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Design of Integrated Precision Infotronics System in Plant Factory

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Abstract

Plant factory is known as the closed controlled plant production systems with the artificial lighting. Environmental factors have been concerned as the most important factors to influence quality of product in plant factory. One of the most applicable technologies for optimizing plant production system in plant factory is Infotronics. In the plant factory, Infotronics is defined as a combination technology between quality control, sensor application, image and intelligent system. In this paper, design of integrated precision infotronics system in plant factory will be highlighted. The objective is to review the strategic utilization of infotronics in order to optimize production system. It was found that infotronics can be integrated as precision system consisting of system identification of plant growth, non destructive method for measuring quality features, speaking plant approach and development of hazard analysis critical control system and quality diagnostic system. It is possible to design the utilization in to the integrated precision infotronics system.

Keywords: Artificial neural network, integrated system, strategic utilisation, texture Analysis

1. Introduction

Quality concern in the world's industries has been brought about by the implementation of quality assurance and total quality management. In the protected controlled horticulture system, environmental factors have been concerned as the most important factors to influence quality of product. Plant factory is known as the closed controlled plant production systems with the artificial lighting. Accordingly, three main Hazard Analysis Critical Control Points (HACCP) factors were classified in to human, environmental and plant. Instead of that, the most of the environmental factors in a fully controlled plant factory are observable and controllable. However, growth chamber as one of the most common and applicable of controlled environment has shown some non-uniformity within the interior location of it. Preliminary observation of growth chamber under condition of relative humidity 80-90% and temperature 15^0C -16^0C has shown high variance value approximately 154 for Photosynthesis Photon Flux Density (PPFD) (88.5 μ mol m^{-2} s^{-1} ± 12), 151 for relative humidity (77.2% ± 11.6) and 4 for temperature (18.3^0C ± 1.9) for specified points. It was measured on 64 points in growth chamber in 8 different spaces.

Recent rapid advances in the world's industries have been brought about by the implementation of technologies such as system modeling of the production process with advanced information processing, and the automation and rationalization of production lines.

Agriculture has not benefited from many of these advanced technologies until very recently (Murase, 2002). One of the most applicable technologies for optimizing plant production system in plant factory is Infotronics. In the plant factory, Infotronics is defined as combination technology between quality control, sensor application, image and intelligent system. In this paper, the strategic utilization of infotronics in plant factory will be discussed.

2. Strategic Utilization

A closed, fully controlled plant-growing factory has great advantages in terms of minimizing all kinds of wastes and losses. In order to make a comprehensive point of view, in Figure 1., the system analysis of plant factory is highlighted related to quality concern. It consists of 4 systems as supplier, plant factory, product quality and customer. For supplier and plant factory, plant, human, Soil Plant Atmosphere Continuum (SPAC) and growth chamber has taken important aspect to influence optimization of its. The expected result is product quality which is influenced from infotronics and Hazard Analysis Critical Control Point (HACCP). It will be remarked by the customer based on decision of mood and cost.

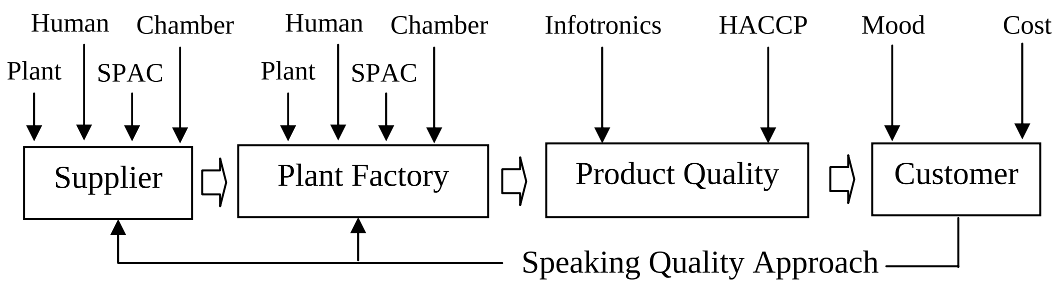

Figure 1. Complex and dynamical system of plant factory

The major utilization of infotronics can be classified as 4 main fields covering:

A. System Identification of Moss Growth System

A moss (*Rhacomitrium canescens*) growth system was identified in order to clarify the clausal relationship between input parameters and output parameters utilizing artificial neural network (ANN) model. Input parameters were defined as three cardinal temperatures in addition to ambient temperature while output parameters defined as heat unit accumulation, relative rate of growth, leaf area index, moss height, moss mass and temperature stress factor. The physical properties of moss were determined using a non-destructive imaging method and a conventional destructive method. Some of the data needed for the system identification were obtained from the literature. The model performance was tested and successfully described the relationship between input and output parameters which can be used for moss growth control. A minimum learning error of 6.96 x 10^{-2} was attained at convergence of the ANN training. The most notable experimentally determined values were specific leaf area of 1.498 m^2/kg and ground area of 28 mm^2/plant in the leaf area index sub-model (Ushada and Murase, 2006).

B. Non-Destructive Method

Direct measuring of physiological and physical activities of the plant has a great possibility to disturb the physiological activity of the plants. This means that optimal condition for growth will not be achieved if such kind of technique was used. Furthermore it means that there will be quality degradation. Therefore an indirect measurement technique was required. Two most usable techniques is non-invasive and non-destructive method. Non-invasive have been applied for specific application of food industries and remote sensing technologies. Non-destructive methods have been applied for micro-application of the green houses although the precision capability is the same as non-invasive method.

In this paper non-destructive method in the plant factory is defined as relationship between plant and sensor. For the sensor, we use the application of texture analysis algorithm in order to detect the changes of water status in the plant. This is based on the fact that changes in appearance of a plant canopy or a community of plants due to the water status reflect tonal variations over the community of plant. Mechanism of opening and closing from the plant will make specific change of canopy. Subsequently it can be detected by texture analysis using characteristic of grey level extraction of co-occurrences matrix (Ushada et al., 2006a). The application of this kind of intelligent system is known as mechanism of feed forward where the input is image features and the output is physiological and physical parameters. The existence of the non destructive method can be utilized as one emerging technology for sensor fusion

C. Speaking Plant Approach

While the non destructive is mentioned as feed-forward mechanism, the speaking plant approach can be stated as the inverse model of non destructive (Ushada et al., 2006a). Murase et al. (1997) stated that the practice of non-destructive measurements in the plants using Speaking Plant Approach (SPA) is essential for the bio-response feedback and/or feed-forward control system of closed ecosystems.

D. Hazard Analysis and Critical Control Points

Hazard Analysis and Critical Control Points (HACCP) are a basic consideration not only for food industries in the initial application, but also for horticultural activities. Although HACCP was designed for food safety purposes, there has been strong support in its application to manage produce quality risk resulting in an improvement in the consistency of quality of plant factory’s product such as cultured sunagoke moss *Rhacomitrium canescens* (Murase et al., 2006b). There is also strong evidence to suggest that the application of the method can lead to increasing awareness of new ways to deal with existing problems and improve or widen the scope of operational processes.

The concept of speaking plant approach is enlarged as a new concept of speaking quality approach related to precision quality. Speaking quality approach is combination between speaking plant approach and quality function deployment. Speaking plant approach is representing micro-precision technology in order to optimize plant production system for environmental safety guard. Quality function deployment is representing quality control system to ensure that quality of product is maintain of every step of production system to achieve total customer satisfactory. By connecting using intelligent image analysis, it is expected to be a systematic quality approach from the first step of production system until the last hand of customers.

In the means time, the concept of local environmental control is highlighted due to non-uniform environmental condition. Local environmental factors are consisting of temperature, humidity, carbon dioxide concentration and PPFD in specific location of growth chamber. These factors have potentiality to stimulate variation of quality features/growth indices of plant such as water status, visual appearance, leaf area index and moisture content. In other view from the customer aspect, the growth indices can also be an indicator of quality features to fulfill its requirement.

In other sides, changes in the appearance of a plant canopy due to growth reflected variations of pattern. Subsequently, various type of plants canopy also reflected variation of visual appearance to the human in plant factory. The canopy of cultured sunagoke moss (*Rhacomitrium canecens*) has been observed in plant factory. Its essential function as an active greening material in order to ease urban heat, has put the high consideration in order to make mass production in the form of plant factory.

It was shown that different type of moss generated different patterns of three textural features which were extracted from grey level co-occurrences matrix. It also generated different growth indices values. This concludes that variation of growth indices can be a potential indicator for safety production procedures and customer requirements. Furthermore, there is a need to utilize an intelligent image analysis system due to local environmental factors. It is possible that variation of its will also generate various patterns of image feature. Therefore, it is expected to support the decision support analysis in local environmental control application in plant factory.

3. Conclusions

It can be concluded that infotronics can provide promising approach towards utilization of information technology in plant factory. However, since the production system in plant factory is dynamical system, the support of biosystems-based algorithm remains the importance related to optimization technique. The intelligent based system is expected to be decision support system in preventing quality degradation.

4. References

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