Accelerating Real-time Processing of the ATST Adaptive Optics System

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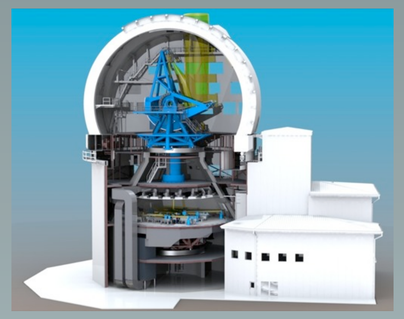
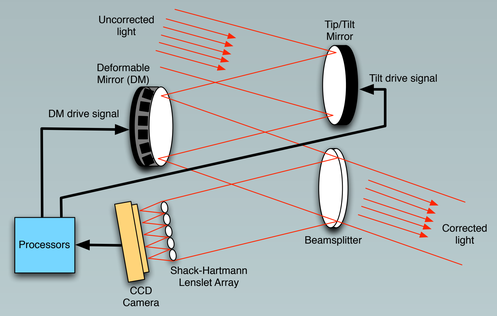
Introduction



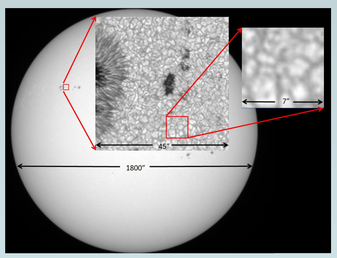
Advanced Technology Solar Telescope

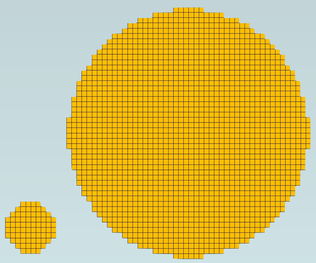
• Atmospheric turbulence distorts the wavefront by generating phase variations in the incoming light and limits the resolution of large solar telescopes such as the four meter solar telescope, Advanced Technology Solar Telescope (ATST) now beginning construction at Maui's Haleakala.



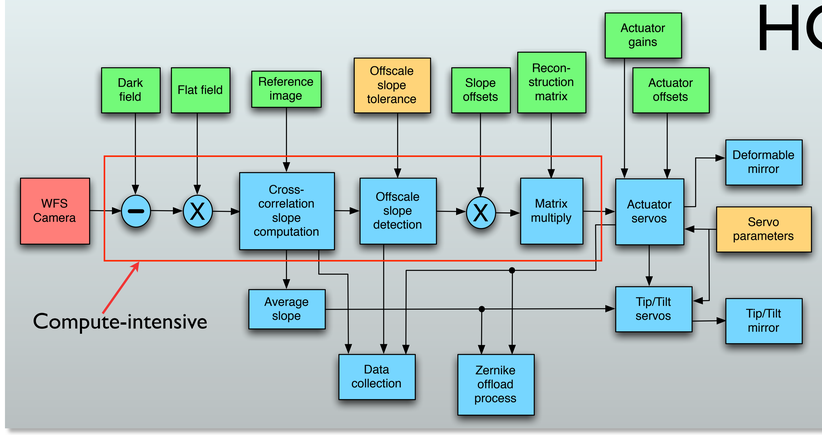
Adaptive Optics system

• The adaptive optics (AO) system senses the wavefront aberrations and applies the corresponding correction to the adjustable deformable mirror to improve the resolution of the telescope.



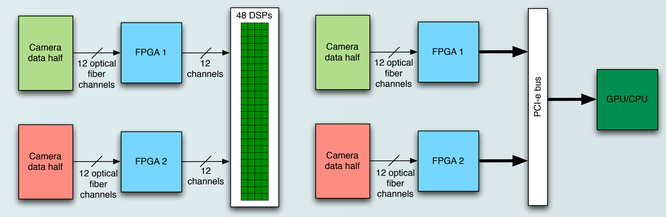


HOAO Real-time system



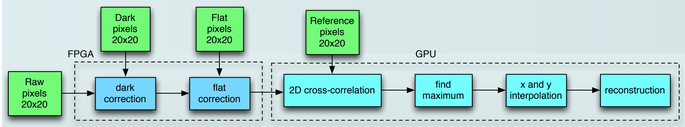
• The high speed camera sends 1750 20x20 pixel raw sub-aperture images to the processing system.
• The sub-apertures undergo a dark field correction followed by a flat field correction, which is the equivalent to correcting the images for zero level and gain equalization.
• The 2D cross-correlation step determines the shift in the x and y direction of each sub-aperture, as compared to the reference image.
• The wavefront reconstruction step consists of a precomputed 3500x1900 reconstruction matrix, which is multiplied with the x and y shifts.

• Test platform: 2 quad-core 2.6GHz AMD processors running Ubuntu Linux OS with Nvidia Tesla C1060 and C2050
• Implementation strategy: 48 DSPs or GPUs?
• 7x7 correlation faster than FFT correlation on GPUs

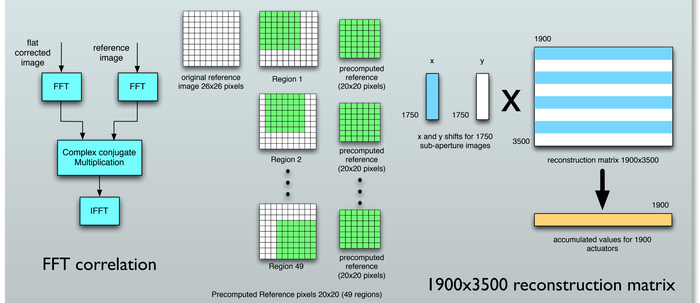


FPGA-DSP solution

FPGA-GPU solution



Process partitioning and mapping

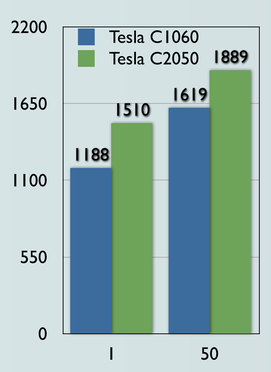


FFT correlation

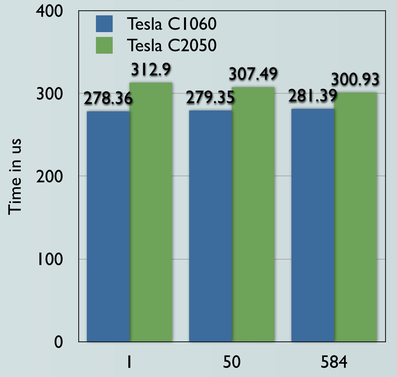
1900x3500 reconstruction matrix

7x7 correlation

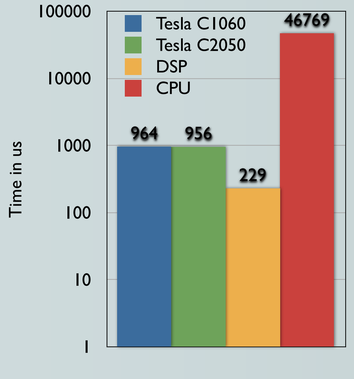
Implementation platforms and Results



FFT correlation results



7x7 correlation results



Wavefront reconstruction results

Conclusion

• Nvidia's GPUs provide computational speedup as compared to the CPU implementation.
• Although DSPs are faster, using 48 DSPs are more expensive than 3 GPUs.
• GPUs provide flexibility in terms of problem scalability as it can handle the computational complexity and at the same time provides more FLOPS/$ as compared to DSPs.

References

[1] S. L. Keil, T. R. Rimmele, J. Wagner, and ATST team. Advanced Technology Solar Telescope: A status report. Astronomische Nachrichten, 331:609–615, 2010.
[2] V. Venugopal, et. al. Accelerating Real-time processing of the ATST Adaptive Optics System using Coarse-grained Parallel Hardware Architectures. In International Conference on Engineering of Reconfigurable Systems and Algorithms (ERSA 2011), pages 296–301, Las Vegas, USA, July 2011.
[3] Nvidia Inc. (Last Accessed: February 2012) Nvidia Tesla C2050 GPU Computing Processor. [Online]. Available: http://www.nvidia.com/object/product_tesla_c2050_us.html