknown

- Symmetric Positive Definite

- $P_N$: full block matrix, each block has same non-zero pattern

- $S_N$ & $SP_N$: block diagonal matrix (angles uncouple)
DANTE
System Storage

- Multi-D Vectors: $v(n\text{points}, n\text{angles})$

- Matrix: complicated, never assembled

- Reverse communication necessary

- Some treatment of dot products necessary
DANTE
Current Solution

- Conjugate Gradient with Jacobi preconditioning (developed in-house)

- Algebraic Unstructured Multigrid (Mantueffel et al., experimental)

- Would like to be able to use standard preconditioners with reverse communication
Augustus / Spartan
Problem Characteristics

- Radiation Transport (Spartan: $SP_N$, Augustus: $P_1$)

- Augustus: 1–D (Cartesian, Cylindrical & Spherical), 2–D (Cartesian & Cylindrical), 3–D (Cartesian)

- Spartan: 2–D (Cartesian & Cylindrical)

- Spartan uses Augustus as its solver, so multi–D version of Spartan is on the way

- 3–D: Hexahedra & Degenerates,
  2–D: Quadrilaterals & Degenerates,
  1–D: Line Segments

- Unstructured Mesh

- Spartan Variables: Intensity for every point, angle and energy group (energy groups and angles always decouple)
Augustus / Spartan
Matrix Characteristics

Main Matrix System:

- Size (rows): \(4n_{cells} + n_{bf}/2\)
- Absolute size (rows): \(10,000 - 100,000\)
- Sparse (7 or 11 non-zeroes per row)
- Unsymmetric
- ELL Storage

Preconditioner Matrix System:

- Size (rows): \(n_{cells}\)
- Sparse (7 non-zeroes per row)
- Symmetric
- ELL Storage
Main system involves cell-equations ($+k$: flux shown, all points would be involved in cell-equation):

and cell-face equations:

Preconditioner eliminates minor directions in flux terms to yield a system involving only cell-centers.
Augustus / Spartan
Current Solution

Main system:

- Krylov space solvers (GMRES, BCGS, etc.) in JTpack by John Turner, LANL
- UMFPACK: incomplete direct method (the unstructured multi-frontal method) by Tim Davis, U of FL

Preconditioner:

- Jacobi, SSOR, ILU from JTpack
- Specialized Low-Order Preconditioner, solved with Conjugate Gradient with SSOR preconditioning using JTpack
- UMFPACK: none
Overall Needs of Radiation Transport

- JTPACK, UMFPACK serving most needs

- Would like to be able to use standard preconditioners with reverse communication

- Reverse communication for matrix multiplication and system solution (possibly for dot products)

- Support for 2-D vectors

- Arithmetic Unstructured Multigrid Package with Documentation
Implementation:
The Augustus Code Package

Author: Michael L. Hall (1/94 - present)

Architectures: Sun (SunOS and Solaris), SGI (IRIX), HP (HP-UX), IBM (AIX)

Language: Fortran-77, plans for Fortran-90

Solver Packages: JTPACK (by John Turner, LANL) for Krylov Space methods, UMFPACK (by Tim Davis, U of FL) for sparse direct methods

Installations: SNLA ALEGRA hydrodynamics code, LANL TELLURIDE low-speed flow code, Solver for the SPARTAN SP\textsubscript{N} radiation transport code.

Status: Completed, active development of new features

Availability: Email hall@lanl.gov and we’ll talk