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Border Detection of Skin Tumor Images

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Border detection of skin tumor images is part of a research project whose purpose is to identify key features in skin tumor images using machine vision techniques. The key features present in a skin tumor guide the dermatologist in making the proper diagnosis. A few examples of key features are crust, scale and ulcer.

The success of this research is largely dependent on accurate border detection. The border defines the boundary of the tumor. From this, features such as regular border and irregular border can be determined giving the dermatologist a measure for the smoothness of the tumor edge. Irregularity of the border often indicates the presence of a malignant tumor. The border also defines the area in the image to restrict the search for other key features present in the skin tumor. If the border errs to the outside of the tumor, features of the skin surrounding the tumor may be improperly identified as key features. If the border errs to the inside of the tumor, features present could be neglected completely. This creates the need for an algorithm which is capable of detecting an accurate border for the skin tumor in a digitized image.

Jeremiah Golston wrote the first version of a border detection program which used radial search methods on a luminance image. The luminance image was generated by replacing the original red, green, and blue (rgb) values with a weighted sum of the rgb values. The luminance border program, lumborder, searched radially outward from the defined center of the tumor looking for a dip in the luminance value with a sustained length. Lum.border would terminate the search on any radius when these conditions were satisfied. If the search reached the boundary of the image without satisfying the above condition the restrictions would be relaxed and the search on that radius performed until a point was found. Under these conditions lumborder may perform multiple searches on the same radius before returning a border point.

Stopping the search with the first point that satisfied the conditions may result in lumborder defining a border point at a false edge of the tumor. A border detection program which searches each radius one time and was capable of returning multiple border candidates would be capable of determining the true border of a tumor with multiple color changes and reduce processing time.

Colborder.simple, written by Michael Tiehes, employs radial search and color information for determining multiple border candidates on each radius of reduced resolution, color segmented images. As in the lumborder program a sustained length condition was required. Unlike lumborder, colborder looked for color changes in segmented images that satisfied the sustained length condition to determine the edge of the tumor. The point with the greatest sustained length was selected as the initial border point. The radial length of each possible border point on the adjacent radius was then compared to the radial length of the previously chosen border point. The point which reduced the difference in radial length to a minimum was selected as the true border point for that radius. The process was repeated for each successive radius until one point had been selected for each radius.

To have a measure of how accurate the selected border points were, a program called Success, written by Michael Tiehes, was used. Success compared the location of each selected border point with a data base, feature files, for that image. If the location of the selected border point was labeled as a partial tumor block in the feature files, the point was considered to be an accurate border point. Success also looked at the location of the selected border point if it wasn't located in a partial tumor block to determine if it was within half a feature block of a partial tumor block. If this condition occurred the point was labeled a near hit inside or near hit outside depending on its actual location. Success then returned a percentage rating for each image. Preliminary results implied that the colborder program had about a ten percent higher accuracy than lumborder.

The work this semester began by running a curve fitting program on the selected border points returned from colborder.simple for images 300 - 400. The closed curves were then compared with the closed curves obtained using the selected border points from lum.border for the same images. The results from the comparison illustrated that the luminance border program was superior espite preliminary results using the success program.

The selected border points from colborder were obtained from a 64 x 64 resolution image. Before the curve fitting program was applied to these points the resolution was increased to 512 x 512. The border points were then located at the left top corner of the 8 x 8 block in the 512 x 512 image. The resulting curve for the border points for the colborder program was extremely irregular and generally transposed slightly. This condition was not present for the border points used from lumborder since the image was 512 x 512 resolution. After further consideration a decision was made to increase the resolution of the image processed by colborder.simple to 128 x 128. This would help reduce the erroneous irregularity of the closed curve. Each pixel in the lower resolution would now represent a 4 x 4 block in a 512 x 512 image compared to the previous 8 x 8 block.

The 64 x 64 image which colborder.simple processed was generated through several processing stages and segmentation of the original 512 x 512 image. All the programs used to generate the segmented 64 x 64 images were written by Scott Umbaugh. Therefore changing the resolution to 128 x 128 would require modifications to the following programs written by Scott: avecol, mask.nskn, spher_xform, find_covmtrx, remap, seuccc, seuuccc, numcol and colfilter. Modifications were also required to colborder.simple and centerpoint.

Avecol will average a color, pixel-interleaved image over a specified block size and replace the block by the average RGB values. Mask.nskn reads the feature file for all nonskin blocks, it then sets the RGB values of the corresponding blocks in the image to zero. Spher_xform transforms the RGB color space, so the first plane is Angle A, the second plane is Angle B, and the third is length. After transforming, the data is converted to byte format. Find_covmtrx finds the covariance matrix for an RGB pixel interleaved image file. Remap transforms an image into principal components and then remaps to the range 1 to 254 for byte size. Seuccc and seuuccc performed a principle components transform which condensed most of the information into one color space, normally the red color plane. Find_numcol finds the number of colors to segment the image, based on a rule generated from First Class Fusion that uses RGB maximum, minimum, and variance to make the determination. Col_filter does spatial filtering by filling in holes and rounding off protruding pixels from objects. Center.point reads the feature file for partial and full tumor blocks. It calculates the center of the tumor and then adjust the coordinates to the resolution of the image being processed. Colborder.simple uses the center point as the starting point and searches out radially for color changes. The point is marked as a possible border candidate if the color change remains constant for the minimum sustained length condition. The radial search continues on the line until four points have been located or the edge of the image is reached. The final border point for each radial line is chosen so the smallest difference in radial length for two neighboring points results.

A test set of images was chosen to verify that the changes made to the programs would not alter their integrity. After the changes, certain images had the information in the red and blue planes reversed. Due to the unfamiliarity with the segmentation programs written by Scott Umbaugh they were checked several times for errors due to programming changes.

The results from the programs remained unchanged. The color border program seemed unaffected by the information being reversed in the red and blue planes. These results could be explained in that the colborder.simple looked for a color change in any of the three color planes. If the point found fulfilled the sustained length condition the point would be labeled a possible border point. For this reason no more time was spent on trying to explain the change of information from the red to blue plane.

When colborder.simple was changed to function on the higher resolution image the sustained length condition was written as a function of the resolution. The sustained length condition for the 64 x 64 images was two pixels; this became four pixels for the 128 x 128 images. Several images were viewed at the higher resolution before sending the data points to the curve fit program. These images reveal that little gain in accuracy of the data points to the actual border of the skin tumor occurred. The border points continued to err to the outside of the tumor.

The error to the outside of the tumor had one constant factor. There was usually a color change that occurred prior to the selected border points but that would be omitted because of the four pixel sustained length condition. The sustained length condition was then changed to two pixel for the 128 x 128 resolution. The change in sustained length moved the border points toward the center of the skin tumor, reducing the error to the outside. About twenty images were then run using the modified sustained length condition and displayed on the Conrac monitor. A significant improvement in the selected border points resulted.

Changing the sustained length condition to two pixels improved the capability of colborder to find the true border for small tumors considerably. Although these changes improved the accuracy of the border for small and medium sized tumors, at the same time the accuracy of the border points for large tumors decreased. Viewing the results of a few large tumors it became apparent, since colborder would terminate the search after finding the first four possible border points on each radius, that the true edge of the tumor often would not be reached. One solution to this problem was to increase the number of points on each radius. The program was modified to find four, five, six, and seven points on each radius for the same 279 images. Table I shows the results for the selected border points returned from colborder. Additionally the results were compared with the same 279 images with an 8 x 8 average block size or 64 x 64 resolution image. From Table I an image resolution of 128 x 128 and selecting four possible border points on each radius returned the highest success rate.

From these results colborder was set to find four possible border points on each radial line. Time did not permit generating the closed curves for images 300 - 400 for comparison with lumborder.

Using the color information in the image and finding multiple points on each radius should give colborder the capability of detecting the border of a tumor with greater accuracy than lumborder.

Point determination, a subroutine of colborder, selects one point on each radius. Selections are made to minimize the difference in radial length with neighboring selected border points. For the final selection process, this is a relatively primitive method. Selections which employ additional information from the image in conjunction with minimal difference in radial length would improve the accuracy of the border detection program, colborder. Future focus on border detection should be guided in this direction.

Table 1. Percent Accuracy for Valid Border Points

No. points per radius	Total Hits	Direct Hits	Near Hits Inside	Near HitsOutside	Image Resolution	Number of Tumors
4	54.84	35.61	15.00	4.22	64x64	279
4	66.90	44.02	13.18	9.69	128x128	279
5	66.43	43.84	12.76	9.83	128x128	279
6	65.32	43.11	12.36	9.85	128x128	279
7	64.44	42.71	12.10	9.63	128x128	279