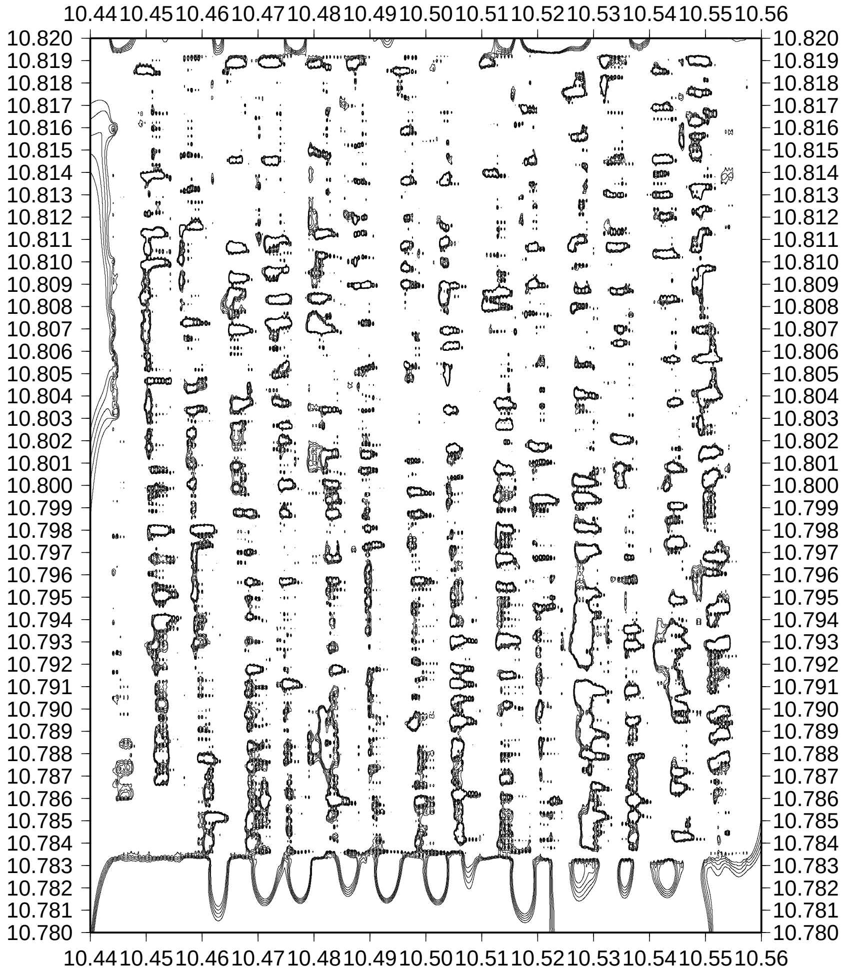
Figure 1:



The method for counting the number of cultivated citrus trees depends on the regular and straight rows which form an orchard. A certain amount of discretion in choosing the number of levels in the contour plot of the original image must be made as well as the longitudes of each row of the orchard.

Band 4 of the mrg image admits the best resolution of the contours over the other bands. From the tif image, an ASCII file is produced from which contours are made by means of the Generic Mapping Tool (GMT).

Each tree corresponds to a packet of pixels around which a contour is constructed. The same reflectance in a packet leads to a contour of constant level. If the packet of pixels is compact, meaning that it can be covered by a disk, then a contour will be closed. If each image of a tree corresponds to a compact packet of pixels, then it would be sufficient to count the number of centers of the contours, in order to estimate the number of trees in an orchard.

The trees, however, appear in different sizes so that the resolution of them is not consistent about the entire image. The trees having a large crown correspond to large packets of pixels with low reflectance, while small trees correspond to small packets with moderate reflectance. As a result, many irregularly shaped contours are produced from the ASCII file. The problem which requires some amount of discretion is the one of choosing the range of reflectance and the levels of contours which produce the finest resolution of the original image.

The contours shown in Figure 1, is the product of using band 4 and the range of reflectance, 45-55 with contours drawn at 2 unit intervals over a grid with .1 second of arc in spacing. It was produced by means of GMT. It generated a surface of co-ordinates taken from the ASCII file with a linear projection by a method of splines in tension such that the curvature of the surface is a minimum. The method used by GMT is based on the theory of harmonic partial differential equations of the fourth order. An important feature of the GMT is its capability to generate an ASCII file for each contour and more importantly to identify which contours are closed or opened. As revealed in Figure 1, the perimeter of the orchard leads to long open contours. We want the closed contours, because they represent the location of a tree.

A careful inspection of Figure 1 shows that a tree may be surrounded by several concentric contours. The centers of them are very close together and may be consolidated into one co-ordinate, and hence a single co-ordinate for a single tree. A more troublesome problem occurs when the crowns of large trees interleave so that a group of large trees might produce an elongated contour. It is in this regard that band 4 proves best because it allows for the highest resolution among the trees and between the trees and the roads. Even though a group of large trees produce elongated contours, the mingling of the crowns is not necessarily uniform. Some aspects of each crown on the fringe of the group produces very small contours. These small contours which lie beside the elongated contours provide sufficient additional information to separate the elongated contour into individual trees.

The third problem with the method concerns the counting of centers. Because a tree might be surrounded by several contours, it is necessary to associate the multiple centers with one tree. This is accomplished by rounding the co-ordinates in such a way as to consolidate the centers of a tree but not confound the centers with the centers of other trees.

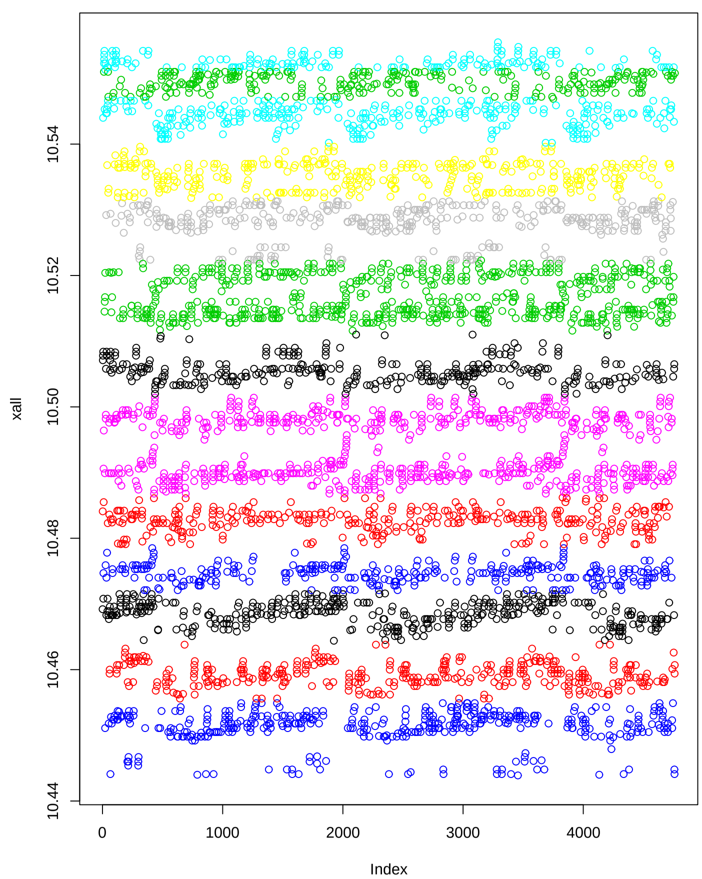
To accomplish the consolidation of centers and the discrimination of neighboring trees from one another require the right amount of rounding and the correct assignment of contours to a row of the orchard. Upon consolidating concentric contours and assigning a center to a row, it is possible to count the number of trees in a row and ultimately the number of trees in the orchard. The assignment of a contour to a row is performed by means of the multivariate statistical procedure known as clustering. Specifically, there is a routine in R which is call *kmeans* which clusters a set of data into k different means and assigns each element of the set of data to a cluster. If the orchard consists of fourteen rows, then the set of consolidated centers can be assigned to fourteen different clusters. The number of centers in each cluster represents the number of trees in that row of the orchard.

The number of rows of the orchard is a necessary ingredient in the method. Figure 2 shows the clustering of the centers into fourteen rows. Each cluster is depicted by a different color except the middle pair.

Of the problems which I cited, the one of rounding appears to affect the estimate of the number of trees the most. To the end of determining the right amount of rounding, four corners of the original image were cropped and the number of trees in each were estimated by this method and an actual count of was gotten by inspecting the original image. In a certain sense, the method must be calibrated for rounding. In my initial attempt of calibrating, the estimated number of trees in the entire image is 1121.

If this method is deemed feasible, then more research needs to be performed for resolving the problems of calibrating for rounding, determining a systematic procedure of finding the best resolution of the contours, and developing an efficient and comprehensive computer program. The method depends on the Generic Mapping Tool and on R both of which are GPL and can be installed on a Solaris system.

Figure 2:


xall
10.44
10.46
10.48
10.50
10.52
10.54
0
1000
2000
3000
4000
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