

A System for Distributed Image Acquisition, Content-Analysis and Similarity Retrieval

Ibrahim Noorzaie, Y. Alp Aslandogan, M. Emre Celebi

Department of Computer Science and Engineering
University of Texas at Arlington
Box 19015, Arlington, TX 76019-0015

noorzaie@cse.uta.edu, alp@cse.uta.edu, celebi@cse.uta.edu

Abstract

Emergence of mobile communications devices capable of acquiring high-resolution images and sensor devices with communication capabilities contributes to the increasing feasibility of remote screening of various medical and environmental conditions. In this work we present a system that supports remote acquisition of images and similarity retrieval from a centralized database after automatic content analysis. The system supports remote image acquisition by a device such as a smart phone, wireless PDA or digital camera, and communication via the Internet. While the system architecture is generic to accommodate various uses, we have implemented a prototype for the remote screening of skin lesion images. Accordingly, the system incorporates content analysis modules such as a segmentation module, shape analyzers and a shape-feature based similarity computation module. The whole process is automated: Clients use a web interface to submit a query image, which goes through an automated analysis procedure and produces an interactive report containing similar images and a risk analysis report. Immediate application areas include distributed detection and monitoring of environmental hazards, recognition of biochemical security threats and medical conditions.

1. Introduction

Simultaneous emergence of mobile communications devices capable of high resolution image acquisition and image acquisition devices (or sensors) with communications capabilities are opening new opportunities for the remote, distributed screening of medical and environmental conditions. In this work we describe a system that supports remote image acquisition and centralized content analysis as well as similarity retrieval from a large database, possibly accompanied by

risk assessment. Medical or environmental expertise and large data banks tend to concentrate in large centers. In the medical domain, for instance, it is difficult to access most expert physicians in rural areas and in certain urban neighborhoods. Environmental hazards similarly occur at places where expertise or large comparable data sets may not be available. The system described in this work enables health-care providers and environmental inspectors to access large data banks and carry out automatic risk analyzes. While the system architecture is generic enough to support multiple uses, our prototype is designed to support remote screening of skin lesions.

The primary goal in screening skin lesions is to identify early occurrences of a deadly skin cancer known as Malignant Melanoma, which is linked with excessive sun exposure and ultraviolet radiations [2]. According to National Cancer Institute, melanoma is the most serious type of skin cancer affecting more than 50,000 people, and causing the deaths of more than 10,000 yearly in the United States [20]. The best cure for melanoma is early detection [2, 25]. Doctors recommend monthly self-exams, which include checking for new moles, change in shape, color, size and texture of moles and sores that are not healing [20]. The diagnosis of malignant melanoma at the primary care level is difficult as confirmed by the somewhat moderate diagnostic rates achieved by dermatologists [19]. For this reason there is a growing body of research on using image analysis methods to aid the diagnosis of melanoma [8].

An overview of the system architecture is shown in Figure 1. The process of lesion image analysis involves isolating lesions in an image and analyzing them for some visual features. The results of this analysis are then used in the process of making a judgment on how similar this query image is to previously diagnosed images. We have so far only experimented with shape features of skin lesion images. Color or texture features can as well be utilized in the system without much effort. Users can

access the system via email with multimedia extensions or over the World Wide Web.

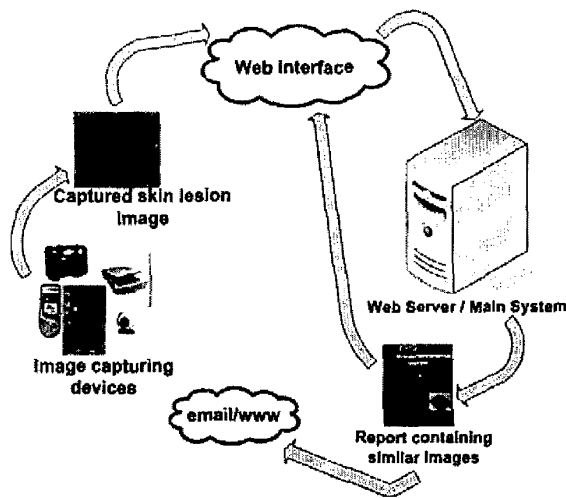


Figure 1. Overview of the System Architecture

The rest of the paper is organized as follows: Section 2 describes the system architecture. Section 3 describes preprocessing and shape feature extraction stages. Section 4 explains data storage and transfer functionalities. Section 5 details image similarity algorithms and dynamic report generation. Section 6 discusses the related work. Finally, Section 7 presents conclusions and the future work.

2. Overview of the architecture

Automatic image analysis helps dermatologists to give accurate and reproducible diagnosis [9]. An important aspect of our system is to automate several processes that would otherwise require tedious user interference and expert domain knowledge. The system is based on a modular design, which allows for multi-user access. Several parts of the system can be accessed independently from other locations in the system. Since most components are reusable, they can independently be used by other systems as well. In the rest of the section we will discuss the steps involved in the entire procedure, which is depicted in Figure 2.

Step 1 is the user input stage. A simple and user-friendly web interface is designed for this purpose. This interface enables the user to submit an image to the system for analysis. At this stage, besides submitting the image, the user can set several options regarding the

analysis procedure. For example, the user can choose the Query Database, which can be the Main Database or User Database. The Main Database is a large repository of skin lesion images maintained for this system. The User Database contains images that are stored as part of previous queries by the same user as well as queries by the other users. The user is required to provide an email address, which will be used for sending the analysis report back. The user can also specify the size of the result set, which is the number of images displayed in the analysis report. This interface also provides the user the option of examining the analysis report immediately after it is ready or receiving an email, which contains the URL of the report. Analysis reports are stored in the server after they are generated for several reasons, which will be discussed later in the paper. The user also has the option to restrict the access to the image he/she has submitted in which case this image will not be available for query in the User Database. The interface also provides several tutorials on using the system and understanding the analysis reports.

Step 2 deals with information extraction stage. The system creates a unique request after reviewing the preferences such as which database to use, email address, secure image etc. set by the user during image submission.

Step 3 deals with the segmentation stage, which is needed to perform shape feature extraction. In this step the lesion in the image is isolated from the healthy skin.

Step 4 deals with the shape feature extraction phase. In this phase, the segmented image is converted to black and white and several shape features are extracted from it.

Step 5 deals with the retrieval of the database images that are similar to the query image. A large database of skin lesion images is prepared using Skin Lesion Database Manager which will be discussed later in detail. This module is used to store segmented skin lesion images into a relational database along with features extracted using the shape feature extraction module. We query the database and store shape features and image related information in a memory. To find similar images, we use an optimum weighted city-block (L1) distance function designed using a genetic algorithm, which utilizes the Mantel test as the fitness function [4].

Step 6 involves the dynamic generation of the analysis report. This report includes a user-specified number of database images that are most similar to the query image.

Step 7 involves the creation of a multimedia email, similar to the analysis report, which is useful in cases where the user does not have access to a web browser.

Step 8 deals with the case where clients have received a URL to the report in their email. When reports are

generated, they are stored on the server. These reports can be viewed from anywhere and any device as long as they have access to the internet. This simplifies the process of viewing and storing the report for the user.

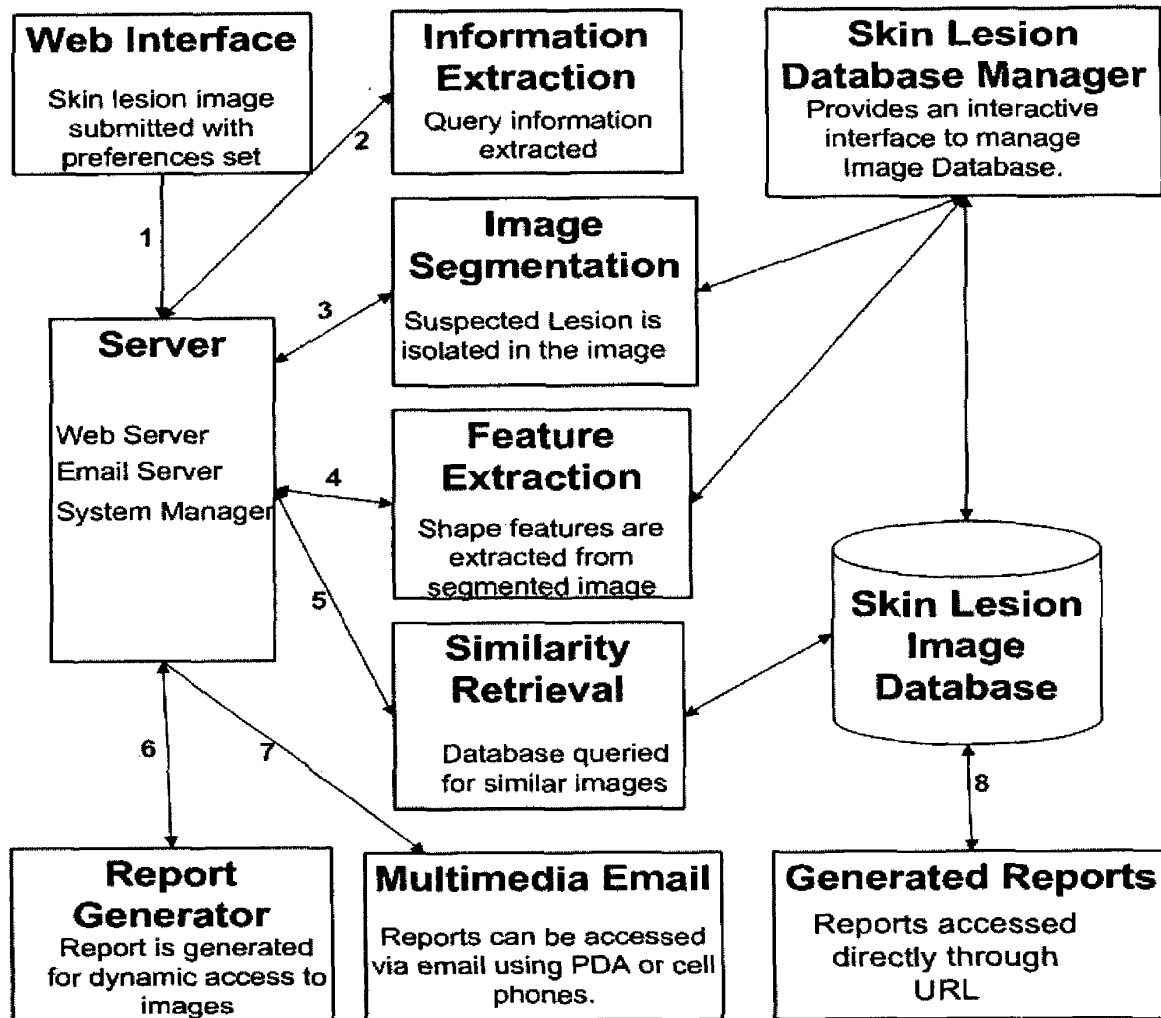


Figure 2. Content-based image similarity system

3. Segmentation and Feature Extraction

Image Segmentation is the process of partitioning an image into different regions that have similar characteristics such as intensity, color, texture, etc. [23]. It is an extremely important step in image retrieval since

accurate computation of shape features depends on good segmentation [27].

In our system we used an automated skin lesion segmentation tool developed by Guo & Aslandogan [13]. The segmentation tool is based on DBSCAN algorithm, which is a density-based clustering method capable of discovering clusters of arbitrary shape in the presence of

noise [12]. Figure 3 shows two examples of segmented skin lesion images.

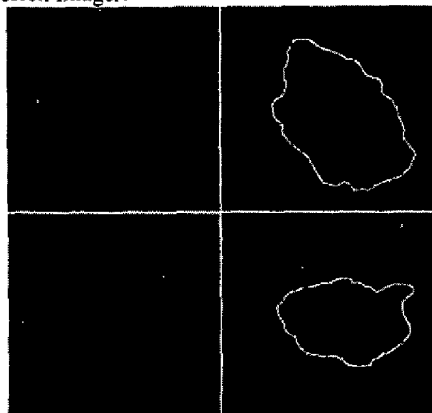


Figure 3. Non-segmented and segmented skin lesion images

For the purpose of shape feature extraction, we used a tool developed by Celebi & Aslandogan [4]. In this work, an initial set of 20 shape features were extracted from the skin lesion images. Then, this set was reduced to 8 features with less than 4% variation loss in the data using Principal Component Analysis. This reduced set of 8 features was used in our system. The list of features includes diameter, compactness, asymmetry [7], contour sequence moments F1 and F2 [14], bending energy, eccentricity, and solidity.

4. Image Database and Transfer

In order to provide concurrency, efficient retrieval and reliability we store the images and the shape features associated with them in an object-relational database management system. PostgreSQL database system was chosen due to its excellent support for media data types and their manipulation. Standard SQL is used for querying the images and the associated metadata. Initially a database of approximately 500 images was setup for this system.

For the management of a large number of images in a database, we created a customized database manager, called the Skin Lesion Database Manager. This tool utilizes the modular design of the system. It uses the image segmentation and shape feature extraction modules to segment images and collect feature information, which will be stored in the database. Storing images and their feature information in the database require many steps.

Part of a successful image analysis system, is the delivery of image data. After the user captures an image, it can be delivered to our system through a web interface.

We also created an email interface, which is used for sending query images to the system as attachments in multimedia email. Web and email interfaces are just two of the several possible ways of communicating with the system.

When a report is generated, only the source is stored in the file system on the server. Images are dynamically loaded into reports, from the database at the time the report is viewed by the user. Loading images directly from a database avoids conflicts, which can be caused by the limitations of file systems, such as uniqueness in filenames.

5. Image Similarity Computation and Report Generation

After the query image is segmented and its shape features are extracted, in order to find the most similar database images to it, we need to compute the distances between the query image and the database images.

We choose the weighted city-block (L1) distance as the distance metric due to its ease of computation and robustness in the presence of outliers [26]. The formula of the weighted city-block (L1) distance function is as follows:

$$d(Q, I) = \sum_{i=1}^n w_i * |Q_i - I_i|$$

where n is the number of features, w_i is the weight of the i^{th} feature, and Q_i and I_i are the values of the i^{th} feature of the query and the database images, respectively.

Following [1], we normalize the features by transforming them to Uniform [0,1] random variables using their cumulative distribution functions (CDFs), since given a random variable x with CDF $F_x(x)$, the random variable $\tilde{x}$ resulting from the transformation $\tilde{x} = F_x(x)$ will be uniformly distributed in the [0,1] range.

Table 1 shows the feature weights used in the weighted city-block distance. These values were determined using a genetic algorithm optimizing the agreement between the computational and perceptual distances between the images [4]. The perceptual distances between the images were obtained by performing psychophysical experiments. The aim of this optimization was to match the results of the similarity retrieval as much close to human perception as possible.

Table 1. Feature weights

Feature	Weight
Diameter	0.23
Compactness	0.17

Asymmetry	0.19
F1	0.10
F2	0.05
Bending Energy	0.09
Eccentricity	0.06
Solidity	0.11

After computing the distances between the query image and the database images, these values are sorted in ascending order. Now, the most similar database images to the query image constitute the top portion of this list. This list is used in the generation of the analysis report, which includes the query image and a user-specified number of database images similar to this image.

Figure 4 shows a sample analysis report.

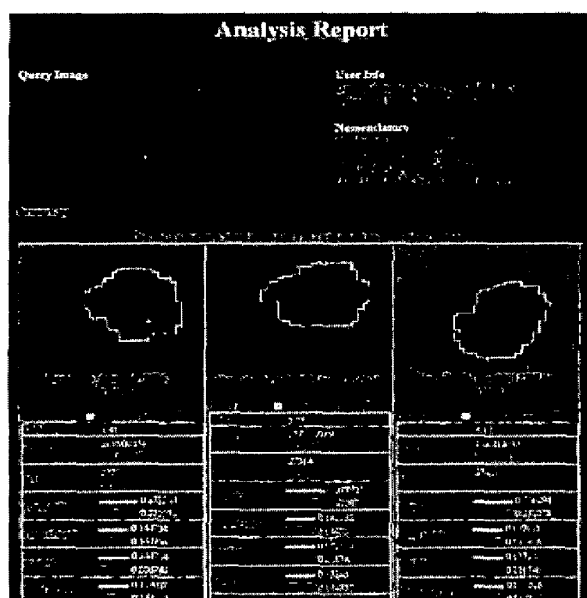


Figure 4. Sample analysis report

The segmented versions of the database images are shown in the report. The user has the option to access the original (non-segmented) versions. In addition to the images, the report also presents other information such as diagnosis of database images (if available) and differences between the query image and the similar database images in terms of the features in Table 1.

6. Related Work

Two kinds of systems are comparable with the work presented here: Online image databases and telemedicine systems. There are numerous pigmented skin lesion image databases available on the web. Notable ones

include Dermatology Online Atlas [11], The Language of Dermatology [24], Skin Cancer Atlas [28], Dermatology Image Bank [3], DermAtlas [6], Atlas of Dermatology [10], and Dermatology Atlas [18]. These databases are typically collections of skin lesion images with a web-based interface that supports browsing and limited querying by diagnosis, location on the body and pigmentation type. The combination of remote acquisition, online feature extraction, risk analysis and similarity retrieval functions provided by our system is not available on these systems. Tele-medicine systems dealing with various aspects of medical imaging have been reported in the literature such as cardiology [30] and radiology [31]. The I²Cnet system described in [31] provides similar functions to our system.

7. Conclusions and Future Work

We have presented an information integration system for providing distributed image acquisition, centralized online content analysis and similarity-based retrieval capabilities. While the present system relies on shape features for similarity, color and texture similarity modules can be integrated without much difficulty. The system architecture provides a model for various scenarios including detection and monitoring of environmental hazards, recognition of biochemical security threats and medical conditions by non-expert health-care professionals.

The accuracy of the system can be further improved by using more sophisticated shape features, such as those adopted by the MPEG-7 consortium [17]. Also, the retrieval efficiency can be enhanced by exploiting a multidimensional indexing structure such as SS-tree [15], SR-tree [16], or M-tree [5]. The resolution of images captured by mobile devices such as smart phones and PDAs are increasing constantly. Our experience suggests that a resolution of 2 mega pixels or above is sufficient for carrying out routine screening tasks on individual lesions. Currently, the system works for images with single focal objects. In order to extend the applicability to multiple significant objects, we plan to use a flexible region matching method such as Integrated Region Matching described in [29].

10. References

- [1] Aksoy S. and Haralick R. M. (2001) "Feature Normalization and Likelihood-Based Similarity Measures for Image Retrieval" *Pattern Recognition Letters*, 22(5): 563-582
- [2] American Academy of Dermatology (2000) "Malignant Melanoma" URL: <http://www.aad.org/pamphlets/malmel.html>

- [3] Bezzant J. L. "Dermatology Image Bank" University of Utah Health Sciences Library, URL: <http://medlib.med.utah.edu/kw/derm/>
- [4] Celebi M. E. and Aslandogan Y. A. (2004) "Content-Based Image Retrieval Incorporating Models of Human Perception" Proceedings of the International Conference on Information Technology: Coding and Computing, 2: 241 – 245
- [5] Ciaccia P., Patella M., and Zezula P. (1997) "M-tree: An efficient access method for similarity search in metric spaces" Proceedings of the 23rd VLDB International Conference, pp. 426-435
- [6] Cohen B. and Lehmann C. U. "DermAtlas" Johns Hopkins Medical Institutions, URL: <http://dermatlas.med.jhmi.edu/derm/>
- [7] Costa L. da F. and Cesar R. M. (2001) "Shape Analysis and Classification: Theory and Practice" CRC Press
- [8] Day G. and Barbour R. H. (2000) "Automated melanoma diagnosis: where are we at?" Skin Research and Technology, 6(1): 1-5
- [9] Debeir O., Goldschmidt D., Kraft T., Kiss R., and Van Ham P. (1995) "Skin Lesions in ELM Color Images" 9th International Conference on Diagnostic Quantitative Pathology, Heidelberg, Germany
- [10] Denguezli M. "Atlas of Dermatology" Service de dermatology CHU Farhat Hached Sousse Tunisie, URL: <http://www.atlas-dermato.org/index.html>
- [11] Diepgen T.L. et al. "Dermatology Online Atlas" Dept. of Clinical Social Medicine at University of Heidelberg and Dept. of Dermatology at University of Erlangen, URL: <http://dermis.multimedica.de/doiia/mainmenu.asp?zuger=d&lang=de>
- [12] Ester M., Kriegel H.-P., Sander J., and Xu X. (1996) "A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise", Proceedings of the 2nd International Conference on Knowledge Discovery and Data Mining, pp. 226-231.
- [13] Guo W. and Aslandogan Y. A. (2003), "Mining Medical Images with Spatial Clustering Techniques" Technical Report CSE-2003-19, University of Texas at Arlington, URL: <http://ranger.uta.edu/~alp/>
- [14] Gupta L. and Srinath M. D. (1987) "Contour Sequence Moments for the Classification of Closed Planar Shapes" Pattern Recognition, 20(3): 267-272
- [15] Jain R. and White D. A. (1996) "Similarity Indexing: Algorithms and Performance" Proceedings of the SPIE Conference on Storage and Retrieval for Image and Video Databases IV, 2670: 62-75
- [16] Katayama N. and Satoh S. (1997) "The SR-tree: An Index Structure for High-Dimensional Nearest Neighbor Queries" Proceedings of the ACM SIGMOD International Conference on Management of Data, pp. 369-380
- [17] Manjunath B. S. and Sikora T. (2002) "Overview of Visual Descriptors" in Manjunath B. S., Salembier P., and Sikora T. (Eds.), Introduction to MPEG 7: Multimedia Content Description Language, John Wiley & Sons, pp. 179-185
- [18] Melton J. L. and Swanson J. "Dermatology Atlas", URL: <http://www.meddean.luc.edu/lumen/MedEd/medicine/dermatology/melton/atlas.htm>
- [19] Morton C. A. and MacKie R. M. (1998) "Clinical accuracy of the diagnosis of cutaneous malignant melanoma" British Journal of Dermatology, 138(2): 283-287
- [20] National Cancer Institute (2003) "What you need to know about melanoma", U.S National Institutes of Health, URL: <http://www.cancer.gov/cancerinfo/wyntk/melanoma>
- [21] Nachbar F., Stolz W., Merkle T., Cogeneta A. B., Vogt T., Landthaler M., Bilek P, Braun-Falco O., and Plewig G. (1994) "The ABCD rule of dermatoscopy: High prospective value in the diagnosis of doubtful melanocytic skin lesions" Journal of the American Academy of Dermatology, 30(4): 551-559
- [22] Roberts M. E. and Claridge E. (2003) "An Artificially Evolved Vision System for Segmenting Skin Lesion Images" Proceedings of Medical Image Computing and Computer-Assisted Intervention Conference, pp. 655-662
- [23] Pratt W. K. (2001) "Digital Image Processing" Wiley-Interscience
- [24] Raugi G. J. "The Language of Dermatology" University of Washington, Seattle, URL: <http://eduser.vhscer.washington.edu/dermUW/lang/>
- [25] Richard L. Edman and Jonathan T. Wolfe (2000) "Prevention and Early Detection of Malignant Melanoma" American Academy of Family Physicians, URL: <http://www.aafp.org/afp/20001115/2277.html>
- [26] Rousseeuw P. J. and Leroy A. M. (1987) "Robust regression and outlier detection" John Wiley & Sons
- [27] Rui Y., Huang T. S., and Chang S. (1999) "Image Retrieval: Current Techniques, Promising Directions and Open Issues" Journal of Visual Communication and Image Representation, 10: 39-62
- [28] "Skin Cancer Atlas", British Columbia Cancer Agency, URL: <http://www.bccancer.bc.ca/HPI/CME/SkinCancer/Atlas/>
- [29] Wang J. Z., Li J., and Wiederhold G. (2001) "SIMPLcity: Semantics-sensitive Integrated Matching for Picture Libraries" IEEE Transactions on Pattern Analysis and Machine Intelligence, 23: 947-963
- [30] C. E. Chronaki, X. Zabulis, D.G. Katehakis, A. Giannopoulos, N. Stathiakis, M. Tsiknakis, P.J. Lees, E.N. Simantirakis, P.E. Vardas, and S.C. Orphanoudakis, "WebOnCOLL-enabled Remote Cardiology Consultation for Suspected Myocardial Infarction," In Proceedings of Mednet98, London, England, 16-19 November 1998, pages 41-43.
- [31] Orphanoudakis SC, Chronaki CE, Vamvaka D. I 2 Cnet: content-based similarity search in geographically distributed repositories of medical images. Comp Med Imaging Graph (Special Issue on Medical Image Databases) 1996.