Optimization under uncertainty for energy efficiency in buildings

Master's degree internship offer

Context

Refurbishing buildings for energy efficiency is one of the main challenges of the coming economic transition. Computer-aided methods to guide the renovations have started being developed at the LaSIE laboratory [1-3] and with the TIPEE[1] company. The objective of the internship is to improve existing numerical methods that optimize buildings energy efficiency.

Scientific challenges

The performance of a building energy renovation is made of several criteria: energy consumption, renewal cost, thermal comfort and life cycle analysis. Renovation decisions are additionally evaluated through criteria that are more difficult to quantify such as ease of implementation or ease of maintenance of the new systems.

Analyzing a renovation strategy is further complicated by uncertainties regarding implementation costs (labor and material), local climate, effective component performance (materials and regulation systems) and the occupancy of the premises.

Nevertheless, the requirements for achieving high energy efficiency grow because of the energy cost and the regulations (e.g., "décret tertiaire" in France).

This internship aims to provide a numerical method for finding optimal energy renewal solutions that are stable with respect to the aforementioned uncertainties. Mathematically, this is a multi-objective optimization problem with uncertainties [4].

Internship topic

The goal of the internship is

- first, to propose a formulation of the problem of multi-objective optimization with uncertainties that fits the energy renovation application
- second, implement an algorithm that solves the problem
- and third, apply it to energy renovation scenarii.

The internship will start with learning the simulation tools for building energy consumption (based on the EnergyPlus software).

Then, the intern will define the parameters affecting the renovation:

- choice of the local climate scenarios and collection of the associated weather records;
- choice and programming of the occupancy scenarios ;

[1] https://www.plateforme-tipee.com/projet/renoir/

- definition of the economic uncertainties : energy costs, labor costs, material costs and inflation scenarios.

The next step will be to define the set of possible renovation actions and program them so that they can be automatically changed in an EnergyPlus [7] input file.

The above three first steps will be started at the TIPEE's premises at La Rochelle during a 1 or 2 weeks long stay.

The rest of the internship will deal with the mathematical formulation and resolution of the problem. An anticipated goal will be to maximize the probability that the solution is a Pareto optimum where the randomness in the probability comes from the above uncertainties.

The multi-objective optimization algorithm will be chosen among existing, state-of-the-art, solutions (like MO-CMA-ES [5] or NSGA-2 [6]) .

Anticipated results for the internship are conclusions about:

- the optimization algorithm ;
- the method for selecting solutions within a Pareto optimal set ;
- the quantification of the stability of these solutions under the uncertain context,
- which renovation actions should be favored or avoided in relation with the context.

Student profile

The internship should serve as a research internship for a Master's degree student or a last year engineering school student. The student should have skills in applied mathematics, probabilities, optimization and programming (python) with a strong interest for building energy simulation. Typically, students with an applied mathematics, or a computer science or a mechanical engineering background should qualify.

Practical information :

- dates: the internship should start between january and may 2023.
- place: the research will take place either at Mines de St-Etienne or at the LIMOS laboratory in Clermont-Ferrand. A training period of 1 or 2 weeks at the TIPEE's premises in La Rochelle will be paid for.
- gratuity: about 800 euros/mois.

Contacts

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4) Ide, Jonas, and Anita Schöbel. "Robustness for uncertain multi-objective optimization: a survey and analysis of different concepts." OR spectrum 38.1 (2016): 235-271.
5) Igel, Christian, Nikolaus Hansen, and Stefan Roth. "Covariance matrix adaptation for multi-objective optimization." Evolutionary computation 15.1 (2007): 1-28.
6) Deb, Kalyanmoy, et al. "A fast and elitist multiobjective genetic algorithm: NSGA-II." IEEE transactions on evolutionary computation 6.2 (2002): 182-197.
7) EnergyPlus, software site : https://energyplus.net/