7 Summary and Conclusions

Segmentation is one of the crucial parts of a computer vision system. In this thesis the potential of using the often ignored color information for segmentation has been studied, in particular, the problem using color information to segment images of wooden boards was investigated. The use of conventional clustering techniques in segmenting the images of wood has been examined along with the effect of 3-dimensional filtering on histograms. A new model based approach has been developed that can accurately segment regions in a multidimensional color histogram relating to some surface features on wood. The performance of the model based approach has also been compared to an existing black and white segmentation algorithm in use in a defect detection system.

Among the different types of segmentation techniques that exist, clustering was identified to be the most suitable one due to the nature of the surface features on wood and the relative simplicity of clustering algorithms, that makes it possible to adapt them for use in realtime systems. Most of the features on the wood surface are color based which makes it possible to use clustering of the histograms rather than use clustering of the image, which has a tremendous advantage in terms of computational power, since the size of the histogram is constant and much smaller that the size of the image.

The applicability of conventional clustering techniques was studied prior to developing a new segmentation algorithm. The study showed that the conventional techniques are not very efficient on histograms of wood images for a number of reasons. First, the basic assumption that distinct clusters correspond to peaks in the histograms is not valid. This is due to the nature of the wood histograms as well as the presence of noise. Second, it is not possible to eliminate this noise with the use of filtering, without destroying useful data. While a very high order filter is necessary to smooth out the deep valleys in the histogram, it also destroys the signal in regions where the defect clusters are not very pronounced. Third, there are a number of conventional iterative techniques that have been suggested to obtain good segmentation. However, iterative solutions are not suitable for wood histograms due to the size of the histograms that must be used.

The study of the conventional clustering techniques and the results they could generate indicated the need for a different approach to the problem. A careful study of the color characteristics of the wood histograms showed that it is possible to model the histograms as gaussian distributions. This feature was used to develop the concept of a model based approach. The model based approach creates an *ideal* or a model histogram based on (part of) the original histogram. Deviations from the model, that are represented as a normal distribution, are used to determine the defect areas. The concept of weighted difference is introduced, which makes the difference measurement immune to noise around the peaks of the histogram, but sensitive to even small deviations from the model in regions away from the mean

The results of testing the model based approach on boards of pine, oak and yellow poplar, showed that such an approach is indeed feasible and that using the color information has some definite advantages for segmentation at the expense of using higher computational power. The results for pine boards indicated that the b-g histogram is most suitable. Obtaining heartwood-sapwood separation in yellow poplar required the use of a smaller part of the original histogram for developing the model, while a larger part of the original histogram is to be used if the heartwood-sapwood separation is necessary.

When color information is used in the segmentation process, in most cases, one is making use of the information that is already there and not adding additional hardware. Color based defects are easily identified by the model based approach. However, it is not possible to do so either with the b/w algorithm or the conventional clustering techniques, while maintaining reasonable speeds. Initial experiments have shown that the model based approach has great potential and flexibility, and can be adapted for specific needs in realtime defect detection systems.

7.1 Recommendations for Future Research

In this thesis, a basic approach has been developed for segmenting the images of wood in order to detect its features. A qualitative analysis is presented due to lack of a large number of samples to justify a quantitative study. The focus of the research was to study the various clustering techniques and their applicability to wood and not developing an algorithm that can be directly used in a realtime system. While the study shows that the model based approach is feasible, extensive testing will have to be performed in order to determine the range of the parameters suitable for each species. Only then can the algorithm be implemented in a real time system. A combination of analytical and experimental results can be used to develop a robust set of parameters, that can be used in a realtime system.

The interdependence of the various parameters needs to be examined in greater detail. For instance, a quantitative relationship needs to be developed between the parameter p and Th, and how they affect one another. The importance of the offset value needs to be examined to study if it has any other role in the segmentation process other than limiting the maximum value of the expression for weighted difference.

An important assumption is that the histogram of the clearwood part of the image resembles the normal distribution. The histogram of a board which is uniform in color, free from irregularities that manifests as abrupt change in colors like knots, wane, bark can be modeled as a gaussian distribution. This basic assumption can be extended to each feature on the surface of the board. For instance on a yellow poplar board, two separate distributions can be developed to model the heartwood and sapwood regions. This can be done instead of modeling the entire board based on the sap wood region alone and treat the heartwood regions as defect. To achieve this, a detailed study of the color characteristics of wood, along with documentation of where each feature of wood is generally seen in the color space is necessary. The color space can be divided into regions for each species indicating where each feature if likely to be present. An example of such a map is shown in Figure 7.1. It has to be noted that this figure is a hypothetical example and is used to illustrate the above discussion.

Once the general regions are identified, a peak detection algorithm can be employed in the regions which need to be modeled. The rest of the area can be treated as unwanted defects. This feature would be particularly useful in those species of wood where there are features on the surface which are undesirable for a particular application but is not in general considered a defect. Color variations on the board surface fall in this category. If there are known to be some prominent color variations on the surface, these can be modeled individually and isolated.

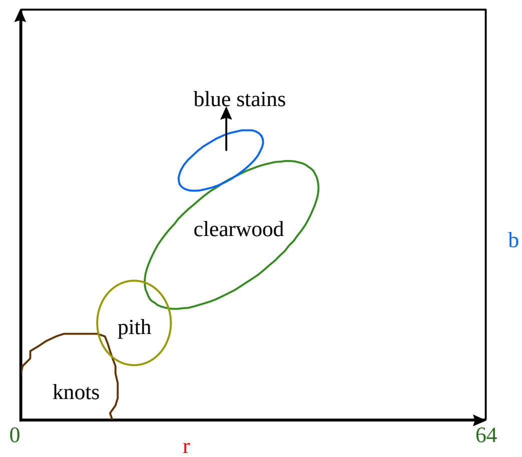

Figure 7.1: Hypothetical map of the color space indicating the probable presence of various features

The color information can be used in the cutting process so as to get boards, which are not only free from defects but also free from unwanted color variations. Modeling each of the individual regions separately can also be extended to three dimensions and the results can be studied. It would also be interesting to study the results of this algorithm if implemented in one dimension or in other words, on the b/w histogram alone.

A few aspects distinctive of three different species of wood are mentioned in this work. It would be worthwhile to extend this study on other species of wood and come up with an exhaustive set of parameters applicable to different species of wood and different types of segmentation. Incorporating all these features in a realtime defect detection system will definitely improve the quality of products obtained, and help realize the full potential of a defect detection system.

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Vita

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