Dept. of Computer Science
Télécom SudParis
IP Paris, France

Intership Program 2023
A Digital Twin approach for Sustainability-aware Smart Buildings
October 11, 2022

Project Description

Providing occupants of a building with thermal comfort results in, among others, a productivity increase. Existing approaches have mostly focused on individual thermal comfort provision but, in most situations, people share the spaces where they live, work, or study. Given the diversity of people and their preferences, it is challenging to provide them with comfort in a shared space. Multiple challenges arise to determine the appropriate thermal comfort level of a group including how to benefit individuals, while maintaining some notion of fairness within the group, and minimizing energy consumption.

In 2022, we conducted an empirical evaluation of group thermal comfort strategies to determine the operation of HVAC systems in buildings. In particular, we introduced a methodology which measures the impact of different strategies (normal, fair, energy efficient) when applied in simulated office buildings located in different climate zones and with a diverse workforce.

By relying on the results of this preliminary work, we now propose to design algorithms for enabling sustainability-aware group thermal comfort in smart buildings by adopting a *Digital Twin approach* [1]. First, we propose to automate the simulation of existing buildings by relying on data models used to represent smart spaces, i.e., the NGSI-LD protocol specification [2]. Second, enhance these models by leveraging synthetic data of Internet of Things (IoT) devices/sensors for balancing energy consumption and thermal comfort [3, 4, 5]. Finally, introduce models of building occupants that take into account their thermal preferences and profile (daily routines that determine their trajectories in buildings).

The Etoile building of Télécom SudParis (Evry) will be used to instantiate the data models presented above. These instances will be parsed to automate the simulation of an HVAC system (using EnergyPlus[1]) with diverse profiles of building occupants (in terms of thermal preferences) moving in the building (using SmartSPEC [6]).

Based on the simulation analysis, a sustainability-aware algorithm will be introduced to regulate the HVAC system and reduce energy consumption.

Internship Objectives

The selected candidate will be working on the following tasks:

- Get familiar with the NGSI-LD smart data models and supporting technologies.
- Define data models with energy aspects and IoT elements of buildings and thermal preferences of building occupants using NGSI-LD. Note that FORTH-ICS, an research institute in Crete and active collaborator [7], will provide support to define NGSI-LD related models.
- Integrate and instantiate these models to the current approach (E4C 2022) to automate the simulation of HVAC systems operating in diverse buildings and building occupants.
- Design a *sustainability-aware* algorithm for the regulation of HVAC systems in buildings. This task includes the exploitation of IoT technologies and devices to reduce energy consumption or increase fairness.

Qualifications

Master 2 or last year of engineering school.

[1] https://energyplus.net/

Skills & qualities

- Fluent in English
- Good knowledge of the JSON data format
- Good knowledge of the REST architectural style and RESTful APIs
- Good knowledge of Object-oriented programming (preferably Java) and data structures....

Useful information

- Starting date: February 2023 (flexible)
- Duration:: 5-6 months
- Location: Télécom SudParis, Evry or Palaiseau

Contact

To apply, contact Georgios Bouloukakis - `georgios.bouloukakis AT telecom-sudparis.eu` by providing the following documents:

1. CV
2. Motivation letter
3. Transcripts of the last 3 years
4. A course report or article written in English (if any)

References and Additional Reading

[1] Adil Rasheed, Omer San, and Trond Kvamsdal. Digital twin: Values, challenges and enablers from a modeling perspective. *Ieee Access*, 8:21980–22012, 2020.

[2] Abid Ahmed, Medvedev Alexey, Hassani Alireza, Le Gall Franck, Tropea Giuseppe, Martinez Juan Antonio, Frost Lindsay, and Bauer Martin. Guidelines for modelling with ngsi-ld. *ETSI White Paper*, (4), 2021.

[3] Eun-Jeong Shin, Roberto Yus, Sharad Mehrotra, and Nalini Venkatasubramanian. Exploring fairness in participatory thermal comfort control in smart buildings. In *Proceedings of the 4th ACM International Conference on Systems for Energy-Efficient Built Environments*, pages 1–10, 2017.

[4] Omid Ardakanian, Arka Bhattacharya, and David Culler. Non-intrusive techniques for establishing occupancy related energy savings in commercial buildings. In *Proceedings of the 3rd ACM International Conference on Systems for Energy-Efficient Built Environments*, pages 21–30, 2016.

[5] Marco Pritoni, Kiernan Salmon, Angela Sanguinetti, Joshua Morejohn, and Mark Modera. Occupant thermal feedback for improved efficiency in university buildings. *Energy and Buildings*, 144:241–250, 2017.

[6] Andrew Chio, Daokun Jiang, Peeyush Gupta, Georgios Bouloukakis, Roberto Yus, Sharad Mehrotra, and Nalini Venkatasubramanian. SmartSPEC: Customizable Smart Space Datasets via Event-driven Simulations. In *The 20th International Conference on Pervasive Computing and Communications (PerCom)*, 2022.

[7] Georgios Bouloukakis, Chrysostomos Zeginis, Nikolaos Papadakis, Panagiotis Zervakis, Dimitris Plexousakis, and Kostas Magoutis. Enabling IoT-enhanced Transportation Systems using the NGSI Protocol. In *12th International Conference on the Internet of Things (IoT)*, 2022.

[8] Roberto Yus, Georgios Bouloukakis, Sharad Mehrotra, and Nalini Venkatasubramanian. Abstracting interactions with iot devices towards a semantic vision of smart spaces. In *Proceedings of the 6th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation*, pages 91–100, 2019.

[9] Ronald Fagin and John H Williams. A fair carpool scheduling algorithm. *IBM Journal of Research and development*, 27(2):133–139, 1983.