

Archimedes, an Archive of Medical Images

<http://www.cs.umd.edu/~hjs/escience.html>

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ABSTRACT -- We present a medical image and medical record database for the storage, research, transmission, and evaluation of medical images. Medical images from any source that supports the DICOM standard can be stored and accessed, as well as associated analysis and annotations. Retrieval is based on patient info, date, doctor's annotations, features in the images, or a spatial combination. This database supports the secure transmission of sensitive data for tele-medicine and follows all HIPAA regulations. Additionally, research into the techniques used by radiologists is possible in Archimedes through double-blind radiologist comparisons based on their annotations and feature markups.

INTRODUCTION -- Most retrievals in medical image database systems are based on the patient identification information or image modality as it is defined in the DICOM standard, and it is hoped that inclusion of other features can improve the effectiveness of this type of system.

Archimedes is an image analysis and patient records management tool intended for the use of the medical community. It allows doctors to search for common features in a database of images via innovative combinations of search techniques and algorithms. This system allows the rapid retrieval of images and patient records, and can also find patients with similar images, conditions, or annotations to compare treatment successes. Searchable images types include common medical images such as x-rays, mammograms, CAT scans and MRIs. Doctors can quickly and easily retrieve patient records with the use of Archimedes' electronic image searching capabilities. The software archives the addition of markups and annotations to images, and supports auditing and reviewing of doctors' decisions. Archimedes satisfies the strict legal constraints of patient information for hospitals and other medical institutions.

Archimedes was originally designed as a research tool for capturing and comparing radiologists' diagnosis in double-blind studies on breast cancer, but the extensive search capabilities and data tools make it an effective tool for tele-radiology, medical research, and medical informatics applications.

SEARCHING CAPABILITIES

Search By
Patient Information Feature Spatial Annotation
First Name:
Last Name:
Social Security #:
Date of Birth (yyyy-mm-dd):
Date of Image (yyyy-mm-dd):

Patient Search --This type of searching over patient information (i.e. First name, Last name, date of birth, etc.) The results are displayed in the result list.

Search By
Patient Information Feature Spatial Annotation
Select a feature: ANY ANY
ANY ANY

Feature Search --Searching by feature allows the doctors to specify feature parameters they wish to see in all the images in the return set.

Search By
Patient Information Feature Spatial Annotation
Search text:

Annotation Search --This allows doctors to search for comments other doctors previously made about certain images. Not only will this help in quickly determining information about a patient, but can also help doctors in understanding new patients' with similar problems or diseases. An example of a doctor using an annotation search would be for the words "biopsy recommended".

Search By
Patient Information Feature Spatial Annotation
Select feature A: ANY
Distance (pxds):
Select feature B: ANY

Spatial Search - Doctors can use this when searching certain information about images. They can be looking for combinations of features in an image, or clusters of features in an image. The results will be displayed in the results list, allowing the doctors to choose or further filter them.

Filters
Pathology: Any
Race: Any
Weight Min: Any
Weight Max: Any
Scanner Type: Any
Image Type: Any
Search

Filters -- After performing a query, users are able to further refine their query by filtering the results set.

Functionality of Archimedes

Feature Based Search

The feature-based search capability of Archimedes enables users to search for predefined and user-defined features within medical images. This ability is useful for doctors who would like to locate existing information on specific features of a tumor. Doctors are provided the flexibility of searching on the basis of existing, pre-defined features or by defining their own user-defined features that will subsequently be added to the list of pre-defined features. By filtering the results sets into malignant or benign, the effectiveness of a feature at predicting malignancy can be measured. Similarly, by filtering the results into malignant or normal and benign, the effectiveness of the feature at predicting cancer can be measured.

Spatial Search

The spatial search capability of Archimedes provides users with the ability to determine the relative positions between two features on an image. This allows the user to search for a combination of features within a small area of the image, as well as find clusters of features in the images. This allows the creation of meta-features, or features combined together to create a more effective feature. This technique can also be used to compare radiologist diagnoses and research radiologist technique through the double-blind capabilities of Archimedes.

Annotate Images

The user is given the ability to associate plain text notes with a particular image. By clicking on the image, the user can also see a full-screen view of the image. Below the full-size image, the editable text box allows users to write notes pertaining to (i.e., annotate) that particular image. Multiple users are allowed to annotate the same image at the same time because they each make changes on a their own overlay.

Textual Search and Patient Information Search

The user can perform a textual search on annotated images. The bottom portion of the Search Options screen enables the user to enter text into a text field that is then used to query all existing annotated images. Queries return images as the result of the search. Images can also be searched for with patient information.

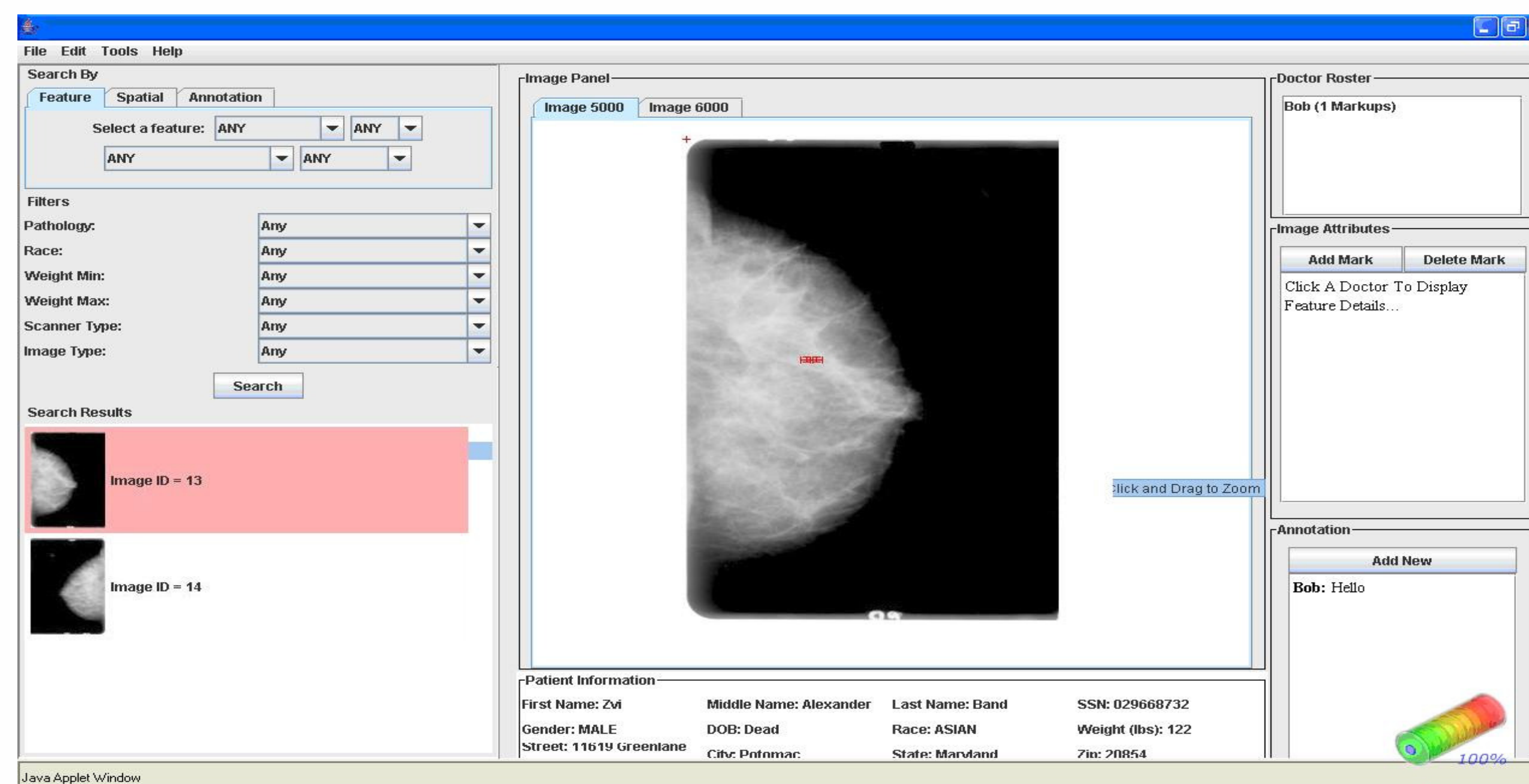
Overlay Image Features

This utility allows the user to markup the image by clicking on it and creating a crosshair representative of an area of interest to the doctor. The user will click on the image and a pop-up window will appear, requiring the doctor to fill in data and specify the size of the annotation.

Zooming and Grabbing of Images

This utility allows the user to zoom into interesting parts of the image, and grab the image to move it around in the screen.

XML Format for Uploading and Downloading of Images, Features, and Related Information
This utility allows the user to easily upload and download data in XML as well as DICOM format.



User Interface of Archimedes

The graphical user interface is arranged into four major sub frames: Search, Image, Attributes and Annotation, and Patient Information.

Search: Initially, this panel contains all the search options available to the user. After the search, the panel shows the image results by thumbnail and associated data as determined from the patient key. The selected image is highlighted in red and displayed in the image panel, along with associated images in the tabs.

Image Panel: Shows the currently active image as well as associated patient data. Users can see thumbnails of the previous and next images in the set, and can move through the images associated with a patient by set and by image. Users can also zoom in and out of the image, as well as repositioning it. Features can be directly entered onto the image.

Attributes and Annotation: Information about the doctors who have annotated this image as well as their associated markups are displayed. An additional text field allows the doctor the ability to make and save notes (termed annotation) specific to the image for future reference as well as view the annotations of other doctors.

Patient Information: The patient information for the image is displayed here. Patient data is only available to authorized doctors, while images can be made public to display research data.

Archimedes Capabilities

Double-Blind Studies of Radiologist Methodology

By using the markup and annotation capabilities of Archimedes, individual radiologists can make their own diagnosis. Since Archimedes is web-based, the doctors can work in separate cities or countries. These can then be compared using the spatial search to find when they are close enough to the "truth" to be valid. A range of distances can be used. Multiple radiologists can be combined using the spatial search to provide a double-reading comparison, and then a triple-reading comparison, all of which can be compared to the "truth" within a range of distances. The results can be instantly published by allowing guest access, which enables public viewing of the anonymized images and markups, as well as results if so desired.

Feature Determination for Diagnosis Technique

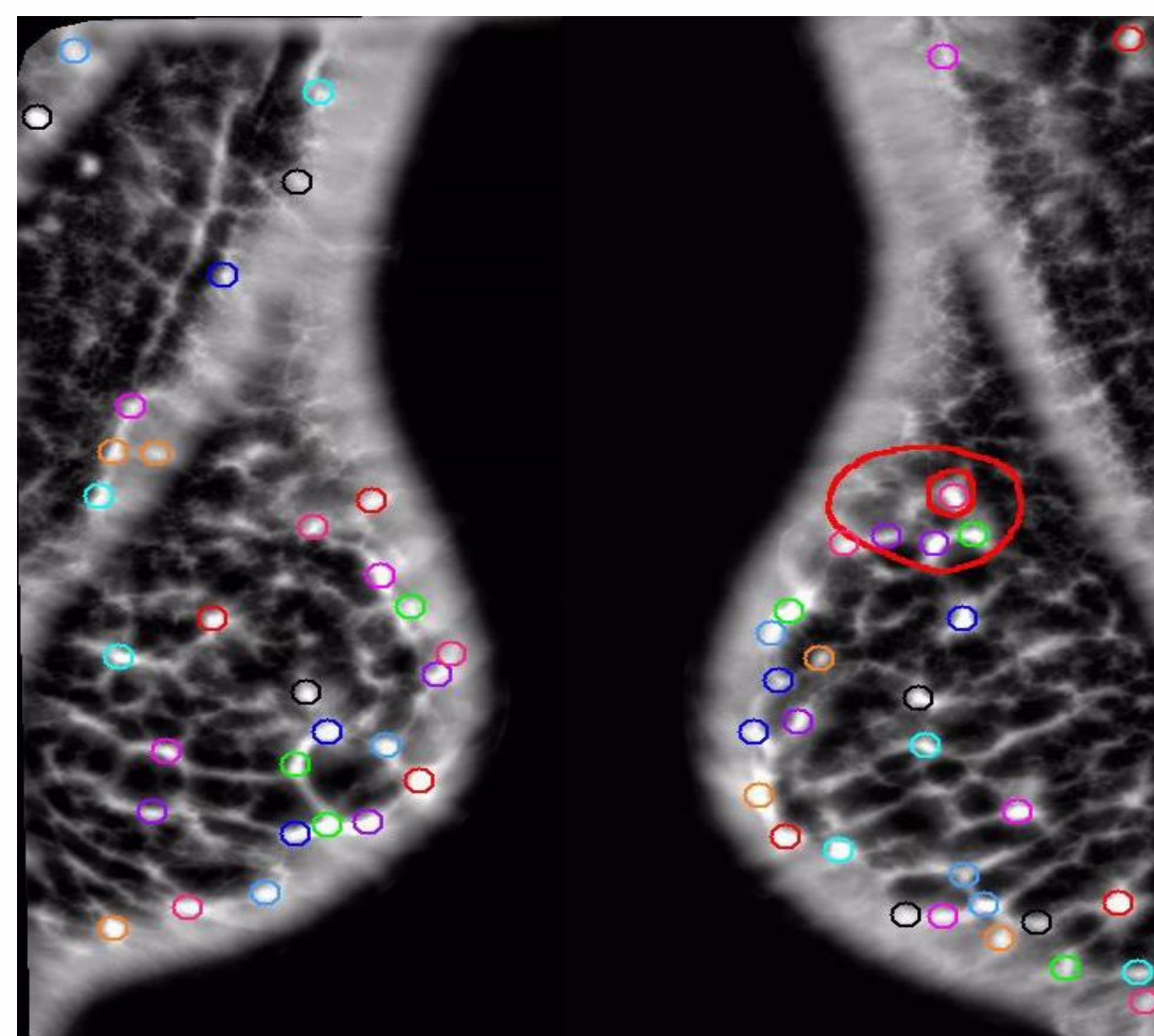
The spatial search capability of Archimedes provides users with the ability to determine which features and feature combinations would provide the optimal set of diagnosis criteria for a given set of medical images. Using the filtering tool to sort the result set into malignant, benign, and normal cases gives the resulting percentages for that particular set of diagnosis criteria.

Tele-Radiology

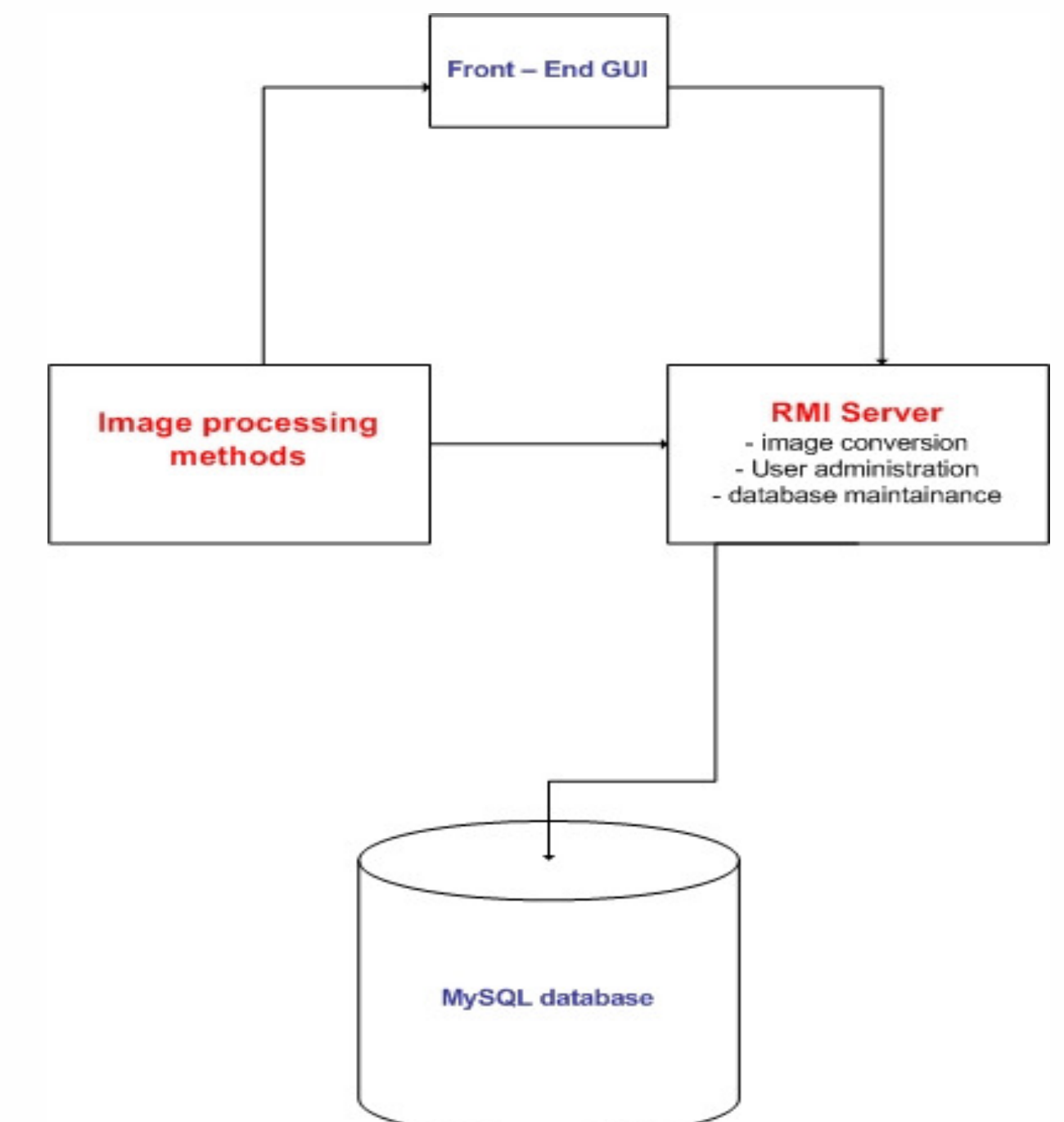
Archimedes can encrypt and upload image sets, patient information, and text to the server from a remote station with internet access. The images can then be diagnosed, marked up, and annotated by a radiologist, and the diagnosis can then be viewed by at the remote station, along with any textual instructions.

CAD Improvement

By storing and sharing images, feature sets, radiologist diagnoses, and CAD results sets, Archimedes simplifies the creation and comparison of Computer-Aided Detection (CAD) approaches.



Mammograms of the left and right breasts, MLO view. The tiny multi-colored circles are automatically extracted shape features, while the thicker red lines are the hand-drawn annotation of a cancer by a radiologist. The shape features cluster in and around the cancer, but there are many false-positives. Combining multiple shape features with a spatial query could reduce the number of false-positives. Additionally, comparing the left and right breast features in a spatial query could also improve the performance, as could a distance query which would pick out the clustering of shape features. Archimedes can incorporate automatically extracted features.

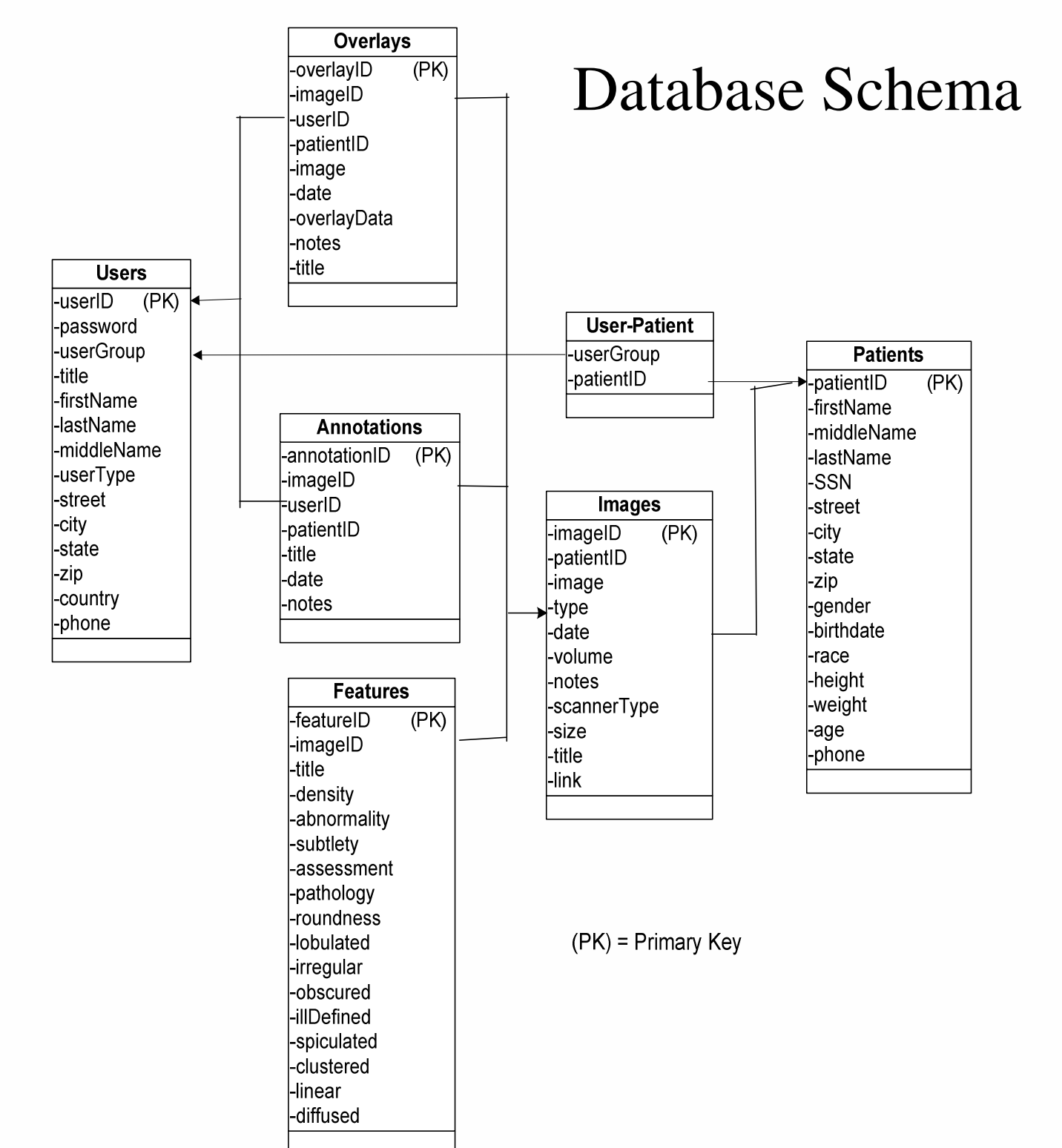


Archimedes Design

Archimedes is a three-tiered application including backend server, server logic unit, and web front end user interface. Access to images can be either tightly controlled and private, public, or semi-private, while access to patient information is always tightly controlled and private. Administration is simplified through the use of groups, where semi-private images have groups of trusted researchers associated with them to help provide analysis. This is also helpful for administering research studies where the research group is set as the image default setting.

System Security

The program must maintain a high level of security due to privacy issues associated with maintaining patient sensitive medical information. The application runs within an applet, independently controlled on the server-side. Information transmitted to the front-end is encrypted via the AES encryption scheme. The user must login with his/her username and password in order to access the system. All modifications during program use are monitored and logged by the system. Any changes to images or image overlays are recorded and time-stamped in a log-file on the server. The administrator is the only user authorized to view the logs.



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