Chapter 6
Conclusions and Future Work

In this study, for the purpose of image processing and analysis, many different approaches are attempted. This section explores the work that leads to the development of the algorithms described in the previous chapters.

The aim of Precision Farming is to:

- Increase the agricultural productivity by maximizing the efficiency of farming resources,
- Save environmental degradation,
- Find alternative for short labor supply in future.

The above factors motivated to provide a cost effective and easy to handle alternative for Precision Farming of sugarcane.

The primary intention is to offer automated process of quality seed selection, which cuts the role of labor and ultimately reduces the planting cost and time. As mentioned in chapter-2, crop status management of sugarcane for initial two stages of growth is most important, with focus on Fertigation rate and disease control.

In relation to this, algorithms are designed for quality seed selection and crop status management. After successful implementation of these algorithms, conclusions are as follow:

6.1 Seed Selection

The success rate of identification of normal node is 95% which shows that the light intensity and the shape of nodes have no significant effect on the identification of node
location in this method. There are two a reason in which algorithm fails to identify node:

1. Nodes with undeveloped growth ring, leaf scare and root band,

2. If leaf is not removed properly from the stalk, sheath part of the leaf covers growth ring, leaf scare and root band.

The success rate of identification of the defective node (cracked) is 86%. There are two factors affecting the crack identification process:

1. Airy root on the node which forms black pixel line in between two consecutive nodes and detects it as a crack.

2. If crack is not in the vision of camera that crack does not come in image of the stalk.

The success rate of identification of stressed node is 100% which shows that algorithm effectively identifies the stressed nodes. Careful observation shows that cut point fixed by the algorithm is at the center of the sugarcane stalk.

This research shows that an image processing is useful tool for automation of planting machine that identifies the normal nodes and cut the stalk to single eye bud. This saves the man power and demand of seed per hectare.

6.2 Crop Status Management

1. Growth measurement: The algorithm developed for growth measurement of sugarcane plant is tested on different conditions of the +1 dewlap. The results of the experiment are compared with growth measured physically using meter scale. The accuracy of measurement of the growth by algorithm is greater than 96% and Root Mean Square Error is 0.2872.

The accuracy is higher at constant light condition. Detecting the boundary curvature, we could find the axils and the dewlap. However it is difficult to determine the dewlap of the +1 leaf if the 0 leaf is almost fully developed.

There are three causes of error:

(a) If withered leaf is not properly eliminated.
(b) Width of the +1 leaf is too narrow therefore the +1 dewlap leaf cuts off during the eroding process.

(c) If the stem of plant is not straight.

This research shows that an image processing is a useful tool to measure the growth of the plant and will be helpful for agricultural scientists and farmers to determine the Fertigation rates and Stress before heavy soil work.

2. **Chlorophyll measurement**: The discussed work of measurement of chlorophyll describes use of image analysis for determination of chlorophyll content of leaves of sugarcane plant using HSV colour space. Linear mathematical HSV model is used to co-relate with the chlorophyll content apart from the simple correlation analysis.

A good agreement between the predicted and actual chlorophyll content is demonstrated. The Root Mean Square Error (RMSE) between predicted chlorophyll and chlorophyll measured by meter comes out to be 1.9334. The result indicates that the proposed colour space analysis is reliable and efficient for estimation of chlorophyll content.

The Chlorophyll meter was used in the present study to determine the chlorophyll content, which has already been established as a useful tool for quantitative estimation of chlorophyll in a non-destructive manner. However, while real time estimation of chlorophyll content of leaves, average of reading of single leaf is the indication of chlorophyll. The use of proposed algorithm avoids the need of average reading. It covers the whole area of the leaf in image and it is possible to calculate the total chlorophyll.

This proposed method is simple and user friendly hence useful tool in laboratory as well as in the fields to measure chlorophyll non-destructively. This methodology is also useful to measure the chlorophyll content of the leaf of other plants by simply changing the model parameters.

3. **Diseases severity measurement**: Disease symptoms of the plant vary significantly under the different stages of the disease. Hence, to some extent the accuracy depends upon segmentation of the image. Otsu threshold segmentation is used for leaf region segmentation but this thresholding method is not suitable to disease region segmentation because of varying characteristics of the disease.
The Triangle method of the thresholding is used to segment the disease region. The average accuracy of the algorithm is tested using known area diagram and comes out to be 98.60%.

The main advantage of image processing method (algorithm) to measure leaf disease severity is its convenience and accuracy. It helps farmers to decide the specific quantity and concentration of pesticide to control the disease which would ultimately reduce the production cost and help to maintain the ecosystem.

6.3 Research Contribution Towards Precision Farming

The main aim of Precision Farming is to find alternative for shortage of labor supply in future for agriculture, to increase the productivity and quality by maximizing the efficiency of farming resources and to save the environmental degradation.

With consideration of Indian scenario of sugarcane agriculture, efficient algorithms are designed to fulfill the aim of Precision Farming. Those are for Seed selection and Crop status management.

- **Seed Selection**: Drawbacks of planting of sugarcane by Traditional method and Machine planting method are overcome by the developed algorithm. The work carried out and presented in this thesis is unique and novel with specially designed GUI for its validation.

  Designed algorithm gives 95% and above accuracy which is useful in the automation of sugarcane planting machine. It not only saves the labor cost but also cuts the single node of the sugarcane stalk. Further, selected single node is suitable for STP method of planting that saves the production cost in the form of the seed. While selecting normal node for the plantation it rejects the diseased or stressed node, which eventually increases average yield and quality of the sugarcane.

  The contribution made in this work is authenticated by the Department of Agriculture Engineering, Vasantdada Sugarcane Institute, Manjadi (Bk), Dist-Pune (M.S.). The authentication letter is given in the Appendix F.
• **Crop Status Management**: Considering the duration of sugarcane crop in India, efficient algorithms designed for crop status management consist of Growth measurement, Chlorophyll measurement and Disease severity measurement.

  – **Growth measurement**: Drawbacks of the Growth measured by Dry weight method and Meter scale method are overcome due to the contribution made by this research work. The accuracy of measurement of Growth by the designed algorithm is 96% and RMSE is 0.2872 for all growth structures of sugarcane. This is superior to above mentioned methods.

  Designed algorithm is accurate and very useful as a growth measuring tool for agricultural scientist and farmers. This can be used to determine the Fertilizer requirement, rate of Irrigation and Stress conditions. This ultimately maximizes the efficiency of farming resources to minimize the production cost.

  This type of research to measure the sugarcane growth is conducted first time. The work is also authenticated by agricultural research laboratory of Shree Datta Shetkari Sahakari Sakhar Karkhana Ltd. Shirol, Dist-Kolhapur (M.S.). Authentication latter is given in Appendix G.

  – **Chlorophyll measurement**: The Chlorophyll meter (CMY 1000) is used for validation of results of presented algorithm, which has already been established as a useful tool for quantitative estimation of chlorophyll content of leaves. In this work spectral information such as, luminosity, hue and saturation colour coordinates are considered to study relationship of colour coordinates with chlorophyll content. RMSE value for measurement of chlorophyll by HSV model is 1.9334, in contrast with 3.00 determined by RGB model.

  The designed algorithm using colour space analysis is simple, reliable and user friendly hence useful tool in laboratory as well as in the fields while measuring the chlorophyll non-destructively. Assessments of content of chlorophyll in the leaves are useful to determine the nutrient deficiency of plant.

  The contribution of work in measurement of chlorophyll is authenticated by Department of Botany, Shivaji University Kolhapur, (M.S.), India. The authentication latter is given in Appendix H. The contribution of work is also appreciated and authenticated by agricultural research laboratory of
Shree Datta Shetkari Sahakari Sakhar Karkhana Ltd. Shirol, Dist-Kolhapur (M.S.). Authentication letter is given in Appendix G.

- **Disease severity measurement**: Excessive use of pesticide against the protection of disease increases the cost of production and results in environmental degradation.

The algorithm developed in this work to measure disease severity of leaf is unique and first attempt to measure the disease severity automatically. To validate the results of this algorithm known area standard diagram is designed. The average accuracy of the algorithm is tested using known area standard diagram and it comes out to be 98.60%.

The main advantage of this algorithm is its convenience and accuracy. It helps the farmers to decide the specific quantity and concentration of pesticides to control the disease, which would reduce the production cost and saves the environmental degradation.

This research work is authenticated by Plant Protection Department of Vas-antdada Sugarcane Institute, Manjari (Bk), Dist- Pune (M.S.). The authentication letter is given in the Appendix I.

Thus presented research work using Image Processing algorithms, fulfill the aims and objectives of Precision Farming of sugarcane.

### 6.4 Future Work

1. Although we have considered the factor of vertical growth measurement of crop Horizontal growth could be measured for crop status management.

2. We have addressed the problem of leaf disease occurring in sugarcane crop, but Researchers can also address different categories of stem disease (Red rot and Pineapple) those are also affects the quality and yield of crop.

3. We also leave an open area of research for weed monitoring and control that would direct to farmers to take appropriate action.
Publications from the Thesis

Journals


