学位論文内容の要旨

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学位論文題名
Development of computer-vision system based on smartphone image and
artificial neural network for postharvest management of agricultural products
（農産物の収穫後の管理のためのスマートフォンのイメージと
ニューラルネットワークを基盤としたコンピュータービジョンシステムの開発）

To deliver high-quality agricultural products to consumers, advancement of various agricultural processes such as harvest, storage, and distribution are indispensable. In particular, since climacteric fruits continue to ripen after harvest and progress physiological changes such as softening, reduction in acidity, and conversion of starch to sugar, changes in the quality are needed to monitor and evaluate non-destructively for appropriate management. There have been some non-destructive methods for evaluating the fruits quality such as sugar content using electromagnetic radiation such as near infrared spectroscopy. However, conventional non-destructive evaluation methods are relatively complex system and expensive. Therefore, more cost-effective and easy-to-use methodology is required to determine the ripening status of fruits to guarantee high product quality during storage and ripening process. In this study, a computer vision system (CVS) based on both smartphone and artificial neural network was developed. The developed CVS applied to determine the quality indices of Hass avocado and Cavendish banana during ripening process at different storage conditions.

1.　Development of computer vision system

The application of computer vision in agriculture has increased considerably in the last few decades. In particular, there have been many efforts to build fruit classification and internal quality prediction systems using computer vision, and near-infrared devices have been generally utilized as a practical solution. Recently, smartphone is actively being used for nondestructive analysis of fruits, because of its ease of use, portability, and variety of functionalities. Thus, the utility of the smartphone camera as computer vision was investigated by comparing the several color features ($L*$, $a*$, $b*$, chroma, hue angle, ΔE, ΔL, ΔC, and ΔH) obtained using a smartphone and a colorimeter. The equivalence between two methods was determined by the root mean square error

(RMSE) of each color features (*L**, *a**, *b**, chroma, hue angle, ΔE, ΔL, ΔC, and ΔH). Because the RMSE of the most color values in different color system ranged from 0.06 to 2.62, which would be sufficient performance for the color evaluation, it would be illustrated that the smartphone camera can be used as a computer vision.

2. **Application of the developed computer vision system into ripening process for Hass avocado**

Avocado is a climacteric fruit that continues to ripen after harvest, and the storage temperature affects the time needed for the avocado to soften and the subsequent avocado quality during ripening process. Thus, the quality changes in 'Hass' avocado during ripening process was investigated at four different temperatures (10, 15, 20, and 25°C). In addition, prediction models for quality indices were developed using several features (color, Hu moments, and histogram of oriented gradients (HOG) extracted via image processing) and artificial neural network (ANN). As a result, the best performance could be achieved using the color feature-based ANN model, and when using the model, several quality indices could be predicted with high accuracy regardless of storage conditions.

3. **Application of the developed computer vision system into ripening process for Cavendish banana**

Banana is one of the most popular fruits in the world, and is the main fruit in international trade. Since banana is a climacteric fruit, it is typically harvested at unripe state and is ripened during storage and distribution. Temperature and relative humidity (RH) are factors that greatly affect banana ripening. Thus, we investigated the quality changes of 'Cavendish' banana during ripening process at four different temperatures (20, 25, 27.5, and 30°C with 90%RH) and three RH (50, 70, and 90% at 20°C temperature). Furthermore, quality indices prediction models using several features (color, Hu moments, and histogram of oriented gradients extracted via image processing) and ANN was developed and compared the performance of each model. As a result, when using color feature-based ANN model, some quality indices such as sugar contents and firmness could be predicted with high accuracy regardless of storage conditions. This result suggested that changes in the peel color are more significantly involved in the progress of ripening banana than that of other features in local shape of the banana.