

## **CHAPTER 8**

### **SUMMARY AND CONCLUSIONS**

#### **8.1 GENERAL**

Quality inspection of agriculture products like fruits is an important factor in food/agricultural industry. Specially picked quality graders have usually performed this visual inspection. The overall quality decisions may be inconsistent and vary among the graders. Use of automated online sorting systems based on machine vision will facilitate quick and efficient sorting of large quantities of produce with consistent and reliable quality. The inspection system should be capable of measuring the important quality parameters like size, shape, colour, etc. To be cost effective, there is a need for investigating less expensive image processing techniques.

#### **8.2 REVIEW OF THE WORK DONE**

In view of the above, an online machine vision system for sorting of fruits like apples has been developed and evaluated. Present thesis has described the details regarding the development of the system comprising of a conveyer system, illumination system, imaging system and image processing based sorting algorithms.

An improved conveyor system containing fruit feeding and singulation, orientation and conveyor units has been developed. A vertical orientation unit for orienting the apple vertically has been fabricated and evaluated. A new horizontal orientation unit for orienting apples horizontally along stem-calyx axis has been developed, evaluated and integrated into the online sorting system. The unit offers increased contact of fruit's surface with rollers resulting in lower slippage and better imaging efficiency compared to bi-cones arrangement. This unit also offers quick and efficient orientation of apples and provides higher throughput. The unit has provision to automatically accommodate different sizes of apples.

An improved illumination system has been developed using front illumination scheme to provide uniform, diffused and balanced white light to illuminate the fruits for imaging. The design utilises a combination of CFL and incandescent lamps to provide white light having fairly equal RGB colour components over the field of view. The system has been verified as per the application requirements and integrated into the online sorter

An imaging system has been developed using a colour CCD camera, frame grabber card and suitable software for the calibration of camera and image capture. A novel scheme has been developed for synchronising the image capture to the fruit's rotation and movement on the conveyer. A novel scheme of colouring the background machine parts has been developed for efficient extraction of the apple images from the captured image. This has been successfully integrated into the online sorter.

Various algorithms have been developed for determination of size, shape and colour for grading of fruits. For size determination, analytical and

statistical methods have been proposed. Analytical methods namely circle, ellipse and parabola methods approximate the image contour by the corresponding shapes for fruits exhibiting reasonable symmetry about the stem-calyx axis. These methods are more suitable for sorting apples produced in a same geographical area and having nearly similar shape. Principal axis method utilises the length of the principal axis as a measure of size for fruits exhibiting asymmetry about stem-calyx axis. The statistical methods utilise radius and area signatures. Coefficient of variation method utilises a relative analyses of the parameter signatures for comparing fruit sizes. Choice of an appropriate method depends on the shape of the fruit. For shape analysis, three new methods, namely radius signature, area signature and contour vectors methods have been proposed and evaluated. These methods facilitate deriving a shape number for shape discrimination. For colour analysis, two methods namely hue histogram analysis and linear discriminant analysis methods have been proposed for classifying fruits based on colour. Histogram analysis method compares the hue histograms. The linear discriminant method uses Mahalanobis distance criterion for classification.

The online sorter fabricated by integrating the above hardware and software has been evaluated using limited number of apples and found to be giving reasonable performance.

### **8.3 SCOPE FOR FUTURE WORK**

Research work described in the present thesis provides scope for further work in the following topics:

- a) Size and shape of fruits are closely interrelated. Algorithms used for size/shape determination utilize the same boundary information to extract

the size/shape measures, which are often interdependent. Considering these factors, there is a need for more careful analysis of the size and shape interdependence and devise a sort of composite measure for fruit quality.

- b) Colour distribution on fruit's surface usually indicates maturity, ripeness, and presence of external defects. Thus, there is scope to improve the colour analysis algorithms to determine these additional quality parameters.
- c) Published literature indicates that regions of fruit having external and internal defects may exhibit a different reflectance behaviour compared to the normal tissue particularly in the NIR range. This property can be utilized to evaluate the internal defects of fruits using machine vision. This may require usage of suitable cameras having good NIR response and matching NIR filters.
- d) The image processing algorithms used for quality inspection may require considerable computational time particularly while analysing high-resolution images for a larger number of parameters. Usage of dedicated DSP based hardware to execute these algorithms can substantially reduce the execution time and help increase the throughput.
- e) A machine vision system assigns a quality grade to an inspected fruit based on several parameters. Considering the natural variability in fruits, the decision-making can become quite complicated while involving large number of parameters. Also, a provision to train the sorting system may be of great use. Considering these requirements, usage of fuzzy logic or neural network techniques for the decision making process may be helpful in realization of high performance sorters.