OVERVIEW OF ORION DOCKING CAMERA BEARING ALGORITHMS

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Abstract. *The Orion vehicle makes use of a visual waveband camera during rendezvous, proximity operations, and docking (RPOD). The docking camera is used by crew for situational awareness and as a relative navigation sensor during RPOD. As a relative navigation sensor, the docking camera produces bearing angles to potential docking targets which are used in the guidance, navigation, and control (GNC) software on Orion. To produce bearing angles to potential docking targets, Orion implements two visual navigation algorithms, ImgAtt and CAPRI. These two algorithms are used to identify docking targets in both resolved and unresolved regimes and across varying illumination environments.*

Introduction. The docking camera is used as a relative navigation sensor on Orion during Artemis missions. Orion's software must produce bearing angles to docking targets in a variety of lighting conditions and in both resolved and unresolved regimes. In order to achieve this, two visual navigation algorithms are implemented. The first of those algorithms, referred to as ImgAtt, includes centroiding, star identification, and camera inertial attitude determination. The second, referred to as CAPRI, logically groups centroids output by ImgAtt to determine a single centroid for the potential target identified in the field of view. This algorithm uses a weighted average of logically grouped centroids to determine a geometric center. ImgAtt is primarily used at long ranges as the docking target may be unresolved and appear similar to stars. CAPRI is used at mid to close ranges as it accounts for the resolved nature of the target and varying illumination environments which may cause the target to be centroided as multiple distinct objects. The final step is to take all the centroids produced by these two algorithms and compute bearing angles in the appropriate reference frame.

ImgAtt Algorithm. The ImgAtt Algorithm determines the attitude of the docking camera using starfield images. The inputs for this algorithm include the centroids determined by a function applied to the starfield image, previously computed camera calibration parameters, and algorithm-specific calibration parameters. The algorithm starts by calculating the un-distorted centroid locations. The star identification function is then used to identify centroids in the image as stellar objects or non-stellar objects. This function outputs the catalog IDs of the identified stars along with the corresponding star body and inertial vectors if at least four stars are identified. The star identification function leverages a highly robust algorithm to solve the general lost in space case, where no a priori estimate of pointing is available. Non-stellar objects whose size in pixels exceeds a predetermined threshold are identified as Extended Objects. The non-stellar and Extended Objects are used as inputs to the CAPRI algorithm when the docking target is in the resolved regime. The attitude determination function first processes the identified star body vectors to estimate the initial attitude quaternion describing the rotation between the inertial frame and the body frame of the docking camera. Using both the inertial and body vectors from the identified stars and Orion's heliocentric velocity, a stellar aberration correction is applied to the initial attitude quaternion. Finally, the attitude determination is performed again to get the updated inertial to body quaternion.

CAPRI Algorithm. CAPRI logically groups centroids output by ImgAtt to determine a single averaged centroid for the identified target. This algorithm is used at mid to close ranges to the docking target since it accounts for the resolved nature of the target. Initially, CAPRI does a pre-assessment of the centroids taken in from ImgAtt. Heuristics are applied to the centroids to remove any that should not be considered as part of the target. The centroids are then sorted by a combination of size and energy to identify the docking target. CAPRI computes a bounding box around the centroided objects, which allows the algorithm to determine the extent of the detected centroids. It then proceeds to the logical grouping, which involves clustering detected centroids into distinct groups based on proximity. This grouping is performed to account for any variation in illumination that would cause an object to appear to be broken up into several sub-objects due to lighting. For example, when approaching the docking target, the Orion vehicle may cast deep shadows onto the target, causing it to be detected as multiple distinct centroids. Once the centroids have been grouped, CAPRI proceeds to its weighted averaging step. The averaged centroid for each logically grouped object are calculated and output.

Testing. CAPRI went through robust testing across a variety of real spaceflight imagery to ensure it performed consistently. The imagery came from several ideal and non-ideal environments. The non-ideal imagery consisted of situations in which there was outgassing from the target, other large objects within frame or close to the correct target, or significant glare. This testing found that across a variety of these non-ideal situations, CAPRI and ImgAtt performed consistently well together; they identified the correct target and provided an accurate centroid location.

Conclusion. All the centroids output from both ImgAtt and CAPRI are post-processed by a final piece of software. This post-processing step produces bearing angles to all centroids in inertial and camera body frames. The bearing angles are then input into the relative navigation filter in order to navigate the Orion vehicle to the identified docking target.