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Characterisation of Thermal Inertia in University Buildings Using Continuous Temperature Monitoring Data

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Context

TERTIARY BUILDINGS
HVAC ≈ 50 % of total energy use

SENSORS ACTUATOR NETWORK SOFTWARE

Integration of the **Internet of Things (IoT)** in **building automation systems (BAS)**

INTELLIGENT CONTROL
Ensure satisfactory indoor environment quality (IEQ) with minimum HVAC energy use

Great potential for energy savings in buildings.

Objective

Improve the management of HVAC schedules in buildings.

Currently	Objective
HVAC schedules are **estimated and introduced manually in SCADA**: Operator time and human error.	HVAC schedules are **calculated automatically in SCADA**.
Based on 48 h in advance **weather forecast**.	Based on **real-time** indoor and outdoor temperature **data**
Without considering the behaviour of each building	HVAC schedules **adapted to the thermal behaviour** of the buildings.

Influencing variables → Effect: Target magnitude ¿ºC/h? → Result: HVAC schedules

- Temperature (indoor, outdoor)
- HVAC
- Orientation
- Envelope
- Thermal power vs demand

Influencing variables have an impact on the **slope value ºC/h** (starting up heating systems).

Impact on:
- Energy efficiency
- IEQ
- Electricity grid interaction

Parameter for characterising the thermal inertia of building-HVAC during heating start-up: Indoor temperature slopes (ºC/h)

Materials and methods

IoT infrastructure

63 monitored buildings

Almost 1,500 indoor temperature sensors

Calculation of the indoor temperature rise slopes (°C/h) during the **heating systems' switch-on period** (between 5-9 a.m.)

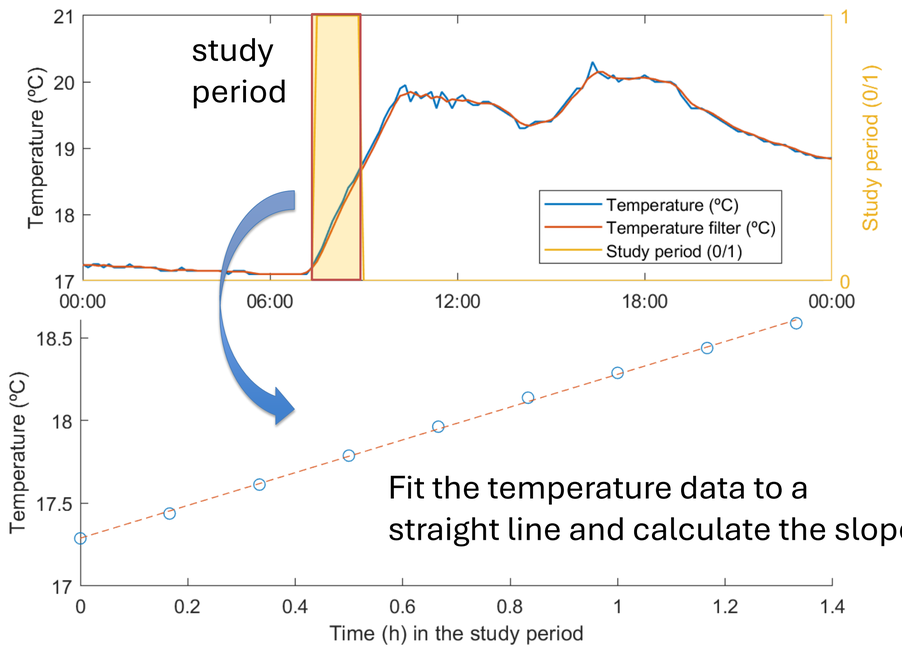


Diagram of the Matlab programme for calculating slopes

CSV download of DB with temperature records → Temperature data processing → Detection of temperature rise ranges and calculation of slopes → Export calculated slope values

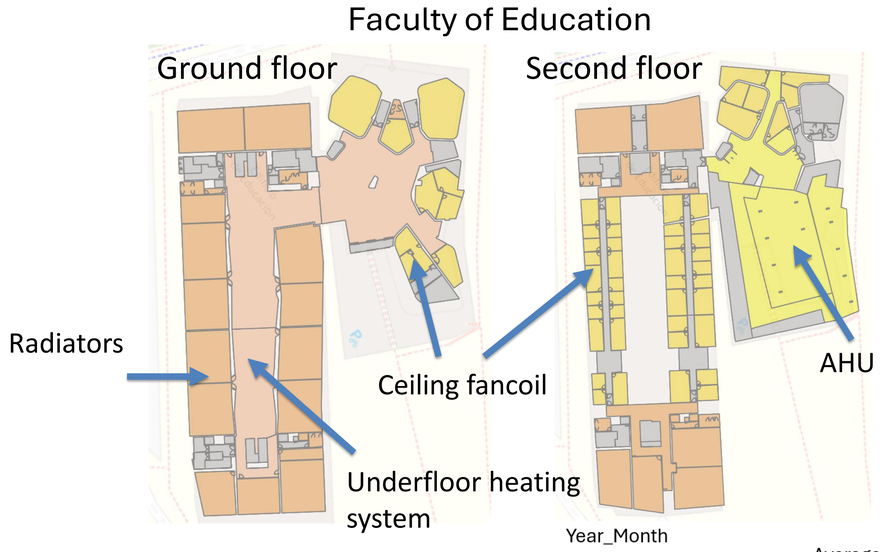
Detection of temperature rise ranges and calculation of slopes:
Temperature signal softening → Difference between consecutive temperature values (ΔT). → Selection of data with a high value of ΔT → Selection of a single daily study period → Calculation of slopes

$\Delta T \geq 0{,}05\ °C/h$ | 8 consecutive records Between 5 and 9 a.m. | Linear fit

Results

Example of behaviour of buildings with different heating systems:

Faculty of Education



Year_Month

Building	2024 11	2024 12	2025 1	2025 2	2025 3	Average slopes
NEW EDUCATION FACULTY						
Fancoils	0,82	1,02	1,01	0,88	0,81	**0,93**
Radiators (Circuit 2)	0,91	0,93	0,87	0,86	0,91	**0,89**
Radiators (Circuit 3)	0,84	0,80	0,80	0,77	0,82	**0,80**
Air Handling Unit (1)	2,06	1,98	2,38	2,22	2,16	**2,17**
Air Handling Unit (3)		0,92	2,04		1,21	**1,32**

Evolution of slopes by month and area

Classification of UNIZAR buildings according to their **average heating rate**

Average heating rate	Buildings	
2 to 2,5 °C/h Very fast buildings	- Central services	
1,5 to 2 °C/h Fast buildings	- EINA - Torres Quevedo - Fac. of Veterinary - Pilot plant – FST (Food Science and Technology) - Building Construction and Maintenance - UTCE	
1 to 1,5 °C/h Medium fast buildings	- Fac.of Business and Public Management - RD. Niños - SAI Building - Research Support Services - SAI - Warehouse No. 5 - SAEA Offices - Vice-Rectorate of Huesca - Vice-Rectorate of Teruel	- School of Engineering - Laboratories - Loreto - Building - Fac. of Education - Service Building - Fac. of Social Sciences and Labor
0,8 to 1 °C/h Medium slow buildings	- Fac. Health Sciences - Fac. Health and Sports Sciences - Dentistry Building - Fac. of Law - Law Building I - Fac. of Medicine - Building A - School of Engineering - Classrooms - B. Gratal - Fac. of Law - Law Building III - School of Engineering - Polytechnic - B. Tozal de Guara	- Interfaculty Building I - EINA - Ada Byron - Fac. of Veterinary Medicine - Lecture Hall - Fac. of Philosophy and Letters - Humanities Library - Fac. of Human and Educational Sciences - Main Building - Fac. of Social and Human Sciences - Fac. of Law - Law Building II
0,6 to 0,8 °C/h Slow buildings	- EINA - Betancourt - Cervantes Building - Faculty of Philosophy and Letters - Fac. of Health and Sports Sciences - Río Isuela - Fac. of Veterinary Medicine - Central Building - Fac. of Medicine - Building B - School of Engineering - Chalets – B. Salto del Roldán	- R&D - Research Institutes - Fac. of Sciences - Building B – Mathematics - Fac. of Sciences - Building A – Physics - Fac. of Human and Educational Sciences – Annex - Fac. of Veterinary Medicine - Zootechnics Building
0,4 to 0,6 °C/h Very slow buildings	- Fac. of Sciences - Building C – Geology - University Hall of Residence Cerbuna - Fine Arts	- Professor Residence - Fac. of Health and Sports Sciences - University Hall of Residence Ramón Acín - Polytechnic School of Teruel

Conclusions

Clear differences in the behaviour of the buildings of the University of Zaragoza, as the **slopes range between 0.3 and 3 °C/h** on a monthly average, due to the **ratio** between the **HVAC installed capacity and the thermal demand and other influencing factors.**

Therefore, it is reasonable to establish **distinct timetables** for each **building and** for each **zone** of the building.

For the calculation of slopes and for setting heating schedules in large buildings, it is vital to consider the **HVAC system and zoning capacity**.

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