ADVANCES IN GREENHOUSE CLIMATE CONTROL

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Abstract

Recent developments in micro-electronics, computer hardware and methodologies are discussed. Advances can be identified in instrumentation, modelling and simulation techniques, control algorithms and in the field of artificial intelligence.

1. Introduction

Prior to this symposium, a working party was held on the topic of advances in greenhouse climate control The contributions of this working party will be summarized here.

In recent years advances can be identified which are due to improved instrumentation, better modelling and simulation techniques, more sophisticated algorithms which take into account crop responses (the speaking plant approach) or physical phenomena like ventilation. Presently, the grower controls his greenhouse by setting desired values (setpoints) for the controlled variables. In the way setpoints are manipulated a lot of expertise is involved. Recent developments in computer science, especially in the area of artificial intelligence provide opportunities to incorporate this expertise in algorithms.

2. Instrumentation

On the level of instrumentation, computer control equipment and sensors are of interest. In computer control the decreasing hardware and - to a lesser extend - interfacing costs make small embedded computer systems easily available. The main trend here is distributed control (Saffell, 1985). This is not only explained because of the increased reliability of embedded systems, but also because this set-up reduces the necessary multitasking resources of the central computer. Interesting is that the decentralized systems perform most control functions and that the control computers are mainly used for man-machine interfacing, alarms and setpoint scheduling. It is not difficult to see data links with management information systems emerge in the near future.

The decreasing costs of micro-electronics also make new sensors available especially in the field of chemical analysis. For example in nutrient film cultivation - in case of recirculation of the nutrient solution - the correct balance of the various nutrients is difficult to measure.

3. Modelling and simulation

Modelling and simulation of the control behaviour of greenhouses can be regarded as the backbone in the development of control algorithms. One can choose here for a physical model - in which the basic heat and mass transports are described - or for a black-box modelling approach which is developed to give the control characteristics. An interesting application of a physical model is described by Kozai et.al (1985) where a greenhouse climate simulation program is developed in a microcomputer. Interfacing is provided in order to facilitate hook-up with a real greenhouse computer. In this manner, tests can be carried out in order to assess the merits of the greenhouse computer climate control algorithms plus its interfacing (software).

In the field of black-box modelling, advances have been made with models in which the soil temperature is considered as energy storage element (Udink ten Cate, 1985). This leads to models of which the parameters are formulated in heating-load coefficients, which are widely available. The models can be easily formulated in transfer functions or (reduced) matrix form suitable to apply modern control theory (Wells et.al., 1985). The transfer functions give the relations between various exogeneous variables (heating system, outside air, radiation) and the greenhouse air temperature. Interesting is that the dynamics of all the transfer functions are similar; only the (static) gains differ. This means that dynamic forms of feedforward compensation can be formulated using static coefficients. An example of the application of this phenomenon is described by Tantau (1985).

Returning to physical models, a similar approach can be followed using other types of representation than ordinary differential equations. Huang (1985) uses a technique based on electrical networks. The advantages of this approach are that the model can be analyzed in the frequency domain, which is most suitable for control analysis.

4. New control methods

Results on the incorporation of plant responses in climate control (the speaking plant approach) are described by Hashimoto et.al (1985). Using parameter estimation methods and an impulse weighting function, carbon dioxide uptake is modelled as affected by environmental changes. With a suitable computer system, this information can be used in an online decision procedure for environmental control.

Bakker (1985) presents a carbon dioxide control algorithm which is developed for a situation where carbon dioxide enrichment is applied. The loss of carbon dioxide due to uptake and ventilation is compensated using feedforward compensation. Clearly the algorithm is the basis for online optimization of enrichment procedures.

Ventilation control in greenhouses remains a problematic area since the ventilation case is neither measurable nor predictable in commercial greenhouses. Hooper et. al. (1985) contribute an adaptive control algorithm, where the ventilation rate is implicitely controlled in a ventilation window aperture control algorithm.

5. Artificial intelligence

An interesting new area of interest is artificial intelligence. As pointed out already, much knowledge of the grower is involved by manipulating the settings of existing computer control algorithms. Artificial intelligence might provide a way to formalize this knowledge. An important paper of this topic is given by Kozai et.al. (1985).

6. Conclusions

Several typical advances have been discussed above. It is seen that developments in micro-electronics and computer hardware as well as new methodologies continue to emerge in the field of greenhouse climate control, leaving a fruitful area for research and development.

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