[[1]](#footnote-1)

*Abstract*—This paper describes an application that converts raster images to vector images (vectorization). The application is capable of extracting polygons as well as curved shapes from color images. It can then save this data in the Scalable Vector Graphics (SVG) format. Region tracing and cubic Bezier fitting are the main techniques employed to achieve the conversion.

*Terms*—Image processing, image decomposition, vectorization, curve fitting <http://www.ieee.org/organizations/pubs/ani_prod/keywrd98.txt>

# INTRODUCTION

Vector graphics use geometrical primitives based on mathematical equations to represent images. Since vector graphics construct displayed images from a mathematical model, it is possible to render the model at any zoom level without causing pixilation. Vector formats are frequently used for images that are meant to appear on a variety of mediums and at different sizes. Vector formats are also useful because they provide a compressed representation of their raster counterparts.

This paper presents the process used by a vectorization application that has been developed in MATLAB, utilizing the Image Processing Toolbox. The implementation consists of a GUI to load images and user controlled vectorization parameters.

# Polygon Detection

Polygons are identified in the image using the process of color quantization, median filtering and then region tracing.

The number of colors in the input image is first quantized to a low number. This number is usually between 2 and 20. Vector images normally contain a low number of colors. Vector formats are generally not useful for representing images with a high number of colors, unless the colors can be simply described by a mathematical model. This vectorization implementation is only concerned with the extraction of uniformly colored shapes. After color reduction, a median filter is applied to the resultant image, in order to remove small colored regions. The image is then separated into several binary images- one for each color.

Region tracing is then performed on the binary images, giving arrays of co-ordinates that outline each shape. This data can then be sampled at different frequencies, to obtain the vertices that can be used to represent the image as a set of colored polygons. The optimal amount of positions sampled highly depends on the resolution and complexity of the original image. If the sampling frequency is too low, the polygon will become distorted, and if the sampling frequency is too high, the non-idealities of the image will be captured by the polygon (such as the shape of the pixels themselves). The percentage of trace points used as polygon vertices can be specified by the user of the application, and the optimal percentage can be easily found through trial and error.

The extracted colored polygon data is now enough to generate a vector image. This works well on images composed of straight lines, but works poorly on images that contain curves.

# Bezier Spline Fitting

Cubic Bezier spline fitting works well to approximate curved traces. Most vector formats allow the rendering of these splines.

Cubic Bezier curves are represented by the eqn:

C:\dev\MATLAB\RasterToVector\doc\cubicbezierformula2.png (1)

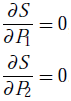
Where P0 through P3 are the curve control points. When fitting, P0 and P3 are the known end points of a curve, and P1 and P2 are the points that need to be determined, based on the intermediate data points.

P1 and P2 were determined using least-square fitting, which minimizes S, in eqn X.

C:\dev\MATLAB\RasterToVector\doc\eqn_leastsquare.png

(2)

This is done by solving eqns X and X for P1 and P2:

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The fitting strategy used by the application is as follows:

1. Try to fit a curve to increasingly larger segments of the polygon, until the minimized S becomes greater than the inputted square error threshold.
2. Save this curve and start a new curve from its end point. Fit a new segment as in step 1.
3. Stop when the full polygon is covered.

# Export

The export function allows export of our data structure to the Scalable Vector Format (SVG). SVG was chosen as this format is widely used. This allows exporting of the vectorized images. Using SVG 1.1 standard which is based on the XML ?. To narrow the scope only polygons and cubic Bezier curves are output. Parameters such as color is also set. The user is prompted upon execution for the filename and path. [#<http://www.w3.org/Graphics/SVG/>]

# Results

The method worked well for the vectorization of simple colored shapes and sketches. It also worked well to vectorize some photographs, but more so as an artistic technique than for accuracy.

Polygon conversion works well for images with straight lines, but is not very useful for images composed of curved shapes. Bezier spline fitting worked well curved shapes. However, it was usually necessary to use adjust the maximum square error threshold to achieve optimal results.

When the threshold is too low, it often causes the non-idealities of the image to be fitted (such as the shape of pixels themselves). It causes curves to become choppy because of the high number of breakpoints. When the threshold is too high (approximately greater than 50), it causes the shapes to be approximated extremely poorly.

# Improvements

One improvement that could be made to the method is the ensuring that corner points are sampled when polygons are extracted. This would require the use of corner detection. It would improve the output of polygon vectorization, allowing the fewest number of trace points to be used to describe the shape.

# Line Detection

The Hough transform method line detection was initially tested as a way of extracting polygons. However, it did not perform as well as simple contour tracing. This method is utilized after the original image has been converted to grayscale and canny edged detection has been applied (converts image to binary). There are three parts to the Hough Transform Method: Standard Hough Transform (SHT), Hough Peaks and Hough Lines.

SHT computes?. Hough Peaks locates peaks in the Hough Transform Matrix [#<http://www.mathworks.com/help/toolbox/images/ref/houghpeaks.html>] [#<http://mathworld.wolfram.com/HoughTransform.html>].

# Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

Acknowledgment

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” **Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.**

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