Offset-Free MPC of Temperature in Smart Greenhouse VESNA

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VESNA HOMEPAGE

OPEN-SOURCE CODE

Abstract

The VESNA smart greenhouse system aims for sustainable, ecological, and organic food production. This study explores an offset-free model predictive controller (MPC) for temperature tracking. The MPC proves effective in maintaining temperature within constraints. Extensive experiments assess different MPC setups, focusing on environmental factors, including energy use and carbon footprint. Additionally, a novel software toolbox simplifies analysis and remote control, enhancing user-friendliness. Together, the designed offset-free reference tracking MPC and the toolbox offer a comprehensive solution for smart greenhouse control.

VESNA

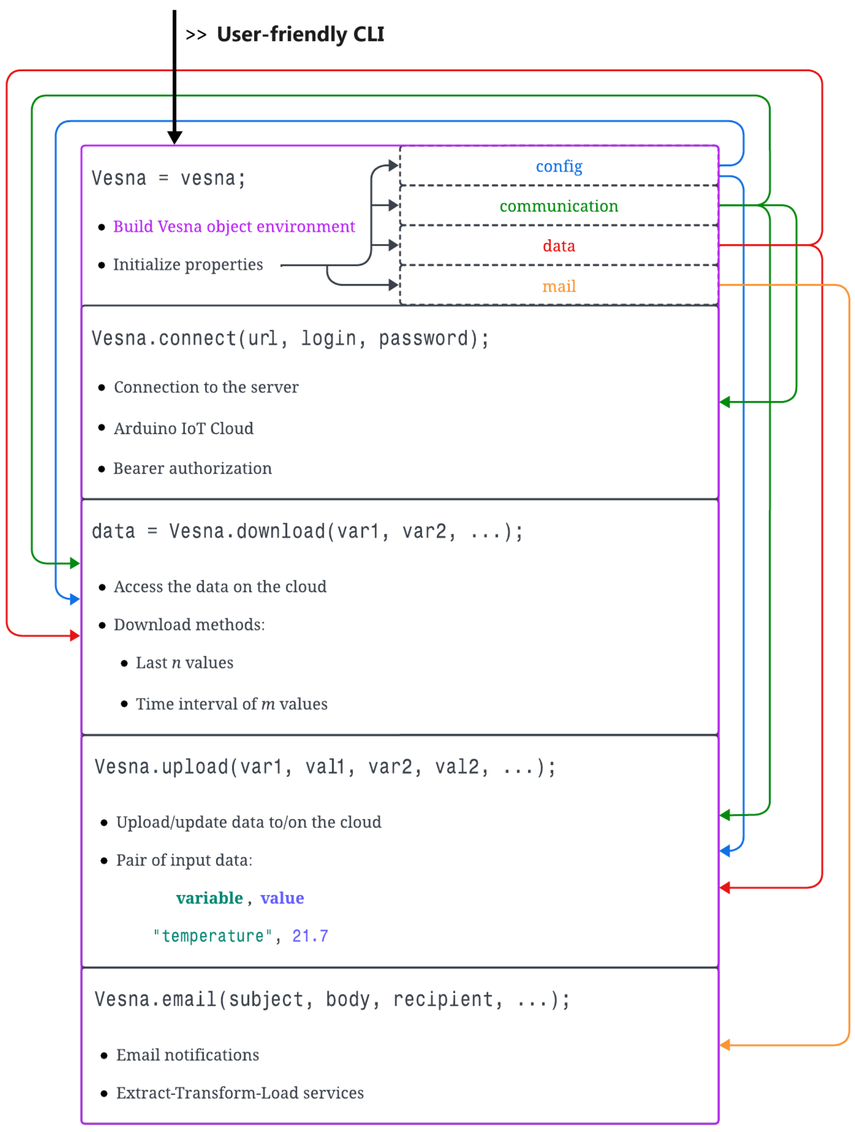
- Smart greenhouse.
- Integrates
  - greenhouse structure,
  - sensors, actuators,
  - communication interface.
- Autonomous control based on ESP-32 microcontrollers.

VESNA

VESNA LIVE STREAM

VESNA CODE

The toolbox is serving as an advanced human-machine interface (HMI) for building an autonomous control for VESNA greenhouse. VESNA CODE is developed in MATLAB environment using a object-oriented framework.



Offset-Free MPC Design

- the optimization problem of the quadratic programming:

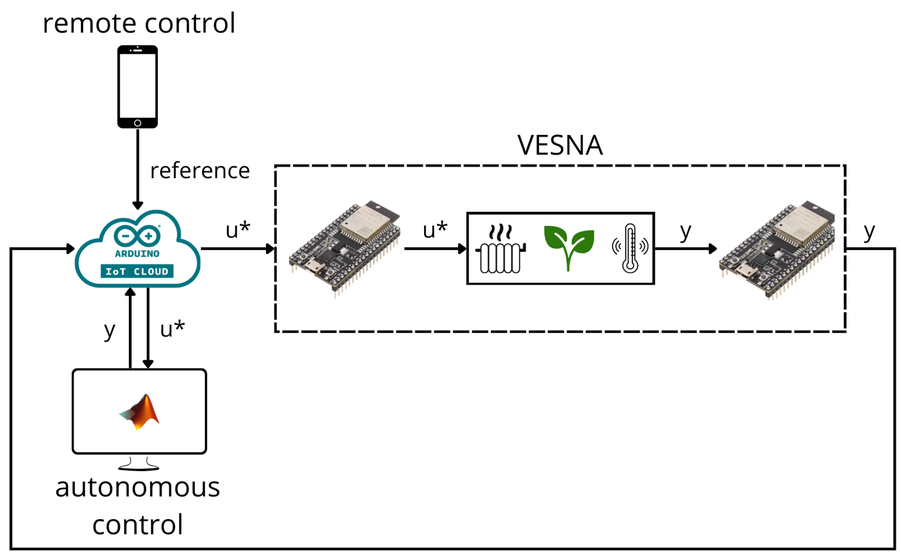
$$\min_{u,x,x_\mathrm{I}} \sum_{k=0}^{N-1} \left(\begin{bmatrix} x(k) \\ x_\mathrm{I}(k) \end{bmatrix}^\top \begin{bmatrix} Q_\mathrm{x} & 0 \\ 0 & Q_\mathrm{I} \end{bmatrix} \begin{bmatrix} x(k) \\ x_\mathrm{I}(k) \end{bmatrix} + u_k^\top R u_k \right)$$

$$\text{s.t.} \begin{bmatrix} x(k+1) \\ x_\mathrm{I}(k+1) \end{bmatrix} = \begin{bmatrix} A & 0 \\ -C\,T_\mathrm{s} & I \end{bmatrix} \begin{bmatrix} x(k) \\ x_\mathrm{I}(k) \end{bmatrix} + \begin{bmatrix} B \\ 0 \end{bmatrix} u(k)$$

$$u(k) \in \mathbb{U}, \begin{bmatrix} x(0) \\ x_\mathrm{I}(0) \end{bmatrix} = \begin{bmatrix} x_t \\ x_{\mathrm{I},t} \end{bmatrix},$$

$$\forall k \in \{0, \dots, N-1\}.$$

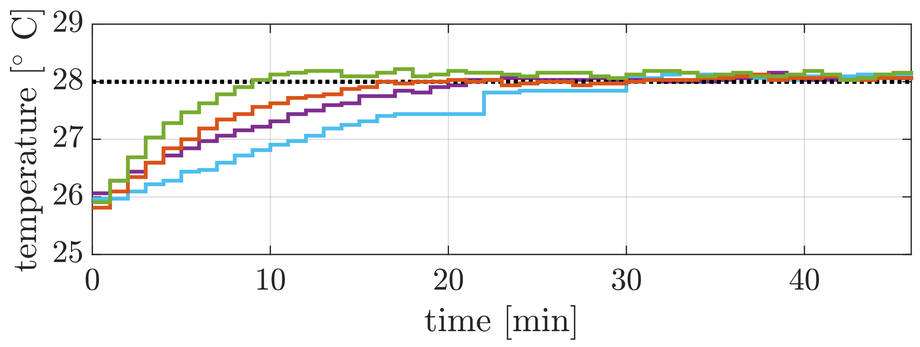
Closed-Loop Scheme

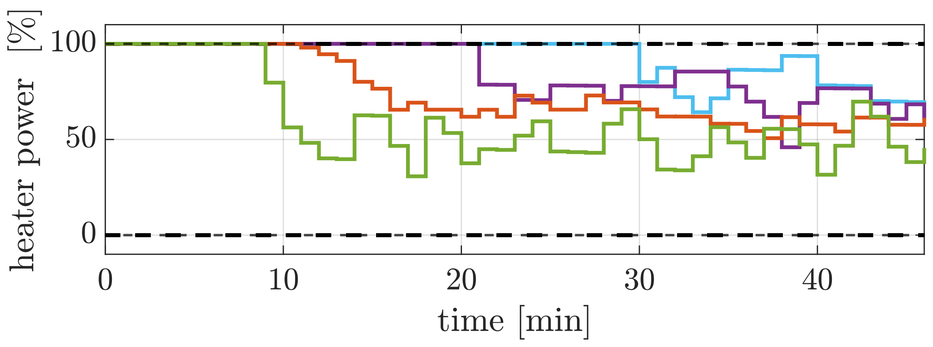


Results

MPC Tuning

Control setup	I	II	III	IV
Q_x	1 000	1 100	1 000	1 500
Q_I	1 000	1 100	1 000	1 000
R	2.0	1.5	100.0	1.5





Performance Criteria

Control setup	I	II	III	IV
t_reg [min]	22	12	9	6
ISE [min·K^2]	35.0	19.1	17.5	11.7
ISI [min]	243 880	307 990	150 600	192 160
SSE [–]	5.9	5.0	3.3	3.1
E [kJ]	104	96	84	67
$m(\mathrm{CO_2})$ [g]	6.2	5.7	5.0	4.0

Acknowledgments

The authors acknowledge Branislav Daráš for his help in realizing the laboratory experiments. The authors gratefully acknowledge the contribution of the Scientific Grant Agency of the Slovak Republic under the grants 1/0490/23, 1/0297/22, and the Slovak Research and Development Agency under the projects APVV-20-0261, APVV-21-0019. This research is funded by the European Commission under the grant no. 101079342 (Fostering Opportunities Towards Slovak Excellence in Advanced Control for Smart Industries). Erika Pavlovičová and Jozef Vargan would also like to thank for a financial contribution from the STU Grant scheme for Support of Young Researchers.