The MAGIC data processing pipeline

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Abstract. The MAGIC data center has recently introduced a new computing service, which is available to the whole collaboration. This service will be complemented with DataCooker, an analysis system currently in development. This system implements the MAGIC data analysis chain and integrates it in the data center infrastructure. DataCooker is designed to provide an easy access to the computing service without the need to know its details or deal with the complexities of its use.

1. Introduction

MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) \cite{1} is a system of two Imaging Atmospheric Cherenkov Telescopes (IACT) for gamma-ray astronomy in the 25 GeV to 10 TeV energy range. The first telescope (MAGIC-I) started regular observations in 2004 and was joined by a second one (MAGIC-II) in 2009. The scientific outcome of the MAGIC collaboration has resulted in more than 40 published papers in high impact, international refereed journals, 4 of which are published in Science Magazine \cite{2, 3, 4, 5}.

The official MAGIC Data Center (DC) \cite{6} is hosted in the Port d’Informació Científica (PIC) \cite{7} in Barcelona, and participated by Institut de Física d’Altes Energies (IFAE), Universitat Autònoma de Barcelona (UAB), Universidad Complutense de Madrid (UCM) and Instituto de Astrofísica de Andalucía (IAA). The DC provides data storage and access resources since its start in 2007. In 2009 the DC services were ported to work in a Grid infrastructure as part of the upgrade to include MAGIC-II data \cite{8}. The computing resources of the DC, initially used exclusively for internal data processing, were expanded with 96 CPU cores and made available to the collaboration in October 2010.

The DC computing service is naturally based on the Grid infrastructure available in PIC and already used for the data storage. The basic computing service provides access to the computing resources in the DC computing farm using the gLite \cite{9} middleware. But we aim also at providing a toolset which integrates the computing with the rest of the DC services. This way the user can benefit the most from the available resources while being shielded from the...
technical complexities of the system. This toolset, codenamed DataCooker, will comprise all the applications required in the complete data analysis chain, and needed to produce high-level scientific output from our raw data. DataCooker will include an interface to help submit and monitor complex data processing requests in a simple way.

2. The Computing Service
The Computing service at the DC offers computing resources to the MAGIC collaboration. The computing needs of a MAGIC analysis include both batch analysis and interactive computing. This service satisfies those needs with a share of the cluster at PIC (total benchmark 1395 HEP-SPEC [10]) and a couple of interactive computing servers with exclusive use for MAGIC which are also used as UI. The cluster can be accessed using the gLite middleware and a couple of exclusive Workload Management System (WMS) servers. The MAGIC software is installed in a disk that is both accessible from the cluster and the interactive servers. This allows users to prepare and test their analysis jobs in the interactive servers, then submit them to the cluster without modifications. This service is complemented with a disk space for users to store the output of their ongoing analysis.

2.1. Scale
This service is scaled to be able to perform 10 complete data analysis jobs simultaneously in 24h starting with calibrated data, plus 2 more analysis starting from raw data stored on tape. Those analyses are defined as the processing of an amount of data equivalent to 50h of observation time. This corresponds to about 10TB in case of (uncompressed) raw or about 350GB of calibrated data.

2.2. Usage
There are typically around fifty unique users which use the data center services over a month. Of those, about twenty are active users who use our computing infrastructure regularly. We expect this number to increase up to thirty within 2011. The typical usage of the computing service by an active user usually involves less amount of data than the 50h used in the design. Typical analysis datasets correspond to 5 to 10 hours of observations, and usually computing jobs are not submitted all at once. On the other hands is not unusual to process the dataset more than once using modified analysis options. This effect is more pronounced at the later stages of the analysis, which is normally done using the interactive servers.

3. DataCooker
DataCooker is a data analysis system which implements the MAGIC data analysis chain in the DC infrastructure at PIC. It is built around the MAGIC Analysis and Reconstruction Software (MARS) [11] software and based on the experience of many years of data processing in the DC. This system has a modular design (see Fig. 1), and aims to provide a complete solution for managing the whole MAGIC data processing. It has been designed for novice to intermediate MAGIC users who want to perform a standard data analysis. Those users will find in DataCooker a simple tool to process their datasets, test different parameters, etc. without needing to code their own tools. Advanced users and developers which require more specific tools may need more flexibility for their analysis, but they can still access the individual components of DataCooker from their own programs and help to develop DataCooker.

3.1. User Interface
All direct interactions between users and DataCooker are done through the User Interface module. These interactions can be either to submit an analysis or to monitor its status.
Figure 1. DataCooker modules and their interconnections. Square boxes represent the main modules accessible by users, cylinders represent databases, and rounded boxes represent software libraries used including the specific MAGIC collaboration software. Arrows indicate the direction of the I/O interaction between modules. CE stands for Computing Element.

The analysis submission process consists in defining a dataset using the observations database, selecting the analysis options and submitting the request. This request, and the corresponding analysis jobs that are created, can also be monitored from the User Interface. This interface will be available as a command-line interface, and also through the DC web.

3.2. Analysis Workflow
The Analysis Workflow module uses an implementation of the MAGIC data analysis chain (see Sect. 4) to process the analysis requests submitted by users and transform them into analysis jobs. This task consists in identifying the necessary applications from the Application Library to produce the analysis requested and preparing the corresponding configuration files. The Observations and Analysis Status databases are used in this module to complete the requests, but also to identify steps of the analysis which may be already completed and are not necessary to resubmit. Each application in the Application Library corresponds to a single MARS executable, and is implemented using the common Data Access Library to access data in the DC storage infrastructure. The Data Access Library uses the Grid Access Library, which is a collection of standard gLite [9] libraries to interact with Grid resources.

3.3. Job Manager
The Job Manager module is responsible for receiving the requests from the Analysis Workflow and generating the actual jobs that will be submitted to the computing farm. This module is also responsible for gathering the status of these jobs and update the Analysis Status database. This information can be accessible from the User Interface, and it can be used to access the corresponding job output. An application request may be divided in several jobs, depending on the dataset and the possibilities of the computing resources. The dependencies between the different applications or jobs are also resolved in this module, resulting in some jobs being put on hold until the jobs they depend on have successfully finished. Finally, the resulting jobs are registered in the Job Id database to be processed.
3.4. Scheduler

The actual submission of jobs to the Grid computing elements is done by the Scheduler module. This module uses the job pilot paradigm, where the jobs that are actually submitted do nothing but pull actual computing jobs from a central job queue in the Job Id database. This computing model allows a better control of the job queue, to define dependencies between jobs and implement a more intelligent priority system based on actual job characteristics.

4. Data Analysis Chain

The MAGIC data analysis chain [12] is the definition of the necessary steps to transform the raw data collected in the telescopes into scientific output. The definition of the chain in terms of MARS applications may not be unique and may evolve with time. In Fig. 2 the implementation of the current analysis chain in DataCooker is shown.

![Analysis chain and Example application](image)

**Figure 2.** MAGIC data analysis chain, as implemented by DataCooker. In (a) the complete chain is depicted, with boxes representing applications, and arrows representing their dependencies. DISP and HADRONNESS are a couple of parameters used in the data analysis [12]. In (b) the calibration application is shown as example. This application make use of the callisto executable, part of the MARS software [11].

4.1. Input

The two main input sources for the analysis chain are raw data gathered in actual telescope observations, and Monte Carlo [13, 14] simulated data. The Monte Carlo simulations are previously generated to match the data from the observations. Telescope subsystems also produce status report files which may be also used as input data in specific parts of the processing. In case of using a subset of the chain, the input may also be preprocessed data already stored in the DC.

4.2. Output

The output of the analysis chain consists of processed data and analysis results. The processed data are produced in each application and is stored in the storage infrastructure of the DC.
This way it can be used for further processing in the same analysis or reused in the future. The analysis results are the final output of the analysis chain, and are not permanently stored but meant to be retrieved by users at the end of the analysis. Examples of those are gamma-ray energy spectrums or sky maps with the reconstructed source position.

4.3. Steering
The steering of the analysis is done through specific input cards for each application and a global configuration file for the whole chain. Both the input cards and the configuration file can be generated in DataCooker based on user input, or be provided by the user.

5. Applications
Each step in the analysis chain is represented by an application, which correspond to a single MARS executable. Those steps can either be used as part of the chain or as a stand-alone program in a regular job. Applications share all a common structure. In the first stage the environment is setup according to the given configuration file, and the system is checked for compatibility issues. In the second stage the data are downloaded to the local disk. The actual data processing follows, using the local disk to store its output. Finally the resulting data are copied to the storage element and published to the LFC (LCG File Catalog [15]) file catalog if required. In some cases the dataset considered is too large for the available space in the local disk. This is solved either by splitting the dataset into subsets, or by using an external disk in case the analysis does not allow it. This last option have a negative impact in the efficiency of the analysis.

6. Conclusions
The Computing Service for the MAGIC DC was deployed in October 2010. There are currently around twenty active users, and we expect this number to increase over thirty within this year. The DataCooker analysis toolset is currently in development. As of March 10th, 2011, there are several of its components and applications already tested and functional, and the development is currently focused in the Data Access Library. We expect to produce a first release within 2011 with all the applications as stand-alone programs. After this point we will invite users to collaborate in the applications’ code, and provide feedback. After that milestone the development will focus on the rest of components. We are also considering to adapt an already developed solution such as DIRAC [16] for the Job Manager and Scheduler modules instead of developing them from scratch. Both solutions are being studied in parallel.

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