Implementation of Postprocessor for CSCM Code by Using Graphic User Interface

Juraeva Makhsuda*[1], Dong Joo Song*[2]

그래픽 환경을 이용한 CSCM 수치해석 코드에서의 후처리 과정 개발

쥬래바 막슈다, 송동주

전산유체공학에서 그래픽 인터페이스를 이용한 후처리 기법은 수렴된 해의 물리적 구조 및 특성을 이해하는데 있어 매우 중요하다. 따라서 본 연구에서는 그래픽 환경을 이용하여 압축성 유동 해석 코드인 CSCM 수치해석 코드의 후처리 과정을 개발함으로서 코드전체의 완전성을 높이고자 하였다. Visual C++프로그램을 이용하여 Mesh plot, XY plot, 벡터 plot 및 contour plot이 가능한 후처리 프로그램을 개발하였으며 실시간으로 수치해석의 수렴정도를 파악할 수 있는 잔류항에 대한 그래픽 기능을 제공하게 하였다. 개발된 후처리 과정을 2차원 Compression ramp 및 Bump 문제의 해석결과에 대해 본 연구결과와 현재 유체해석의 후처리 프로그램으로 많은 사용자를 확보하고 있는 AMTEC사의 Tecplot 8.0 버전의 결과를 서로 비교해 본 결과 좋은 일치성을 보여주었다.

Key Words: Postprocessor, XY plot, Vector plot, Contour plot, Residual plot

1. Introduction

The postprocessor visualizes the data produced by the solver and this is bundled in a program along with the preprocessor and the solver.

Generally, the postprocessor of CFD codes requires user friend visualization environment, so Tecplot of AMTEC postprocessor program has been widely used [1].

In this study, to develope the postprocessor for in-house code, 2-dimensional CSCM upwind Navier-Stokes code, existing programs such as Tecplot and FEM flow and Fluent programs are analyzed and then present postprocessor program has been made by using Graphic User Interface [2, 3, 4, 5]. Present program contains the capabilities to show contour plot of any scalar quantities such as the Mach number, pressure and temperature, vector plot of velocity, XY plot, interactive error history plot and so on.

2. Contents of Postprocessor

2.1 XY plot and Mesh plot

The XY plot option can be used to produce plots of results. Program initially sets the ranges on the X-and Y axes, so that user can see all of data points and text. FindLimits() function finds data limits and it is important to choose axis ranges. Lines are drawn using a solid line pattern and with same thickness. The colors of plot lines are different. User can draw same range lines for

*1 영남대학교 대학원 기계공학과
*2 종신회원, 영남대학교 기계공학부
E-mail *1:maxsuda@hotmail.com *2:djsong@yu.ac.kr

example: measurements of pressure taken at four different locations.

And in a mesh plot, (X,Y) are two matrices which describe a surface. The surface is composed of four sided polygons. The data points for 2-D surface field plots are organized in a two-parameter mesh. Each data point is addressable by a set of the two parameters i and j. At each data point, we would define two spatial variables X and Y and more variables like temperature, velocity components.

2.2 Vector plot

Vector plots are field plots of the direction and magnitude of vector quantities. Vector plot vectors are plotted as straight colored lines with arrows. Vector plots are created with two variables associated with the vector components. The selection of vector length makes it possible to do several overlapping plots with colors appropriate to vector length. Optionally vectors can be annotated by the value of their length. The vector length is proportional to the local velocity magnitude. The tail of the vector is positioned at the data point, which for ordered data is a corner of the cell. Vector plot can draw vectors with $[\pi ; -\pi]$ interval by using atan2(u,v) function. For the arrowheads arrowhead angel and arrowhead coordinates are chosen. Color of color vector plot is chosen vector length difference from maximum and minimum vector length. Color spreads between three colors: red, green, and blue. The vector scale factor is specified in screen centimeters per unit magnitude of the vector.

2.3 Contour plot

A plot of several contour lines is called a contour plot. An input data values at a set of points irregularly distributed over a plane. Object boundaries are checked to find points with same level by Findlinepoints() function. If function finds started line point with same level, it calls findpoints() function and this function continues to find next point with same level. By using following way: if line passes through one of a grid side and it needs to pass one of the other 3 sides of grid [6]. These two functions also can find points of circle contour lines. The condition of finding same contour level points at the grid sides is

$$(pt(i,j)-step)*(pt(i+1,j)- step)<=0$$

$pt(i,j)$ is the flow character value at the i and j index, *step* is a contour level that user wanted to see in the line contour. Step has chosen by adding the contour period to minimal flow character value. Flow character period is computed by adding maximal contour value to minimal contour value and divided by the wanted contour levels number. Present program can automatically select the values of the contour levels. Contour lines can be automatically labeled with color. There is a logic condition for not to check grid boundary twice with same line level. To find point coordinates we used first order linear interpolation along the grid lines [7]. We have chosen color by steps, maximum and minimum contour values for color contour line. And it spreads between three colors: red, green, blue.

2.4 Residual plot

At the end of each solver iteration the residual sum for each of the conserved variables is computed and stored, thus recording the convergence history. This history is saved in the data file. Residual view has special Dialog Window with black color backgroun, and own menu bar. Residual menu has Grid and Legend submenu. The grid areas are rectangular regions defined and bounded by the axes. The grid allows the view of the plot a better opportunity to determine the values of data points. Data4Residual() function reads data every time and OnPaint() function draws lines. During the plotting vertical axis shows error value and horizontal axis shows iterations.

2.5 Control tools and functions

All cases such as XY plot, Vector plot, Contour plot and Mesh plot are drawn in the OnDraw() function. Each plot has used developed function, for example DrawAxis(), ColorContourLine(), ColorVelocity(), and so on. Also present program used MFC classes and functions. There are three types of messages floating around an MFC application: Window Messages, Command Messages, and Control Notifications. Each plot has used Command Messages and Window messages, for example: Command ID is either the ID of the menu item selected or the toolbar button that was clicked. Same format is used to read the data files as Tecplot data files format. It is useful to see the results and to compare.

3. Postprocessor Results

3.1 The program view

The Program starts with a splash notice, which shows the starting of the program. After starting, the screen appears as shown in Fig. 1. At the top of the screen are two horizontal lines of text. The top line shows data file name and program name. It is called Title Bar. And next line is called Menu line. This is where menu are displayed and where you make menu selections. User can control options from menu. Tool Bar is located under Menu line. The easiest and quickest way to change the view is to use options from Toolbar. There are Zoom, Real size, Mesh, and Axis option in the Tool Bar. Larger region on the left is called a Plot Window. User can create plots in this window. The smaller and thinner rectangular region on the right is called the Side Bar. The Side Bar is used to display plot settings and to make selections in lists of items. Side bar shows XY plot, Contour plot, Vector plot options. Residual button helps us to see residual window. At the bottom part of screen is called Status Bar. Status bar message part shows function character. Cursor position parts show X-axis value and Y axis value, when user moves cursor over a plot Window.

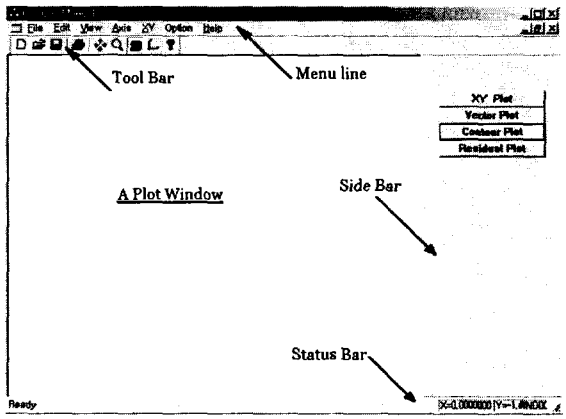

Fig.1 Present program view

3.2 Program using options

User can choose needed data from /File/Open submenu. For XY plot lines are drawn in the plot window. For contour plot and vector plot mesh plot appears on the plot window. User can choose contour plot options from Side bar or /Option menu. There are contour line levels, line contour, color line contour and contour legends for contour plot. For vector plot user can choose vector plot options from Side Bar or /Option/Velocity submenu. And display 2-D vector plots with some options, including colored vector and vector scale. For interactive plot, user can open data from residual menu, and control drawing from /View/Residual Monitoring submenu.

3.3 Compression Ramp problem

The Navier-Stokes numerical simulation of supersonic flow over 16 deg compression ramp has been performed. Simulations of compressible boundary layer flows were performed to provide initial condition and inlet conditions for a direct numerical simulation of a compression ramp [8].

Present program initially controls axes value, and we can see only object region. Value of Vertical axis and horizontal axis of present program are 4 digit real numbers. Currently user cannot control axes range in this program as Tecplot program.

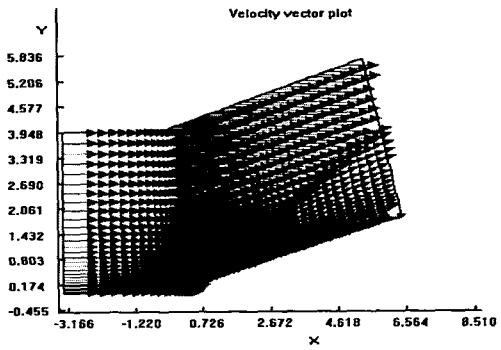

Fig.2 Velocity vector plot of the 16 deg compression ramp in the present program

Vector plot has filled arrowhead vectors as shown on Fig.2. And user can control vector length. Present program does not have plain arrowhead as Tecplot does. FEM flow and present program have velocity vector plot options. And Tecplot has common vector plot options

User can control options from menu and Side bar as in Tecplot program and FEM flow program. Present program contour plot initially choose contour line level and contour line step. User can control contour line levels. Tecplot has common options for contour plot, FEM flow program and present program have options for special flow characters. Present program contour plot shows legend level with color in an increasing way. Present program has only limited line contour plot type, however, Tecplot program and FEM flow program have line and flood contour plot type.

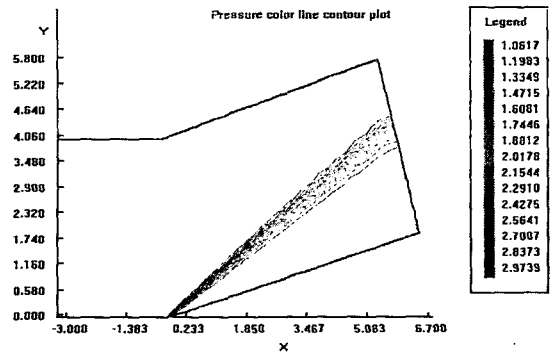

Fig.3 Pressure contours of the 16 deg compression ramp flow in the present program

Figures 3 and 4 show pressure contour plot in the present program and in the Tecplot program. From these figures we can see the similarity of contour plots.

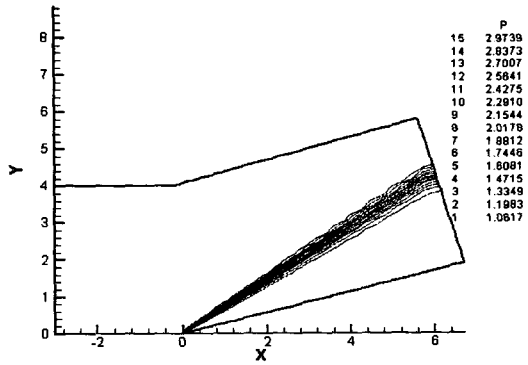

Fig.4 Pressure contours of the 16 deg compression ramp flow in Tecplot program

Residual plot in the present program draws lines on the screen with the common minimum and maximum error value as shown on Fig.5. In the plotting iteration and error value always renew axis value in milliseconds. Present program is not connected with preprocessor program and program reads data from Solver to plot interactive plot and program does not have residual monitoring yet as Fluent program.

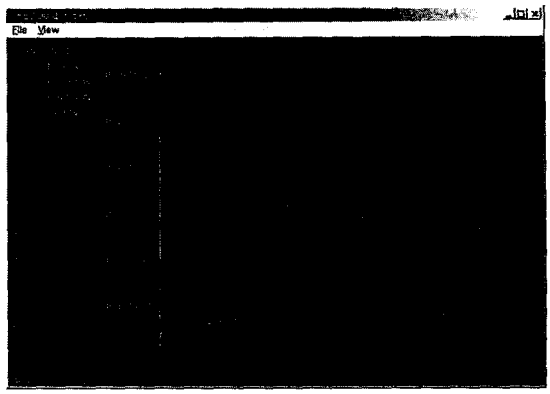

Fig. 5 Residual plot of the 16 deg compression ramp flow in the present program

3.4 Axisymmetric bump problem

The flow over axisymmetric bump is the supersonic two-dimensional compressible flow. An oblique shock, generated on the boundary layer