Development of a Generalized Building Energy Management System Leveraging Large Language Models

**Background and Objective**

Energy management in buildings is crucial for sustainability, operational cost reduction, and occupant comfort. The Combined Smart Energy Systems (CoSES) research group has established and offers an expansive environment (refer to Fig. 1) conducive to exploring innovative strategies in Building Energy Management Systems (BEMS). Contemporary BEMS predominantly employ fixed rule-based systems or utilize linear and convex optimization algorithms within model predictive control solutions. While effective, these methods are designed for specific building configurations and necessitate a high degree of expert knowledge for development, limiting their adaptability as universal solutions for diverse building setups.

In pursuit of more adaptable solutions, the exploration of machine learning models for BEMS has emerged, offering a semblance of adaptability and a capacity to learn from data. However, current machine learning solutions still encounter the limitation of being overly specialized to individual building characteristics, thereby lacking the requisite generalizability across a broad spectrum of building configurations.

The advent of Large Language Models (LLMs) like GPT-3 and GPT-4, trained on an extensive amount of text-based knowledge, presents a promising horizon for the development of more generalized, adaptable, and efficient BEMS (GBEMS). Unlike conventional models, LLMs are not confined to specific input and output formats, other than text, and come with a pre-trained broad knowledge base. They potentially offer a level of abstraction and understanding that could significantly advance the field of energy management.

The objective is to investigate the potential of LLMs in developing a GBEMS that can autonomously adapt to varying building configurations and control tasks with minimal retraining or new simulations required.

![CoSES](image_url)  
*Fig. 1: Microgrid of the CoSES laboratory containing four single-family houses and an apartment building. The laboratory can be divided into heat, power and communication levels.*

**Project Goal**

Explore, design, and develop a GBEMS by harnessing the capabilities of LLMs such as GPT-3 or GPT-4.

1. **Literature Review and Domain Understanding:** Conduct a comprehensive literature review to capture the current state of LLMs and fine-tuning methods for domain-specific knowledge acquisition.

2. **Building and Energy-Specific Knowledge Tuning:** Gather a building and energy management data set and use it to fine-tune an LLM to ensure the model gains a solid understanding of building and energy management principles.
3. **Advanced Fine-tuning for BEMS Control Tasks**: Transition into a more specialized fine-tuning phase, orienting the LLMs towards BEMS control tasks utilizing reward-based training methodologies.

4. **Evaluation and Real-world Testing**: Evaluate the developed GBEMS using various building simulations and extend testing to real-world scenarios in the CoSES laboratory to determine system performance, adaptability, and efficiency.

The anticipated GBEMS will serve as a prototype for future energy management systems and illustrate the potential of combining state-of-the-art energy management practices with the capabilities of LLMs.

**Requirements**

- Strong programming skills, preferably in Python.
- Basic knowledge of machine learning and natural language processing.
- An understanding of building energy management systems is desirable but not mandatory.
- Excellent problem-solving abilities and a willingness to learn and adapt to new challenges.

**Learning Outcomes**

- Gain hands-on experience in applying machine learning and natural language processing techniques in a real-world domain.
- Acquire a deep understanding of the challenges and solutions associated with building energy management.
- Develop skills in data collection, preprocessing, model fine-tuning, system design, testing, and evaluation.
- Have the opportunity to contribute to a pioneering endeavor that could set a precedent in the field of AI-integrated building energy management.

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