Unique Linear Solver Needs of the Los Alamos Radiation Transport Team

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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: $n_{nodes} \times F\left(n_{angles}\right)$
- 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(npoints, nangles)`

- 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:

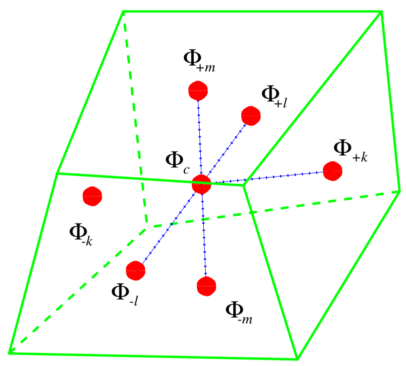
- Size (rows): $4\, n_{cells} + n_{bf}/2$
- Absolute size (rows): 10,000 – 100,000
- Sparse (7 or 11 non-zeroes per row)
- Unsymmetric
- ELL Storage

Preconditioner Matrix System:

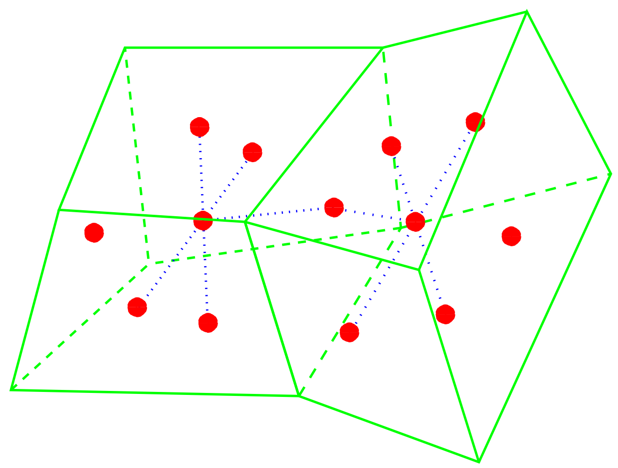
- Size (rows): n_{cells}
- Sparse (7 non-zeroes per row)
- Symmetric
- ELL Storage

Augustus / Spartan Discretization

Main system involves cell-equations ($+\boldsymbol{k}$ 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_N radiation transport code.
Status:	Completed, active development of new features
Availability:	Email **`hall@lanl.gov`** and we'll talk