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Greenhouse lighting control by chlorophyll fluorescence

Project plan in course SSY226

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1
Background

The key to the rise of the sedentary human civilization was agriculture, to cultivate land and breed plants and animals for food and other necessities. Nowadays agriculture is essential to feed the growing population and food production needs to be increased by 60 % by 2050 to satisfy the rising demand [3]. Thus farming industries will increase and effectiveness in the cultivation will be essential for the future.
It is beneficial for plant growing industry to maximize the growth of the plants and minimize the energy usage. One factor that influences the growth is light. The light can come from natural sources or by the use of artificial light. If a plant receives too little light, the plant growth is diminished. On the other hand, if the light intensity is too high, the plants become stressed, which will again reduce the growth, and energy used for the lights is wasted.
It is possible to estimate the stress level of plants by measuring a fluorescence signal emitted by plants. It has been noticed during earlier research that the signal differs depending on the stress level of the plant. The idea is to use these measurements to design a feedback control of the lighting in order to use the optimal level of lighting.
Much work has already been carried out in this field. Thorough studies have been done to confirm that remote measuring of plant stress level is possible and methods are being developed to analyze it through chlorophyll fluorescence response signal [2]. Research has been done to find the optimal spectrum of the light [1]. The frequency response of the fluorescence signal has been thoroughly analyzed, mostly how the magnitude changes with the light intensities applied [4].
The focus in this project is put on phase shift, it means an analysis will be done to look at how the phase shift changes in response to changing the light intensity. The optimal phase shift will be determined and a control will be designed which locks the phase shift to the optimal value. It has been shown that phase shift can be used to estimate light induced stress [2], but no control design has been implemented yet.

2
Purpose

The aim of this project is to design a controller that keeps the lighting at a predefined light stress level for the plants. In order to achieve this final goal, much preparatory work has to be done. How the measured fluorescence signal translates to plant stress level needs to be analyzed. Since a phase shift is used as an indicator of the plant stress level, an estimation of the phase shift is required to be made. Thus the first objective is to achieve a robust way to estimate phase shift from the measurements, thereafter a robust feedback controller to lock the specified phase shift can be implemented.

3
Problem

The goal is to measure plants health by looking at the phase shift between the fluorescence signal the plants emit and the excitation signal. With the feedback of the phase shift the lights should automatically adjust the light intensity to create optimal growth of the plants. The setup needs to be easy to use so others can carry out experiments with only a short introduction to the system.

The first thing that needs to be done is to create a good setup and working communication between the lamps, spectrometer, fluorescence sensor and MATLAB in the computer. Calibration of the fluorescence measurement is required and a filter needs to be designed for the signal to reduce noise.

A sinusoidal excitation signal is desirable, because if the excitation signal is sinusoidal, the fluorescence signal will also be approximately sinusoidal, assuming that the amplitude of the light signal has small variations. However, the system between power input and emitted light from the plant is nonlinear, meaning the output will not change proportionally with the change of input. To achieve sinusoidal light emission, a correct mapping between the power input and the emitted light needs to be created.

When this is achieved, the relation between excitation signal and fluorescence signal will be approximately linear [2], though some nonlinearity and measurement noise will be present. A method needs to be derived that can be used for estimating the phase shift, despite the nonlinearity and noise.

A transfer function showing the relationship between the emitted light and the fluorescence will be created. System identification can be used for that, with the help of already existing models and data. If necessary, new experiments can also be made. Based on the model, a feedback controller which locks the phase shift needs to be designed and implemented in MATLAB and Simulink.

The robustness needs to be analyzed for the system. It is important to know if the system can handle a large span of different power inputs and that a satisfying performance is achieved in spite of model uncertainties and approximations.

The final step is to test the system on the plants and see if their wellness and health can be correctly monitored and that the designed controller automatically adjusts the lamps to maximize the growth.

4
Boundaries

This project is a small part of an ongoing research. There are many ways in which the fluorescence measurements can be used to achieve the optimal lighting control. This project focus only on adjusting the light intensity depending on the phase shift of the fluorescence signal. No attempts will be made within this project to change the spectrum of the light and to analyze the magnitude of frequency response or other signal properties. Different signal outputs from the lamps can also be considered, but in this project only the sinusoidal signal is investigated.

5
Method

A small growth cabinet with basil plants is available to carry out the experiments in the project. All necessary equipment is provided there. LED lamps, which allow to adjust the intensity of each color, are used to produce artificial light. For measurement a spectrometer is used. The fluorescence sensor is only recently developed, and due to this some signal processing is needed to get it to work correctly.
For analysis and control design, MATLAB will be used and will be communicating with the lamps and the measurement devices.
Different control methods can be tried, possibly PID, LQR, robust control, model predictive control, etc. The exact control method will be decided when this phase is reached.
An evaluation of the project will be made in the end, this is to check if all the objectives are met. Initially the robustness of the control design will be analyzed. The project will finish with a physical test of the whole system. The lights will be controlled using the phase shift given by the fluorescence measurements. Hopefully, given enough time, experiments could also be carried out in the laboratory of Heliospectra AB.

6
Timetable

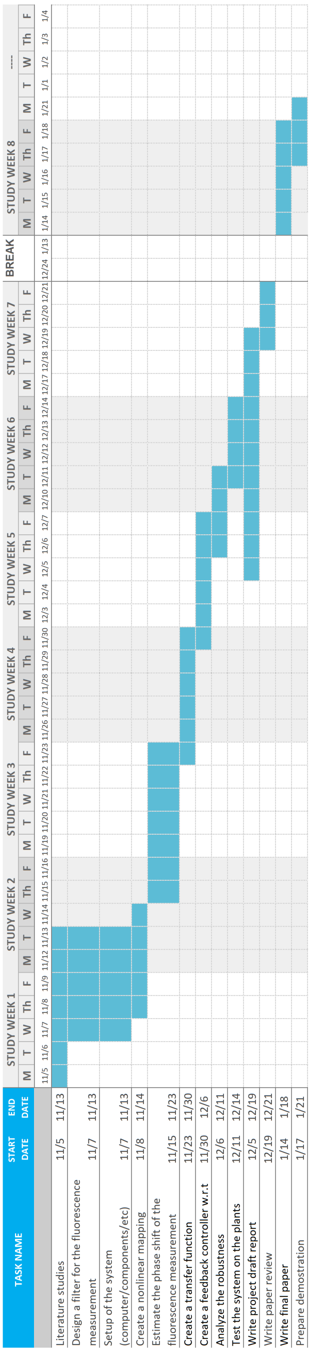

Figure 6.1: Schedule of the project presented through a GANTT-scheme

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