論 文 の 内 容 の 要 旨

生物･環境工学専攻

平成 22 年度博士課程　入学

氏名：　許　永偉

指導教員名：　芋生憲司

論文題目：Image Processing of a Binocular Stereovision System for Strawberry Harvesting Robot

（イチゴ収穫ロボットのためのステレオビジョンシステムの画像処理）

Strawberries are one of the most popular fruits in Japan, and are profitable for farmers because of their high price. Japanese strawberries are mainly grown in greenhouses and have a long, labor-intensive harvest season, which has hindered the expansion of production scale, so the processes need to be automated.

In previous studies, the strawberry harvesting robot’s machine vision was mainly based on several plane pictures without stereoscopic vision, which used color information, morphology, edge extraction or neural network to detect the strawberry region and then give enough stem position information. The detecting accuracy for single strawberry was high. However, when the strawberries are overlapped each other, the stems are dense, or fruits (including unripe fruit) and leaves are crowded together, the detecting accuracy was extreme low. Moreover, considering the actual cultivation conditions and the problems indicated in previous studies, there is a low rate of accuracy for detecting the strawberry peduncle using images on multiple planes without stereovision even for a particular variety of strawberry. For successful strawberry picking, the robot end-effector must be provided with sufficient information on the peduncle position. Meanwhile, for strawberries that are sorted according to shape and size, the shape information will be useful for the automatic sorting and packing processes.

Inspired by the earlier studies, with the goal of obtaining the 3D shape (surface information) and peduncle position of the strawberries, we proposed a new system: a binocular stereovision system capable

of reconstructing the 3D shape of a strawberry and calculating the 3D coordinate position of the peduncle. We eagerly looked forward to obtaining the precise position (even for the overlap strawberries) and shape information of each strawberry using only two cameras.

Our system worked as follows: in the strawberry detection operation, the binocular cameras simultaneously acquired left and right images of the plantlet. Then, we detected the strawberries and segmented the peduncle region. For the peduncles, the picking point was determined from the lines in the left image and the corresponding lines in the right image, using the Hough method. Having established the 2D coordinates of the picking point in both images, the stereovision algorithm was applied to calculate the corresponding 3D world coordinates. Then, the 3D coordinate data was supplied to draw the position of each strawberry in a new picture to determine the picking order. Finally, we used a template matching algorithm to reconstruct the strawberry surface.

For recognizing/detecting of the strawberries, we developed a new method of detecting strawberries in images based on Histogram of Oriented Gradient (HOG) descriptor associated with a Support Vector Machine (SVM) classifier and evaluate its efficiency. The detection includes two stages: first get the HSV color information to detect the strawberry-like region, use the 5 Region of Interest (ROI) regions to calculate the HOG descriptor, and then feed it to the HOG/SVM classifier to detect the strawberries. The dimensions of the vector were reduced effectively and can achieve higher detection speed and accuracy. The final results show that this classifier achieves good detection accuracy (86.53%) performance at reasonable run time, and can deal well with the overlap strawberries.

For the setup and the peduncle position accuracy, after detected the strawberries, we tested several different sized spaces between the binocular cameras to find the optimal spacing of the setup. We calculated various distances between the strawberries and the cameras from 260 mm to 760 mm, and each point's result is the average of three times. The binocular cameras with a spacing of 55mm performance best, and when the distance between strawberries and the cameras is about 500 mm with the highest accuracy. The effects of this system were evaluated and the results indicated successful extraction of the peduncle's 3D coordinates, especially the calculated Z coordinate (distance) at a high accuracy (RMSE 1.958 mm). Finally, according to the strawberries distance and size, the algorithms for calculating the picking order were proposed.

For the 3D shape of the strawberry, it was reconstructed using the binocular stereovision system based on pattern matching. The positional root mean square errors in the reconstructed contours were less than 1.5 mm for most of the tested samples. The results also showed that this system can reconstruct the

strawberry's 3D shape as effectively as a laser scanner.

Furthermore, the method of recognizing/detecting the strawberries using the reconstructed 3D shape information was also developed and tested.

Keywords: Strawberry, Binocular, HOG/SVM, Peduncle location, 3D Shape, matching