Astigmatism 3D Particle Tracking investigating Hard Drive Fluid Flow

MSE Focus Thesis FS 2024

Student

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Introduction: A Hard Disk Drive (HDD) resembles a fluid system of multiple co-rotating platters, a moving arm with different insertion angles into the rotating flow and the working fluid. Research has shown that flow velocities are highly complex, unsteady and three-dimensional. This can affect the head's data reading, influence the system's energy efficiency and potentially lead to hardware failure, which makes understanding these mechanisms valuable for the industry.

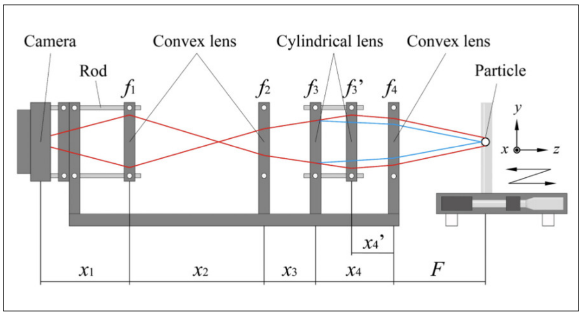
Cameras and transparent HDD models, allow particle tracking methods like particle tracking velocimetry (PTV) and particle image velocimetry (PIV). Since the fluid flow is three dimensional, there are also techniques to measure the third dimension, like laser sheet illumination to selectively scan the third dimension or using multiple cameras to gain the depth information. It would resemble a great research tool if it was possible to easily track particles continuously in 3D with just one camera.

Approach: A lens set up is used to create an astigmatism effect, elongating the particle's image horizontally or vertically depending on the distance to the optical set up. This effect encodes the information about the particles's location in the third dimension. An image processing algorithm was developed that robustly and accurately retrieves this information. For this, 4 centroids in the 4 quadrants of the segmented particle shape are calculated. From the distances between the centroids, the depth information can be reconstructed with sub-pixel accuracy.

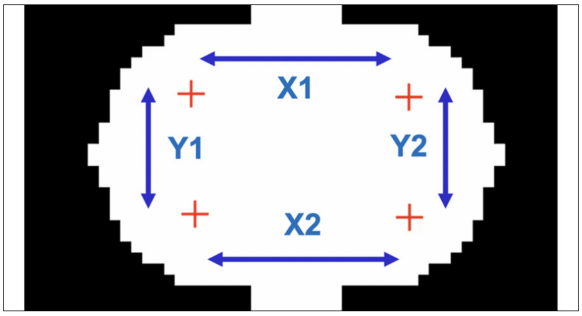
Result: The biggest issue affecting the accuracy are distortion effects introduced by the lens set up, making the error highly dependent on the particle's location in the image. To mitigate this problem, multiple calibration models were trained in different locations of the frame. This allows for interpolation of the calibration model's parameters based on the particle's location. Further problems identified were too large pixels, leading to most available pixels being wasted, due to the optical set up only projecting to a small portion of the sensor. Thus, it was suggested to use a camera with smaller pixels and using larger lenses to image a larger area of the platter in one frame, which was adapted accordingly.

The algorithm proofed its potential to evaluate the astigmatism effect robustly and accurately, even with minimal available resolution. The suggested modifications to the optical set up were incorporated, which lead to testing of the algorithm being only possible in the last week of the project, not leaving time to further investigate the following problems: The interpolation method of the calibration parameters seems to have a problem, leading to non-consistent and inaccurate predictions. This must be further investigated within the project group.

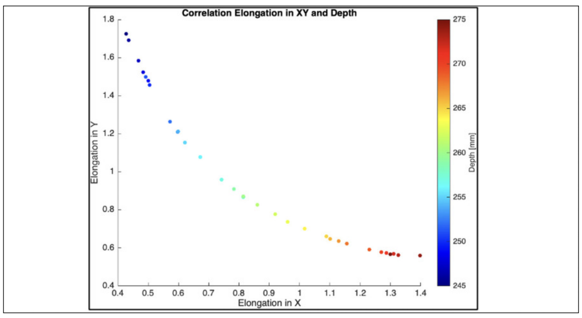
Diagram of the Lens Set Up and the associated Parameters
Mr. Hirofumi Suzuki, SIT Tokyo



Distances between the 4 Centroids in 4 Quadrants
Own presentment



Calibration Model generated for the Top Right Corner of Image Frame
Own presentment



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