Budapest University of Technology and Economics
Department of Measurement and Information Systems

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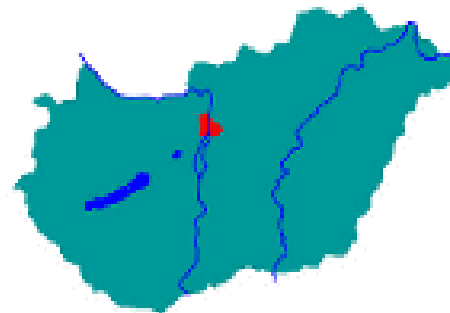# The Intelligent Greenhouse

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BME-MIT

Introduction

- Budapest University of Technology and Economics

- Department of Measurement and Information Systems

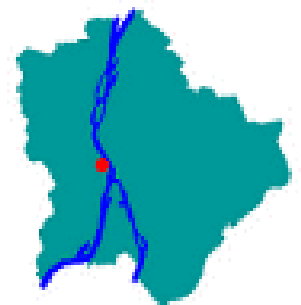- Intelligent Systems Research Group

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BME-MIT

IS Intelligent Systems Research Group

Earth

Europe

Hungary

Budapest

Greenhouses / Glasshouses

Greenhouses are built in various sizes and for many different purposes.

Actuators

Common actuators in greenhouses:

- Windows
- Roof vents
- Shading curtains
- Heating
- Irrigation
- Misting
- etc.

Traditional Control

Traditional solution: independent, level based controllers.

Drawbacks:

I. The control parameters have to be specified by the operator

II. The control is strongly reactive

III. Missing synchronization of the actuators

Optimal Control

- The goal is to maintain the physical parameters inside the greenhouse in the optimum range required by the plants with the lowest possible cost.

Requirements:

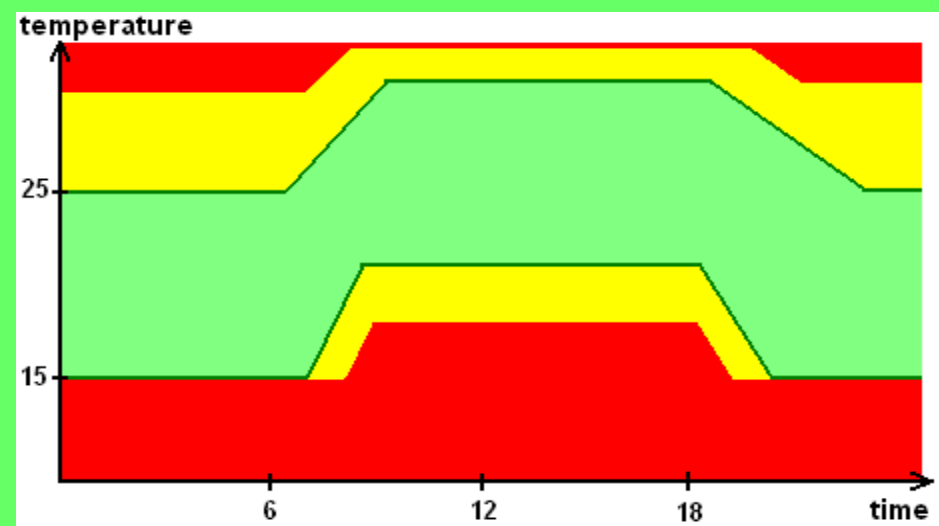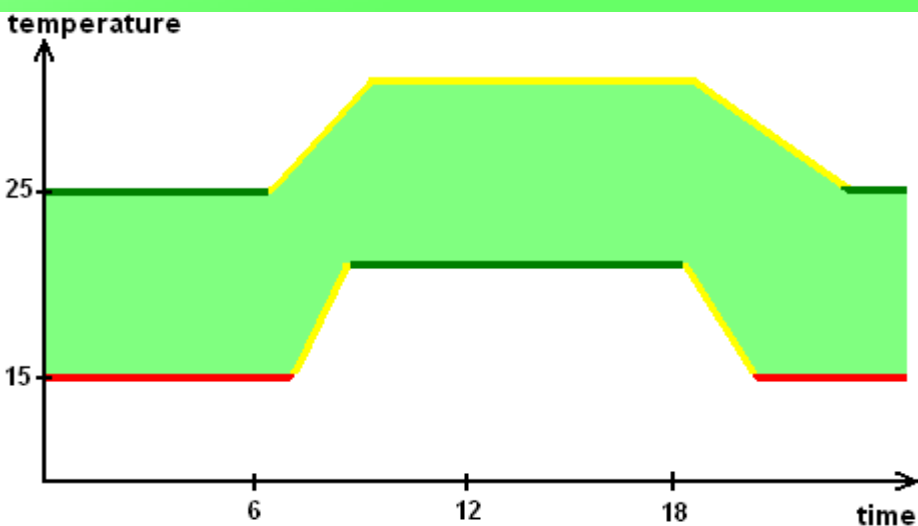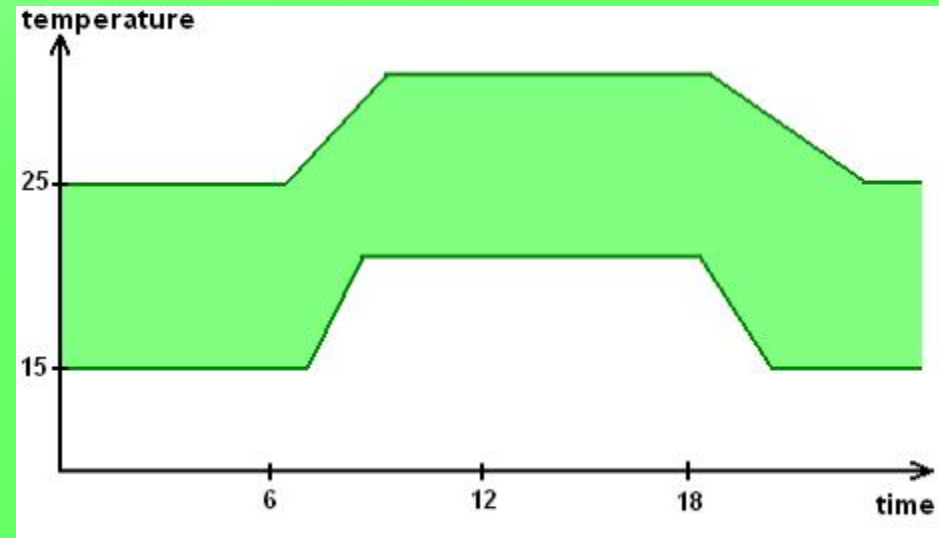- Maximize the comfort of the plants
- Minimize costs

Problem I.

- The goal is to make the plants feel good.

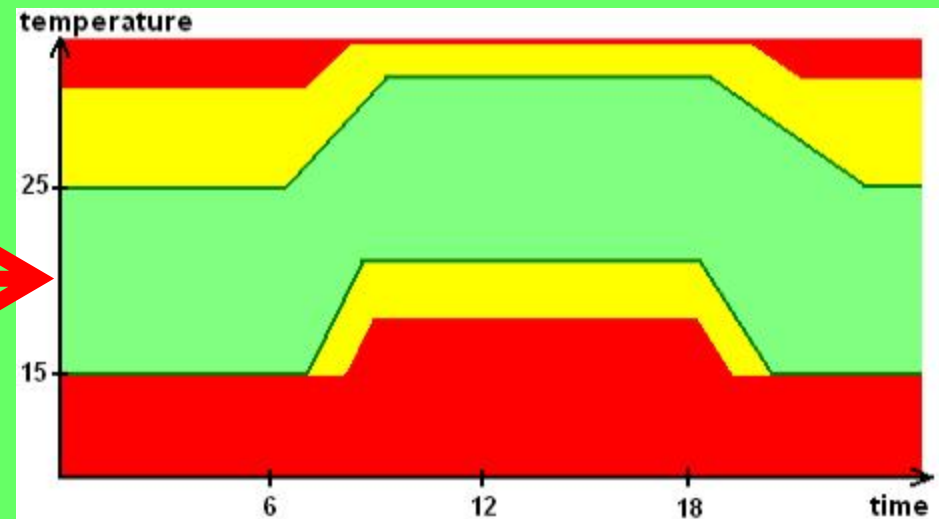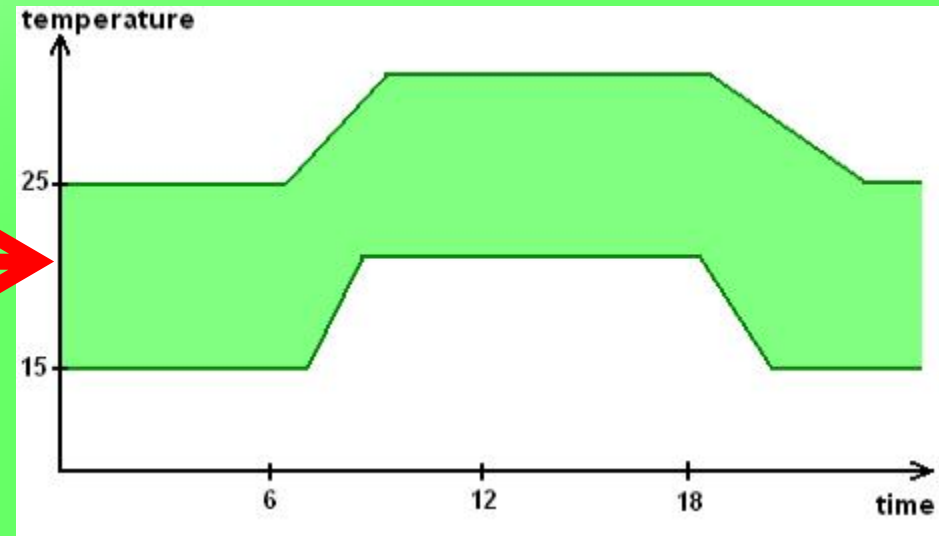- The owner knows the physical parameters that make the plants feel good.

- The traditional control system requires control parameters.

Solution I.

- Let's replace the control parameters with control goals!

Remarks I.

Problem II.

- If the temperature is above limit #1
    - let's activate the shading.
- If the temperature is above limit #2
    - let's open the windows.

        .
        .
        .

- If the temperature is below limit #n
    - let's turn on the heating.

The temperature should not be allowed to pass the limits!
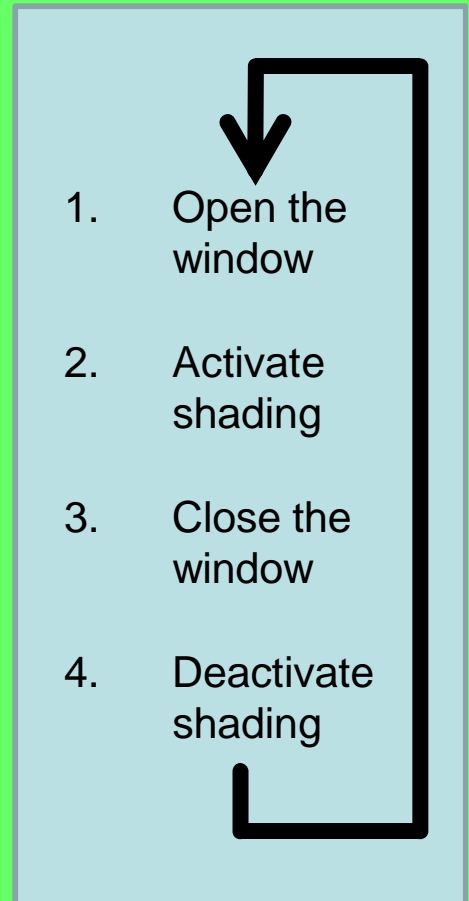
Solution II.

- Predictive modeling:

  1. Assume an actuator configuration
  2. Predict the future state of the greenhouse with this configuration
  3. Calculate the utility and the cost of the given configuration based on the specified goals of the control

- Repeat steps 1-3 with all possible actuator configuration, and choose the best.
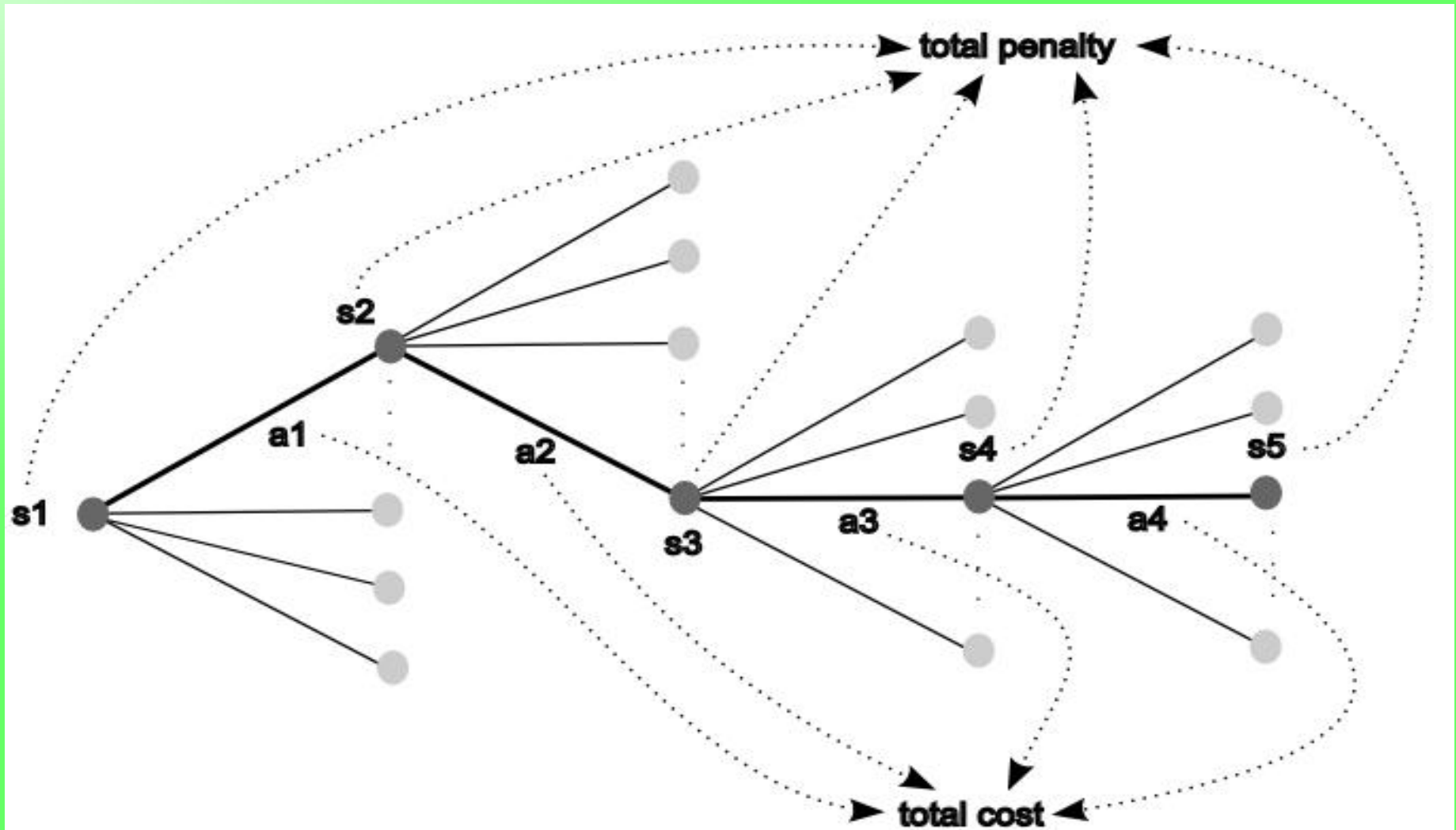
Remarks II.

- Choosing the actuator configuration with the best utility value means the best environment for the plants.

- The calculation of the utility and cost values is a key factor.

- Some configurations are not useful for the whole predicting horizon, e.g. heating turned on.

Problem III.

1. The actuators are not synchronized by the traditional control.

2. The fixed prediction horizon of Solution II is not realistic.

3. Control loops are only evaded by the predictive modeling in case of large control cost specifications.

1. Open the window

2. Activate shading

3. Close the window

4. Deactivate shading

Solution III.

Remarks III.

- ## New problem:
  - The search space of plans is huge: for 4 hours with 5 minutes sampling time and 18 allowed actuator configuration it are more then 10^{60} potential plans

- ## Possible solutions:
  - AI planning methods (bi-directional planning, hierarchical planning, etc.)
  - Restrictions on the plans
  - Smart usage of former optimal plans

Questions

?

- **Does it work?**

- **Does it worth?**

- **Is it vendible?**

?

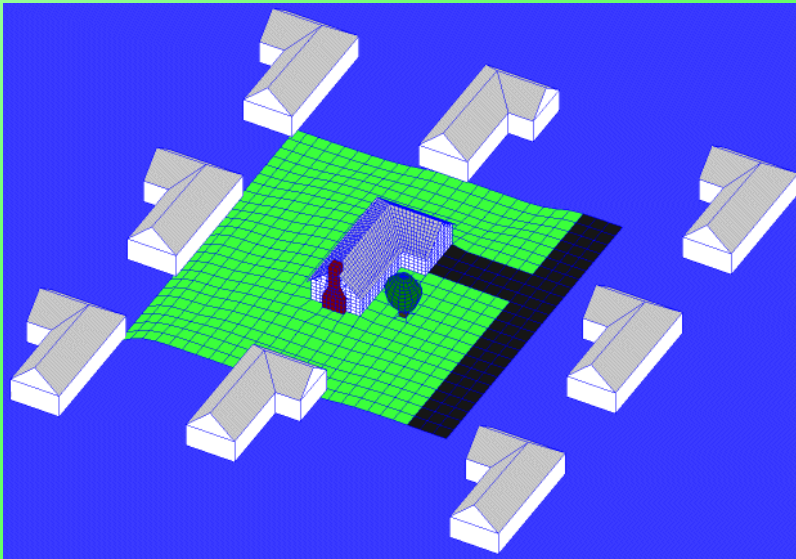# Does it work/worth?

The system should be tested in a
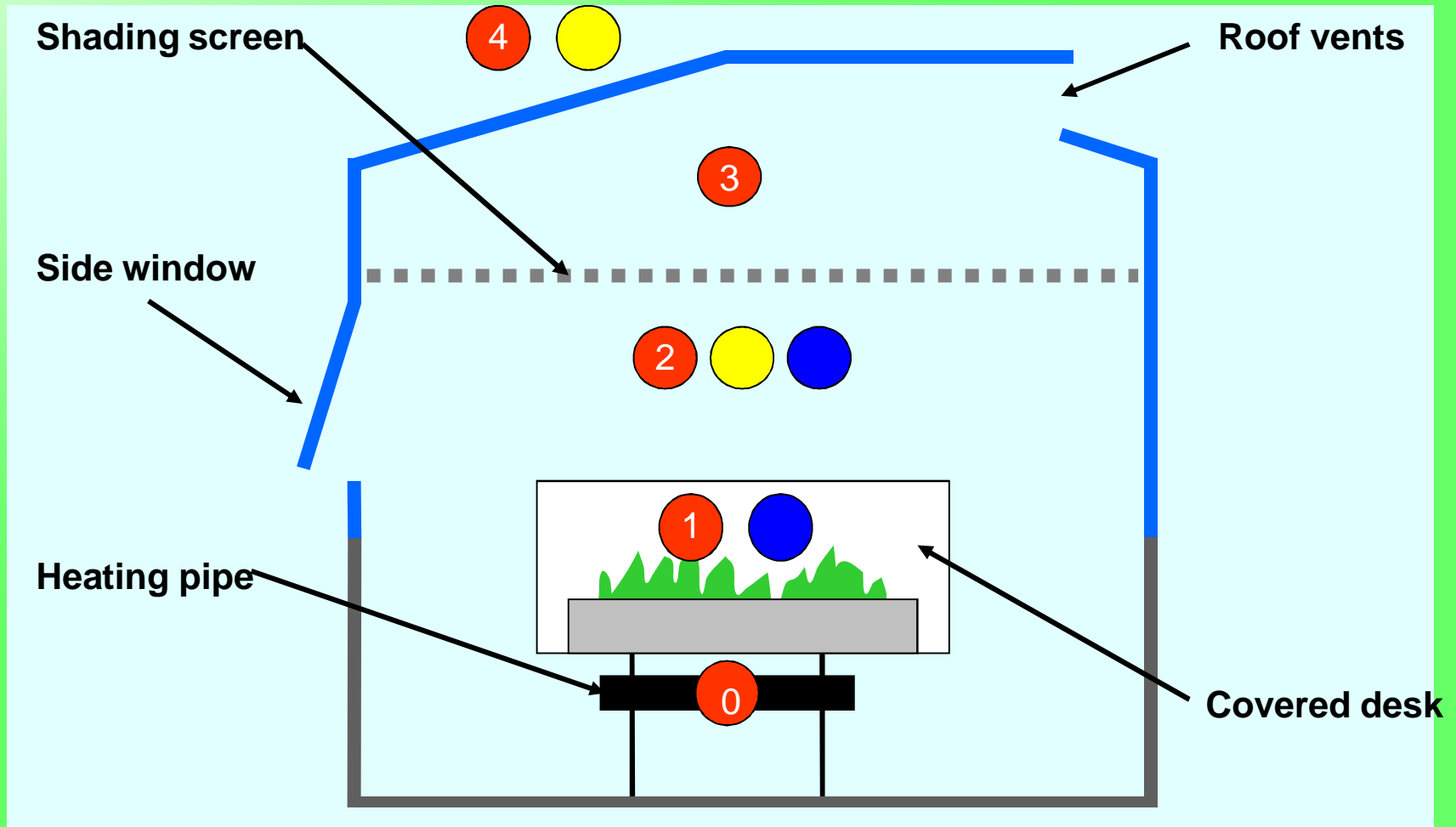
simulation   or   production
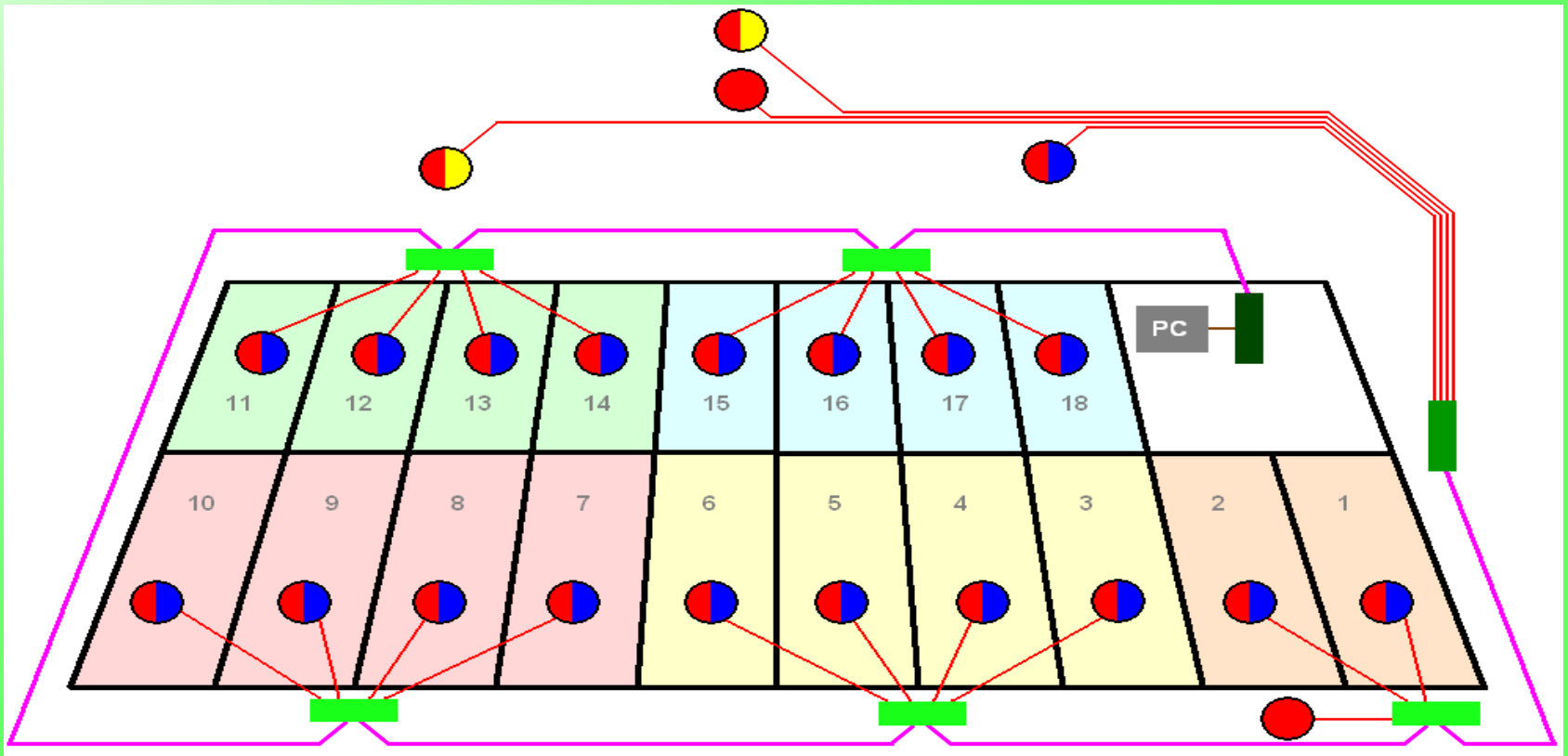

environment.

The Experimental Greenhouse

Measurement & Control

Shading screen

Side window

Heating pipe

Roof vents

Covered desk

4 3 2 1 0

🔴 / 🟡 / 🔵 Temperature / Light / Humidity measurement point

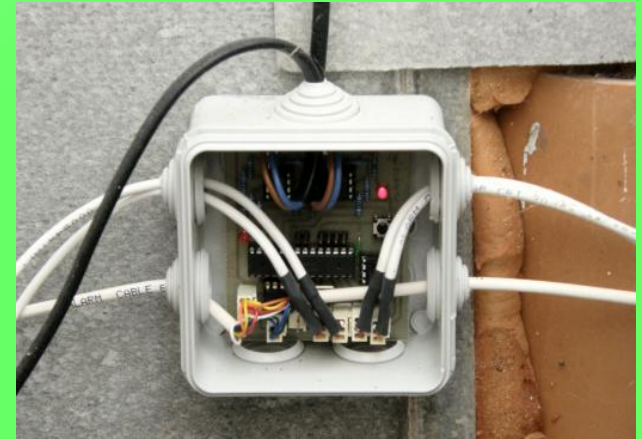# Topology

- Using 7 microcontrollers for measuring 44 physical quantities on 23 locations every 5 minutes
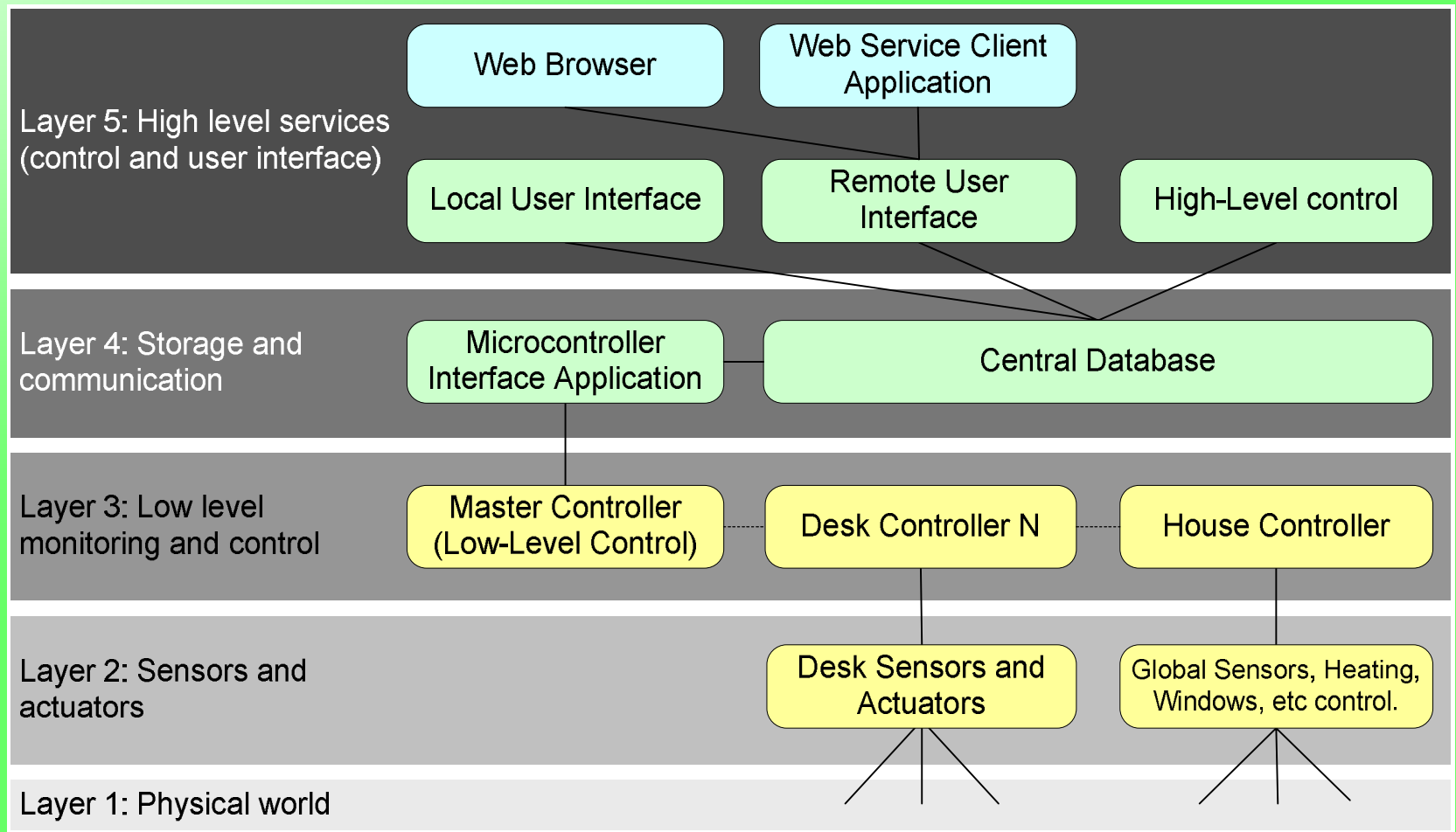
Software and Structure

- ATmega microcontrollers applied for running:
  - global control
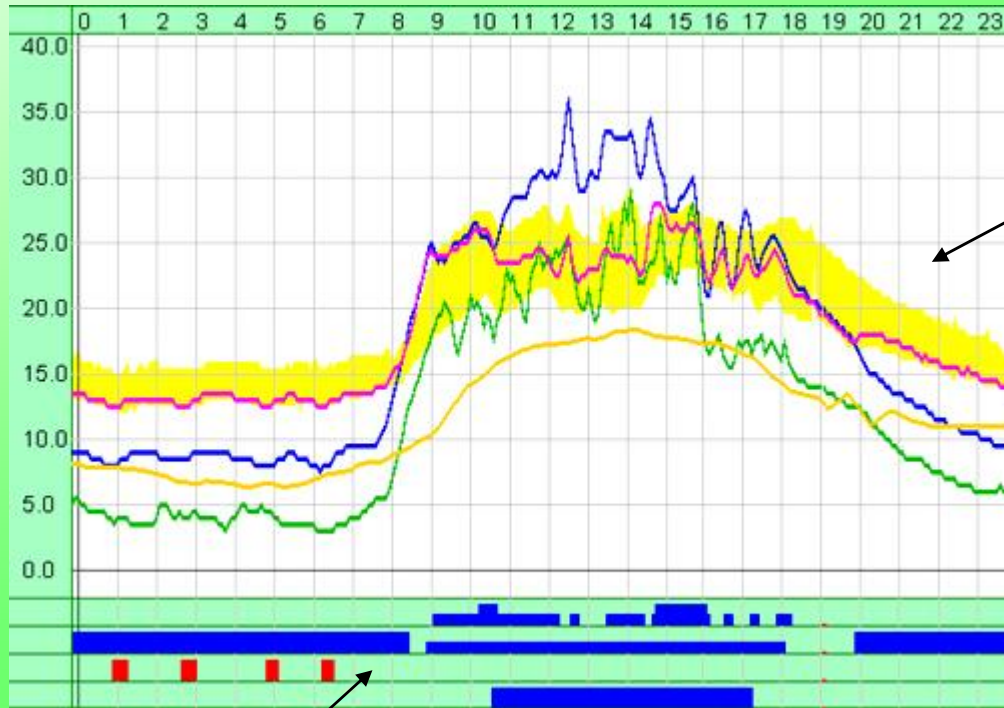 - local measurements every 4 desks
  - global measurements

- EIA-485 bus between microcontrollers and EIA-232 for PC connection

- Using 7 microcontrollers for measuring 44 physical quantities on 23 locations every 5 minutes

Functional Architecture

Layer 5: High level services (control and user interface)
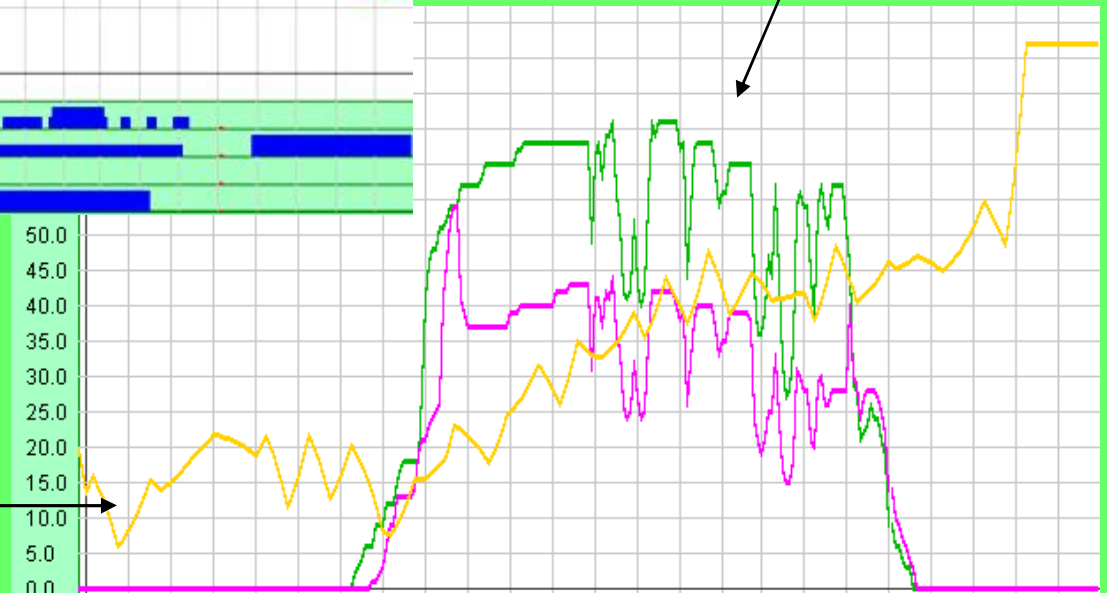
- Web Browser
- Web Service Client Application
- Local User Interface
- Remote User Interface
- High-Level control

Layer 4: Storage and communication

- Microcontroller Interface Application
- Central Database

Layer 3: Low level monitoring and control

- Master Controller (Low-Level Control)
- Desk Controller N
- House Controller

Layer 2: Sensors and actuators

- Desk Sensors and Actuators
- Global Sensors, Heating, Windows, etc control.

Layer 1: Physical world

Data Visualization

Results so far

- The measurement system is collecting data.

- The local external temperature prediction module has been implemented.

- The heating system module has been implemented.

- Currently working on the missing modules of the model decomposition to build the whole predictive model of the greenhouse.

Thank you for your attention!