Pervasive Agriculture
IoT-Enabled Greenhouse for Plant Growth Control

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Overview

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Introduction

• Earth population will increase to 8.5 Billion by 2030 this will lead to problems regarding food:
  ➢ Quantity
  ➢ Quality
  ➢ Price

• Pervasive computing will replace growers and allow the greenhouse manager to:
  ➢ Increase the yield of the greenhouse.
  ➢ Efficiently use the available resources (water, energy, fertilizer).
  ➢ Decrease the dependency on pesticides.
  ➢ Determine the ideal harvesting time.
  ➢ Better manage the costs of the entire greenhouse.
  ➢ Predict the productivity of the greenhouse.
Objectives and applied IoT technologies

• Objectives
  ➢ Monitor plants.
  ➢ Monitor and control greenhouse conditions.
  ➢ Predict the growth rate of plants.

• IoT(Internet of things) technologies applied in the greenhouse
  ➢ Wireless sensor networks
  ➢ Cloud computing.
  ➢ Artificial intelligence techniques by machine learning.
The IoT subsystem is composed of four subsystems

1. Sensing and actuation (supported by WSN)
   • Monitoring of greenhouse and plants condition.
   • Plant growth rate monitoring.
   • Greenhouse environment control (humidity actuators, ventilation).
   • Actuators control for plants watering and fertilization.

2. System management and data storage, includes:
   • System management software for interaction with the WSN and control devices.
   • Web server with the database for data storage, retrieval and visualization.
3. Modeling and optimal planning, includes:
   • The mathematical model
     ➢ describes the dynamics of plant grows.
     ➢ perform optimal control using RL approach.
   • Cloud-Based software for resource-intensive simulation.

4. Monitoring and visualization
   • Is the option to guarantee the 24/7 monitoring of the greenhouse.
Figure 1: Greenhouse system [1]
System challenges

Sensing process can be effected by

- Watering and feeding
- Pests and diseases.
- Feeding of plants create dust and dirt.
- Growing plants

The packaging of sensors must meet general requirements:

- Waterproof
- Dustproof
Wireless sensor network (WSN)

- Waspmote nodes
  - Atmega microcontroller.
  - Communication frequency 2.4 GHz
  - Transmitted power: -0.77 dBm
  - Powered by 3.7V, 6600 mAh battery.

- Sensor nodes are equipped with the following sensors:
  - pH
  - Electric conductivity (EC)
  - Solution flow
  - Temperature
  - Photosynthetically active radiation (PAR)
  - Humidity
  - CO₂
Wireless sensor network (WSN)

- Measurements are taken at room of plants and sent every 30 minutes to a gateway.
- Extra sensors sense the environment conditions (air temperature, light intensity, humidity) and send them to the gateway.
- Collected data at the gateway will be then sent to the cloud for planning and modelling process.
- Greenhouse heating and ventilation system.

- Wireless actuator blocks:
  1. Power management
  2. Control unit
  3. Set of 12V relays to turn on/off actuators

- Audio alarm system defined by a threshold.

Figure 4: Waspmote hardware [5]
Cloud computing: software and data storage

- Measurements are time series data.

- Different types of measured data (images, voltage)
  - Additional storage and retrieval requirements
  - Preprocessing before actual analysis.

- Storage/retrieval system components:
  - Open-source database management system, MongoDB (allows the storage of unstructured data)
  - Open-source platform, InfluxData (efficient storage and visualization of time-series data)
Artificial intelligence technique

• Reinforcement Learning (RL)

➢ Agent with no information about environment structure.
➢ Except for its observations (states).
➢ Agent can be trained to perform optimal actions given the state.
➢ Each action is rewarded (positively or negatively).
➢ Agent learns optimal behavior by trial and error.
➢ Goal to maximize cumulative gain.
➢ For plant growth:
   ✓ Positive reward for good growth arte, final crop yield.
   ✓ Negative reward for resources consumption.
Artificial intelligence technique

• Markov decision process (RL math model)

  ➢ Environment state space (states: air temp. & humidity, solution content, plant type and size)
  ➢ Actions set (light on/off, irrigate and harvest)
  ➢ Reward function generates +/- reward value after an action.
  ➢ Each state transition depends only on the current state and action taken by the agent.
Deployment

- Two zones for different climate and nutrition conditions
  - Zone A (720 m²)
    - For initial speed plants growing
    - Equipped with:
      - Sensors for environment control.
      - High pressure sodium bulbs (600 W)
      - Hydroponic system for constant feeding
      - Water-heating system
      - Ventilation system
  - Zone B (2700 m²)
    - Generation process take place
    - Sensors
    - Only the Sun as light source.
    - Rockwool substrate in hydroponic system
    - Drip irrigation at a rate of 2 liters per hour

Figure 5 : Zone A [1]

Figure 6 : Zone B [1]
2-D Imaging and Growth Prediction

- 2-D high resolution images of plant leaves every 2 days.
- It needs a reference object (1cm² red square).
- Calculate the leave area by:
  - Setting up an RGB palette boundary for green color.
  - Counting the pixels that have the RGB value defined in the boundary.
  - Allows us to predict the dynamics of plant growth.
- Evaluating the growth rate:

![Figure 7: growing leaf images](image1)

![Figure 8: growth dynamics](image2)
Online Monitoring

- Web interface for online monitoring
- Advantages:
  - Accessing stored data anytime, anywhere.
  - Better flexibility.
  - Better scalability.

Figure 9: Real time monitoring [3]

Figure 10: a) Leaf area, b) Electronic connectivity, c) Humidity
d) Pump flow rate, e) pH level, f) Temperature [1]
Reinforcement Learning

• Goal: optimal light policy
  ➢ Q-learning technique [2].
  ➢ Decreasing electricity costs.
  ➢ Maintaining production rate.

• Compare 3 different policies:
  1. Light is always on.
  2. Random on/off every 3h.

• RL simulator components:
  2. Action: turning electricity on/off for 3 hours.
  3. Reward result from the action of the agent:
     a) Positive: increased biomass.
     b) Negative: electricity wasting.
     c) Negative: not achieving expected leaf area after 28 days.
Results:

- Final leaf area: no significant difference.
- Light hours: RL 50% less than random policy.

Figure 11: Cumulative reward

Figure 12: Probability leaf area

Figure 13: Probability leaf area


Thanks for your attention