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ADAPTIVE ORDER NODAL TRANSPORT METHOD

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High order nodal transport methods have demonstrated high accuracy and computational efficiency in solving transport problems for systems composed of large homogeneous regions. In addition to these properties, the Arbitrarily High Order Transport Method of the Nodal type (AHOT-N)[1], possesses simple final equations and allows modifying the order of the spatial approximation without modifying the programming of the method. However, AHOT-N requires solving the system with the same order in all nodes and discrete directions. This feature could force the use of more equations and unknowns than needed to obtain a given accuracy with a consequent loss of computational efficiency.

In a previous work[2] a slight modification to AHOT-N was presented that allows solving a problem with a different order per node per direction. This was applied in an automatic adaptive order scheme aimed at improving the computational efficiency of AHOT-N and simplifying the error estimation of the obtained solutions. If the problem to be solved does not require a uniform order distribution (UOD), the variable order scheme could reduce significantly the number of equations and unknowns evaluated. In addition, the automatic increasing of the order depending on error estimates avoids the pre-selection of the order distribution per node per direction necessary to obtain accurate solutions, practically an impossible task that requires extensive knowledge about the shape of the solution. Since the automatic increasing of the method order depending on the estimated errors concerns data quality rather than quantity, and the optimization of user time rather than CPU time, in this work we focus on the behavior of the solutions obtained with the adaptive method.

Starting with a previous order distribution, $\Lambda_{n,m}^{(t)}$, the adaptive scheme[2] increases the order of the approximation for angular directions m in the nodes n whose error estimator $E^{(t)}_{n,m}$ lies within a given range above the maximum estimator $E^{(t)}_{max,m}$. For a prefixed value of $B>1$:

$$\Lambda_{n,m}^{(t+1)} = \Lambda_{n,m}^{(t)} + 1 \qquad if \ \frac{E^{(t)}_{max,m}}{E^{(t)}_{n,m}} \le B$$

$$\Lambda_{n,m}^{(t+1)} = \Lambda_{n,m}^{(t)} \qquad \text{otherwise}$$

where t denotes the iteration of the adaptive process, and $E^{(t)}_{max,m}$ is the maximum estimator over the nodes of the system for the direction m in the iteration t.

We implemented the adaptive AHOT-N method in a discrete-ordinates steady-state code for solving monoenergetic, fixed source, isotropic scattering problems in two-dimensional Cartesian geometry. A modified version of the second test problem of Ref. 2 was solved with UOD and the adaptive schemes. This has the same geometric configuration and fixed source distribution as in Ref. 2, but with total cross section and scattering ratio 100 m^{-1} and 0 in the source-free region. The problem was solved on an 8x8 mesh using an S_4 angular quadrature and a pointwise relative convergence criterion of 10^{-4} for all the calculated scalar flux spatial moments to test convergence of the inner iterations. In order to investigate the evolution of the solutions in the adaptive process, we did not apply any convergence test on the adaptive scheme; instead we allowed the system to evolve until reaching a prefixed number of adaptive iterations. The UOD with order equal to 6 was taken as reference.

The maximum relative error in the Region-averaged scalar fluxes obtained with UOD and the adaptive scheme using different values of B vs. the number of unknowns employed is shown in Fig. 1a. The relative error in the spatially reconstructed scalar flux averaged over .0125 m^{-1} squares at the upper right corner of each region is depicted in Fig. 1b.

Referring to the Region-averaged scalar flux, the maximum relative error obtained in the last adaptive step with $B=10$ is 4×10^{-4}, and this case uses 40.5% of the number of unknowns that the uniform order case uses to reach the final values. On the other hand, the adaptive $B=50$ case produces the highest saving for the vertex reconstructed fluxes using 47% of the number of unknowns. The adaptive $B=100$ and $B=1000$ cases produce the same Region- and Vertex-averaged fluxes as the uniform order case in each increasing order step.

We observe that the value of B that maximizes the savings in the number of unknowns depends on the size of the regions over which the fluxes are calculated. This result is in agreement with other observations made for the behavior of averaged fluxes obtained using the AHOT-N method. For example, in Ref. 3 a relative insensitivity of the Region-averaged scalar flux to the value of the spatial weights used for the AHOT-N method was detected. In that work, accurate Region-averaged scalar fluxes were obtained even when higher flux moments were in large error. We also observed that accurate Region-averaged scalar fluxes are obtained if the convergence test for the inner iterations is applied only to the averaged scalar fluxes in spite of testing the convergence over all the calculated moments of the flux.

This interesting phenomenon must be studied in more detail since it can be used not only for improving the adaptive schemes but also to accelerate the iterative process related to the AHOT-N method in problems where Region-averaged fluxes are the quantities of prime interest.

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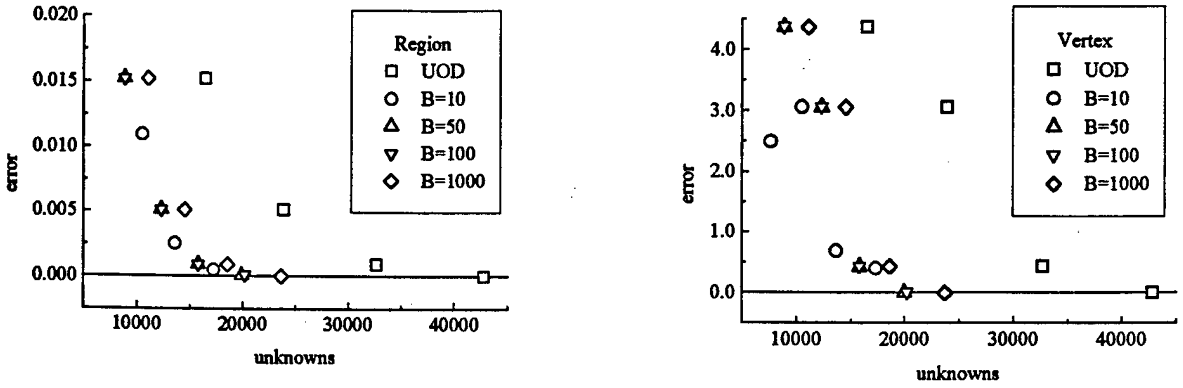

Fig. 1. Relative error in Region- and Vertex-averaged scalar fluxes.

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