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Usage of variety of Preconditioners in CFD with Various Computer Technologies: A survey

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ABSTRACT: Computational fluid dynamics is a field of applied engineering in which flow of fluid is studied with the help of computer technologies. In CFD the equations are much more complex and of higher orders thus numerical methods used in the solving process of the equations are very compute intensive thus requiring high performance computing. Now days with the advancement of the computer hardware able to compute parallelly is available. Thus taking advantage of available computer technology for the purpose of solving equations from CFD is challenge and having prior knowledge about these technologies ,CFD equation and process of solving them.

KEYWORDS: Pre-Conditioner, iterativesolver, Directsolver, Finite difference method.

I. INTRODUCTION

In the field of computer aided engineering the simulation of the system is very essential factor. Simulation leads to the simplified study of the system in action.A branch of computer aided engineering is computational fluid dynamics in which the flow of the fluid is studied with the help of computers.The computational power is harnessed by the computer to numerically solve the various equations from the field of fluid dynamics.In this way the computational fluid dynamics not only takes the equal efforts to solve the problem from domains like maths, computer science and fluid dynamics.The equations in the field of fluid dynamics are usually continuous equations and that to partial differential equations of varying order.To find the exact solution of the equations is a very difficult task for even mathematical experts.There are some equations from the field of fluid dynamics which are very difficult to solve that some of the prestigious institutes have put monetary prize to those who will solve this equations.as these equations are hard to solve there are some other ways to solve these equations and that is to solve these equations approximately.Thus the numerical method to solve the equations comes into the picture.Numerical methods[2] can be assumed to be the best effort methods that these methods tries their best to get the solution and there are numerous numerical methods.As the exact solution of these equation is under question the approximate solution saves the day.But to get the approximate solution we have to use various approaches to discretize[1] the equations namely from explicit ways and implicit ways.After using one of these ways we discretise the equation and forms a system of equation which could be solved using computational power available to us.In this process of finding out the solution of the of the equation various preconditioner can be used which allows the solution of the equation to get with ease.

II. MOTIVATION

The field of computational fluid dynamics or computer aided engineering are application field of the computer technology which makes a bridge between the computer domain and engineering domain. These equation from the

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field of CFD(Computational Fluid Dynamics) are of varying order and partial differential equations. To solve these equations various things have to taken into consideration like discretisation,preconditioners[3],type of solvers as there is very rich mathematical background included with those equations. As there is very rich set of possibilities from which the method of discretisation,type of preconditioned and type of solver confusion is inevitable. This paper will help to understand the various methods of discretisation , type of preconditions and solvers.

III. LITERATURE SURVEY

Discretisation is a mathematical concept which is used frequently. Discretisation could be defined as the “the process of transferring continuous functions, models and equations into it’s discrete counterparts”[5].The analytical solution gives the solution of the equation everywhere as it involves the answer in terms of continuous variables which are continuous in the range where as we are only able to handle finite number of point we are only interested in solution at those points. Discretisation helps to get the solution at those points of interest. There are mainly are following

- 1.Finite Volume Method
- 2.Finite Element Methods
- 3.FiniteDifference Methods

1.Finite Volume Methods:

If the equation is in integral form then this method of discretization is used. Basically in this method of discretisation[6][8]the solution domain is divided into chunks of continuous control volumes. This method is used for complex geometries.

2.Finite Element Method:

In this method of discretization solution domain is subdivided into a finite number of elements, the governing equation is solved for each element and then overall solution is obtained by assembly. Before making the assembly different weights are usually used to multiply them with.

3.Finite Difference Method:

This method of discretization is used when the governing equations are in the form of differential equations.in this type of discretization we get the a equation at each concerned point.This method of discretization is good for the structured geometries.

Preconditioners:

Preconditioning is the process by which the data /given problem is transformed such a way that the numerical methods work suitably and efficiently.This preconditioning is done by application,program or function called as preconditioner.Preconditioner are usually used by the iterative methods.This preconditioning is aimed at the optimization of the process of generating solution.Various types of preconditioners are:

1. Jacobi Preconditioner
2. Block Jacobi Preconditioner
3. Multigrid Preconditioner
4. Point Block Preconditioner
5. Gauss Siedel Preconditioner

Types of Solver:

Solvers mainly solves the system of equations which are being discretized by the use of various discretization techniques.In theory there are basically two solvers

1. Direct solvers
2. Iterative solvers

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1. Direct Solvers

The direct solvers are based on the LU decomposition[]. In LU decomposition augmented matrix formed is converted in a lower triangular matrix and upper triangular matrix and then the solution of the given system is found. The main advantage of direct solver is that these solvers gives the exact solution to the system of equation. but the memory footprinting of these type of solvers is high thus needing a high memory requirements thus viable option for the small problem size.

2. Iterative Solvers

Iterative solvers are based on the conjugate gradient method. In these solvers solution is made by small computational steps rather than depending on to the complex algorithms as involved in direct solvers. Iterative solver uses lesser memory that the direct solver but it involves error as its an iterative solver. in iterative solvers the solution is not exact solution and it have less memory footprints thus the problem size handled by the iterative solvers is more than direct solvers.

Technologies:

Parallel computing[9] is jargon in computer industry. There are various ways to perform the parallel computing. The pioneer technologies in parallel computing are mainly OpenMP, OpenMPI, CUDA, Intel MIC. Brief understanding of these technologies will suffice the purpose.

OpenMP:

- Shared Memory Multiprocessing
- Enables parallel programing in C/C++
- consist set of compiler directives, library routines, and environment variables that influence run-time behavior
- Cross-Platform

OpenMPI:

- A message passing interface(MPI)
- Have Distributed memory
- Supports variety of high-performance computing platforms and environments
- Cross-Platform

CUDA:

- Compute Unified Device Architecture
- Proprietary architecture of NVIDIA
- A parallel computing platform and application programming interface (API)
- Uses Graphics Processing Unit (GPU)

Intel MIC:

- Intel Many Integrated Core Architecture(Intel MIC)
- Combines many Intel processor cores onto a single chip
- Uses Intel MIC cards

IV. OUTCOMES

1. While solving a equation to decide appropriate discretization scheme is essential and crucial task.
2. While deciding the appropriate discretization scheme proper understanding of mathematics and physics behind the equation along with the characteristics of the equation is must.

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3. using a preconditioner is advantage but using a proper preconditioner will help to boost the solving process significantly so selecting preconditioner among all the available preconditioner is important task
4. Direct solvers needs high memory where as iterative solver requires low memory.
5. Direct solvers gives exact solution where as iterative solvers gives appropriate solution.
6. Direct solvers are good for comparatively smaller problems whereas iterative solvers are compatible with larger problems.
7. Available parallel technologies are effectively to do the data crunching and give a significant speed up.

V. CONCLUSION

The field of CFD is having rich variety of algorithms to solve the equation ; have various approaches to visualize the problem at hand.To properly understand probles/equation and using various choices to tackle these problems/equations is a big challenge.Using the latest technologies from the field of computer science will enable the robustness ,accuracy and speed to the process of solving equation.The latest technologies like OpenMPI,OpenMP,CUDA,Intel MIC are pioneers of parallel technology using which anyone can harness greater computation power available.Thus it could be concluded that the use of parallel technologies in CFD would give us better results.

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