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WAVEFRONT CORRECTION OF OPTICAL BEAM FOR LARGE SPACE MIRRORS USING ROBUST CONTROL TECHNIQUES

Abstract

For an imaging spacecraft to provide a truly persistent imaging capability, the satellite should be in a higher orbit. In order to achieve image of similar quality to low earth orbiting systems, fine attitude control of the spacecraft is required. Coarse pointing is achieved by attitude control of a spacecraft bus; however, fine control is typically done by the optical payload such as fast steering mirrors and control of mirror segments. Placing spacecraft at a higher orbit will also require larger mirrors in the range of 10-20 meters in diameter. Because of the weight constraints for space-based optics systems, the mirrors will have to be light-weight, resulting in increased flexibility and lower structural frequencies. Consequently, achieving surface accuracy requirements for high resolution imaging with these large aperture light weight mirrors becomes a challenging task. Using adaptive optics with deformable mirrors and wavefront sensors for space telescopes presents a possible solution for fine control of mirror surface. This paper investigates robust control techniques for a segmented space mirror system comprised of six identical hexagonal segments. Each segment has a grid of 156 face sheet actuators, for a total of 936 shape control inputs, making each segment a deformable mirror. Each of the six segments has 61 Shack-Hartmann lenslets associated with it. Each of these lenslets provides two output measurements, an x slope, and a y slope of a wavefront. This results in 732 total Shack-Hartmann wavefront sensor outputs. The model has 166 structural modes identified via a Finite Element Analysis. For this analytical model, two model reduction techniques using Singular Value Decomposition and Zernike polynomials are developed to reduce the number of inputs and outputs. Additionally, a Hankel singular value reduction is performed to reduce the number of states. An H-infinity robust controller is synthesized with the reduced model. The controller from the SVD reduced model and Zernike reduced model result in a closed loop control bandwidth which exceed the required 10 Hz bandwidth that the existing classical control techniques were unable to achieve. The robust controller design is also validated on a simpler adaptive optics testbed to show the effectiveness over the classical control techniques in the presence of disturbances. The superior performance of the robust controller on the testbed versus the classical controller is further verification that the techniques implemented in this research are valid.