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The Dark Energy Survey Data Management System: The Processing Framework

Michelle Gower, Joseph J. Mohr, Darren Adams, Y. Dora Cai, Gregory E. Daues, Tony Darnell, Chow-Choong Ngeow, Shantanu Desai, Cristina Beldica, Mike Freemon

University of Illinois, Urbana, IL, USA

Huan Lin, Eric H. Neilsen, Douglas Tucker

Fermi National Accelerator Laboratory, Batavia, IL, USA

Emmanuel Bertin

Institut d' Astrophysique, Paris, France

Luiz A. Nicolaci da Costa, Leandro Martelli, Ricardo L. C. Ogando

Observatorio Nacional R. Gal. Jose Cristino, Rio de Janeiro, RJ, Brazil

Michael Jarvis

University of Pennsylvania, Philadelphia, PA, USA

Erin Sheldon

Brookhaven National Laboratory, New York, NY, USA

Abstract.
The Dark Energy Survey Data Management (DESDM) system will process and archive the data from the Dark Energy Survey (DES) over the five year period of operation. This paper focuses on a new adaptable processing framework developed to perform highly automated, high performance data parallel processing. The new processing framework has been used to process 45 nights of simulated DECam supernova imaging data, and was extensively used in the DES Data Challenge 4, where it was used to process thousands of square degrees of simulated DES data.

1. Introduction

The Dark Energy Survey (DES, 2011-2016) is an optical survey of 5000 deg^2 of the South Galactic Cap to ~24th magnitude in multiple filter bands (grizY) using a new wide field CCD camera, DECam, mounted on the Blanco 4-m telescope at Cerro Tololo Inter-American Observatory (CTIO). The DECam is a large focal plane array with a short readout time which will collect approximately 300 GB of science images per night of observation. Additional data products

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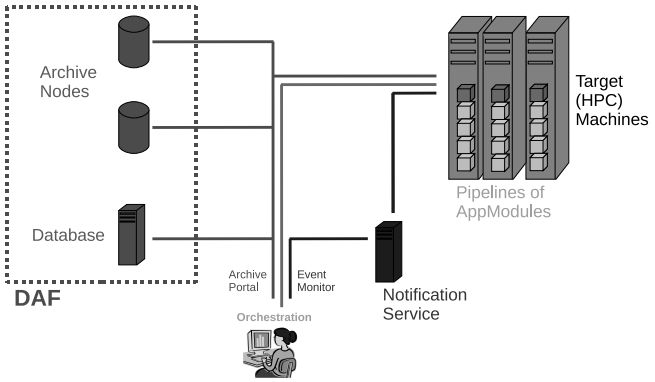

Figure 1. DESDM Overview.

will be generated through a series of image processing steps resulting in a total of approximately 3 TB (uncompressed) of data for each night.

The Dark Energy Survey Data Management system (DESDM[1]) (see Figure 1) will process and archive the data from the Dark Energy Survey (DES) over the five year period of operation. This paper focuses on a new adaptable processing framework developed to perform highly automated, high performance data parallel processing. The new processing framework has been used to process 45 nights of simulated DECam supernova imaging data, and was extensively used in the DES Data Challenge 4, where it was used to process thousands of square degrees of simulated DES data.

2. Processing Framework

The processing framework consists of two main components: (1) modular pipelines that execute science codes and (2) an orchestration layer to manage the pipelines. The DESDM pipelines make use of application containers to wrap astronomical pipeline modules to be executed on the compute nodes of HPC resources. These application containers send events to the Notification service for viewing by the operator. The orchestration layer of the DESDM processing framework is responsible for preparing job descriptions (using operator input parameters coupled with the results of database queries), deploying required files and data to high-performance computing platforms, and executing and monitoring the sets of data-parallel jobs that comprise the astronomical processing. It interfaces

[1]DESDM URL: http://desweb.cosmology.uiuc.edu

with the DESDM Data Access Framework for efficient and reliable transfer of files and image data to compute platforms.

2.1. Application Modules

DESDM processing pipelines are constructed with a Java middleware layer provided by the Elf/OgreScript[2] software developed at the NCSA. Elf is an robust application container, and OgreScript is a workflow scripting language with scripts encoded in XML. The container middleware wraps the astronomical modules to be executed on the compute nodes of a target machine, for example, a TeraGrid cluster. Elf/OgreScript allows important status and quality assurance information to be issued within events from running applications. The container middleware supports the parsing of the streaming stdout and stderr from application science codes, and by this mechanism astronomy codes can send vital information and updates through the events system. The events are sent to remote Notification services, which gather the events from distributed processes into a central repository,

A single Elf/OgreScript execution may be composed of a sequence of application modules. New codes are easily added into processing pipelines by writing simple module descriptions with information such as the executable to be launched, command line arguments, and descriptions of input lists or files.

2.2. Orchestration

The orchestration layer is written in Perl and utilizes the Perl DBI module to abstract its interactions with the database persistence layer. This will enable transparent access to different database types (Oracle, MySQL, PostgreSQL, etc.). Perl scripts of the orchestration layer serve as wrappers for various Condor[3] (Thain, Tannenbaum, & Livny 2005) commands, converting between more customized scientific inputs/outputs and the general Condor inputs/outputs. For each data-parallel block of codes, the Orchestration layer must perform several tasks. First it queries the central database to get a list of input images and divides that into sublists for the data-parallel jobs. It stages the input images to the target machine. The orchestration then creates the Elf/OgreScript XML scripts and properties files for the jobs and stages these files and the input lists to the target machine. Then the orchestration submits the pipeline jobs using vanilla Condor jobs if submitting to the local condor pool or using Condor-G jobs to remote target machines such as the TeraGrid cluster. To automatically control the sequence of these steps through the entire image processing, the orchestration uses Condor's Directed Acyclic Graph Manager (DAGMan).

Orchestration uses the Data Access Framework (DAF) to stage files in multiple cases. The DAF is a set of programs that can also be used by operators to transfer files while updating the central database. There are locally created input lists and files that need to be copied to the target machine. Sometimes the images need to be copied from other archive locations. And after processing, the newly created images and files can be backed up to other archive locations. The

[2]Elf/OgreScript URL: https://wiki.ncsa.uiuc.edu/display/MRDPUB/Elf

[3]Condor URL: http://www.cs.wisc.edu/Condor

processing framework also uses the centralized database to create input lists of images and metadata for the target jobs.

3. Results

The processing framework has been used to process several pipelines on simulated DES data as well as real data from the Blanco Cosmology Survey (BCS). An earlier version was used to reduce 45 nights of simulated DECam supernova imaging data. In Data Challenge 4 (DC4), which finished at the end of January, 2009, the processing framework was used to process three different astronomy pipelines for almost the entire DC4 data. These include the nightly processing pipeline, coaddition pipeline and Weak lensing pipeline. The nitely processing pipeline involves crosstalk corrections, detrending, astrometric refinement, followed by remapping and catalog ingestion. The nitely processing was run on 10 nights of simulated DES data, out of which 3 were nonphotometric. The coaddition and weak-lensing pipelines were processed on a tile-by-tile basis where the sky was divided into nonoverlapping rectangular regions called tiles. The coaddition and weak lensing pipelines were run on about 250 tiles for simulated DC4 data. The coaddition pipeline involves combining multiple images of the same region of sky and different bands into multiple images. Weak lensing pipeline involves identification of bright stars which are useful for PSF description, measurement of shapelet decomposition of stars and estimation of shear of deconvolved galaxies. In addition, we also developed the PSF homogenization and difference imaging pipeline which was tested on a small subset of DC4 data. More details of these pipelines can be found in Mohr et al (2008).

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