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SCIENCES POUR LA CONCEPTION, L'OPTIMISATION ET LA PRODUCTION

SUBJECT OF THESIS 2021 2022

Thesis title : **Active learning for home energy management**

Thesis director (s) : **Doctoral school: EEATS**

Beginning of thesis : **Funding envisaged - Context - Possible partners : possible funding by ANR, or Ministry of Research**

Brief Description:

Better integration of sobriety and flexibility of the human actor behaviors in the design of energy systems is a need highlighted by the development of energy efficiency solutions and associated regulations (RT2012 mainly in France). Indeed, numerous research works have been carried out on energy efficiency at the scale of housing, offices, urban blocks,... It deals with optimized energy management [1], modeling techniques/simulations of buildings (ANR MAEVIA) and neighborhoods/islets (MERUBBI projects), transformation of building system models (Y. Hadjsaid's PhD), methods for guaranteeing performances (OMEGA project) or performance verification methods (Rozenn Josse's PhD). It appears that when a building is low energy consuming, it becomes very sensitive to the occupant activities (E. Vorger's PhD). The E+C- standard, prefiguring the next energy standard in France for buildings (RE2020), summarily integrates all the energy usages into the required performance of a building. Models to represent the diversity of human behaviors have been developed (see E. Vorger's PhD) and have been implemented by the AMAPOLA add-on, developed by Kocliko, to the dynamic energy simulation software IZUBA/PLEIADES. As an article in Le Monde (https://www.lemonde.fr/economie/article/2020/10/04/en-allemagne-les-renovations-energetiques-des-batiments-n-ont-pas-fait-baisser-la-consommation_6054715_3234.html) pointed out, the major renovation effort carried out in Germany did not lead to any form of effective reduction in thermal consumption in private homes: In 2010, a household consumed an average of 131 kilowatt primary energy/hour and square meter. In 2018, it consumes 130kWhpe/m2/year. The cause is the rebound effect, i.e. fundamentally a question of practice of the inhabitants who increase their comfort requirements and are less careful about consumption which is supposed to be low after the retrofitting. In addition to the mere consideration of occupants, with the stakes on collective self-consumption in particular, research is oriented towards the involvement of occupants (EcoSESA IDEX/CDP projects), bringing together researchers in the human and social sciences in the analysis of human practices with energy impact and in engineering sciences in methodological and technological innovation.

Although there is a little difference between commercial and residential buildings, the solutions for helping people to become more sober are different: the former can be based on automations because the often large investment can be supported by the companies and the diversity of activities is often low, while the latter remains problematic today. The INVOLVED project (ANR2014) has provided responses by developing concepts for an Interactive Home Energy Management Aid System (IHEMAS) aiming at involving the occupants of the Elithis Rhine-Danube tower in daily decisions that have an impact on consumption and comfort. This IHEMAS focuses on the perception, understanding

and action capabilities of the inhabitants, thus avoiding the pitfall of excessive automation. Beliefs, resistance to change, perception and misunderstanding were taken into account by the IHEMAS by generating explanations [1] and advice after the inhabitants specified their expectations [2]. It emerges from the sociological studies that there is no reference for sober practices insofar as the comfort requirements are specific to each household, but above all, the inhabitants intentions remain inaccessible to the IHEMAS. Mirroring, replay, explanation, focus and counselling services have been developed and tested in vivo for some aspects, in vitro for others [3].

The PhD project will start with the key findings of the INVOLVED project but focusing on the following limitation: each site is unique because of its architecture, equipment and sensors but also because of its occupants. The site models, including sensors locations and human activities/preferences used in INVOLVED are mostly not available. Therefore, an alternative approach has to be designed considering that site knowledge results from a symmetrical confrontation between occupants' knowledge and IHEMAS knowledge. Each party is informing, explaining, asking, suggesting and learning from the other in a symmetrical way. In [4], we showed a first application of a symmetrical co-definition of activities where occupants depicted daily what they did with their own meaningful labels and the IHEMAS analyzes whether it can match its perception based on sensor data and, if not, it suggests a more global activity label or labeling errors depending on the context. In LearningHome, we want to go further in (1) actively discovering non-Pareto-optimal occupant behaviors regarding costs/comforts compromises by driving occupants in exploring the space of possible actions and generating contextual dynamic causal explanations [3] (2) validating the efficiency of the approach by comparing it to different ways of pricing and/or billing, of involving by gaming approaches, of providing inhabitants with regular home energy/activity reports.

The research work aims at developing cooperative and active learning for home inhabitants to confront to the IHEMAS to yield knowledge about occupant activities and costs/comforts preferred compromise. This work should extend the promising concepts opened up by the ANR INVOLVED project regarding interactions by developing cooperative solutions to learn a global human-system learnt representation. The aim is to identify the practices as well as the activities of the occupants by reconciling the perceptions of the IHEMAS and its sensors with the perceptions of the inhabitants. These perceptions will be translated into activity labels and preferences, taking into account the volatility of the inhabitants' memory and their limited consent to interact with an IHEMAS. It induces learning methods with ad hoc notifications [5,6] but also mechanisms for matching the inhabitants and IHEMAS perceptions. The number of sensors is more or less important and may induce confusions that must be resolved when the system is not able to discriminate labels provided by the inhabitants. Combining sensor data with labels from occupants yield a model thanks to learning algorithms. Active learning is a complementary method to discover the energy behavior of a site. Contrary to the INVOLVED approach, explanations and advice are generated without an a priori physical model, but by exploiting similar encountered situations. The aim is to conceive an exploratory approach guiding the inhabitants in the discovery of the effects of actions in similar situations. Inhabitants will thus be put in

situation of experimenters of their environment and the IHEMAS will have the role of recording the experiments and guiding inhabitants towards new exploratory. This research front will lead to different prototypes delivered to the research front 2 for the design of a relevant HSI.

References

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