GPU Accelerated Real Time Rotation, Scale and Translation Invariant Image Registration Method

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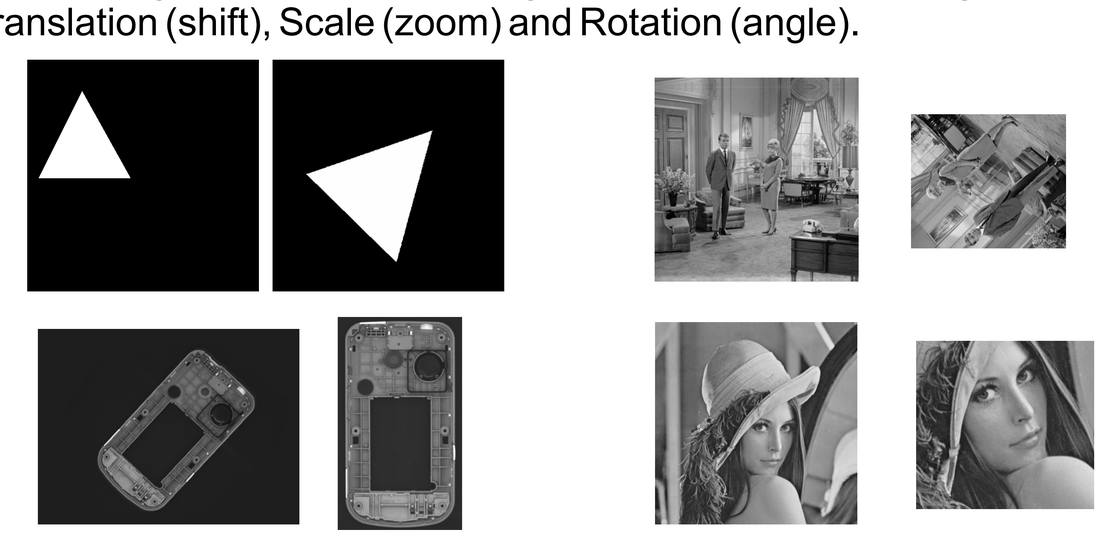
Introduction

Image registration (IR) - detection of the presence of complete or partial image in a reference image. Estimation of following parameters: Translation (shift), Scale (zoom) and Rotation (angle).



Examples of the images that need to be registered.

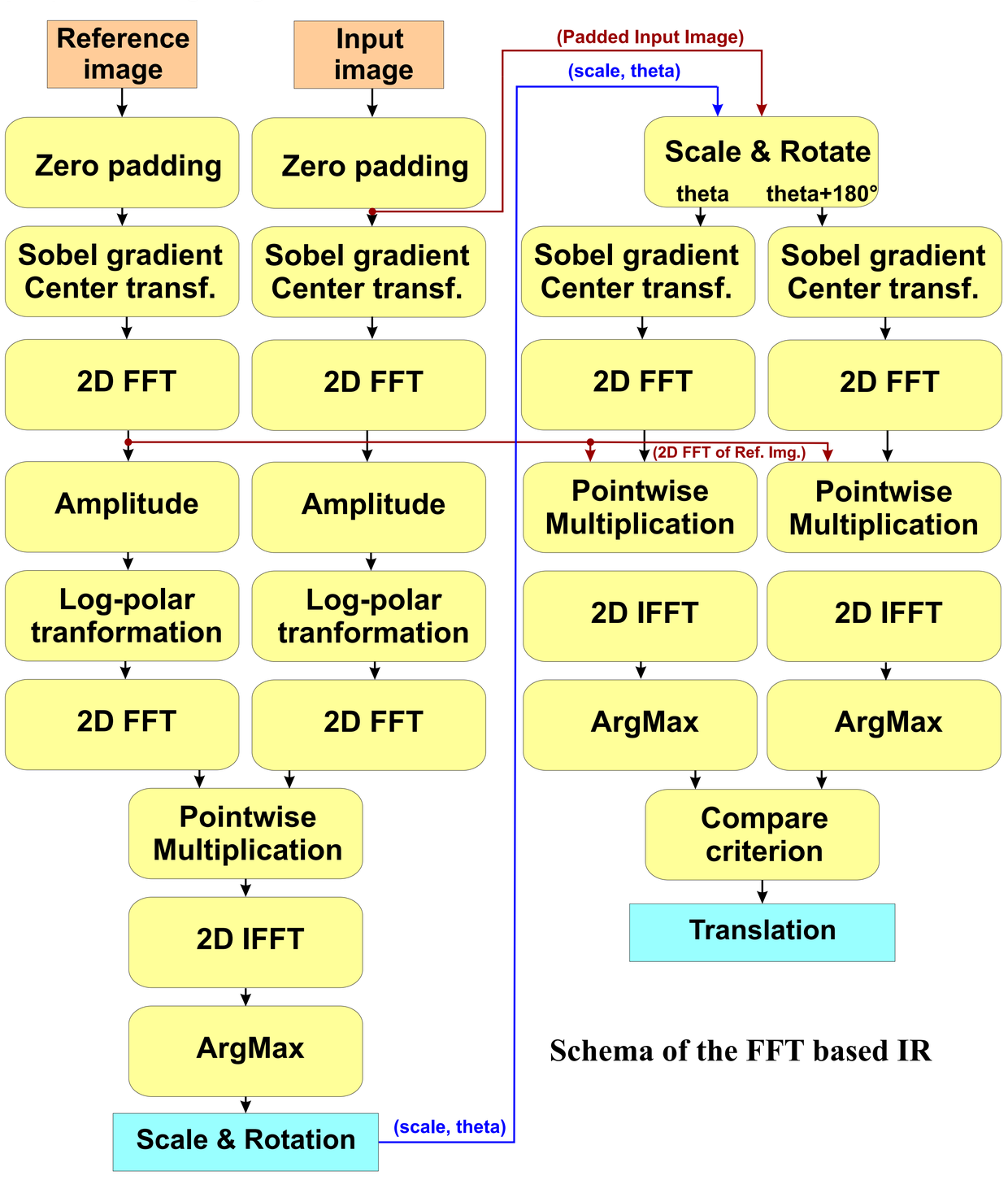
FFT Based Method

The method utilizes properties of the Fourier transform.

Translation is estimated by a phase difference via the phase correlation method [1].

Scale and **Rotation** are estimated from the log-polar transformed FFT amplitudes [2,3,4,5].

Sobel gradient and **Center transformation** are used in the preprocessing stage.



Schema of the FFT based IR

GPU Implementation

Two highly optimized implementations for GPU were done:

- NVIDIA CUDA
- AMD OpenCL

Both the implementations follow the method scheme. Individual blocks are implemented as kernels. We used FFT libraries included in the vendors SDKs, which are optimized for the individual GPU architectures. The rest of the kernels have been hand-coded and tuned. We followed the performance guides and our-own experience with the GPU programming. Please note that the performance optimization of the kernels are the crucial part and our final implementation is almost 50x faster than the first one.

The key parts of the implementation:

Sobel gradient - our approach utilizes the pixels locality and lowers the memory bandwidth requirements via data interchange between threads in the local memory. Needed computations are also reduced by a utilizing of the specific Sobel 3x3 mask properties. The final kernel is more than 3x faster than the Sobel examples in SDKs.

Log-polar transformation - the transformation is a memory intensive operation that is hard to be optimized on GPU. We used the texture cache and we tuned the kernel block size and shape to maximize the texture cache-hit ratio.

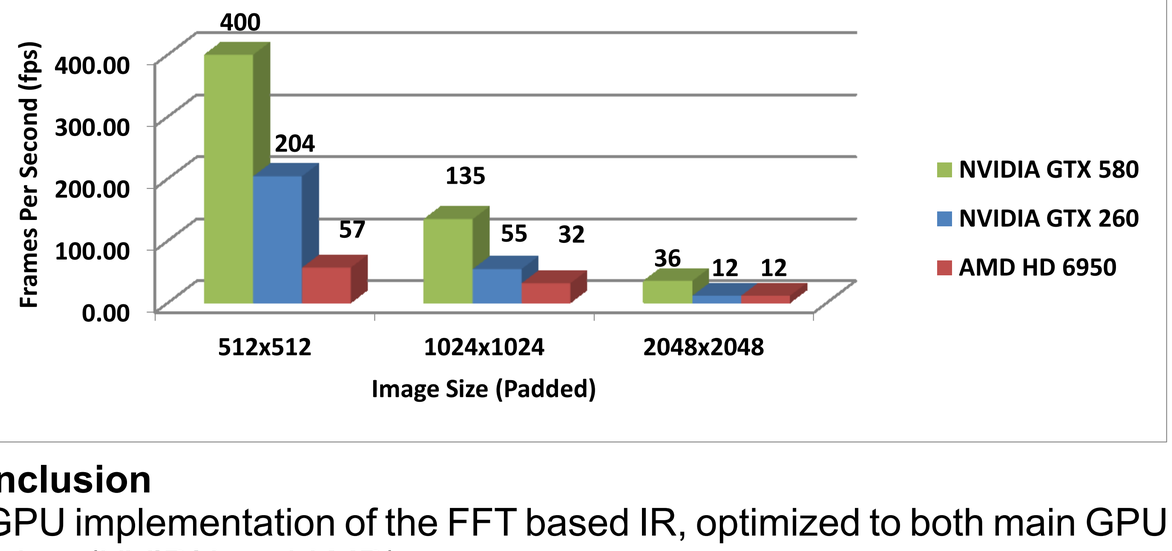
ArgMax - searching for the maximum coordinates in a large 2D array can be parallelized in various ways. We used the two-kernel approach inspired by a persistent-threads programming style.

Reduction of the API and PCI transfers overhead - The results below were obtained by the pair-image benchmark. The API and PCI transfers overhead are significant for small images especially for AMD OpenCL variant. The overhead can be hidden by the triple-buffering multi-stream approach if the continuous stream of the images is processed in a practical real-time application.

Results

Image Size	Time (ms) CPU	Time(ms) / Speed up GTX 580, CUDA	Time(ms) / Speed up GTX 260, CUDA	Time(ms) / Speed up HD 6950, OpenCL
512 x 512	513	2.6 / 197x	4.9 / 105x	17.6 / 29x
1024 x 1024	2240	7.7 / 291x	18.3 / 122x	31.5 / 71x
2048 x 2048	9972	28.9 / 345x	86.3 / 116x	85.9 / 116x

Performance of IR method for different image size, GPU and APIs



Conclusion

- GPU implementation of the FFT based IR, optimized to both main GPU vendors (NVIDIA and AMD).
- Real-time performance for image size up to 2k x 2k.
- Maximum speed-up up to 345x compared to the CPU single-core code.
- AMD OpenCL may suffer with high API and PCI transfers overhead.
- Resolution of rotation angle and scale factor is as low as 0.01
- Applications: Vision based industrial automation, defect identification, remote sensing applications etc.

References

[1] Kuglin, Hines, "The Phase Correlation Image Alignment Method", 1975.
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