# Study of Particle Image Velocimetry Algorithm for fluid flow and its Implementation using Graphical Processing Unit (GPU)

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*Abstract*-**Particle Image Velocimetry (PIV) is a non-invasive optical technique used to measure and visualize the whole-area velocity map of a real flow. This flow is seeded with particles of similar properties like viscosity, density of fluid etc. The basic requirements for a PIV system are an optically transparent test -section, an illuminating light source, a recording medium, and a computer for image processing. The post-process of optical images is done by PIV software. There are many PIV algorithm reported and their use depends upon the requirement. Most common algorithm employed are Three Search Algorithm (TSS), Full Search Block Matching Algorithm (FSBM), New Three -Step Search Algorithm (NTSS), Full Search Motion Estimation (FS), Diamond Search Motion Estimation (DS). In this project we compare the algorithm FSBM and NTSS. Moreover the most suitable algorithm is implemented first on CPU and later on GPU. Now a days GPU based computation are most preferred over CPU due to parallel processing available on GPU. Effort is done to utilize GPU based acceleration techniques for faster post-processing of PIV images.**

## I. INTRODUCTION

PIV is basically designed, high visibility, low aerodynamics-diameter particles are needed to follow high-acceleration flows. PIV measurements are of instantaneous fields of velocity, usually on a plane using pulsed laser light sheets to illuminate fine particles at multiple times. Different software are used in PIV, like MatPIV, OpenPIV, OpenCV, GeoPIV. MatPIV is a free software tool, which are used for MATLAB coding. The current version of MatPIV 1.6.1 is used in PIV. MatPIV is a platform independent which means that the code will run on any platform. OpenPIV is also free software for Particle Image Velocimetry. OpenPIV is written in Matlab, Python and C++. OpenPIV is good to evaluate PIV images, acquired with frame-stride or continuous, time-resolved PIV system. GeoPIV implements the software of Particle Image Velocimetry in a style suitedto the analysis of geotechnical tests. GeoPIV is also used for Matlab developments .GeoPIV is used for measuring displacements value from digital images. Open source Computer vision (OpenCV) is a library of programming function. OpenCV is written in language C++, C, Python and Java and supports Windows, Linux, MacOS and Android. It works on computational efficiency and main focus on real-time applications. In this project we use the software Open Source Particle Image Velocimetry (OpenPIV), it is a free open source software. OpenPIV are written in many languages but due its simplicity, development is done on Python.

### *Particle Image Velocimetry*

Particle Image Velocimetry (PIV) utilize a planar laser sheet technique which records images of seeded tracer particles flow in these sheet on a video camera.

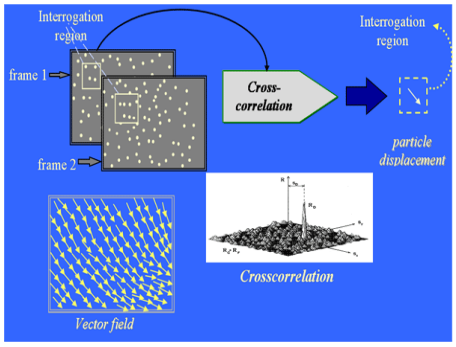


*Fig.1: Principle of PIV*

PIV is the powerful and efficient technique for visualization and measurement of fluid velocity field for understanding the fluid dynamics .This technique was most prominently used in aerospace research. Due

to reduce in cost of digital equipments it has found many applications in industry and education. PIV records the position over time of small tracer particles introduced into the flow to extract the local fluid velocity. The use of the PIV in the whole flow field measurement technique requires the use of fast, reliable and computer based method for tracking velocity vectors.

### *New Three Step Search (NTSS) Algorithm*

It is the modification of Three Step Search (TSS) algorithm and deals with near by displacement more adequately by a center-based constraint. TSS is derived by making the search modifying to the motion vector divide, and a halfway- stop technology to detect the computation test. The three step search algorithm evaluate in decreasing search radii based on the fact that the spike of cross-correlation value is always smooth .

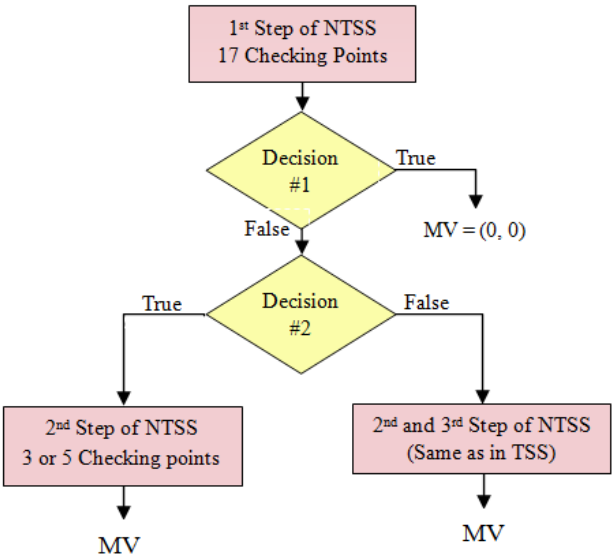


*Fig.3: Algorithm of NTSS*

### *Full Search Block Matching Algorithm (FSBM)*

Full Search Block Matching Algorithm is a way to match the macro blocks in a sequence of digital video or images. Its main focus is on the motion estimation. Motion estimation is the process to find the best computational complexity. FSBM determines the motion between two or more frames and also find the best possible macro block. In FSBM algorithm, the current images is partitioned into many small blocks of size N*N pixel the displacements between the current references block and the N*N region in the previous frame is denoted as -

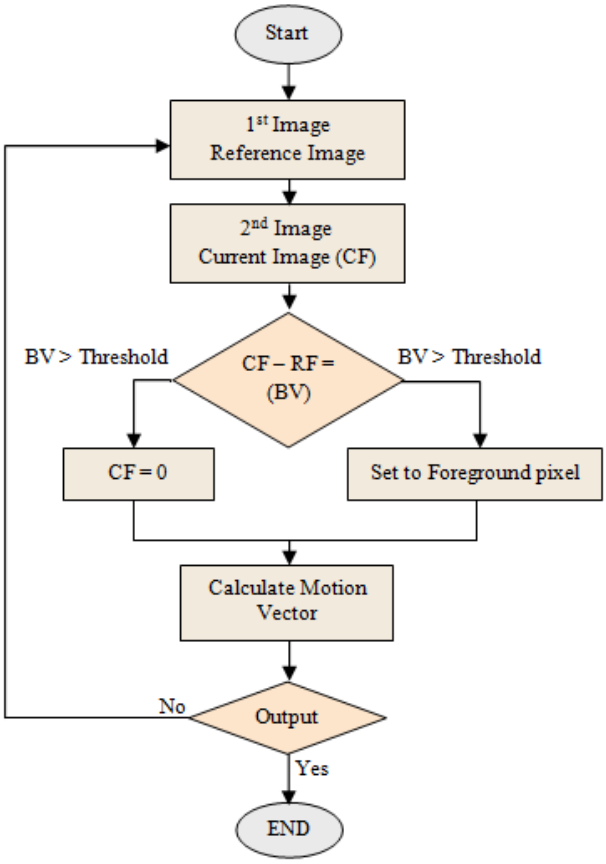


*Fig.3: Algorithm of FSBM*

## II. GRAPHICAL PROCESSING UNIT (GPU)

There are many hardware and software to be used in PIV. In this project work is done on GPU (Graphic Processing Unit) and CPU(Control Processing Unit). Now a day, GPU are most preferred over CPU based computation. Efforts are done to utilize GPU based acceleration technique for faster post-processing PIV images, the diagrams show the relation between GPU and CPU. GPU is very complex to design consisting of hundreds of millions to billions of transistors inside a single integrated circuit. GPU were developed primarily to perform the computation for computer graphics mainly texture mapping, shading and rendering polygons etc. All PCs have processors that render displayed images to monitor, not all these processors are created equally. Intel's integrated graphics controller provides basic graphics. CPUs consist of single Control Unit and ALU whereas GPU incorporates multiple Control Units and ALU. In this

project, Nvidia Geforce GT980Ti GPU, having 2816 Compute Unified Device Architecture (CUDA) cores and 6 GB RAM is employed. GPU is used for multi core processor in addition to graphics provide. CUDA mostly work on heterogeneous programming model, where GPU used for parallel computation or CPU used for serial computation .In CPU code are written to be top to bottom but in GPU code are written multi thread-race conditions .CPU is fully Independent but in case of GPU dependent on CPU .Many programming language are used in GPU like CUDA C/C++, CUDA Fortran, PyCUDA, OpenGL etc. In this project NVIDIA CUDA used for GPU programming .NVIDIA GPU with compute capability 1.1 or higher. CUDA is used for computing platforms and API (Application Programming Interface) model is created by NVIDIA. CUDA is the first software which provides the facility to direct access to the GPUs .NVIDIA defines different CUDA compute capabilities to describe the features supported by CUDA hardware.

More memory types in a GPU:

1. Register file
2. Shared Memory
3. Constant Memory
4. Texture Memory

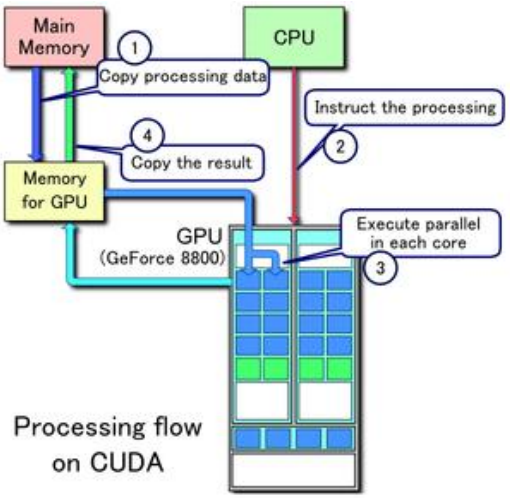


*Fig.4: GPU and CPU*

## III. METHODOLOGY

Particle Image Velocimetry find a displacement between two images and its also find the actual position with maximum value using cross -correlation method. FSBM is used for Image Coding and compression . There are many algorithm which are used in PIV . In this project comparison of two algorithm New Three Step Search (NTSS) Algorithm andFull Search Motion Estimation (FSBM) Algorithm and finding the best algorithm after that it gets perform on GPU and CPU using the software OpenPIV. OpenPIV is written in python language .OpenPIV is a effort of Scientists to deliver a tool for the analysis of PIV images using state-of-the-art algorithms. OpenPIV is released under which means that the source code is freely available for users to study, copy, modify and improve. OpenPIV is the successor of the popular *URAPIV* software, but it is faster, more user-friendly and much more flexible.

## IV. CONCLUSION

Full Search Block Matching Algorithm(FSBM) is a way of locating matching macro blocks in a sequences of digital frames for the purpose of motion estimation . Three dimensional modification of the new three step search (NTSS) developed in the area of image compression is to be introduced for the fast vector tracking in three dimensional PIV From the application of NTSS to translation and simple shear flow cases, while accuracy in NTSS and FSBM is almost same but not finding the actual output . The next work is Comparison between the GPU or CPU on performing the best algorithm.

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