GPU TECHNOLOGY CONFERENCE

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GPU Accelerated Haze Removal on Tegra K1

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Introduction

Toxic haze has become a major air pollution threat in China, which affects not only public health but also the visibility and clarity of computer vision systems. Hence, haze removal, or dehazing, has become a must for high-resolution outdoor computer vision systems. The dark channel prior is used to remove the haze on embedded system Tegra K1. By adapting CUDA-based methodology, very good effect is achieved.

Problems

The thickness of haze on each pixel location is estimated and then removed from the original ones. The depth map is also achieved to be used for the following processing pipeline.

However, each pixel is to be processed with huge computing complexity, which makes the algorithm time consuming. As in real-time computer vision on embedded systems, the high computing and throughput requirements bring big challenges.

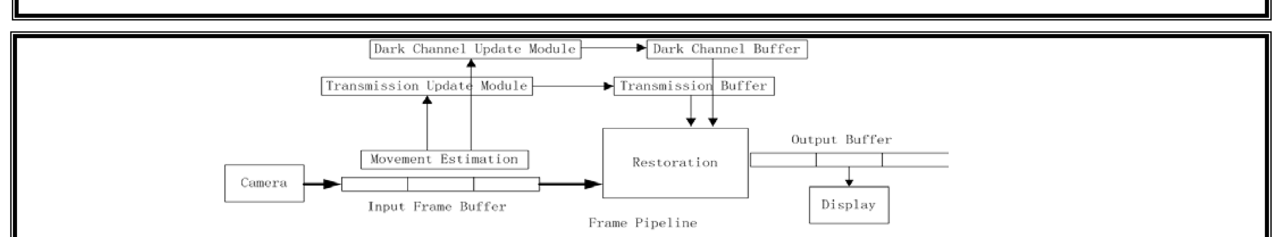
Besides huge computing requirements, memory throughput is also critical for this application.

Objectives

We refined the parallel algorithm and performed deep-optimization on Tegra K1 Jetson platform. By analyzing the whole algorithm carefully, the parallel algorithm is refined to fit the GPU architecture.

Parallelism

Procedure On GPU	Major Operation	Parallelism
Dark Channel	Min Value inside blocks	m*n
Atmospheric Light	Min, Sorting	$\text{Log}_2(m*n)$
Transmission Estimation	Min, Scalar	m*n
Transmission Optimization	Scalar, Matrix Inversion	m, or n
Scene Radiance Restoration	Scalar	m*n



Method

Partial speedup of critical performance bottlenecks

•matrix inversion

-- To calculate inversion of 3X3 matrix formed by covariance of r, g, b for each pixel. By CUDA we get a speedup of 1,500.

•interest value search

-- In order to recover the transmission from dark channel, we compared the central target value among a window and replaced it by the minimum. While porting to CUDA, using texture memory and optimized thread hierarchy, we got a speedup of 50.

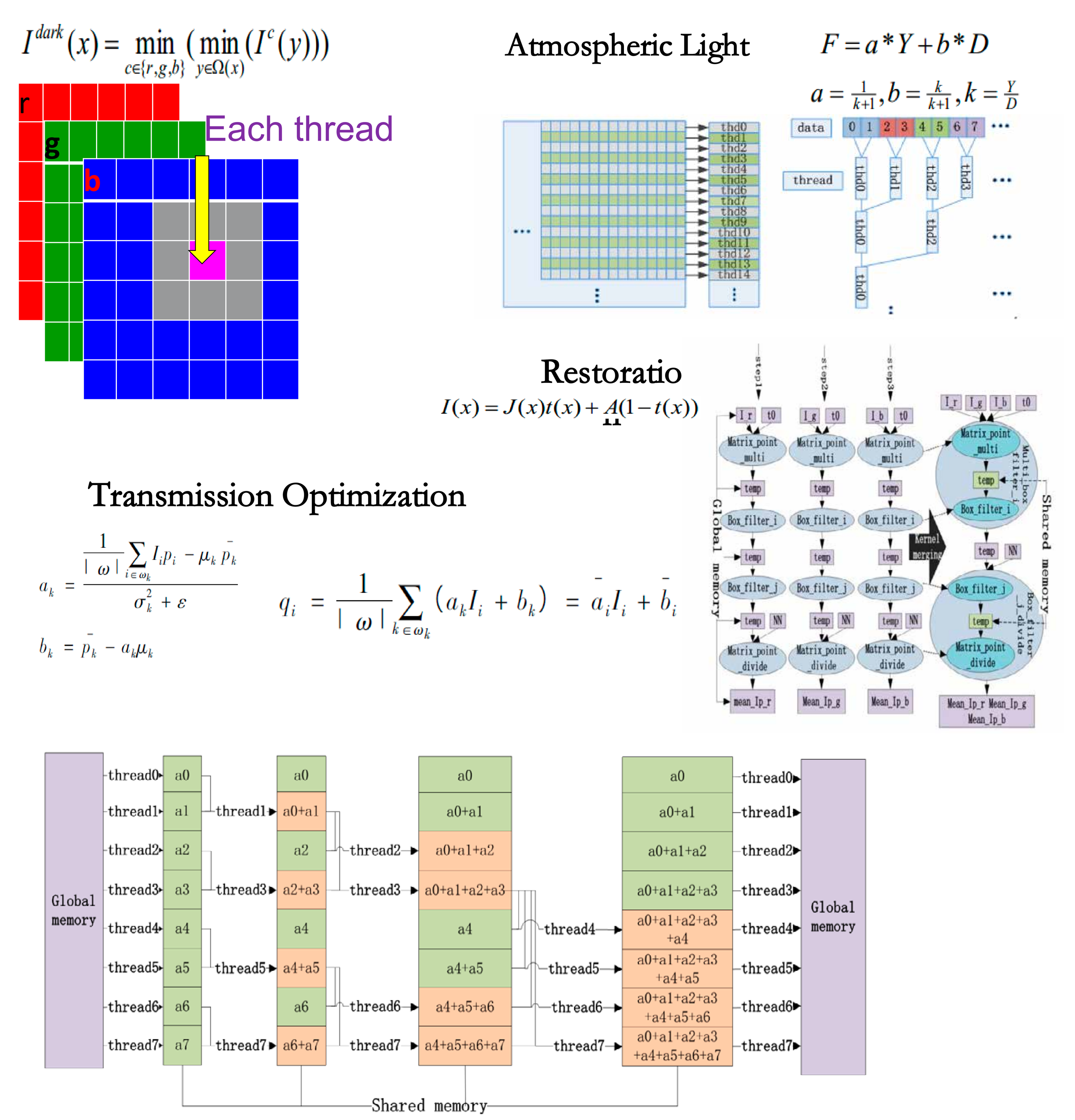
•cumulative sum

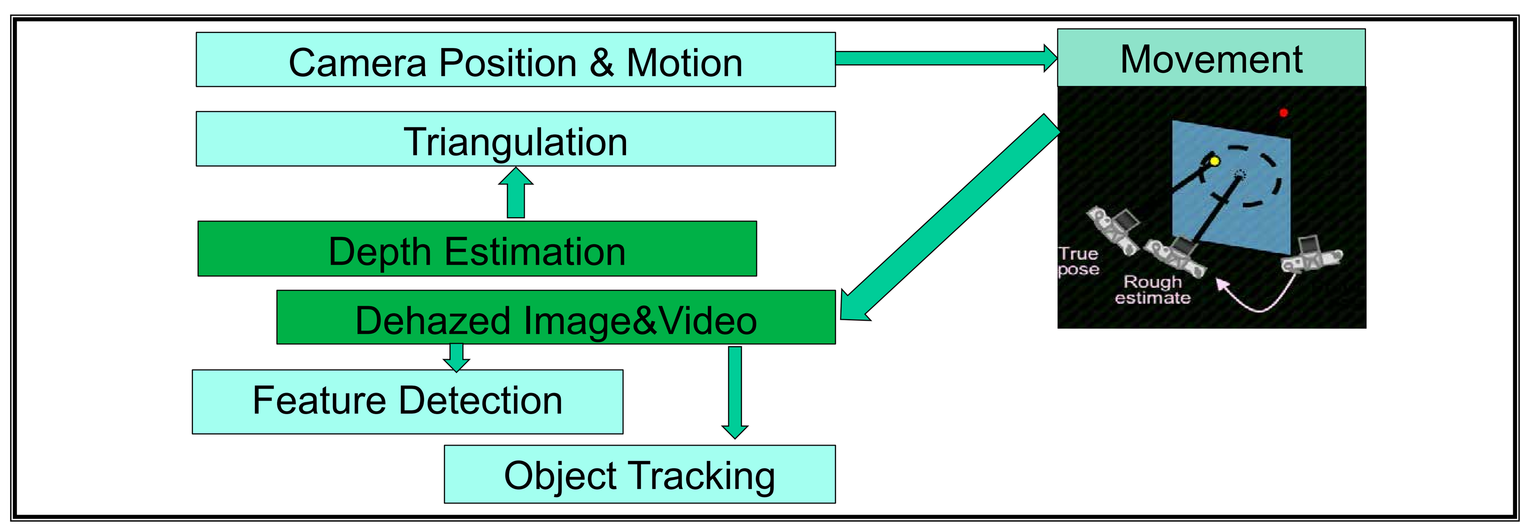
-- The kernel function of box filter for guided filter was cumulative sum of a window. We used double buffer of shared memory to optimize the scanning procedure horizontally and vertically. we harvested a speedup of 18.

•sort by key

-- We used primitives of CUDA thrust and got 10 times speedup.

On GPU





Results

Compared to ARM CPU, our experiment on Tegra K1 shows 156x speedup (Single thread vs. GPU). Scaled to 4 cores in an ARM CPU, we get nearly 39x speedup. Tegra K1 achieved 3 frames/sec, which could be applicable in real-life applications. Considering its 5 Watts power consumption, it could serve as a powerful computer vision processor. Meanwhile, compared to desktop GPU, Tegra K1 presents great power efficiency. For a single frame of 1280*720 resolution image, The following table showed the processing speed.

Processor	OS	Time (seconds)
ARM Cortex of TK1(ST)	Ubuntu 14.04 lts	50.0
TK1	Ubuntu 14.04 lts	0.32
TK1 on MIPAD	Android 4.4.4	0.40
Intel Core2 E8200/(ST)	Ubuntu 14.04 64 bit	18.0
NVIDIA GTX480	Ubuntu 14.04 64 bit	0.041
NVIDIA GTX480	windows 7 64 bit	0.050

The following figure showed the processing effect.

Experiments were also carried out on an Android pad equipped with this GPU and showed very promising results for consumer applications. An MIPAD with android 4.4.4 is used, which achieved comparable results with Tegra K1, which shows great potential for mobile computer vision applications. The following figure shows the processing results on MIPAD.

Conclusions

The results show that Tegra K1 is well-suited for computer vision processing and has great potential for embedded real-time processing systems. Also the android capability expands Tegra K1 to a much wider spread of consumer mobile super-computing applications.

The future research includes continuous optimization and porting a wide range of real-time computer vision applications, such as 3D reconstruction, object/movement detection, and DNN-based target recognition, to TK1 platform.

Acknowledgements: [1]He's "Single Image Haze Removal Using Dark Channel Prior", CVPR 2009; [2]Parallel Implementation and Optimization of Dehazing Using Dark Channel Prior Based on CUDA, Xue Yun-gang, Ren Jv, SU Hua-You, Wen Mei, Zhang Chun-Yuan;[3] Some pictures and slides are from USTC ESB5316 CTC class project, by Yang XU, Renjun Tang, and etc.