Recent Developments in Advanced Automated Post-Processing at AMOS

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ABSTRACT

A new automated post-processing system has been developed to facilitate with the processing of data recorded with the 1.6m and 3.6m telescopes of the Air Force Maui Optical & Supercomputing (AMOS) site. This system automatically transfers data from AMOS telescopes to supercomputing hardware to process the data as imagery, photometry, or both, dependent on sensor parameters. Users are given an interface that provides access to many additional advanced image manipulation and reconstruction capabilities, allowing users to create new processing results or to further process and annotate existing results. The user interface also provides instant access to collection metadata that was obtained during automated processing. This new data handling and processing system has significantly enhanced the capabilities of the AMOS site while also reducing the time that it takes for data to be processed and disseminated.

1. INTRODUCTION

The AMOS site has several advanced sensors for generating high-resolution images of space objects in addition to photometric data. A significant enhancement to the processing capabilities of the site was deployed in 2007 [1]. This improvement resulted in a relatively straightforward workflow, but numerous menial tasks were appended to the data processing procedure due to evolving mission requirements and file format requirements. Years later, the number of required utilities and workaround scripts had increased exponentially, and most of these pieces of software each served only a single purpose. These factors made it difficult to train new data analysts and reduced the rate at which good results could be produced and disseminated.

Data processing engineers proposed a new software project that could simplify and improve the processing system. Many of the menial tasks would be automated with modular software, thereby reducing human error and improving processing time while making it straightforward to implement modifications. Basic error and state checking would reduce risk due to upstream software changes. A single processing framework would allow various data processing algorithms to be chained together in straightforward pipelines that a user could observe and easily understand. Analysts would be provided with a user interface that would provide advanced processing tools and access to a processing database. This system was fully deployed in early 2014. In this paper we describe the new processing system in terms of its major components, which include automated raw data handling, advanced automated data processing, and the post-processing user interface.

2. AUTOMATED DATA HANDLING

AMOS data is recorded in data files that comply with the fifth version of the Hierarchical Data Format (HDF5) [2]. These files are recorded to a high-capacity storage device at the Maui Space Surveillance Complex (MSSC) before they are transferred to the Maui High Performance Computing Center (MHPCC) for processing. Under the old processing system, analysts would manually initiate file transfers and would have to wait for their completion before being able to process them. New files would be manually inspected, and important metadata would be recorded by hand into a database.

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The automated data handling system improves this process in a number of ways. When a new collection is recorded, the camera system sends a notification to the Raw Data Handling Daemon. This notification is received and a file transfer to MHPCC is initiated. Upon transfer completion, file consistency checks are performed on the data, and files are automatically re-transferred if there are any inconsistencies found in the received file. File parameters that were not stored in the old processing system, such as file checksum, file size, and whether the contents of the file are compressed, are now recorded in a new database. Metadata related to pass parameters, such as camera settings and mount angles, are also stored in the database. The Automated Processing Manager is then notified that a new raw file is ready to be processed.

Every action performed by the data handling daemon is logged in a database, a feature that provides numerous advantages. Data consistency checking between archival systems becomes a straightforward task, as the database tracks all file locations and original checksums. If a discrepancy is found during a routine check, the true file information is already known, and a copy of the uncorrupted file can be brought in from anywhere else in the system. The database also makes it straightforward to use HDF5's optimized compression features while maintaining the system's file consistency checking capabilities. A flowchart describing the new raw data handling daemon is shown in Fig. 1.

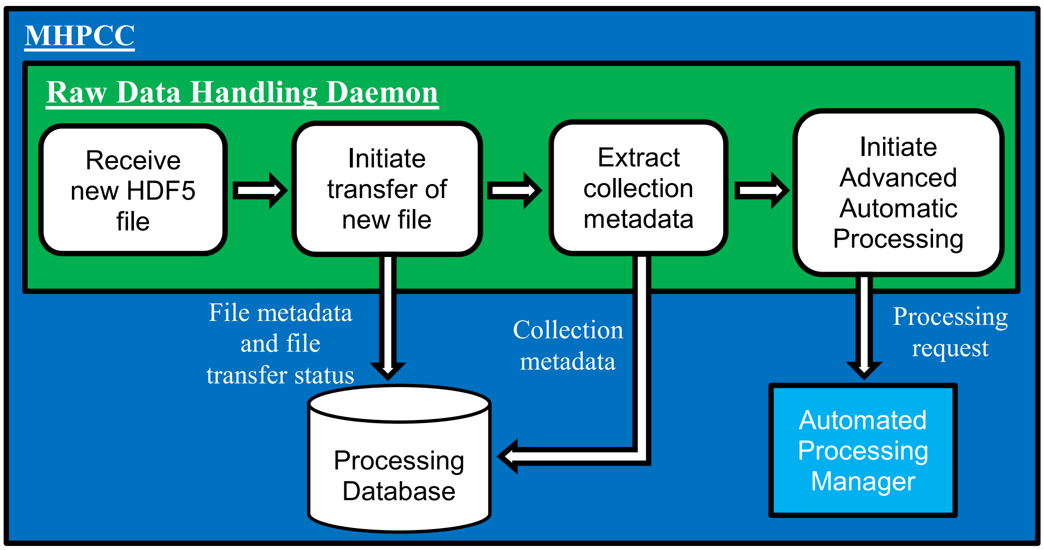

Fig. 1. The Raw Data Handling Daemon receives a notification of a new file from the camera systems. It handles the transfer of new data, data consistency checking, metadata and database management, and it sends a processing request to the Automated Processing Manager.

3. AUTOMATED PROCESSING

Data processing is a multi-step procedure, shown in Figure 2. First, raw data frames are analyzed and assessed for basic quality using a number of parameters. Frames with a closed shutter are marked as camera calibration frames. Frames with an open shutter that are on open sky can be suitable as flat field calibration frames, depending on camera settings and the statistical properties of the raw data. When suitable dark or flat field data is discovered, its properties are stored in the database for later use.

When a new collection that is not camera calibration has been taken, the database is queried for files containing dark current and flat field data frames. The image data is calibrated in order to remove noise and background, and flat field correction is applied to the data in order to remove optical path distortions. At this point, the calibrated data and its metadata are saved to a new file, the properties of which are stored in the database. The sensor configuration and object type are examined and one of several processing pipelines is chosen for the calibrated images. In this paper we will be describing the two most important pipelines for narrow field of view (FOV) data processing: physically constrained iterative deconvolution (PCID) and photometric calibration.

PCID is a multi-frame blind deconvolution algorithm with physical constraints [3]. It accepts a number of blurred images as input and simultaneously produces pristine images in addition to estimates of the point-spread functions (PSFs) that produced the blurring in the calibrated imagery. The PCID algorithm has been parallelized and installed on several AMOS computing networks. The optimal PCID settings often depend on sky conditions and target parameters, and the parallelization of the PCID processing pipeline allows us to automatically explore the parameter space while searching for an optimal set of input values. The output images of the PCID algorithm are saved in a file, and the location of this file is recorded in the database.

Photometric calibration is a capability available to narrow field imagery. An instrumental magnitude curve is extracted from a target object. A zero-point and extinction is calculated from camera-calibrated data of photometric stars with known brightness, and these values are applied to the instrumental magnitude in order to obtain a calibrated light curve. Pass parameters and light curve data are saved in the database and exported to a file that can be disseminated for further analysis.

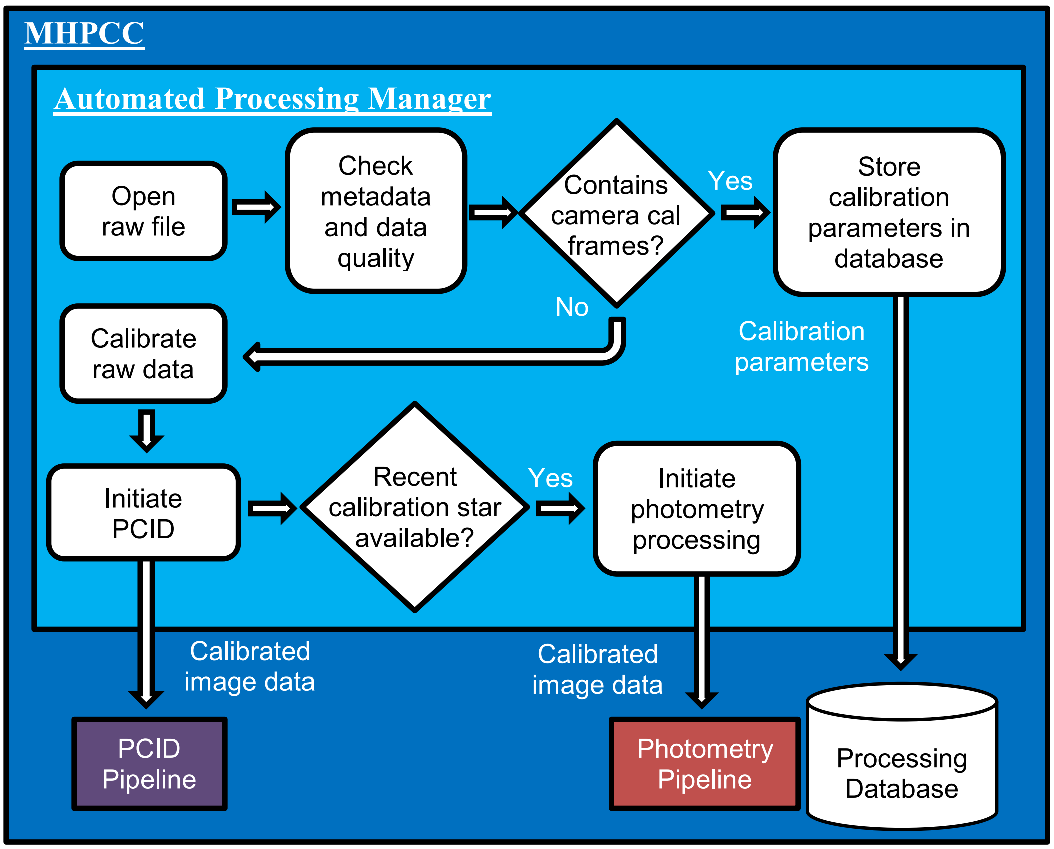

Fig. 2. The Automated Processing Manager receives processing requests from the raw data handling daemon or from users. Camera calibration procedures are applied, and then the data undergoes PCID and/or Photometry processing, depending on sensor and pass parameters.

4. POST-PROCESSING USER INTERFACE

Analysts have been provided with the Processing System Overview, a user interface that displays the status of all processing tasks and access to image data and metadata. The interface maintains a connection to the database, giving it up-to-date information on all processing tasks. Users are able to see files transfer and processing status in real time. Passes are sorted chronologically and may be filtered in several ways, including by sensor name, object name, object number, or by pass parameters such as maximum elevation angle. Files corresponding to a pass are listed based on what kind of processing has been performed on them. Raw data, camera calibrated data, and data products that have been produced by one of the processing pipelines, such as PCID and photometry results, are displayed under the metadata for each pass. Raw data and intermediate data products can be manually submitted to the automated processing pipelines described in Section 3 with user-provided parameters. Any file listed in this display can be opened in an image manipulation GUI from the Processing System Overview. The overview GUI is shown in Fig. 3.

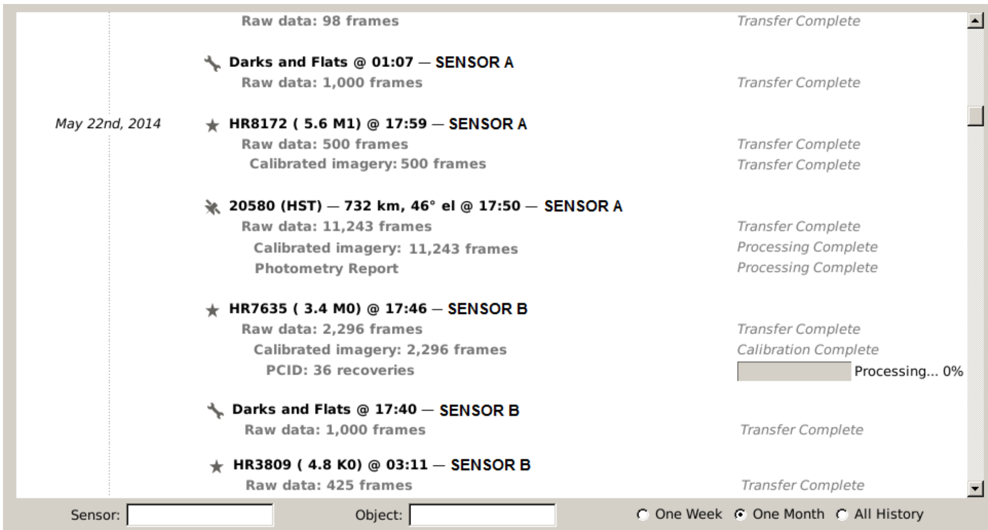

Fig. 3. The Processing System Overview interface allows analysts to see the status of all files and data processing jobs in real time. Results can be opened, annotated, and sent to customers, reprocessed in the automated system with user-provided parameters, or manually processed.

The image manipulation GUI provides a number of image manipulation and annotation tools. The metadata for the pass is shown below the imagery and is grouped into a number of categories, such as camera metadata or mount state data. A suite of annotation tools may be applied to the data, and it is possible to export image sets and movies with the overlaid annotations. Raw data may be opened, manually calibrated, and bispectrum processed [4] from within the image manipulation GUI. The image manipulation GUI is shown in Fig. 4. A sample of a user-generated plot of instrumental magnitude is shown in Fig. 5.

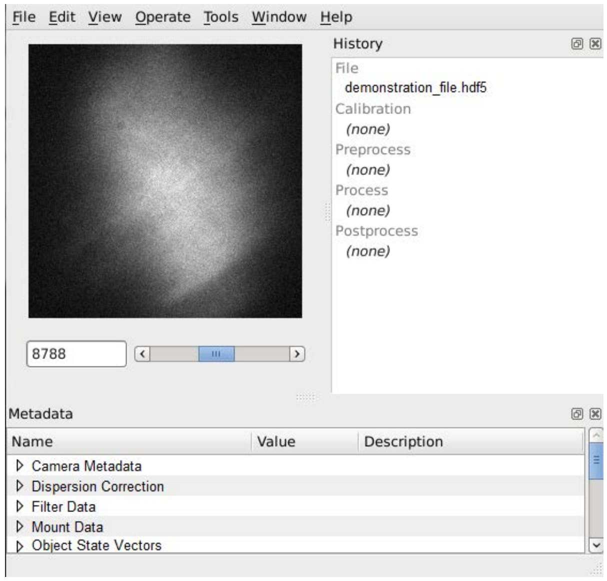

Fig. 4. The processing system image manipulation GUI displays pass metadata below the imagery. Various image operations may be applied to the images, including speckle imaging algorithms.

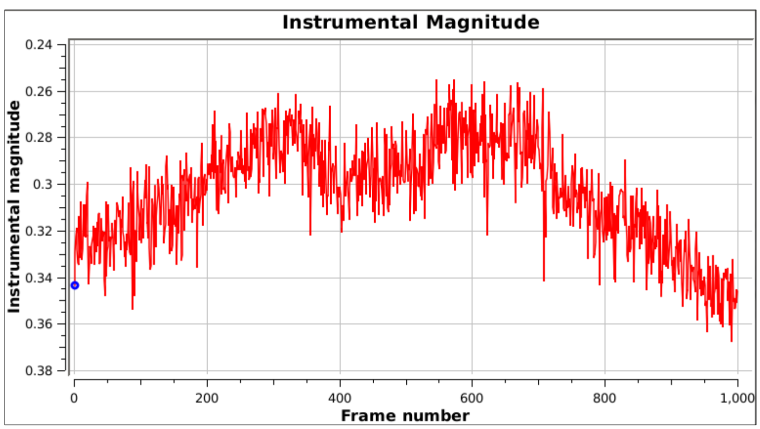

Fig. 5. The image manipulation GUI provides access to a variety of image modification and processing features, including the creation of calibrated light curves.

5. CONCLUSIONS AND FUTURE WORK

AMOS data processing has undergone a number of improvements that have significantly increased workflow efficiency. Raw data is automatically transferred to a high performance computing facility for processing and analysis. Advanced post-processing algorithms are applied to the raw data, allowing analysts to more rapidly view, annotate, and disseminate imagery. The PCID processing pipeline results in high-quality image reconstructions while the photometric processing pipeline provides powerful photometric calibration tools. Analysts spend less time on menial data management tasks, allowing more time to be committed toward analyzing and improving data products. The new data processing GUI provides analysts with additional image processing algorithms and other capabilities, providing alternative workflow options in case of supercomputing downtime.

The processing pipeline architecture features a modular design that makes it straightforward to add new algorithms. Future work should include additional optimization to the existing algorithms in addition to the development of new data processing features.

6. REFERENCES

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