Yet Another Vector Representation for Images Using Eikonal Surfaces

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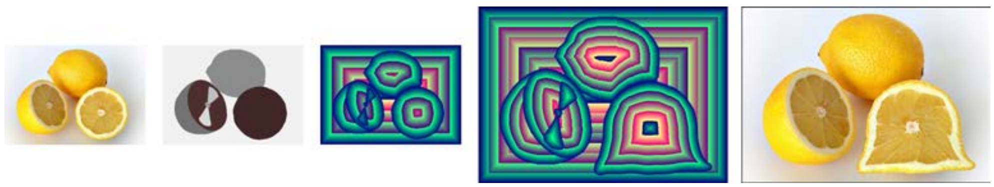

Figure 1: *From left to right: the input image, segmentation of the input image, Eikonal Surfaces of the image segments, scaled and deformed Eikonal Surfaces, and the output image*

1 Introduction

Scaling and deformation of raster images almost always causes the decrease of image quality. On the other hand vector graphics offers easy image manipulation without any quality loss. Many algorithms have been presented in the recent years to convert raster images into vector ones. However, all the solutions assume that the image discontinuities need to be decomposed into a set of multiple piecewise smooth surfaces. This may cause data losses or extremely high complexity of the underlying vector structure, in the areas with high variance (noise, patterns etc.). Our method does not rely on gradients generated from a triangular decomposition of the image plane and piecewise smooth loop subdivision surfaces [Liao et al. 2012], nor extracted diffusion curves defining the gradient propagation [Orzan et al. 2008]. Instead it uses separately sampled pixel values. It gives a user the freedom to manipulate easily the elements of the raster image as it is in case of vector graphics. At the same time it keeps the underlying image representation simple, even in the areas of high variance. Sharpness of details is achieved by proper segmentation and edge selection. In the worst case the quality gets reduced to the correspondent interpolated raster quality.

2 Our Approach

Similarly to [Orzan et al. 2008], where user extracts diffusion curves to model heat transfer and perform gradient propagation in the 2D image domain, we use curvilinear contours to model Eikonal Equation and perform per-pixel color interpolation in directions defined by the Eikonal Surfaces.

The most basic input for our algorithm is a segmented raster image. A user may want to store boundaries of the segments in the form of b-splines. In this case they will be rasterized in the preliminary step of the algorithm. The segmentation can be performed manually or automatically. It may, but does not have to follow the image semantics. Any segmentation algorithm may be used for this purpose. Hard edges are defined by segment boundaries. Additional hard edges may be defined within the image segments. Having a segmented raster image, we then define Eikonal Surfaces of the image segments. The physical meaning of the eikonal equation is related to the formula, $E = -\nabla V$ where E is the electric field strength and is the electric potential. To obtain the values of the electric field relating to the segmented image, we use the advancing front algorithm where seed points are the pixels belonging to the previously specified edges. In this way we create narrow bands (called "chains"). All the pixels within one chain lie within the same distance from the corresponding segment's edge. In the second step we sample the points along the chains. Each chain is assigned an indexed list of pixel values called "links". When a user changes the shape boundaries of a given image segment - the length, the number of chains and/or their layout changes too. In such a case we generate a new Eikonal Surface and chain structure, in the same way as in the previous step. Having the old and the new set of chains, from before and after the deformation, we calculate the ratio between the new and the old number of chains. This way we can match chains from the old and the new Eikonal Surfaces. Next we compare the length of each chain from the new Eikonal Surface with the length of the corresponding chains from the old Eikonal Surface. We change the number of links in the old chains to match the length of the new chain and perform one dimensional interpolation of colors. For each link in the new chain, the final color is a weighted average of the links with equal indexes, taken from the contributing, scaled, old chains. To obtain the final result we assign the newly calculated color values to pixels along the chains in the new Eikonal Surface.

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References

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