A Grid based Medical Image Retrieval System using Alchemi

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Abstract: This paper proposes an approach to perform retrieval process on medical image databases by extracting semantic information from the dataset values of the DICOM (Digital Imaging and Communications in Medicine) format which produces a set of images relevant to the given query. Image retrieval in general has the goal to allow for the retrieval of similar images over very heterogeneous image collections to help the diagnostic process. With modern radiology, departments produce tens of thousands of images per day. It is apparent that infrastructures are required to treat this large amount of data. Grid technologies are among those approaches deployed to make computing power available to large-scale research projects. Often, the goal is to have a very large number of resources in various locations that can be shared for performing computationally intensive tasks. Grid computing has the potential to help computer science researchers in medical institutions to better use an existing infrastructure. It shows that particularly computationally–intensive tasks such as the extraction of features from large image databases can be performed much faster. Alchemi framework has been deployed in this paper to provide grid-based environment .Speeding up the retrieval process was one of the major achievements of this work.

1 INTRODUCTION

Computer grids are promising architectures with a strong potential for sharing resources. They are generally valued for the large computing power and data storage space they provide. Beyond this interest, grid technologies allow scientists federated in Virtual Organizations (VOs) to easily share datasets and algorithms across boundaries of their organizations. All these grid characteristics make them particularly interesting for the medical community who deals with large and fragmented amounts of medical images. As a consequence, various medical images simulation, storage, and processing applications have recently been developed on grids (Montagnat et al., 2004b). The problem of large scale image indexing and retrieval remains relevant for many of them.

The proposed system uses Alchemi which is an open source software framework that can be deployed to aggregate the computing power of networked machines into a virtual supercomputer (desktop grid) and to develop applications to run on the grid. The proposed system uses the DICOM information for performing the retrieval on medical images. The retrieval is performed by extracting semantic features from the dataset values of the DICOM format. The extracted information can be used to perform the retrieval which produces a set of images relevant to the given query.

The rest of this paper is organized as follows: section 2 provides a brief introducing to general grid computing principles. Section3 explains database partitioning on grid. Section 4 discusses content based image retrieval. Section 5 presents our proposed system and its modules. Section 6 discusses the experimental results. Section 7 provides some concluding remarks.

2 GRID ENVIRONMENT

Computer grids consist of a network of computers providing distributed computing and storage resources to their users through a grid middleware. The middleware is the software layer implementing basic services to access a grid infrastructure and hiding the system complexity to the user (Camarasu

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et al., 2008). Alchemi is one of the Software frameworks to enable grid computing. It has been primarily written for UNIX operating systems. However, Microsoft .Net framework provides a platform to implement windows based grid computing environment with Alchemi as shown in Figure1. In particular, it also provides remote execution, security, multithreading,, asynchronous programming, disconnected data access, and managed execution. This makes it an ideal platform for grid computing middleware (Dhivya and Ruba, 2012).

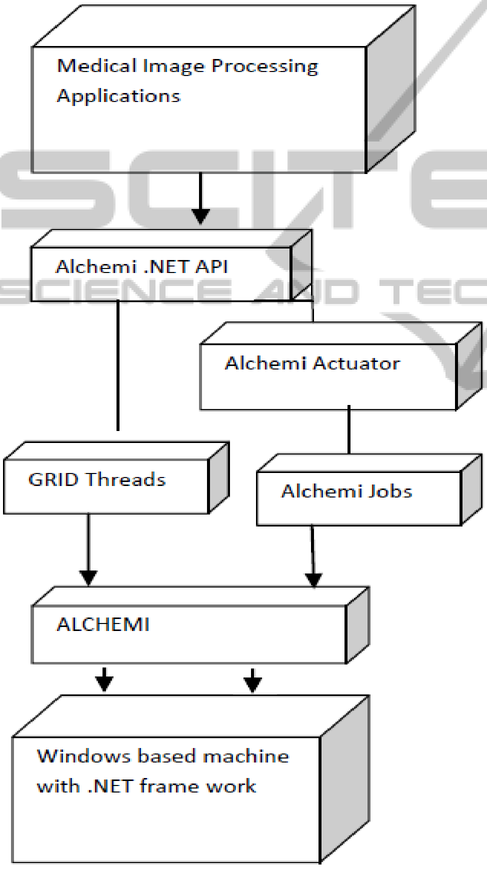


Figure 1: Layered Architecture of distributed Windows.

2.1 Architecture

Alchemi (Luther et al., 2005) follows the master-worker parallel programming paradigm in which a central component dispatches independent units of parallel execution to workers and manages them. This smallest unit of parallel execution is a grid thread. A grid application is defined simply as an application that is to be executed on a grid and that consists of a number of grid threads. Grid applications and grid threads are exposed to the grid application developer via the object- oriented Alchemi .NET API. Alchemi tool describes the four components. They are:

- Manager
- Executor
- Cross-platform manager
- Owner

These components allow Alchemi to be utilized to create different grid configurations desktop cluster grid, multi cluster grid, and cross-platform grid (global grid). (Dhivya and Ruba, 2012)

2.1.1 Cluster Desktop Grid

The cluster desktop grid (shown in Figure 2), consists of a single Manager and multiple Executors. One or more Owners can execute their applications on the cluster by connecting to the Manager. Such environment is appropriate for the deployment on Local Area Networks as well as the Internet. (Dhivya and Ruba, 2012).

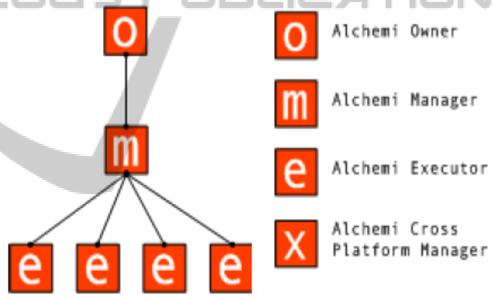


Figure 2: Cluster (Desktop Grid) Deployment.

2.1.2 Multi Cluster Deployment

A multi-cluster environment (shown in Figure 3) is created by connecting Managers hierarchically .As in a single-cluster environment, any number of Executors and Owners can connect to a Manager at any level in the hierarchy. The key to accomplishing multi-clustering in Alchemi's architecture is the fact that a Manager at a given “intermediate” level is treated by the higher level-Manager as an Executor. Such an environment is more appropriate for the deployment over the Internet.

2.1.3 Cross-Platform Manager

A grid middleware component such as a broker can use the Cross-Platform Manager (Shown in Figure 4) web service to execute cross-platform applications (jobs within tasks) on an Alchemi node (cluster or multi-cluster) as well as resources gridenabled using other technologies such as Globus. (Dhivya and Ruba, 2012).

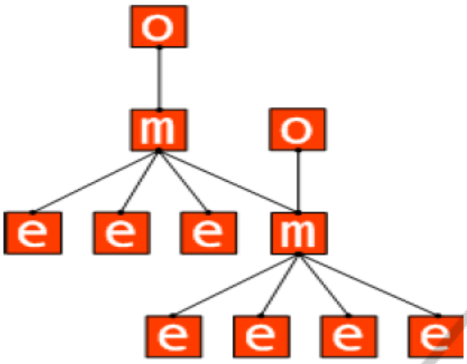


Figure 3: Multi Cluster Deployment.

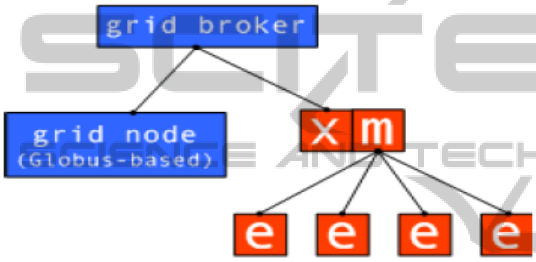


Figure 4: Cross-Platform Manager.

3 DATABASE PARTITIONING

In this paper we study the impact of executing a medical image database query application on the grid. For lowering the total computation time, the image database is partitioned in equal subsets to be processed on different grid nodes. A theoretical model of the application computation cost and estimates of the grid execution overhead are used to efficiently partition the database. Smart partitioning of the database can lead to significant improvements in terms of total computation time (Montagnat et al., 2004).

If the database is partitioned in bags of images to be analyzed, each bag can be analyzed by a single computing job. If one bag is representing one image so that all images could be processed in parallel, then Alchemi threads could work in parallel. Hence, the execution time would be the maximum of the execution times of each image processing. See Figure 5.

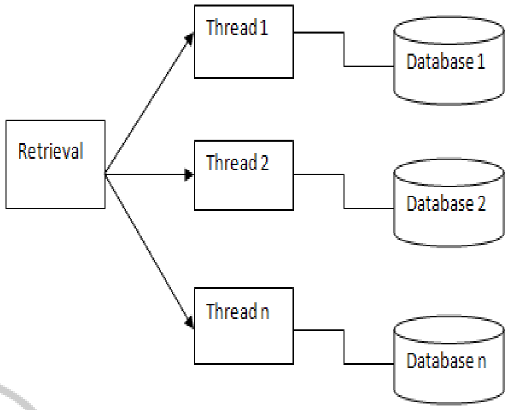


Figure 5: Database Partitioning Process.

4 CONTENT BASED IMAGE RETRIEVAL

A large number of medical images in digital format are generated by hospitals and clinics every day. Such images constitute an important source of anatomical and functional information for diagnosis of diseases, medical research, and education. It is well known that medical image databases are the key component in diagnosis and preventive medicine. This increasing trend towards digitization of medical images creates a need of technologies for storage, organization, and retrieval of the medical images. Content based image retrieval (CBIR) is the digital image searching problem in large databases that makes use of the contents of the images themselves rather than relying on the textual information. These techniques use the automatically derived features (low level feature) such as color, texture and shape as search criteria. Medical images generated in hospitals contain semantic information (high level feature). This information can be used to retrieve the images.

4.1 Semantic Feature Extraction

The DICOM standard was created by the National Electrical Manufacturers Association (NEMA) to aid the distribution and viewing of medical images, such as CT(Computed Tomography) scans, MR(Magnetic Resonance), and US (Ultrasound). Imaging equipment used in hospitals generates images which are in DICOM format. It is a standard format used to obtain, store and distribute medical images. DICOM comprise standardized textual descriptions of study, patient, body region examined and modality. A single DICOM file contains both a header (which stores information about the patient's name, the type of scan, image dimensions, etc), as well as all of the image data. This is different from the popular Analyze format, which stores the image data in one file (*.img) and the header data in another file (*.hdr). The DICOM header size varies depending on how much header information is stored. The header describes the image dimensions and retains other text information about the scan. DICOM files are composed by one image and tags describing the image. Tags are textual or numerical sequences of <attribute, value> pairs. The textual information is considered as the semantic information. For all the DICOM files the image and the relevant tags are extracted and are stored in the database. The image is stored in jpeg file format. The extracted semantic information is stored in the database which is used during the retrieval process. (Selvarani and Annadurai, 2007).

4.2 Content Feature Extraction

Content Based Retrieval system represents each image as a feature vector and measures the similarity between images as the distance between their corresponding feature vectors. For medical images, shape and texture are the two important low level features which describe the content of the image. The shape and texture features are extracted and stored in the database as feature vectors. (Selvarani and Annadurai, 2007).

5 PROPOSED SYSTEM

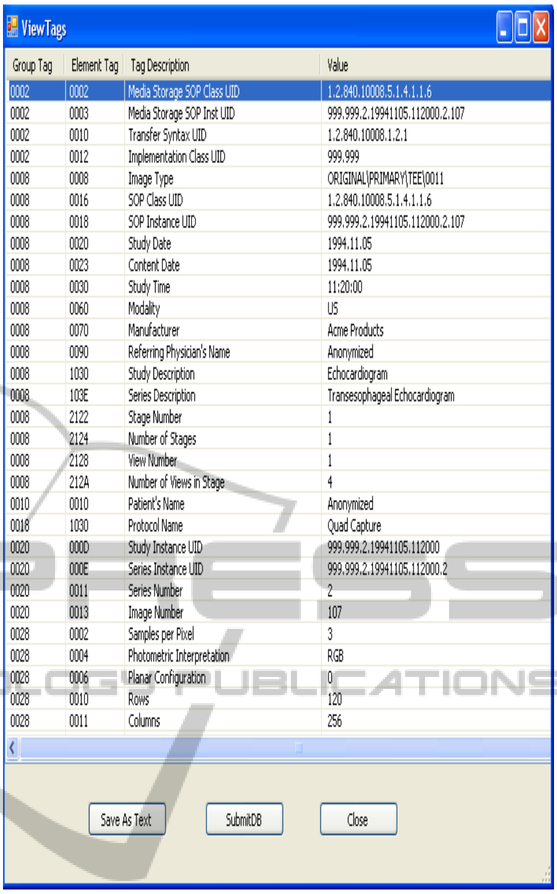
5.1 Semantic Feature Extraction Module

Semantic features module extracts DICOM tags information from .dcm files format. Some extracted DICOM information can be observed in Figure 6.

After extracting all needed features from images, it will be stored in SQL database server to be used in searching process, and then the database is transported to computation nodes and partitioned to equally sized subsets.

5.2 Database Modules

The database consists of 2 parts: DICOM images and DICOM tags (Semantic Feature).



Group Tag	Element Tag	Tag Description	Value
0002	0002	Media Storage SOP Class UID	1.2.840.10008.5.1.4.1.1.6
0002	0003	Media Storage SOP Inst UID	999.999.2.19941105.112000.2.107
0002	0010	Transfer Syntax UID	1.2.840.10008.1.2.1
0002	0012	Implementation Class UID	999.999
0008	0008	Image Type	ORIGINAL\PRIMARY\TEE\0011
0008	0016	SOP Class UID	1.2.840.10008.5.1.4.1.1.6
0008	0018	SOP Instance UID	999.999.2.19941105.112000.2.107
0008	0020	Study Date	1994.11.05
0008	0023	Content Date	1994.11.05
0008	0030	Study Time	11:20:00
0008	0060	Modality	US
0008	0070	Manufacturer	Acme Products
0008	0090	Referring Physician's Name	Anonymized
0008	1030	Study Description	Echocardiogram
0008	103E	Series Description	Transesophageal Echocardiogram
0008	2122	Stage Number	1
0008	2124	Number of Stages	1
0008	2128	View Number	1
0008	212A	Number of Views in Stage	4
0010	0010	Patient's Name	Anonymized
0018	1030	Protocol Name	Quad Capture
0020	000D	Study Instance UID	999.999.2.19941105.112000
0020	000E	Series Instance UID	999.999.2.19941105.112000.2
0020	0011	Series Number	2
0020	0013	Image Number	107
0028	0002	Samples per Pixel	3
0028	0004	Photometric Interpretation	RGB
0028	0006	Planar Configuration	0
0028	0010	Rows	120
0028	0011	Columns	256

Figure 6: DICOM Tags.

5.2.1 DICOM Images

We used a database of 100,000 images from 6000 patients. The selected images were composed by CT and MR images representing different anatomical structure: Head, heart, Shoulders ..., etc. DICOM images are stored as image data types, which are data types that hold any type of binary data. We read BLOBs (Binary Large Objects) as streams and manipulate/display images according to the information (e.g., Bit Depth) extracted from the DICOM Info file.

5.2.2 DICOM Tags

For each DICOM image we extract all DICOM semantic features and store it in SQL database and make relation between image and its semantic information for the ease of retrieval process.

5.3 DICOM Selection Module

In this module, the user interface guides user to construct the query performing the selection by querying DICOM tags. The system then selects the most appropriate images related to these tags. The selection is based on a simple SQL database query.

5.4 Output Module

In this module, the proposed system collects the resulted images from all threads and then displays it on the screen .Also all information related to the resulted images are available to users who can save it in a text or xml file format.

6 EXPERIMENTAL RESULTS AND DISCUSSION

We construct Dictionary containing all DICOM tags to allow users to choose tags related to their query attributes. Assume that the user query is to retrieve all the images of US modality. The user must specify the query attributes (e.g., Acquisition Date, Modality, Patient Name, Admitting Diagnosis Description) using interface module. This is shown in Figure 7.

When the user selects the search operation, the system connects to grid middleware, and then Alchemi imitates traditional multi threaded programming. GThread is a grid thread and GApplication is application thread. “*Just in time scheduler algorithm”* is used for splitting the comparison job into different threads. Assume that *T1, T2, T3….Tn* are the threads generated by Alchemi. Alchemi owner provides an interface with the grid application between the application developer and the grid. The owner submits the completed threads to the Alchemi Manager. The Alchemi Manager manages the execution of threads responsible for the searching process in its own dataset.

The executors register themselves with the Manager which in turn keeps track of their availability. Threads received from the Owner are placed in a pool and scheduled to be executed on the various available Executors. The Executor accepts threads from the Manager and executes them. Executor API is used to make an interface with the Alchemi Manager.

Figure 8 shows the configuration of Alchemi Manager. In the figure, setup connection enables or starts the Alchemi manager. Figure 9 shows the configuration of Alchemi Executor that contains the host and the port number of connectivity, and

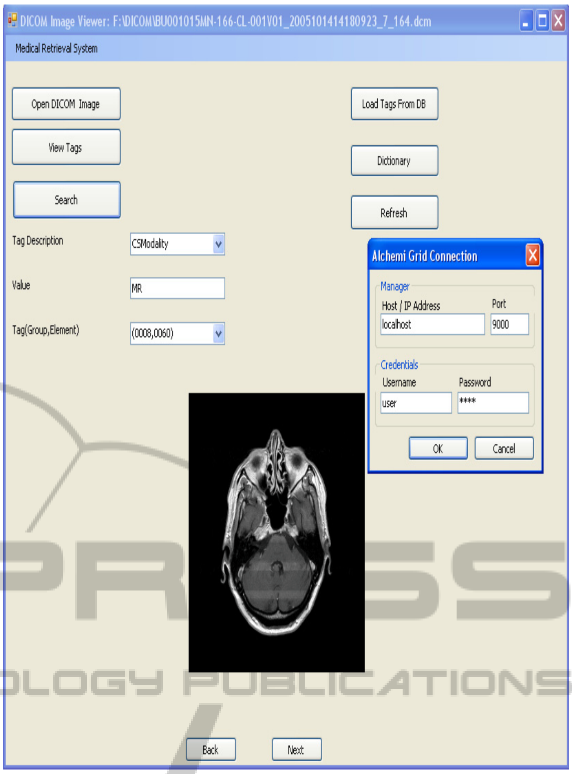


Figure 7: User Interface.

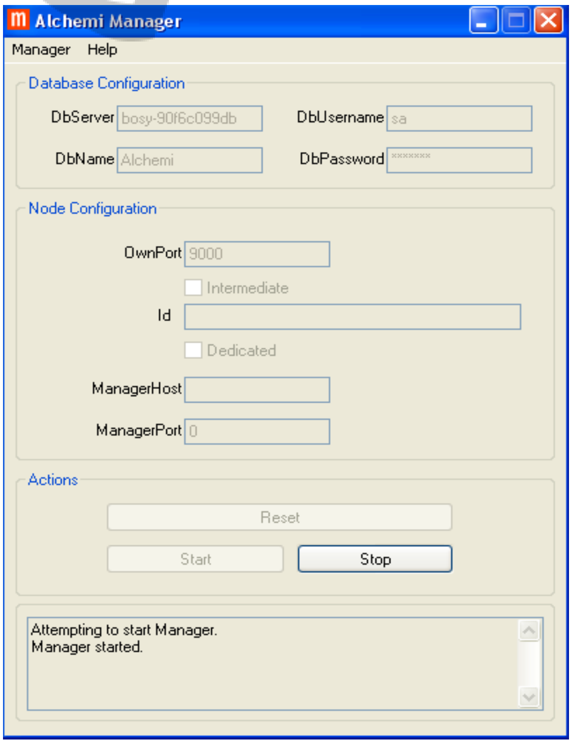


Figure 8: Manager Window.

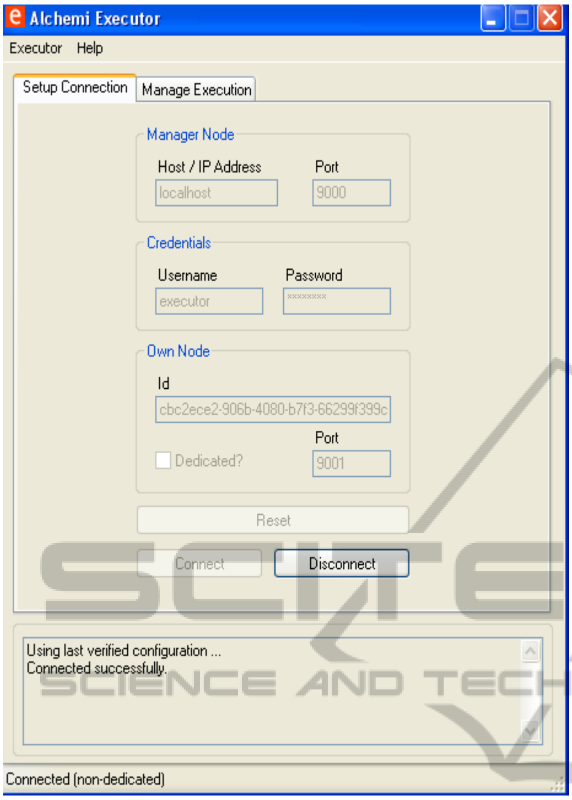


Figure 9: Executor Window.

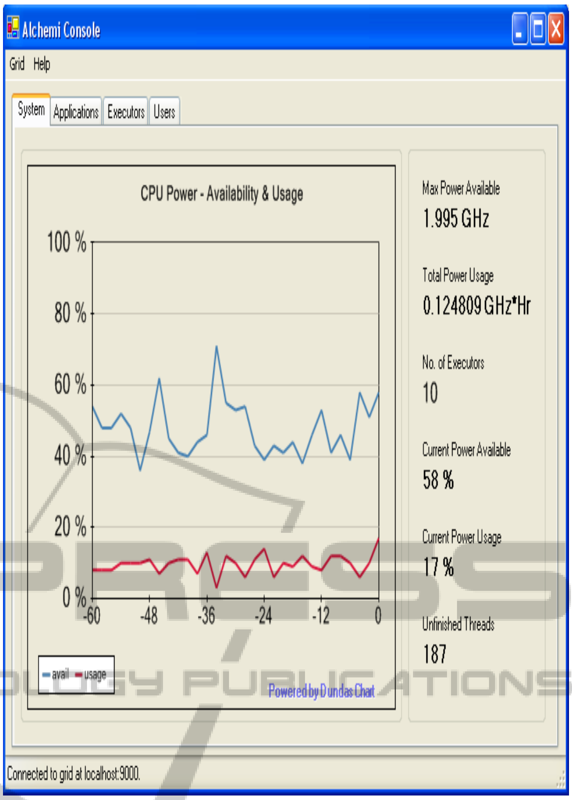


Figure 10: Console Form.

credentials required to login on to the system. Figure 10 shows Console Form .This form provides the system statistics and real time graph of power availability and usage.

We can see that partitioning the dataset on different executor nodes while there is no task dependency can lead to a significant improvement in the retrieval time. Figure 11 provides a comparison between sequential and parallel execution time. The system was tested on set of 100,000 images .We had provisioned 10 executor nodes.

Processing sequentially can be an inefficient way to handle large datasets. The gap in runtime greatly increases as the dataset grows larger in size .These results demonstrate that the grid computing can dramatically reduce the time required to retrieve medical images.

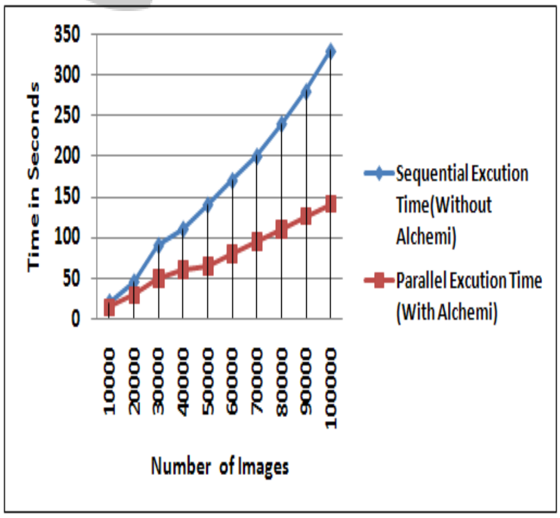


Figure 11: Comparison between Sequential and Parallel Execution Time.

7 CONCLUSIONS

In this paper we propose a grid based system for retrieving medical images. Grids are promising architectures that can bring different solutions to medical image storage and retrieval problems. The proposed system performs content based medical image retrieval by extracting semantic information from the dataset values of the DICOM format which produces a set of images relevant to the given query. To speedup retrieval process, we partitioned the database into equally sized subsets. So, queries can benefit from the grid computing parallelism and execute different queries, each on a different subset of images. We can see that Alchemi framework is ideally qualified to be deployed in medical image retrieval system .Of course, as the number of executors increases, the overall system performance increases. The system is considered a step towards a complete grid-based implementation for a complete medical retrieval system.

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