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Cyclic Reduction Multigrid Revisited

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We revisit an early 90's technique due to Golub and Tuminaro, originally suggested for two-dimensional convection-diffusion. The idea is to perform a single cyclic reduction step before reverting to multigrid. We generalize this idea and introduce a novel smoothing analysis for the resulting problem, which yields explicit analytical results. In particular, we prove for $2d+1$ point "star" stencils, where d is the dimension, that the suitably defined h-ellipticity measure is always increased by the cyclic reduction step for symmetric M-matrices. Additionally, we introduce a novel relaxation method employing a cyclic reduction step, dubbed cyclic reduction relaxation (CRR), and analyze its smoothing properties, which turn out to be exceptional. Numerical computations show a close agreement between the smoothing analysis results and actual V-cycle convergence factors.