Temporal Error Minimization In Adaptive Optics Control Loop

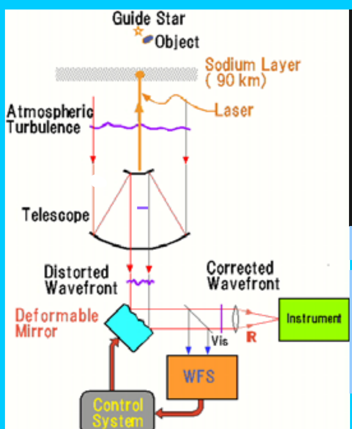
Mark Nishimura, Olivier Guyon, Hideki Takami, Subaru Telescope AO Group

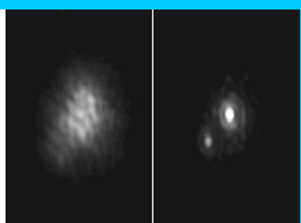
Subaru Telescope (NAOJ), Center For Adaptive Optics

Abstract

Adaptive optics (AO) systems are used to correct the image distortions caused by turbulence in the earth's atmosphere. Most AO systems include three main elements: a wave-front sensor(WFS), deformable mirror(DM), and control computer. Subaru is in the process of designing a second generation AO system that has a 188 actuator deformable mirror. Using C language, a computer simulation of the AO system was created representing a single actuator of the AO system. By manipulating different variables, one can see how they affect the performance of the system. The goal of this project was to find ways of minimizing the temporal error of the AO system by running computer simulations. Improvements such as sending updates to the DM twice as often per sampling period and averaging the photon counts to minimize the effects of photon noise have improved the performance of the system.

Subaru Adaptive Optics System



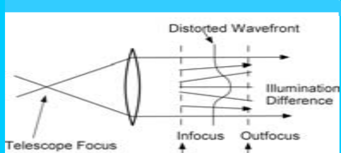


Without AO **With AO**

Subaru 2nd generation AO system with laser guide star

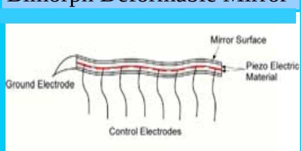
188 element wave-front sensor is the largest curvature system

Curvature Wave-Front Sensor



Measures the difference in intensities of light with the help of vibrating membrane

Bimorph Deformable Mirror



Voltage supplied to the electrodes provides the desired bending

Problem

The mechanical response of the DM, and the computing time of the control computer cause time delays in the AO system. Because of the time delay, measurements from the WFS are not current. This inaccuracy forces the AO system to run well below its theoretical limits. Different ideas exist on how to improve the performance of the AO system, but little is known about their effectiveness or limitations.

Solution

By creating a computer simulation of the AO system, theoretical ideas can be tested.

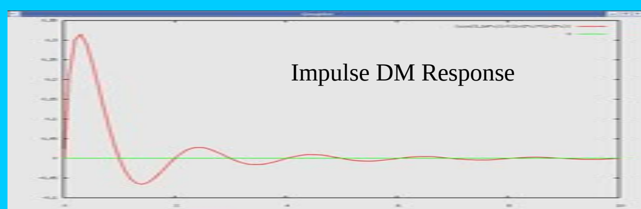
Adaptive Optics Simulation

Computer Simulation Written in C

Elements of accurate simulation:

Photon Noise

Time Delay 125 ms



Adding realistic variable such as these makes the simulation more accurate. Theoretical improvements can now be tested in more realistic situations showing their benefits and limitations.

Improvements and Results

Increasing DM Update Frequency

Curvature is normally calculated after photons are counted from a full cycle of the vibrating membrane. Now curvature is calculated every half cycle using the previous measurement.

Minimal improvements, less than expected

Limited by the frequency of the vibrating membrane

Average Photon Count

Original curvature formula

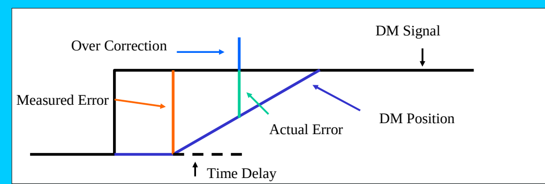
I(+)-I(-)/ I(+)+I(-) = Curvature

New curvature formula decreasing the effect of photon noise

I(+)-I(-) / I(ave)+I(ave) = Curvature

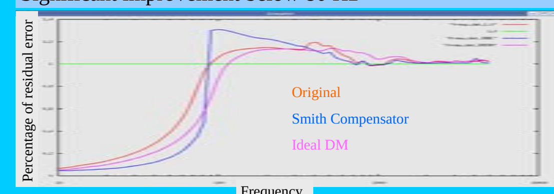
Increased correction with guide stars dimmer than Mag. 9

Smith Compensator (Predictor)



Prevents over correction due to time delay

Significant improvement below 80 Hz



Limited by the response of the DM

By testing Smith compensator with a more ideal DM, higher performance was achieved over larger range of frequencies

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