Image query and indexing for digital x-rays

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At the Lister Hill National Center for Biomedical Communications, a research and development part of the National Library of Medicine, we are building a biomedical information resource consisting of digitized x-ray images and associated textual data. We have described this resource and the software system (the Web-based Medical Information Retrieval System, or WebMIRS) elsewhere [1]. In this paper we discuss our work to incorporate into our archive quantitative and structural data that is directly derived from the digital images. We also discuss methods to enable query of this data.

As detailed in the WebMIRS paper[1] referenced above, our archive consists of two databases, the records corresponding to the survey data collected in the second and third National Health and Nutrition Examination Surveys (NHANES). In this paper we focus on the NHANES II survey, in which the records contain information for approximately 20,000 survey participants. Each record contains several hundred data points, including demographic information, answers to health questionnaires, and the results of laboratory analyses and physicians' examinations. In addition, many of the participants were x-rayed: approximately 10,000 cervical spine and 7,000 lumbar spine x-rays were collected. The WebMIRS system makes this health text dataavailable for query in a relational database system, and, at the user'soption, also returns the image data for display.

We are now doing research into providing users the capability to retrieve records and images by means of the quantitative features of the images themselves. This capability will include a direct query for images satisfying particular feature conditions, and a search by similarity to an input image. We are further researching the feasibility of methods to automatically index the images for particular features of interest. These images of the spine are of most interest to medical researchers in the field of osteoarthitis, so we have given priority to providing search capability and doing automatic indexing for conditions known or hypothesized to be related to osteoarthritis. At the user level, the features of interest are anterior osteophytes (spurs on the anterior corners of the vertebrae), disc space narrowing, and (for the cervical spine alone) subluxation (slippage of one vertebra relative to another). It appears a priori that these features are associated primarily with image structure, as opposed to histogram or texture characteristics. For example, an anterior osteophyte at the C4 vertebra is a particular shape extending from a corner of the vertebra. In general, this shape may be irregular and highly variable from person to person or even for a single person. While the shape may be difficult to accurately describe in words, a radiologist may be expected to recognize it on viewing it. The above applies equally to many features in medical images: they tend to be (1) primarily characterized by shape or structure; (2) are recognizable y a medical expert on viewing; and (3) have a high degree of irregularity in shape and a high degree of variability in shape from instance to instance. These characteristics create a high level of challenge for the development of reliable image processing and pattern recognition algorithms to identify the features under computer control.

The first step we have taken is acquiring a baseline set of manually-segmented images, where the segmentation was done under supervision of a medical expert. This baseline set of data, when incorporated into our database system, allows testing of queries which ask direct questions based on quantitative image characteristics. It also serves as ground truth for our research into automatic indexing of additional images.

To do the manual segmentation, it was decided after consultation with a rheumatologist and a radiologist, both skilled in interpreting x-rays for osteoarthitis, that the images would be segmented using a modified version of the 6-points-per-vertebra method used by researchers in the field of vertebral morphometry [2] to identify the key boundary points of the vertebra. In addition to the standard 6 points, two additional points were collected if anterior osteophytes were present. Images were chosen for the segmentation from the NHANES II x-ray images according to the estimated probability of the images containing features showing the presence of osteoarthritis or degenerative disc disease. Two image groups

were chosen; the first group was expected to contain a high probability of osteoarthritis or disc disease, and the second group was expected to contain a low probability. The NHANES II survey data was used to select images for these groups. All of the images selected were of people 60 years of age or older. The cervical spine images selected for the high probability of osteoarthitis correspond to the group whose members all answered "Yes" to the question, "Have you ever had a period of at least two weeks of neck pain?" All of those in the low probability group answered "No" to this question. Similarly, for the lumbar spine images, those selected for high probability of osteoarthritis all answered "Yes" to the question, "Have you ever had a period of at least two weeks of back pain?" and "Yes" to the question, "Was the pain in the lower back?" Those selected for the low probability group answered "No" to the first of these questions.

A total of 600 images were selected in this fashion and segmented. Software to support the image display, point placement, and data recording for the segmentation was custom written for operation under the X Window/Motif system on a Solaris 2.6 SPARC workstation. This segmentation data allows features such as anterior and posterior vertebral heights to be entered into relational database tables and to become available for user query. For example, the user will be able to query the system for images satisfying a specified range of ratios for anterior/posterior height, a feature which has been correlated with findings of fracture of the spinal vertebra [3]. Also, by specifying one of the segmented images as an exemplary image for searching, a rudimentary query by example becomes possible.

We are further exploiting the manual segmentation data for identification of local image features which may support automated or semi-automated segmentation now being done completely manually. An automated indexing system for these images would include (1) accepting a completely unsegmented, "raw" image as input; (2) a segmentation function which would replace the current all-manual segmentation; and (3) a function to derive features from the segmented image. The approach we are researching is to develop a two-stage algorithm for the required image processing. In the first "global processing" stage, key landmarks are identified in the image which are sufficient to determine and fix an anatomy-based coordinate system and provide a first-order estimate of the location of the vertebral region. In the second "local processing" stage, individual vertebrae are located and marked with the segmentation points. Finally, after all image processing is done, desired features are extracted by using the segmentation points.

This paper reports on all results to date in carrying out the manual segmentation, choosing and extracting image features, implementing the database and query capability, and developing automated indexing for the images.

References:

1. Long LR, Pillemer SR, Lawrence RC, Goh G-H, Neve L, Thoma GR. WebMIRS: Web-based Medical Information Retrieval System, Proceedings of SPIE Storage and Retrieval for Image and Video Databases VI, SPIE vol. 3312, San Jose, CA, 392-403.

2. Rosol MS, Cohen GL, Halpern EF, Chew FS, Kattapuram SV, Palmer WE, Dupuy DE, Rosenthal DI. Vertebral morphometry derived from digital images, American Journal of Roentgenology, December 1996, 1545-1549.

3. Hedlund LR, Gallagher JC. Vertebral morphometry in diagnosis of spinal fractures, Bone and Mineral, vol. 5, 1988, 59-67.

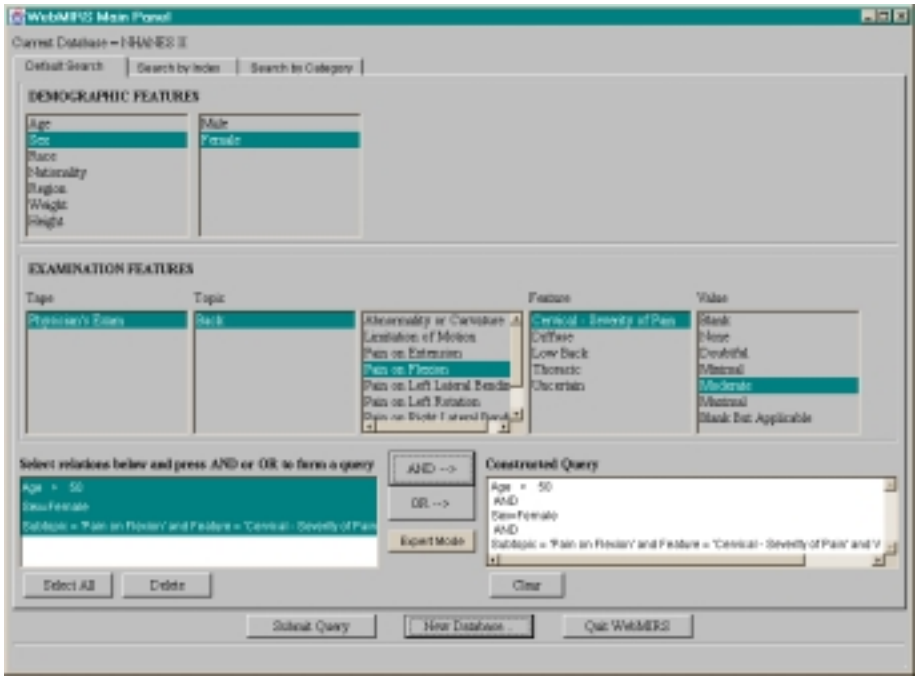

Figure 2. WebMIRS Main Panel showing NHANES II database query, *Find records for all women older than 40 who had moderate pain on flexing the cervical spine*. The tabs will provide three different search interfaces.

Figure 3. WebMIRS Database Information screen, showing results of Figure 2 query. The text describes the person with image highlighted with a red border. The image area may be scrolled horizontally; the text may be scrolled vertically.

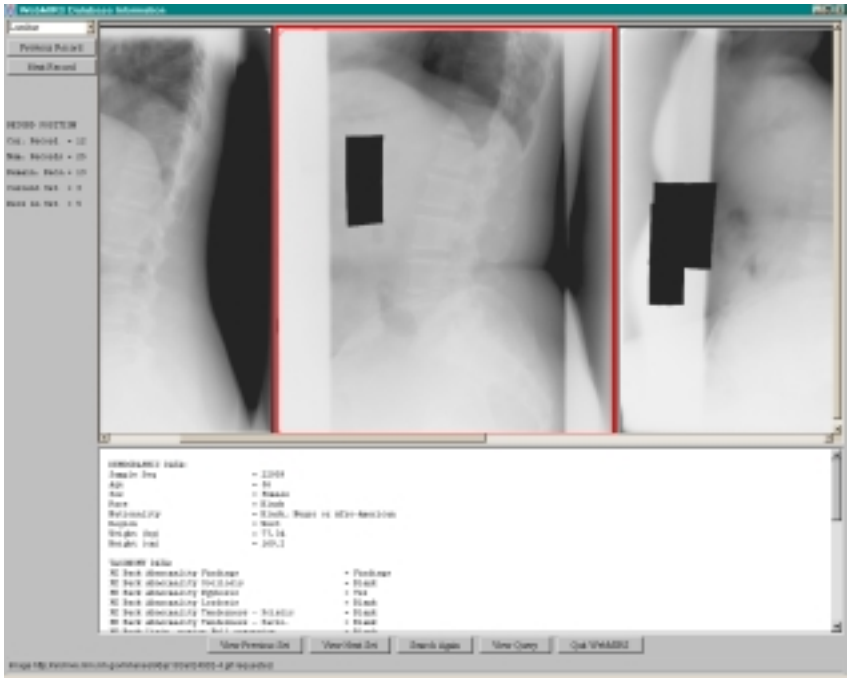

Figure 4. Results from Figure 2 query, showing the lumbar spine images available. WebMIRS can provide access to multiple images for each text record. The list box control in the upper left allows selection of the image type (*lumbar*, in this case).

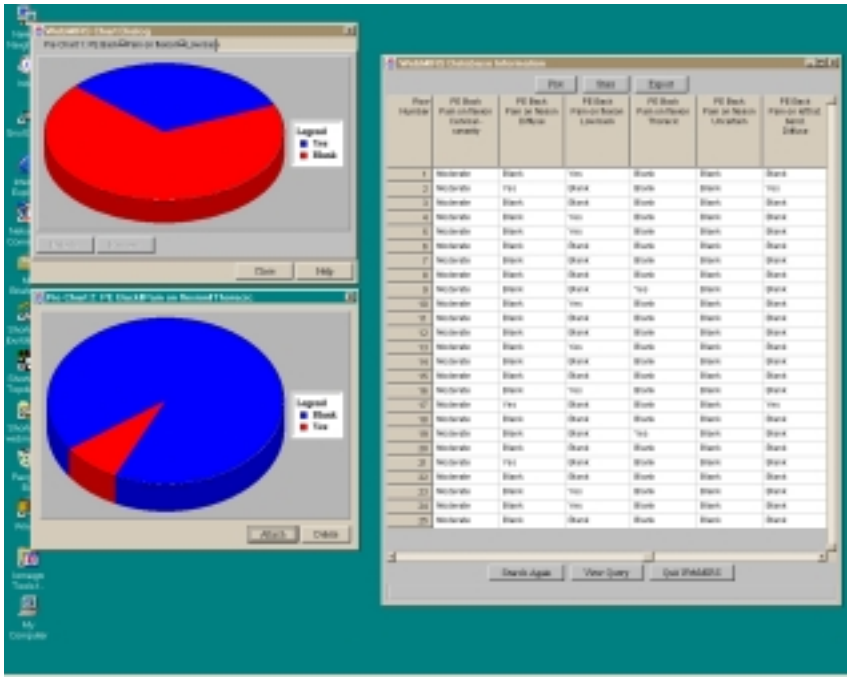

Figure 5. Results from Figure 2 query, in Table View format. Columns of results may be selected and plotted on screen. Here the pie charts show the proportion of records having pain on flexing the low back (top) and thoracic spine (bottom).