Measuring Low-Order Aberrations in a Segmented Telescope

This algorithm requires less computation than prescription-retrieval algorithms do.

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The in-focus PSF optimizer (IPO) is an algorithm for use in monitoring and controlling the alignment of the segments of a segmented-mirror astronomical telescope. IPO is so named because it computes wave-front aberrations of the telescope from digitized point-spread functions (PSFs) measured in in-focus images. Inasmuch as distant astronomical objects that behave optically as point sources can typically be seen in almost any astronomical image, the main benefit afforded by IPO may be to enable maintenance of mirror-segment alignments without detracting from valuable scientific-observation time.

IPO evolved from prescription-retrieval type algorithms. Prescription retrieval uses in-focus and out-of-focus PSFs to infer the state of an imaging optical system. The state, in this context, refers to the positions, orientations, and low-order figure errors of the optical elements in the system. Both prescription-retrieval and IPO use an iterative, nonlinear, least-squares optimizer to compute the optimal state parameters such that a digital computer-generated model image matches the digitized image acquired from the real system.

The difference between IPO and prescription-retrieval algorithms is that IPO is specifically designed to utilize in-focus images only. Although the restriction to in-focus images limits IPO to calculating only the lowest-order wave front aberrations, it also causes the resulting computation to take much less time because fewer degrees of freedom are included in the optimization process.

In the prescription retrieval software developed at JPL, the model images are generated using the ray-trace/physical optics program, MACOS. IPO, on the other hand, uses a linear sensitivity matrix to compute the exit-pupil wave front from the system parameters; the wave front is then converted into a complex pupil field, which is then propagated to the image plane via a fast Fourier transform. This approach is computationally faster and requires less computer memory than is needed for prescription retrieval.

This work was done by Catherine Ohara, David Redding, Fang Shi, Joseph Green, Philip Dumont, Scott Basinger, and Andrew Lowman of Caltech for **NASA's Jet Propulsion Laboratory** *and Laura Burns and Peter Petrone of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). NPO-30733*

Mapping From an Instrumented Glove to a Robot Hand

Fingertip positions can be made to match in a fast, simple calibration procedure.

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An algorithm has been developed to solve the problem of mapping from (1) a glove instrumented with joint-angle sensors to (2) an anthropomorphic robot hand. Such a mapping is needed to generate control signals to make the robot hand mimic the configuration of the hand of a human attempting to control the robot. The mapping problem is complicated by uncertainties in sensor locations caused by variations in sizes and shapes of hands and variations in the fit of the glove. The present mapping algorithm is robust in the face of these uncertainties, largely because it includes a calibration subalgorithm that inherently adapts the mapping to the specific hand and glove, without need for measuring the hand and without regard for goodness of fit.

The algorithm utilizes a forward-kinematics model of the glove derived from documentation provided by the manufacturer of the glove. In this case, "forward-kinematics model" signifies a mathematical model of the glove fingertip positions as functions of the sensor readings. More specifically, given the sensor readings, the forward-kinematics model calculates the glove fingertip positions in a Cartesian reference frame nominally attached to the palm.

The algorithm also utilizes an inverse-kinematics model of the robot hand. In this case, "inverse-kinematics model" signifies a mathematical model of the robot finger-joint angles as functions of the robot fingertip positions. Again, more specifically, the inverse-kinematics model calculates the finger-joint commands needed to place the fingertips at specified positions in a Cartesian reference frame that is attached to the palm of the robot hand and that nominally corresponds to the Cartesian reference frame attached to the palm of the glove.

Initially, because of the aforementioned uncertainties, the glove fingertip positions calculated by the forward-kinematics model in the glove Cartesian reference frame cannot be expected to match the robot fingertip positions in the robot-hand Cartesian reference frame. A calibration must be performed to make the glove and robot-hand fingertip positions correspond more precisely. The calibration procedure involves a few simple hand poses designed to provide well-defined fingertip positions. One of the poses is a fist. In each of the other poses, a finger touches the thumb. The calibration subalgorithm uses the sensor readings from these poses to modify the kinematical models to make the two sets of fingertip positions agree more closely.

In tests of software that implements the algorithm, the entire calibration process was found to take less than 30 seconds. Operators immediately noted a difference between the accuracy of fingertip positions as computed by this algorithm and as computed by a prior algorithm. The increased accuracy afforded by this algorithm was found to improve control of the robot hand. The algorithm and software were also adapted to use with an optically tracked glove for hand control, with similar results.

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