DAME: A Distributed Data Mining & Exploration Framework within the Virtual Observatory

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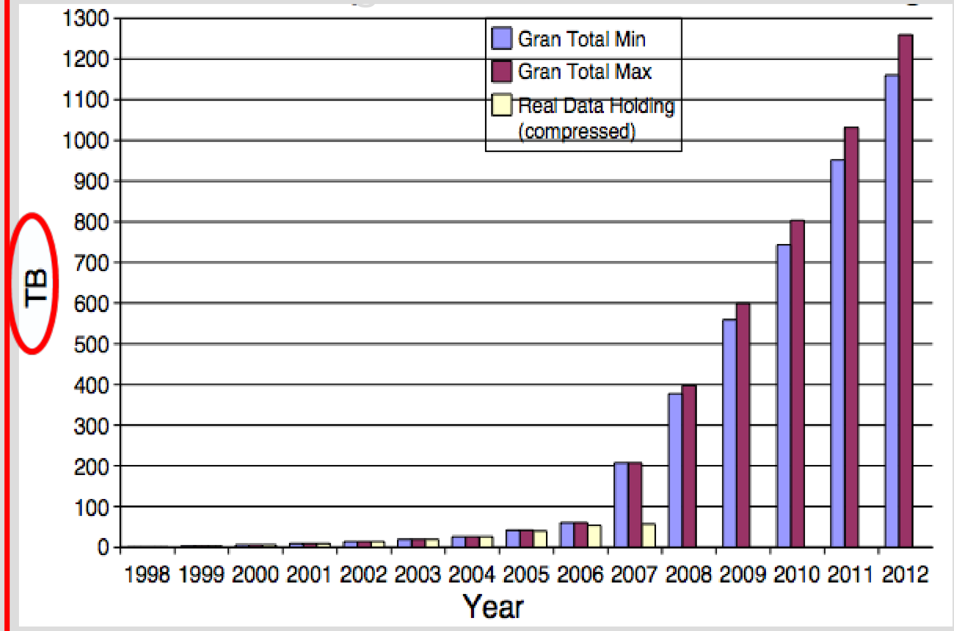
Astrophysics as a Data Rich Science

- Telescopes (ground-based and space-based, covering the full electromagnetic spectrum)

- Instruments (telescope/band dependent)

- Large digital sky surveys are becoming the dominant source of data in astronomy: ~ 10-100 TB/survey (soon PB), ~ 10^6 - 10^9 sources/survey, many wavelengths…

- Data sets many orders of magnitude larger, more complex, and more homogeneous than in the past



The General Astrophysical Problem

Due to new instruments and new diagnostic tools, the information volume grows exponentially

➡ ***Most data will never be seen by humans!***

The need for data storage, network, database-related technologies, standards, etc.

Information complexity is also increasing greatly

➡ ***Most knowledge hidden behind data complexity is lost***

Most (all) empirical relationships known so far depend on 3 parameters …. Simple universe or rather human bias?

➡ ***Most data (and data constructs) cannot be comprehended by humans directly!***

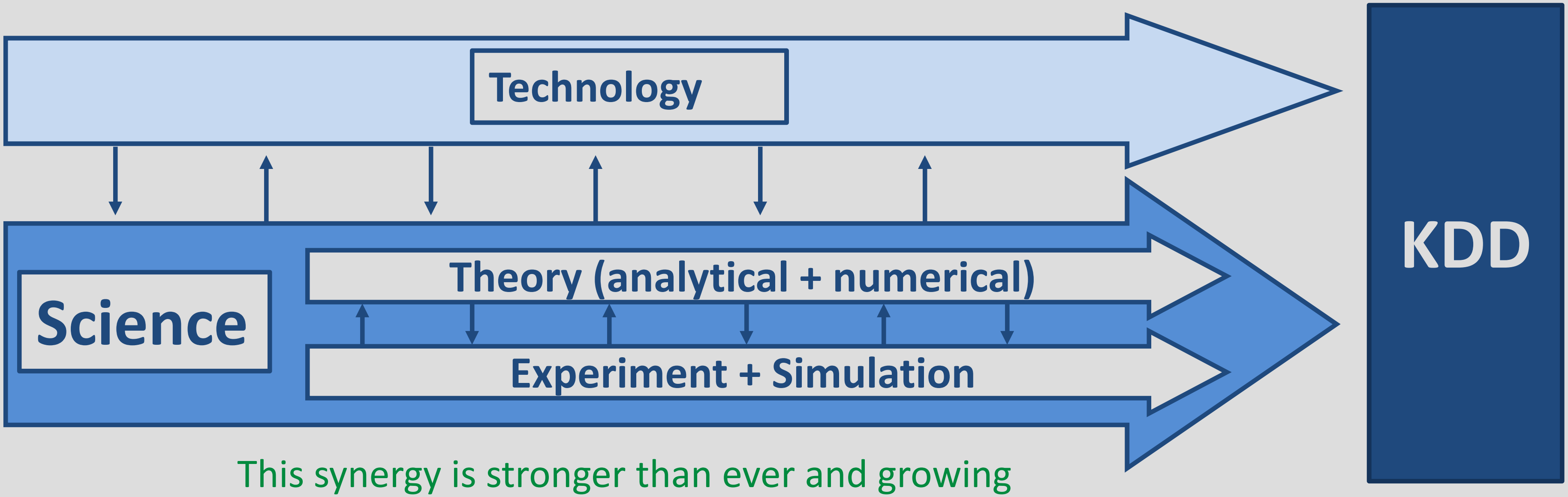
The need for data mining, KDD (Knowledge Discovery in Databases), data understanding technologies, hyper dimensional visualization, AI/Machine-assisted discovery

Data Mining (KDD) as the Fourth Paradigm Of Science

The old traditional, “Platonic” view:

Pure Theory → Experiment → Technology & Practical Applications

The modern and realistic view when dealing with complex data sets:



This synergy is stronger than ever and growing

The BoK's Problem

Limited number of problems due to limited number of reliable BoKs

(BoK) Bases of knowledge
(set of well known templates for supervised (training) or unsupervised (labeling) methods

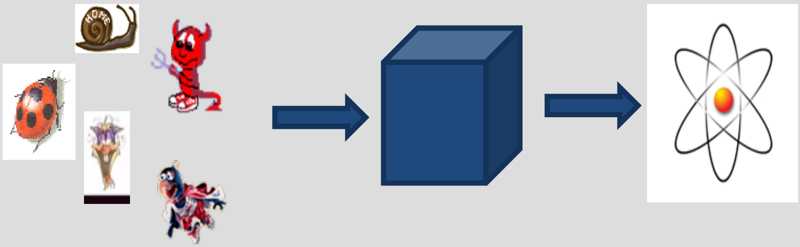
So far

- Limited number of BoK (and of limited scope) available
- Painstaking work for each application (es. spectroscopic redshifts for photometric redshifts training)
- Fine tuning on specific data sets needed (e.g., if you add a band you need to re-train the methods)

Bases of knowledge need to be built automatically from Vobs Data repositories

•There's a need of standardization and interoperability between data together with DM application

Community believes AI/DM methods are black boxes
You feed in something, and obtain patters, trends, i.e. knowledge....



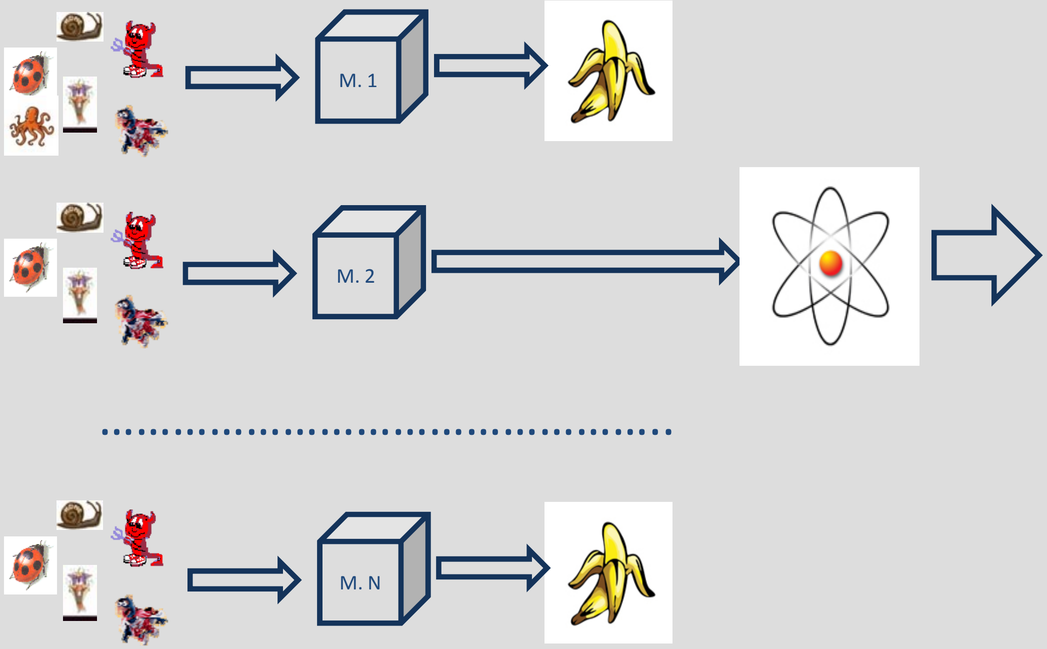
The Choice Problem

Exposed to a wide choice of algorithms to solve a problem, the r.m.s. astronomer usually panics and is not willing to make an effort to learn them ….

The r.m.s astronomer doesn't want to become a computer scientist or a mathematician
(large survey projects overcome the problem)

Tools must run without knowledge of GRID/Cloud no personal certificates, no deep understanding of the DM tool etc.

Allow each astronomer to build his black box using own algorithm to run on the infrastructure without knowledge about the infrastructure



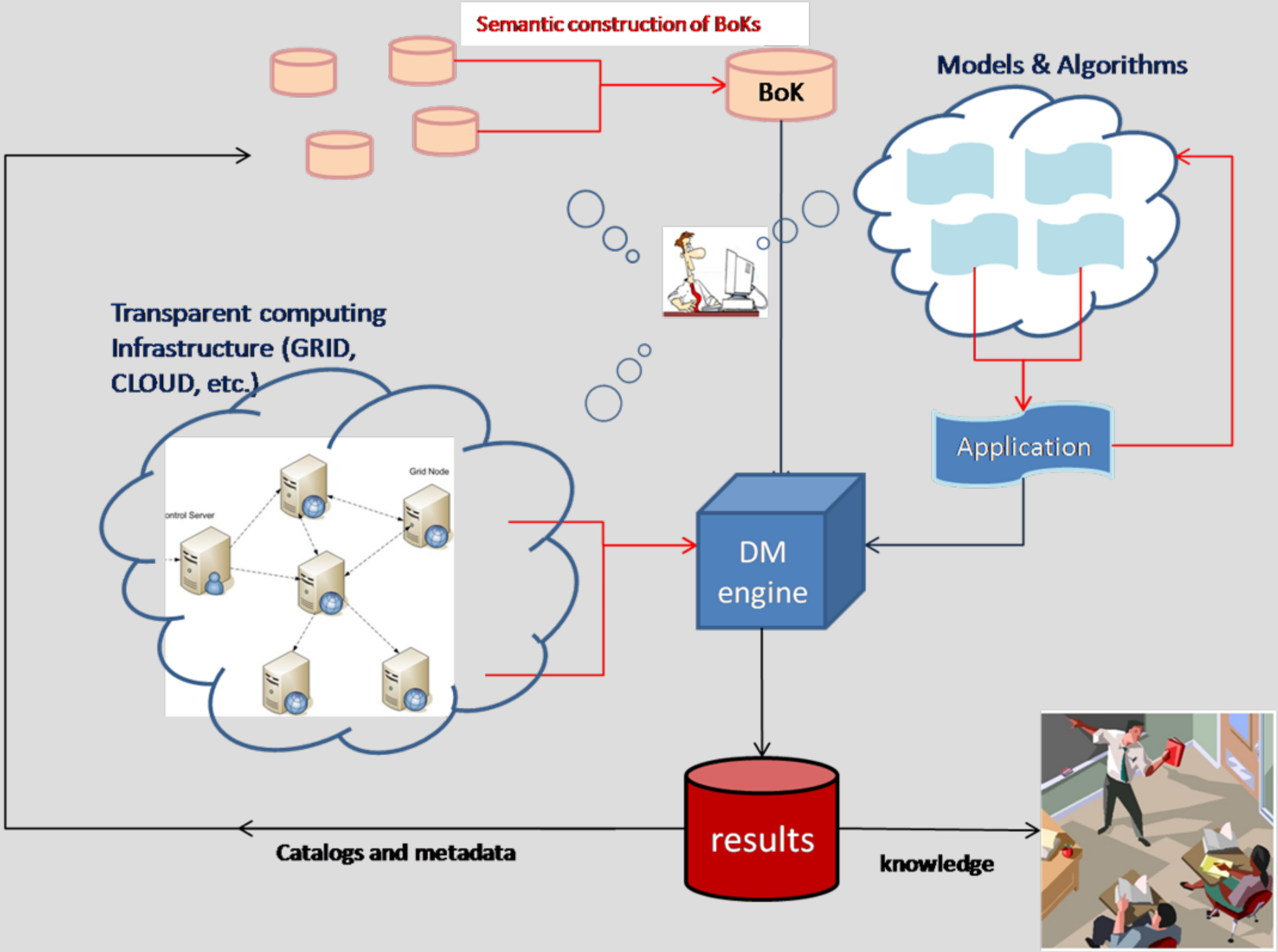
Formation of a new generation of experts

(…… suggesting the solutions)

AND/OR

Implementation of a second generation of tools

Effective DM process break-down



The Black box Infrastructure

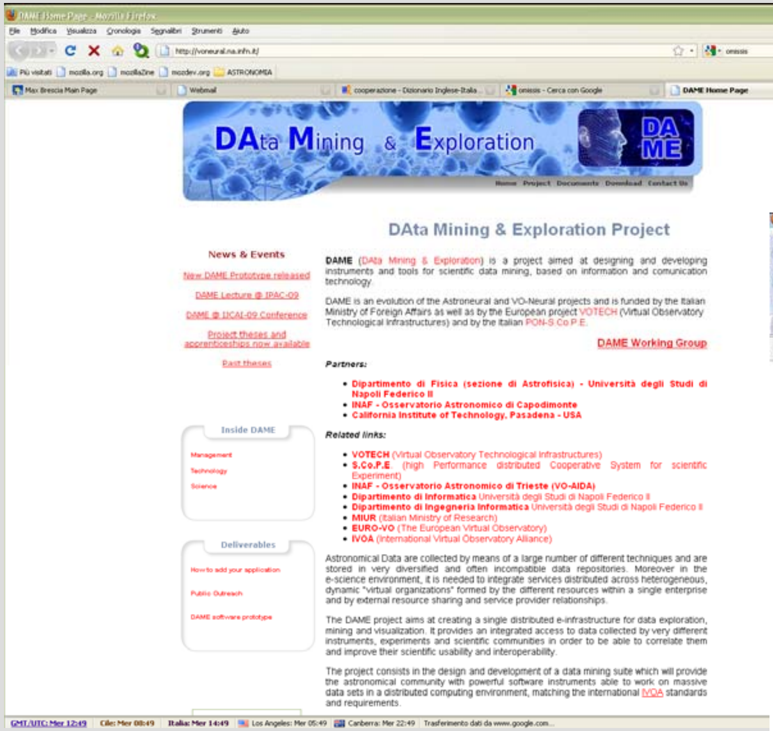
In this scenario DAME (Data Mining & Exploration) project, starting from astrophysics requirements domain, has investigated the Massive Data Sets (MDS) exploration by producing a taxonomy of data mining applications (hereinafter called functionalities) and collected a set of machine learning algorithms (hereinafter called models).

This association functionality-model represents what we defined as simply "use case", easily configurable by the user through specific tutorials. At low level, any experiment launched on the DAME framework, externally configurable through dynamical interactive web pages, is treated in a standard way, making completely transparent to the user the specific computing infrastructure used and specific data format given as input.

So the user doesn’t need to know anything about GRID, Cloud or what else.

What DAME is

DAME is a joint effort between University Federico II, INAF-OACN, and Caltech aimed at implementing (as web application) a scientific gateway for data analysis, exploration, mining and visualization tools, on top of virtualized distributed computing environment.



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DAta Mining & Exploration Project

News & Events

New DAME Prototype released

DAME Lecture @ IPAC-09

DAME @ IJCAI-09 Conference

Project theses and apprenticeships now available

Past theses

Inside DAME

Management

Technology

Science

Deliverables

How to add your application

Public Outreach

DAME software prototype

DAME (DAta Mining & Exploration) is a project aimed at designing and developing instruments and tools for scientific data mining, based on information and comunication technology.

DAME is an evolution of the Astroneural and VO-Neural projects and is funded by the Italian Ministry of Foreign Affairs as well as by the European project VOTECH (Virtual Observatory Technological Infrastructures) and by the Italian PON-S.Co.P.E.

DAME Working Group

Partners:

- **Dipartimento di Fisica (sezione di Astrofisica) - Università degli Studi di Napoli Federico II**
- **INAF - Osservatorio Astronomico di Capodimonte**
- **California Institute of Technology, Pasadena - USA**

Related links:

- **VOTECH** (Virtual Observatory Technological Infrastructures)
- **S.Co.P.E.** (high Performance distributed Cooperative System for scientific Experiment)
- **INAF - Osservatorio Astronomico di Trieste (VO-AIDA)**
- **Dipartimento di Informatica** Università degli Studi di Napoli Federico II
- **Dipartimento di Ingegneria Informatica** Università degli Studi di Napoli Federico II
- **MIUR** (Italian Ministry of Research)
- **EURO-VO** (The European Virtual Observatory)
- **IVOA** (International Virtual Observatory Alliance)

Astronomical Data are collected by means of a large number of different techniques and are stored in very diversified and often incompatible data repositories. Moreover in the e-science environment, it is needed to integrate services distributed across heterogeneous, dynamic "virtual organizations" formed by the different resources within a single enterprise and by external resource sharing and service provider relationships.

The DAME project aims at creating a single distributed e-infrastructure for data exploration, mining and visualization. It provides an integrated access to data collected by very different instruments, experiments and scientific communities in order to be able to correlate them and improve their scientific usability and interoperability.

The project consists in the design and development of a data mining suite which will provide the astronomical community with powerful software instruments able to work on massive data sets in a distributed computing environment, matching the international IVOA standards and requirements.

http://dame.na.infn.it/

Web application PROTOTYPE

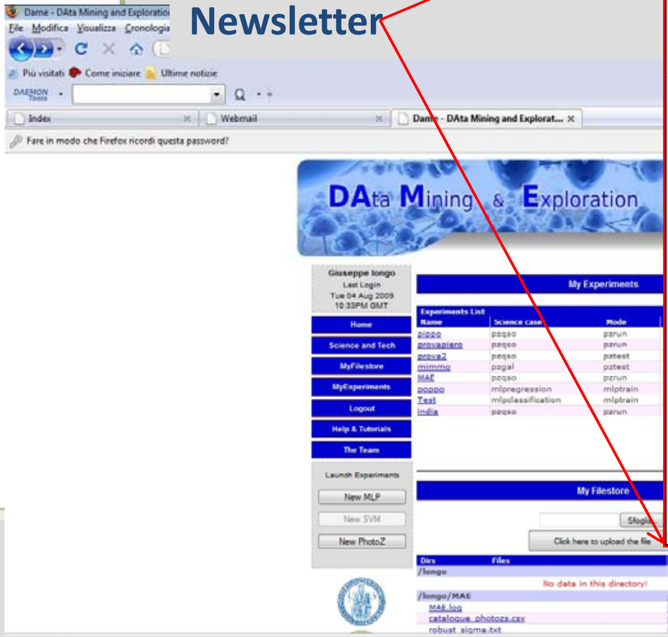
http://voneural.na.infn.it/

Technical and management info

Documents

Science cases

Newsletter



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File Modifica Visualizza Cronologia
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MyFilestore
MyExperiments
Logout
Help & Tutorials
The Team
Launch Experiments
New MLP
New SVM
New PhotoZ
Sfoglia...
Click here to upload the file

Fare in modo che Firefox ricordi questa password?

Giuseppe longo
Last Login
Tue 04 Aug 2009
10:33PM GMT

My Experiments

Experiments List

Name	Science case	Mode
pippo	pzqso	pzrun
provapiero	pzqso	pzrun
prova2	pzqso	pztest
mimmo	pzgal	pztest
MAE	pzqso	pzrun
poppo	mlpregression	mlptrain
Test	mlpclassification	mlptrain
india	pzqso	pzrun

My Filestore

Dirs	Files	Actions
/longo		
	No data in this directory!	
/longo/MAE		Delete Download
	MAE.log	Delete
	catalogue_photozs.csv	Delete
	robust_sigma.txt	Delete

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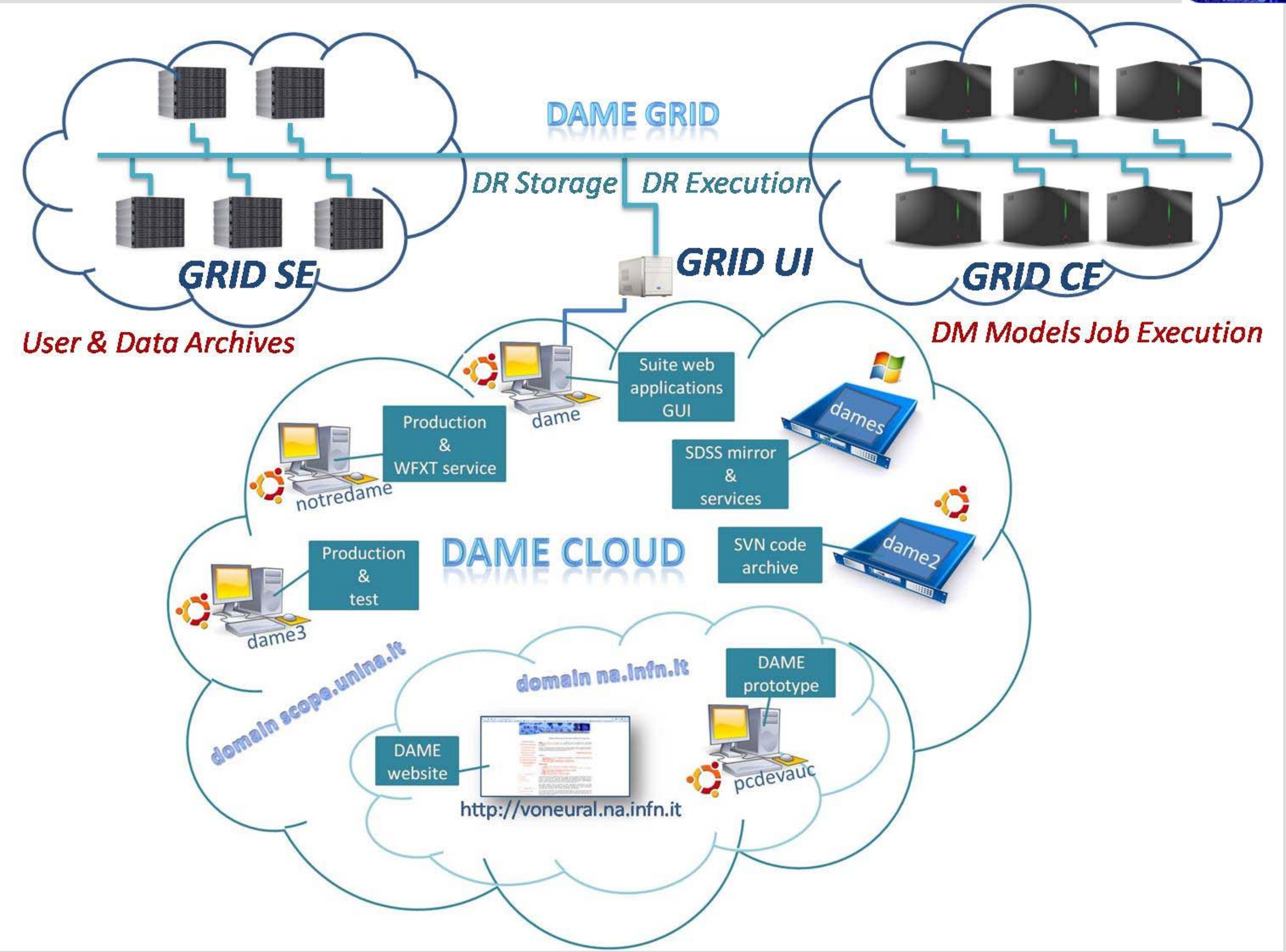
DAta Mining & Exploration
In this edition
A New trend in Astrophysics
Web Solutions for Data Mining in Astrophysics

The Infrastructure



DAME GRID

DR Storage

DR Execution

GRID SE

GRID UI

GRID CE

User & Data Archives

DM Models Job Execution

dame

Suite web applications GUI

dames

Production & WFXT service

notredame

SDSS mirror & services

DAME CLOUD

SVN code archive

dame2

Production & test

dame3

domain scope.unina.it

domain na.infn.it

DAME prototype

pcdevauc

DAME website

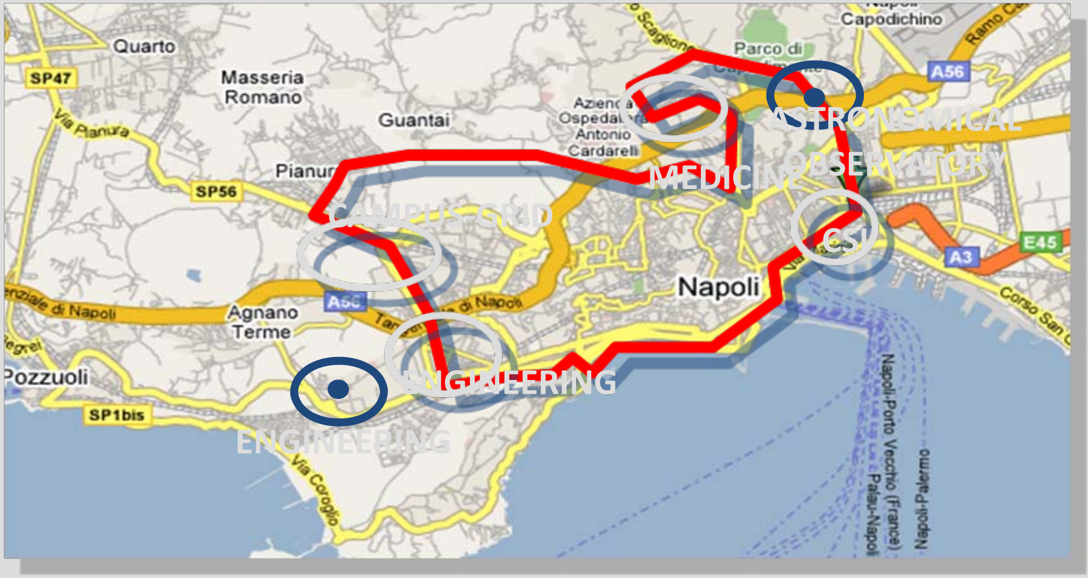
http://voneural.na.infn.it

The SCoPE GRID Infrastructure

SCoPE – Sistema Cooperativo distribuito ad alte Prestazioni per Elaborazioni Scientifiche Multidisciplinari (*High Performance Cooperative distributed system for multidisciplinary scientific applications*)

Objectives:

- Innovative and original software for fundamental scientific research
- High performance Data & Computing Center for multidisciplinary applications
- Grid infrastructure and middleware INFNGRID LCG/gLite
- Compatibility with EGEE middleware
- Interoperability with the other three “PON 1575” projects and SPACI in GRISU’
- Integration in the Italian and European Grid Infrastructure



The SCoPE Data Center

33 Racks (of which 10 for Tier2 ATLAS)

304 Servers for a total of 2.432 procs

300 Terabytes storage (100 for DAME)

5 remote sites (2 in progress)

The Available Services

DM WEB Application Prototype

Simplified Web Application providing via browser tools to configure and launch experiments:

SDSS (Sloan Digital Sky Survey)

Local mirror website hosting a complete SDSS Data Archive and Exploration System;

WFXT (Wide Field X-Ray Telescope) Transient Calculator

Web application to estimate the number of transient and variable sources that can be detected by WFXT within the 3 main planned extragalactic surveys, with a given significant threshold;

Coming soon (under commissioning):

VOGCLUSTERS

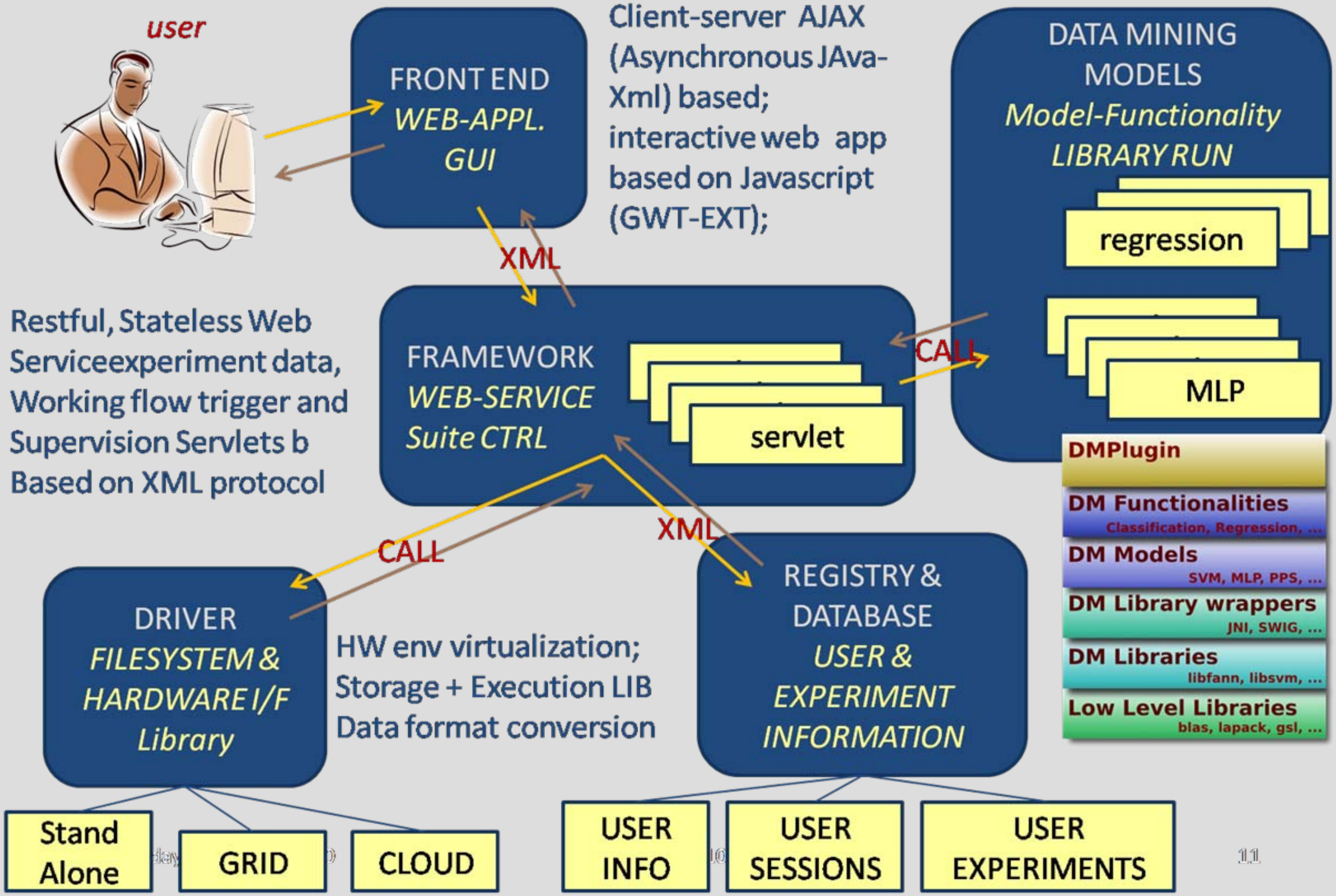
VO-compliant Web Application for data and text mining on globular clusters;

DM WEB Application Suite (the evolution of prototype)

Main service providing via browser a list of algorithms and tools to configure and launch experiments as complete workflows (dataset creation, model setup and run, graphical/text output):

- *Functionalities: Regression, Classification, Image Segmentation, Multi-layer Clustering;*
- *Models: MLP+BP, MLP+GA, SVM, PPS, SOM, NEXT-II;*

The DAME Architecture



FRONT END
WEB-APPL.
GUI

Client-server AJAX (Asynchronous JAva-Xml) based; interactive web app based on Javascript (GWT-EXT);

DATA MINING MODELS
Model-Functionality
LIBRARY RUN

regression

MLP

Restful, Stateless Web Serviceexperiment data, Working flow trigger and Supervision Servlets b Based on XML protocol

FRAMEWORK
WEB-SERVICE
Suite CTRL

servlet

DMPlugin

DM Functionalities
Classification, Regression, ...

DM Models
SVM, MLP, PPS, ...

DM Library wrappers
JNI, SWIG, ...

DM Libraries
libfann, libsvm, ...

Low Level Libraries
blas, lapack, gsl, ...

DRIVER
FILESYSTEM &
HARDWARE I/F
Library

HW env virtualization; Storage + Execution LIB Data format conversion

REGISTRY & DATABASE
USER &
EXPERIMENT
INFORMATION

Stand Alone

GRID

CLOUD

USER INFO

USER SESSIONS

USER EXPERIMENTS

Scientific Results

Photometric redshifts for the SDSS galaxies: It makes use of a nested chain of MLP (Multi Layer Perceptron) and allowed to derive the photometric redshifts for ca. 30 million SDSS galaxies with an accuracy of 0.02 in redshift. This result which has appeared in the Astrophysical Journal, was also crucial for a further analysis of low multiplicity groups of galaxies (Shakhbazian) in the SDSS sample;

D'Abrusco, R. et al., 2007. Mining the SDSS archive I. Photometric Redshifts in the Nearby Universe. Astrophysical Journal, Vol. 663, pp. 752-764

Search for candidate quasars in the SDSS: The work was performed using the PPS (Probabilistic Principal Surfaces) module applied to the SDSS and SDSS+UKIDS data. It consisted in the search for candidate quasars in absence of a priori constrains and in a high dimensionality photometric parameter space,

D'Abrusco, R. et al., 2009. Quasar Candidate Selection in the Virtual Observatory era. Under press in MNRAS

AGN classification in the SDSS: Using the GRID-S.Co.P.E. to execute 110 jobs on 110 WN, the SVM model is employed to produce a classification of different types of AGN using the photometric data from the SDSS and the base of knowledge provided by the SDSS spectroscopic subsamples.

A paper on the results is in preparation

Conclusion

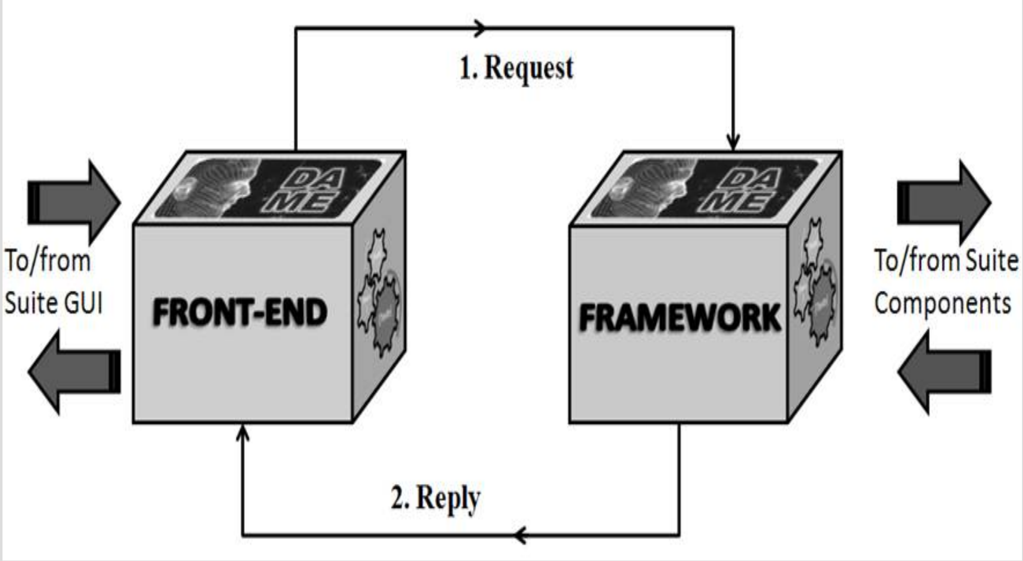
- we have designed and provided the DAME infrastructure to empower those who are not machine learning experts to apply these techniques to the problems that arise in daily working life.
- DAME project comes out as an astrophysical data exploration and mining tool, originating from the very simple consideration that, with data obtained by the new generation of instruments, we have reached the physical limit of observations (single photon counting) at almost all wavelengths.
- If extended to other scientific or applied research disciplines, the opportunity to gain new insights on the knowledge will depend mainly on the capability to recognize patterns or trends in the parameter space, which are not limited to the 3-D human visualization, from very large datasets. In this sense DAME approach can be easily and widely applied to other scientific, social, industrial and technological scenarios.
- Our project has recently passed the R&D phase, de facto entering in the implementation commissioning step and by performing in parallel the scientific testing with first infrastructure prototype, accessible, after a simple authentication procedure, through the official project website address.
- First scientific test results confirm the goodness of the theoretical approach and technological strategy.

Framework

The FW is the core of the Suite. It handles all communication flow from/to FE (i.e. the end user) and the rest of the components, in order to register the user, to show user working session information, to configure and execute all user experiments, to report output and status/log information about the applications running or already finished. One of the most critical factors of the FW component is the interaction of a newly created experiment with the GRID environment. The FW needs to create and configure the plug-in (hereinafter called DMPlugin) associated to the experiment. After the DMPlugin is configured the DR component needs to run the experiment by calling the run method of the plug-in. When executed on the GRID, the process needs to migrate on a Worker Node (WN). To implement this migration we've chosen to serialize the DMPlugin in a file. Serialization is a process of converting an object into a sequence of bits so that it can be stored on a storage medium. Our tests on the GRID environment indicates that this solution works fine and that the jdl file needed to manage the whole process is very simple.

Front End

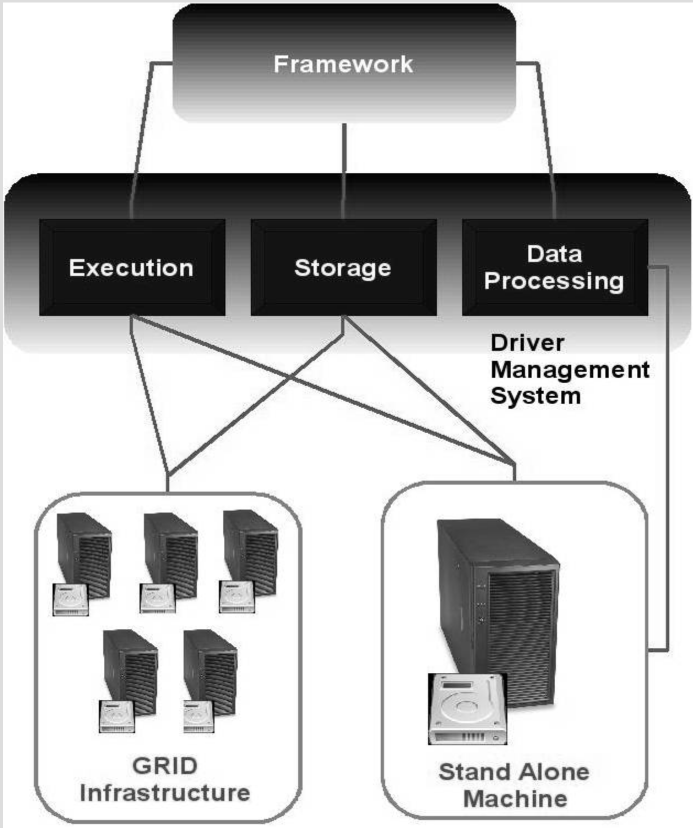
The component FE includes the main GUI (Graphical User Interface) of the Suite and it is based on dynamical WEB pages, rendered by the Google Web Toolkit (GWT), able to interface the end users with the applications, models and facilities to launch scientific experiments. The interface foresees an authentication procedure which redirects the user to a personal session environment, collecting uploaded data, check experiment status and driven procedures to configure and execute new scientific experiments, using all available data mining algorithms and tools. From the engineering point of view, the FE is organized by means of a bidirectional information exchange, through XML files, with the component FW, suite engine component.



Driver

The component DR is the package responsible of the physical implementation of the HW resources handled by other components at a virtual level. It permits the abstraction of the real platform (HW environment and related operative system calls) to the rest of Suite software components, including also I/O interface (file loading/storing), user data intermediate formatting and conversions (ASCII, CSV, FITS, VO-TABLE), job scheduler, memory management and process redirection (Fig. 3).

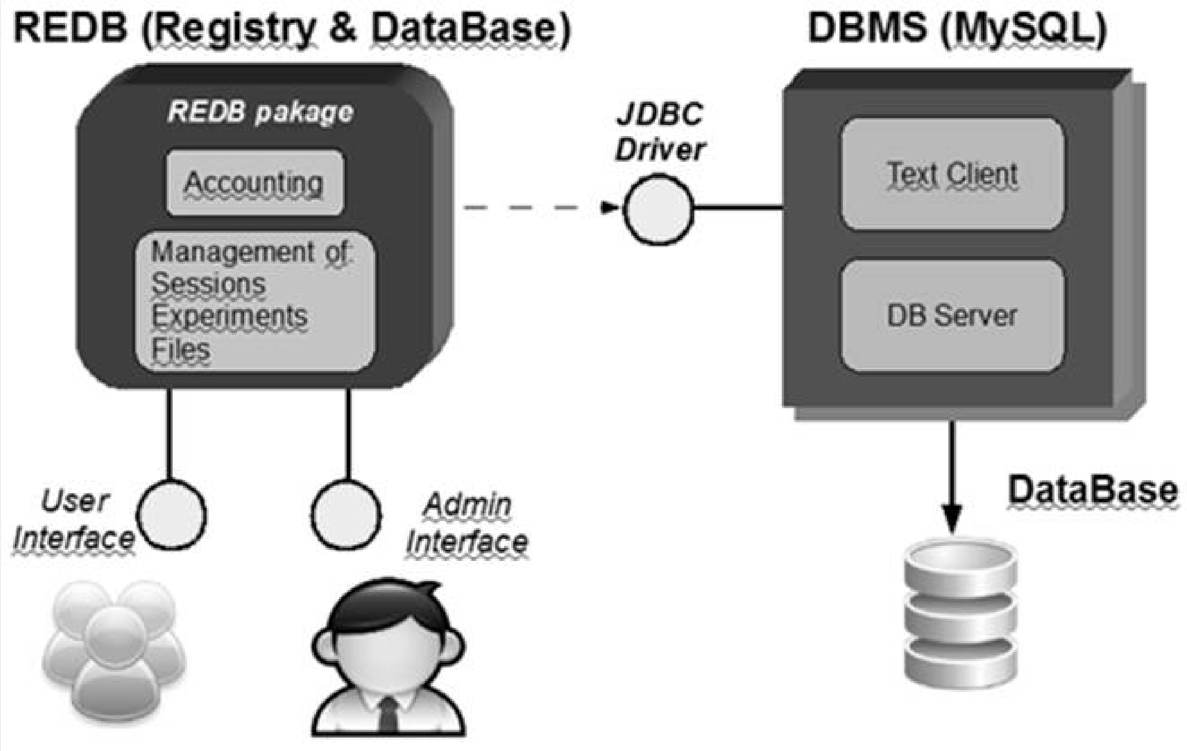
More in detail, a specific sub-system of the DR component, called DRiver Management System (DRMS), has been implemented to delegate at runtime the choice of the computing infrastructure should be selected to launch the experiment.



Registry and Data Base

The component REDB is the base of knowledge repository for the Suite. It is a registry in the sense that contains all information related to user registration and accounts, his working sessions and related experiments.

It is also a Database containing information about experiment input/output data and all temporary/final data coming from user jobs and applications.



Data Mining Models

The component DMM is the package implementing all data processing models and algorithms available in the Suite. They are referred to supervised/unsupervised models, coming from Soft Computing, Self-adaptive, Statistical and Deterministic computing environments. It is structured by means of a package of libraries (Java API) referred to the following items:

- Data mining models libraries (Multi Layer Perceptron, Support Vector Machine, Genetic Algorithms, Self Organizing Maps, etc…);
- Visualization tools;
- Statistical tools;
- List of functionalities (Classification, Regression, Clustering, etc…);
- Custom libraries required by the user;