[[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 is the use of geometric primitives and other parameters to represent images in computer graphics. The geometric primitives are based on mathematical models, which include points, paths, and polygons. Since vector graphics are rendered using a mathematical model, the quality of the rendered image is independent of its scale. This contrasts to the more commonly used raster formats, which represent images as pixels. Vector formats are frequently used for images that are meant to appear on a variety of mediums and at different sizes (e.g. fonts, logos, blueprints and maps). Vector formats usually have a smaller file size than raster formats, although this is proportional to the complexity of the image.

This paper presents one method of vectorization, which is the conversion of raster graphics to vector graphics. This method was implemented in MATLAB, utilizing its Image Processing Toolbox and a library for cubic Bezier curve fitting. The implementation consists of a GUI to load raster images, set parameters for vectorization and export the vectorized images. The scope was constrained by limiting primitive extraction to polygons and beziergons (closed paths of Bezier curves) were extracted in the Vectorization process.

# 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.

# Beziergon Fitting

Cubic beziergon fitting works well to approximate curved traces. Most vector formats allow the rendering of Bezier paths, which are a superset of beziergons.

In the implementation, an open source library was used for the fitting of Bezier curves, which is found at [#]..

Cubic Bezier curves are represented by the eqn:

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

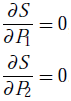
Where P0 through P3 are the curve control points. When fitting, P0 and P3 are the known end points of a curve, and P1 and P2 are the points that need to be determined, based on the intermediate data points.

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 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

To complete the vectorization process, the vectorized image model has to be exported. The Scalable Vector Format (SVG) was chosen for exporting as this format is open, widely used and can be edited in a simple text editor. The SVG 1.1 standard is XML-based and is maintained by the World Wide Web Consortium. Polygons, cubic bezier paths and fill colors were exported to an SVG file. [#<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.

Another improvement that could be made is the fitting of other primitives such as circles, rectangles and lines of varying widths. This would ensure that if these shapes are present in the image, that they are represented with maximum accuracy.

# Line Detection

The Hough transform method of line detection was initially tested as a way of extracting lines. However, it did not perform as well as expected.

The method first involves some pre-processing of the image by converting it to grayscale and using Canny edge detection, which results in a binary image. The next step is to compute the Standard Hough Transform (SHT). Next, peaks are identified in the SHT. The final step is to compute Hough Lines using the information obtained in the previous steps.

The results from this method were inadequate because most lines did not get detected. It was not included in the final vectorization process.

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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