SAGE

A 2-D Self-Adaptive Grid Evolution Code and its Application in Computational Fluid Dynamics

by

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Abstract

SAGE is a user-friendly, highly efficient, 2-dimensional self-adaptive grid code based on Nakahashi & Deiwert's variational principles method. Grid points are redistributed into regions of high flowfield gradients while maintaining smoothness and orthogonality of the grid. CPU efficiency is obtained by splitting the adaption into 2 directions and applying one-sided torsion control, thus producing a 1-D elliptic system that can be solved as a set of tridiagonal equations.

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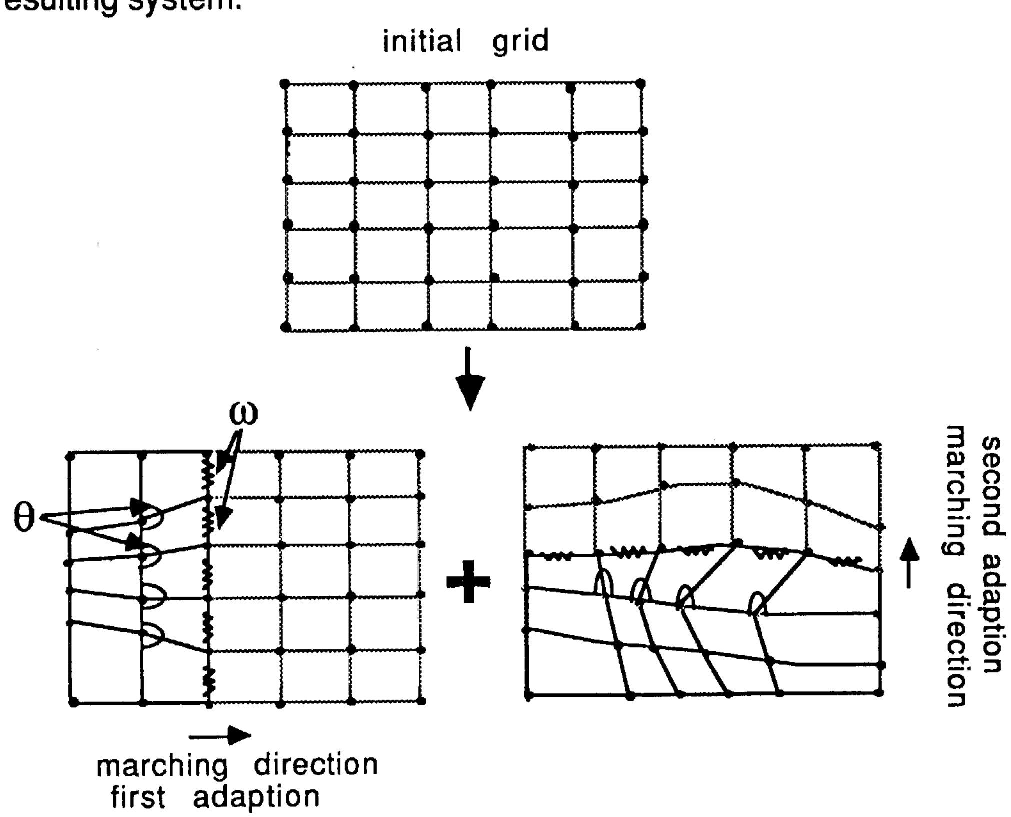
Outline of Presentation

- Brief Description of Self-Adaptive Method (based on Nakahashi & Deiwert's variational principles scheme.)
- SAGE code features, including input parameters.
- Application of SAGE to various flow problems:
  - Hypersonic blunt body
  - Supersonic shock impingement
  - Hypersonic inlet with cowl
  - Supersonic plume flow
  - Supersonic inlet

Self-Adaptive Grid Method of Nakahashi & Deiwert

Objective: to redistribute points into regions of high flow gradients (utilizing minimization principles) while maintaining smoothness and orthogonality between adapted lines. The technique is analogous to connecting each node by tension and torsion springs and locating the equilibrium position of the resulting system.



Adaption Equation

Splitting the adaption into 2 directions and applying one sided torsion control reduces the problem to the following 1-D elliptic system which can be solved as a tridiagonal system of equations:

$$\omega_i \Delta s_{i+1} + \omega_{i-1} \Delta s_i - C_i \theta_i = 0$$

where:

tension spring constants, $\omega_i = 1 + A f_i^B$

$f_i = f(\text{gradient of } Q_i)$ {error measure}

self-adaptive mesh size controlled by A and B:
$A = \Delta s_{max} / \Delta s_{min} - 1$, B enforces computed $\Delta s_{min} = \Delta s_{min}$

torsion spring constant, $C_i = f(\omega_i, \lambda_i, \text{cell aspect ratio})$

and $\theta_i = f(C_t, \text{smoothness}, \text{orthogonality})$

SAGE Input Parameters

Control parameters:

λ, Ct, $\Delta smin$ and $\Delta smax$

Adaption parameters:

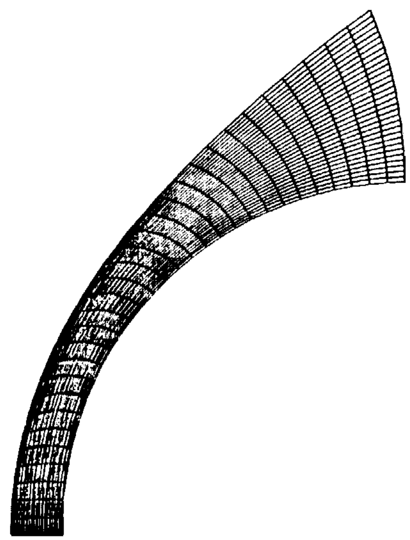
Limits of adaption domain.
Stepping direction.
Adaption variable (or combination or user defined).
Boundary spacing controls.
Addition of grid points.
Order of interpolation and smoothing.

SAGE Code Features

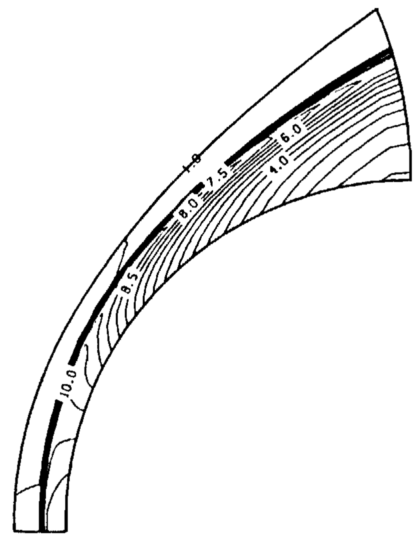
- Fast and efficient - ~0.005 secs/grid point on a VMS/VAX
  e.g. 30x30 grid takes 5 secs
- Small size: 1900 lines of code (40% comments)
- Structured code and detailed user guide available - easy to customise
- Few user input parameters necessary but many options for great flexiblility
- Can be applied to zonal, patched and multiple grids

Application 1: Hypersonic Blunt Body

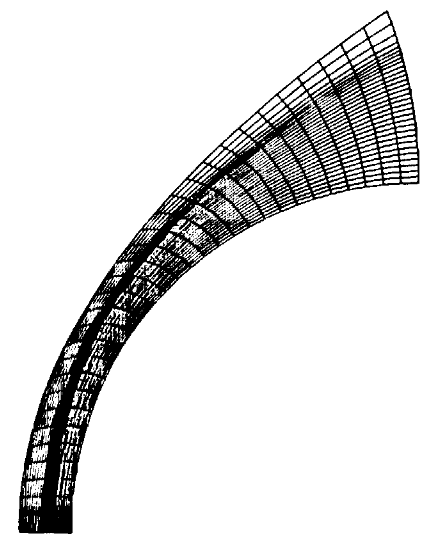
Flow features: Simple 1-directional problem, shock shape aligned with grid.



Initial grid (32x32)



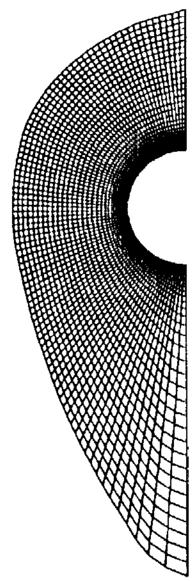
Initial flow solution
(density contours)



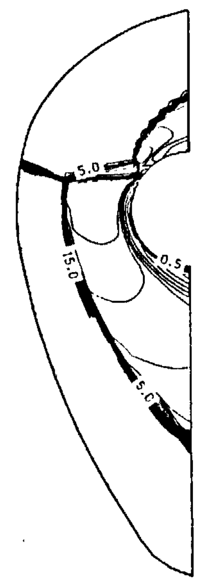
Adapted grid
(i step): λ=.001

Application 2: Cowl Lip with Shock Impingement

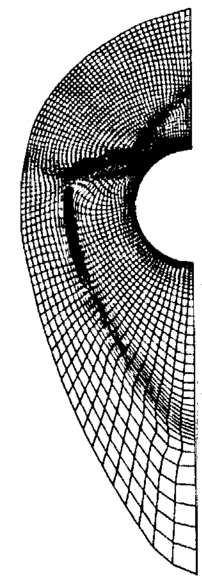
Flow features: blunt body shocks, impinging shock and shear layers



Initial Grid(91x46)



Initial density solution



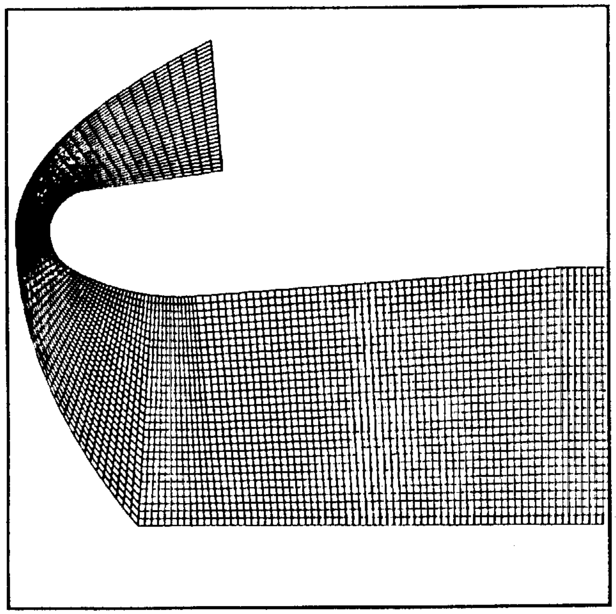
Adapted grid

i: Δs_{min}=.25, C_t=.7, λ=.005

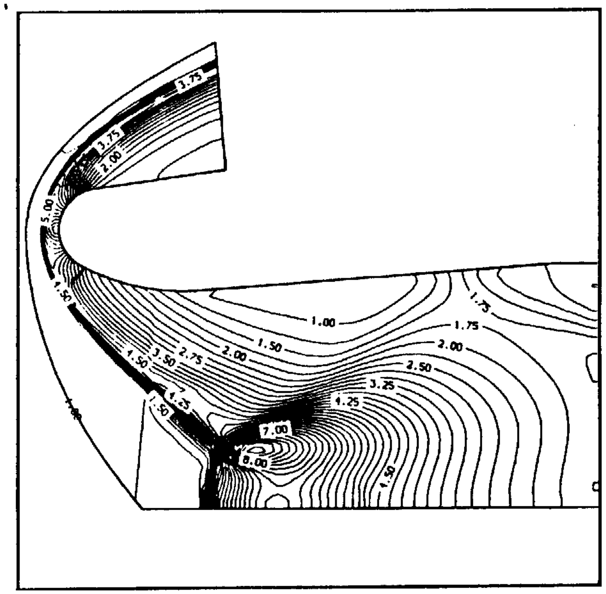
j: Δs_{min}=.25, orthe=false

Application 3: Hypersonic Inlet with Cowl

Flow features: Cowl blunt body shock, Mach stem & reflected shocks



Initial Grid (128x32)



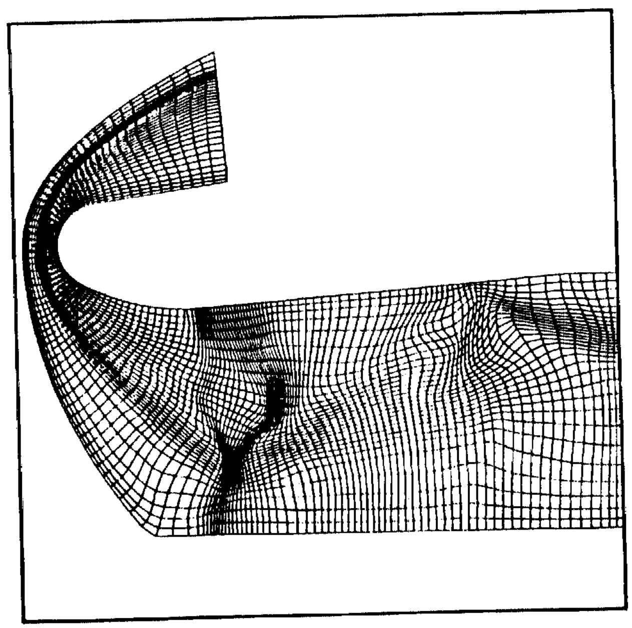
Initial density contours

Application 3 continued: Adapted Grid

Example of zonal adaption

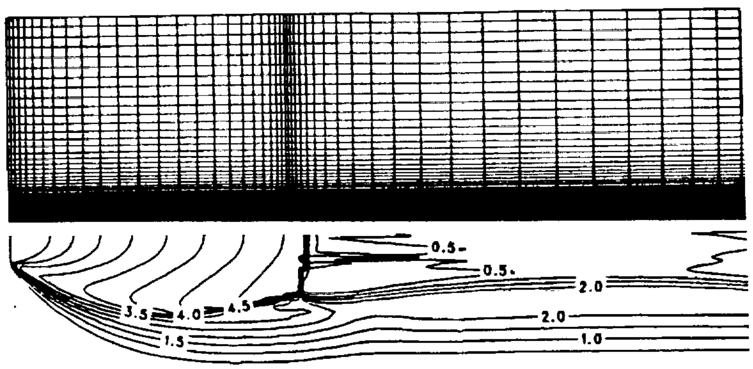
i-direction - full domain adaption

j-direction - 3 zonal adaptions:
1) cowl region
2) lower inlet region
3) upper inlet region

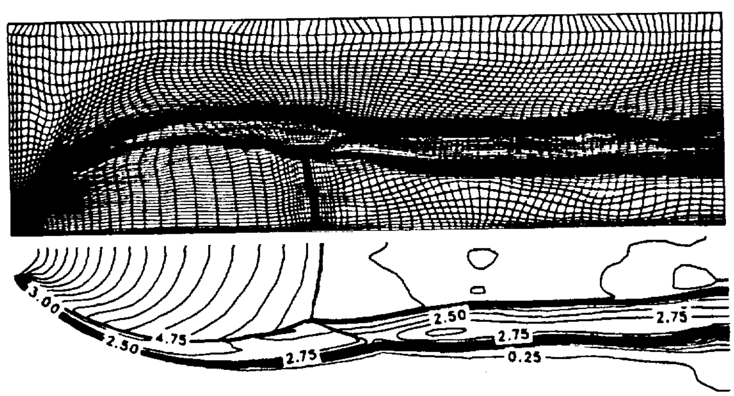


Application 4: Plume Flow

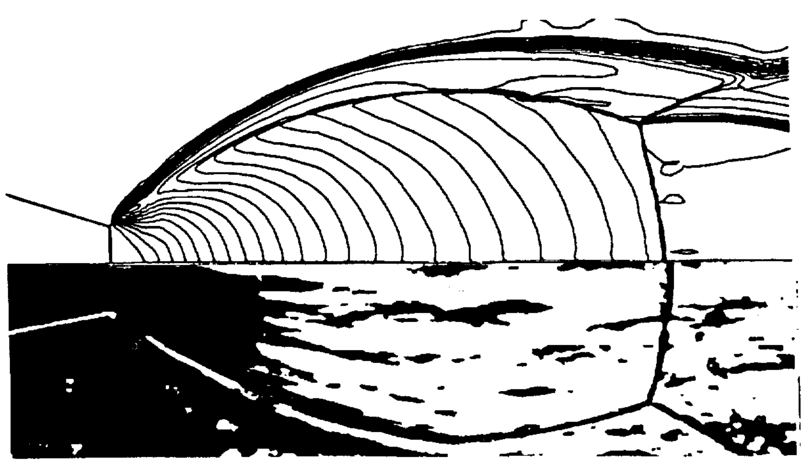
Flow features: Outer shear layer, barrel shock, Mach disc, reflected shock, triple-point shear layer



Initial grid and Mach contours



Adapted grid and solution (after 3 iterations)

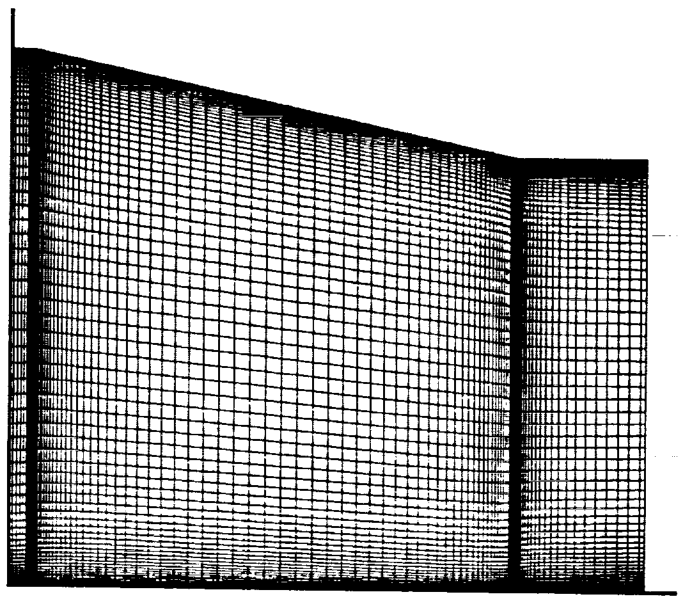


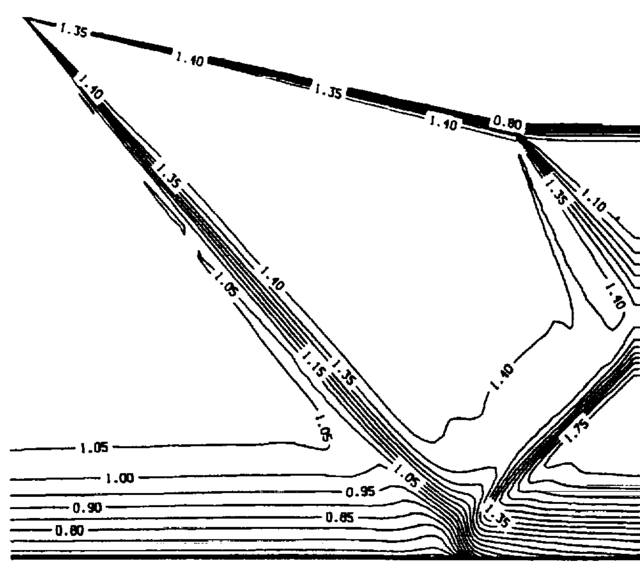
Comparison with shadowgraph

Application 5: Supersonic Inlet

Flow features: Corner shock, reflected shock and expansion fan

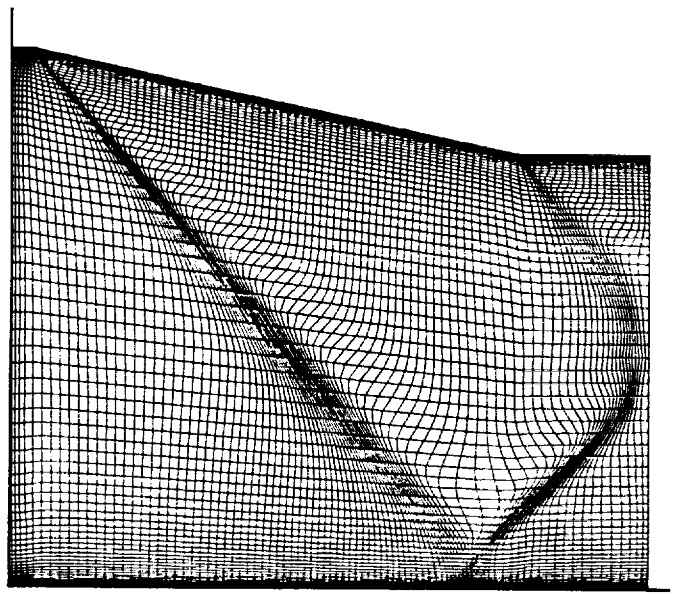
Initial grid (101x81) and density solution contours

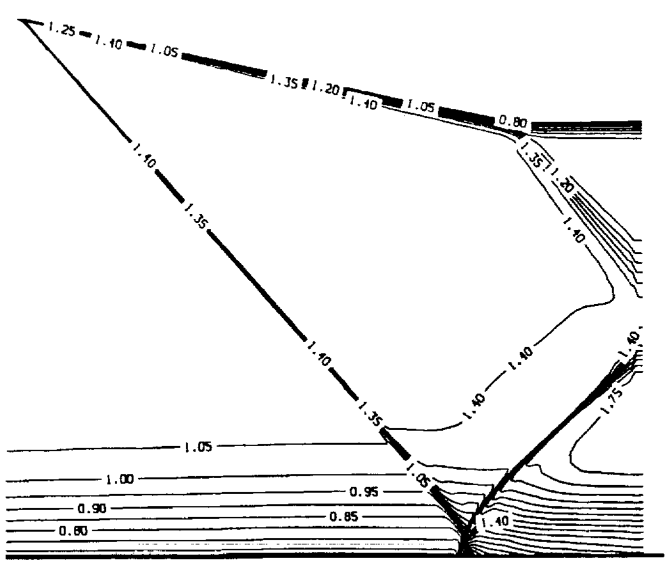




Application 5 continued: Adapted grid (marching in j) and Solution

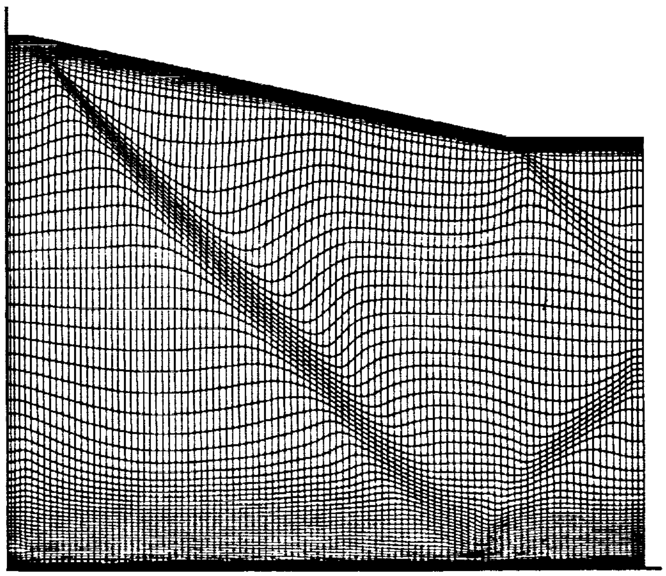
Input parameters: Δs_{min}=.25, Δs_{max}=2.5, λ=.0005

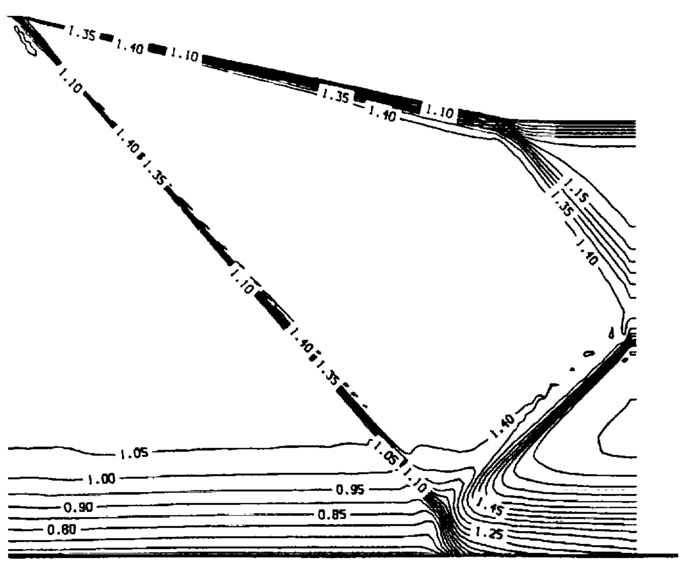




Application 5 continued: Adapted Grid (marching in i) and Solution

Input parameters: jstep=false, Δs_{min}=.25, λ=.001





Concluding Remarks

- SAGE is a new 2-D self-adaptive grid code that is user-friendly, flexible and efficient.
- Appropriate for a variety of CFD applications.
- Use of the SAGE code will efficiently improve the flowfield solution