Scientific Application Project – *"Terascale Supernova Initiative"*

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Summary

This Scientific Application Project (SAP) assists the astrophysics scientists in the SciDAC project "Tera-scale Supernova Initiative" (TSI) in exploring and implementing efficient algorithms for modeling core collapse supernova explosions. Models of such supernovae require three-dimensional, general relativistic, radiation magnetohydrodynamics simulations that severely challenges the existing computational science infrastructure. We have developed and implemented in parallel an efficient ADI like preconditioner for 1DBOLTZTRAN. We are extending the technique for efficient solution on the CRAY X1 of sparse linear systems arising from adaptively refined meshes from GenASis in two and three dimensions.

The search for the explosion mechanism of core collapse supernovae and the computation of the nucleosynthesis in these spectacular stellar explosions is one of the most important and most challenging problems in computational nuclear astrophysics. Core collapse supernovae are among the most energetic explosions in the Cosmos, disrupting almost entirely stars more massive than ten Suns and disseminating and producing many of the elements in the Periodic Table heavier than hydrogen and helium. They are a nexus for nuclear physics, particle physics, fluid dynamics, radiation transport, and general relativity. The SciDAC Terascale Supernova Initiative (TSI) is a multidisciplinary collaboration of one national lab and eight universities to develop models for core collapse supernovae and enabling technologies in radiation transport, radiation hydrodynamics, nuclear structure, linear systems and eigenvalue solution, and collaborative visualization. This Science Application Project (SAP) supports the TSI effort by collaborating closely with the astrophysics scientists to provide the best mathematical techniques and algorithms to achieve high efficiency on terascale computing platforms.

We have developed and implemented in parallel an efficient ADI like preconditioned for 1DBOLTZTRAN. The supernova models in one dimension commonly produce sparse block tridiagonal matrices where the off-diagonal blocks are exactly diagonal. Such systems arise in MGFLD (multi-group flux-limited diffusion), MGBT (Multi-group Boltzmann Transport) and nucleosynthesis calculation performed by Bradley Meyer's astrophysics group at Clemson University. The ADI-like preconditioner has been demonstrated to be effective for block tridiagonal system on MGFLD, MGBT and nucleosynthesis calculations. A sparse incomplete LU factorization with a prescribed sparsity pattern has also been found to be an effective replacement for the costly

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complete direct factorization of the diagonal blocks. A parallel implementation has been implemented. We expect the ADI-like preconditioner to be equally effective for larger problems in two and three dimensions. The sparse matrices arising from adaptively refined meshes from GenASis will have sub-blocks that mimic the block tridiagonal patterns.

Initial implementation of sparse matrix algorithms on the CRAY X1 suggests the commonly used Compressed Sparse Row Storage scheme (CSR), which is used in PETSc, may not be the most efficient. The CSR is efficient on scalar processors such as the Power4 since it stores only the nonzero entries and accesses memory in unit stride. However, vectorization is limited to the small number of non-zeros per row. Alternate storage schemes such as ELLPACK, jagged diagonal, and diagonal band storage are evaluated on the CRAY X1. Table 1 shows the time (in seconds) for performing 1000 calls of matrix vector multiply on a problem on supernova nucleosynthesis. The bottom row shows the megaflop rate for the best storage scheme. Figure 1 shows the block tridiagonal sparsity pattern. We plan to continue development of effective sparse linear solver based on the proven ADI-like preconditioner for adaptively refined meshes produced in GenASis and efficiently implemented in parallel on the CRAY X1 vector supercomputer.

[1] "An ADI-Like Preconditioner for Boltzmann Transport" by E. F. D'Azevedo, B. Messer, A. Mezzacappa, M. Liebendoerfer, accepted in SIAM Journal on Scientific Computing

[2] "On the performance of SPAI and ADI-like preconditioners for core collapse supernova simulations in one spatial dimension", R. Blakrishnan, E. F. D'Azevedo et al, submitted to the Journal of Scientific Computing.

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	IBM Power4	SGI Altix	Cray X1
CSR	0.24s	0.33s	0.89s
JAG	0.22s	0.21s	0.38s
Ellpack	15.5s	59s	5.0s
Diag	26.0s	80.9s	6.3s
Mflops	553	579	320

Table 1: Performance of sparse matrix multiply

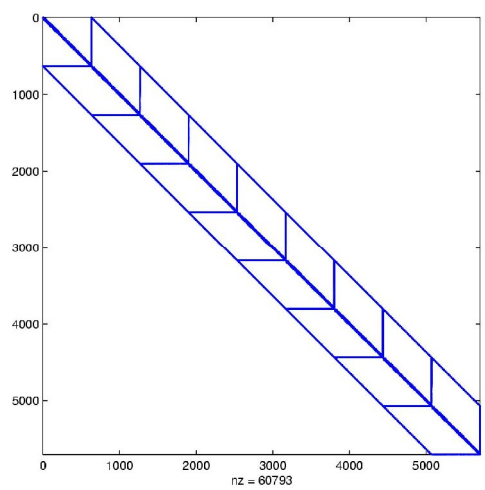

Figure 1: Block tridiagonal sparsity from nucleosynthesis, N=5706.