Since the defocused images of seed particles are fuzzy rings, the task of tracking the micron-scale particles is to identify the rings of various sizes on each frame and reconstruct their trajectories. For this project, We have developed a fast algorithm based on Hough Transform for particle tracking. With the help of UFO parallel computing framework, we implement our new algorithm on heterogeneous computing platforms with graphic cards.

The old Matlab software uses template matching method based on order statistic filter algorithm. However template matching is not efficient in dealing with patterns of large sizes. Indeed it shows poor performance in searching for rings with radius that is about 20 and larger pixels. In addition, when the algorithm is implemented on parallel computing devices like GPUs, it can not support patterns with arbitrary large radius, since the patterns can be too large to be hold in device caches. Therefore we investigate on a new algorithm based on Hough Transform (HT). We find that Hough Transform for circular patterns can be efficiently carried out with Fast Fourier Transform. Our approach is therefore both computing time and memory efficient.

The flow of our algorithm is shown in Fig. 1. We first apply standard image processing filters, such as local contrast enhancement and noise reduction, to the input images. Then they are sent to HT filter. In our problem, the standard procedure of edge detection before HT does not apply, since the rings are fuzzy and do not have crisp edges. Our approach is to apply HT filters without edge detection and devise an efficient blob detection algorithm, because the HT votes tend to form blurred blobs at position of ring centers. In this step, most unwanted pixels are filtered out, leaving the rest pixels as candidates for ring centers. We further use a azimuthal filter to eliminate the false positives in the candidates. The azimuthal filter is a test on the pixel histogram in radius direction respect to the center of candidate ring. The histogram calculated from true ring center shall show strong peak at the position of ring radii. To identify the peaks, we have to apply a fitting procedure with a Gaussian fitting function. The benefit is that the precisions of ring centers and ring radius can be determined to pixel level. However, the task is not suitable to be paralleled on GPUs.

The UFO framework let us develop software in OpenCL with relative ease and distribute the more computational intensive part on to graphic cards. The UFO framework also supports to stream images on to multiple GPUs on same or different hosts. It is our future work to speed up the software with a GPU cluster. At the moment, we have use UFO to develop our software with GPU acceleration. Benchmarking on our particle tracking software shows that it takes roughly 300 to process each frame on a computer with a Nvidia GTX Titan GPU card and Xeon E3-1200 CPU.

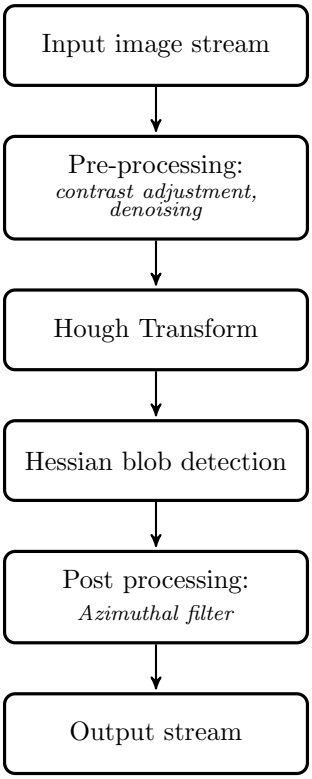


Figure 1: uptv algorithm

| Algorithm | Benchmark |
|---|---|
| Order Statistic Filter | 200 s |
| Hough Transform | 300 ms |

Table 1: Benchmark: Hough transform compared to order statistic filter algorithm.

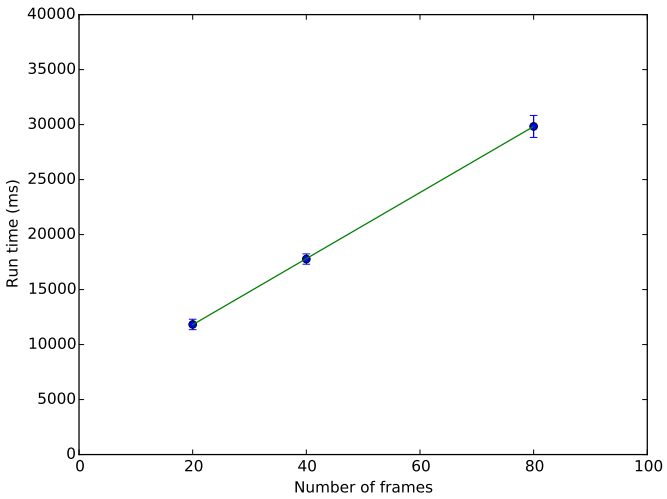


Figure 2: Performance measured with various number of frames. Fitting of the data shows that the processing of image stream takes roughly 300 ms per frame without initial setup time.