Raster Map Image Analysis

Thomas C. Henderson and Trevor Linton
School of Computing
University of Utah
Salt Lake City, UT 84112 USA
tch@cs.utah.edu

Abstract

Raster map images (e.g., USGS) provide much information in digital form; however, the color assignments and pixel labels leave many serious ambiguities. A color histogram classification scheme is described, followed by the application of a tensor voting method to classify linear features in the map as well as intersections in linear feature networks. The major result is an excellent segmentation of roads, and road intersections are detected with about 93% recall and 66 % precision.

1. Introduction

Digital maps contain a wealth of information which can be used for a variety of applications, including the analysis of cultural features, topographical terrain shape, land use classes, transportation networks, or maps can be registered (conflated) with aerial images in order to localize and identify photo imagery structures. Unfortunately, raster map images are typically encoded in such a way that semantic features are difficult to extract due to noise, error or overlapping features. Semantic features of interest include roads, road intersectoins, water regions, vegetation, political boundaries, and iso-elevation contours.

We propose to exploit specific knowledge about the use of color in maps (USGS maps, in particular) as the basis for a color histogram classification first step, and then use this as the starting point for a tensor voting method for the segmentation of linear features (roads, rivers, iso-contours, etc.) and road intersections. The tensor voting method uses a special representation to allow linear pixel level features to reinforce other such features to increase belief in larger scale segments Likewise, pixel-level terminations, corners and crossing points can be precisely determined by input (votes) from neighboring pixels.

More specifically, the following Gestalt principles will be used to segment semantic features; also given is the technical approach for exploiting the principles:

- *Similarity*: Color histograms will be used for all categories, and parallel orientation between linear elements will be used for city street line pairs.
- *Proximity*: Spatial proximity will be emphasized both in the tensor voting method, A*, as well as in the city road line pair analysis. While proximity is important Gestalt's principle of continuity is taken to be more important and emphasized more by the tensor voting method than proximity.
- *Continuation*: Continuation is discovered through the tensor voting method.
- *Closure*: The ability to fill gaps and nd the most optimal curve to close a region. This is done with the tensor voting method.

Analysis of the Gestalt's principle of similarity is performed first with a histogram analysis. Similar segments are identied in the histogram analysis and all similar components are extracted to separate sparse raster maps. Once the sparse raster maps are created they are further treated to clean noise out using dilation and eroding techniques. Smaller features such as parallel road lines or distinct subtle features are improved to prevent loss of these details in the Tensor Voting framework.

These segmentation methods are applied to USGS maps, and the performance is analyzed. For general linear features, a qualitative analysis is given in which a human observer estimates the quality of the segmented features, and the overall result is excellent for the segmentation of roads, rivers and iso-contours. Road intersection detection results are also give; here the performance is analyzed in terms of recall and precision with respect to a set of ground truth road intersections from sub-images in USGS maps. The recall is about 93% while precision is about 66%.

2. Related Work

Raster map image analysis has a long history [?], and more recent work has focused on various aspects of the problems studied here. Many of these methods attempt more general solutions, and do not take advantage of the specific map knowledge as is exploited here. Also, the analysis of linear features in other types of documents (e.g., engineering drawings) has been reported in the literature [?, ?, ?]. A significant feature of maps is that the road networks, iso-contours, political boundaries, etc. offer a more extensive and coherent linear network than other types of documents; this is also exploited by our approach.

Podlaso et al. [?] propose a mathematical morphology approach to the extraction of map classes, but do not exploit the deep knowledge of the use of color in the map as we do here. Chiang et al. have proposed methods for both road intersection detection [?] and line pixel classification [?] (achieving 75% recall and 90% precision in road detection). Our method provides an improvement in the recall statistic (i.e., the number of correctly extracted intersections divided by the number of ground truth intersections).

3. Color Histogram Pixel Classification

The number of colors in a USGS map is limited to a few specific colors, and this information is exploited in the analysis of the USGA maps. Note that the number of colors used may differ from map to map (from 6 to 13 colors, including black). USGS maps have a well-defined structure which is exploited here to extract semantic contents. The elements of the legend are described in terms of their location in the map image, and their constituent (non-white) pixel values. Note that the pixel values in a USGS image are coded as follows:

Index Value	*Color*	*R*	*G*	*B*
0	Black	0	0	0
1	White	255	255	255
2	Blue	0	151	164
3	Red	203	0	23
4	Brown	131	66	37
5	Green	201	234	157
6	Purple	137	51	128
7	Yellow	255	234	0
8	Light Blue	167	226	226
9	Light Red	255	184	184
10	Light Purple	218	179	214
11	Light Gray	209	209	209
12	Light Brown	207	164	142

From the legend, representative color histograms can be found; for example, consider *Primary Highways* where the histogram is:

Index Value	*Color*	Number in Sub-image
0	Black	1030
1	White	2925
2	Blue	7
3	Red	456
4	Brown	352
5-12	Green	0

This kind of information is exploited to produce a set of rules for classification of image pixels.

The color usage information is determined from the map legend. However, color histogram information alone is not sufficient to discriminate all classes; for example, roads of different types may have the same color histogram and may only be distinguished by their width (in pixels). It is also possible that some classes have erroneous mixtures of color pixels (e.g., waterways may have a significant amount of black, especially near roads). Given the color histogram data extracted from the map legend, the following set of rules were constructed.

```
for each pixel
  Get max_color and max_count
  if (max_color is BLUE) and
     (max_count > BLUE_THRESH)
    then class is WATER
  elseif (max_count is BLACK) and
         (amount of RED < BLUE) and
         (amount of BROWN < BLUE)
    then class is LIGHT_ROAD
  elseif (max_count is BLACK) and
         (amount BLUE < RED) and
         (amount BLUE < BROWN) and
         (amount BLUE > 0) and
         (amount BROWN > 0)
    then class is PRIMARY_ROAD
  elseif (amount BLACK < POLI_BLACK) &
         (amount BLUE < POLI_BLUE) and
         (POLI_RED < amount RED) and
         (POLI_BROWN < amount BROWN)
    then class is POLITICAL BOUNDARY
  elseif (max_color is black) and
         (amount BLUE < BROWN) and
         ((amount RED < BROWN) or
     (BLACK_THRESH < amount of BLACK))
    then class is TRANSPORT
  elseif (max_color is BROWN) and
         (BROWN_THRESH < amount BROWN)
    then class is ISO-CONTOUR
```

An example USGS sub-image is shown in Figure 1 and the results of the application of this method are shown in Figure 2 as binary classification images.

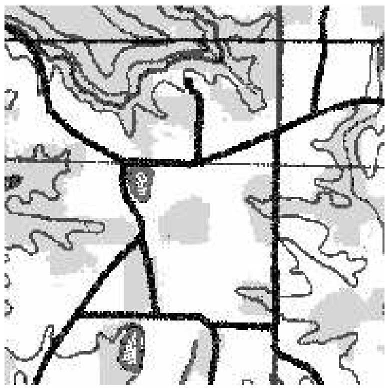

Figure 1. Sub-image from USGS map.

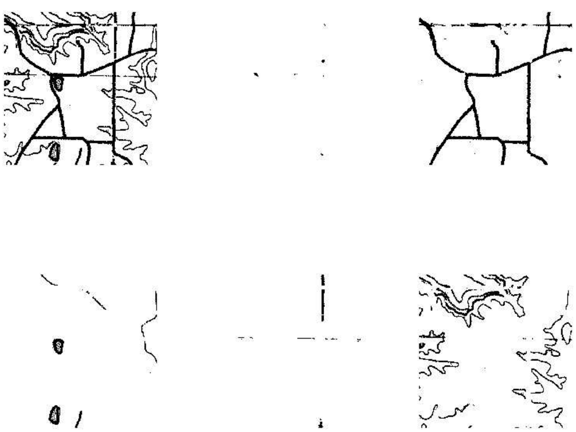

Figure 2. Classification Result for Example Sub-Image.