Optimization of Energy Efficiency in Buildings with Cognitive Knowledge-Based Control

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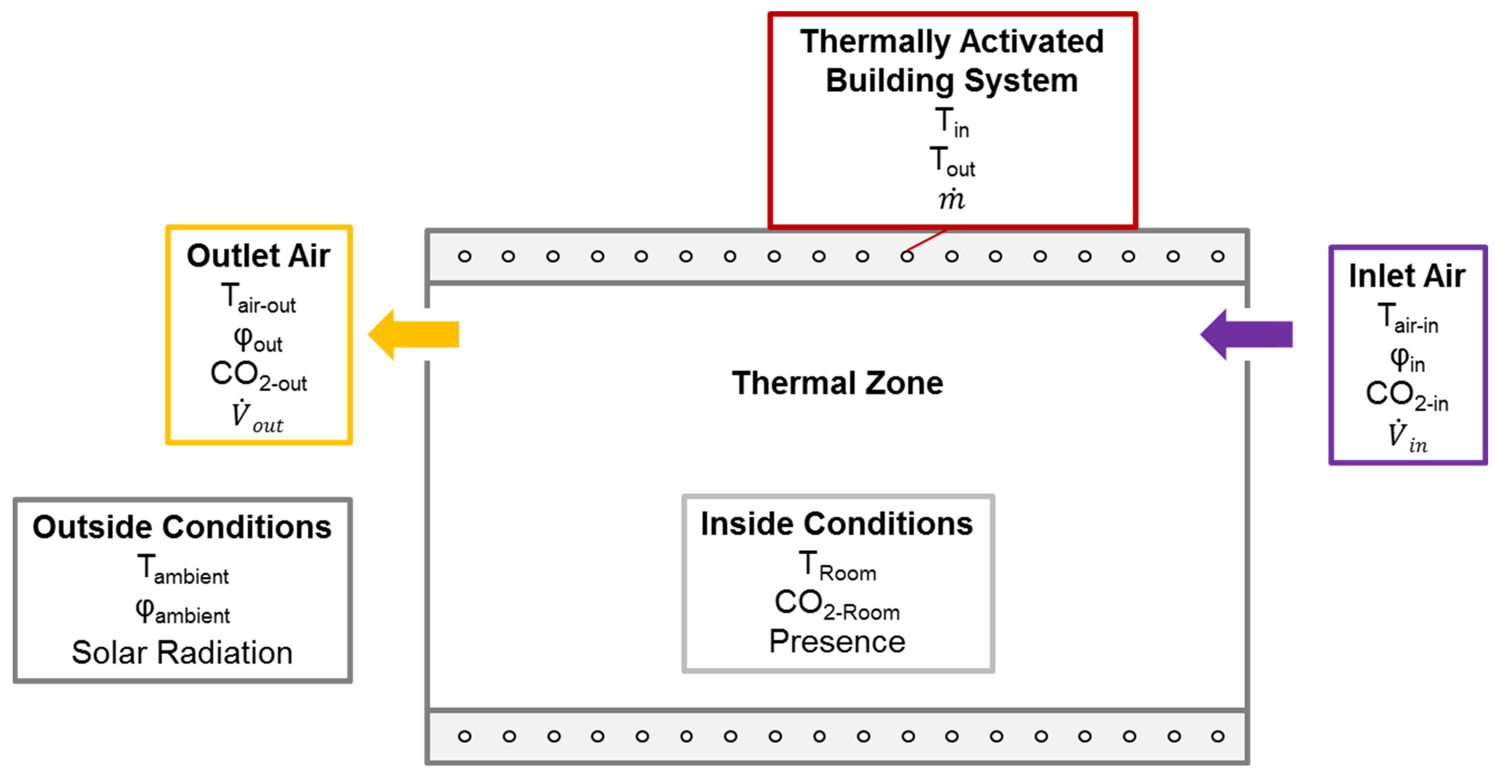
Abstract – In the project KORE (Cognitive Optimization of Control Strategies for Increasing Energy-efficiency in Buildings), a novel approach based on a cognitive system is proposed to enhance current building automation systems regarding unused energy efficiency potential. Instead of manually configured rules, rule sets are generated and optimized automatically.

Energy Efficiency in Buildings

Motivation and Problem Statement

The tasks of a **Building Energy Management System** (BEMS) are to operate heating, ventilation and air conditioning (HVAC) systems, to maintain **indoor comfort** and finally to maximize **energy efficiency**. The challenges for the near future are to develop **adaptive controls**, in order to reduce commissioning effort and to allow flexible operation to incorporate volatile production. For instance, comfort may not be kept all the time and maybe not to any price. In order to fulfill those tasks, the building management system needs a semantic representation of building services, which are used to **autonomously generate control strategies**.

In KORE, a control strategy for a specific building in a specific context (e.g. summer, winter) is defined by a rule set. Rules can be recombined and varied in several ways, defining a **huge problem space**.



Use-Case

The system will be built to generate control strategies for a demonstration building (e.g. the AIT building ENERGYbase in Vienna), where several rooms to control by using comfort relevant sensors (CO_2 and temperature) as well as energy consuming sensors (ventilation volume flow rate). Before KORE is deployed in a real building, a simulation as well as historical sensor data will be used to train it and to test different strategies.

Proposed Solution

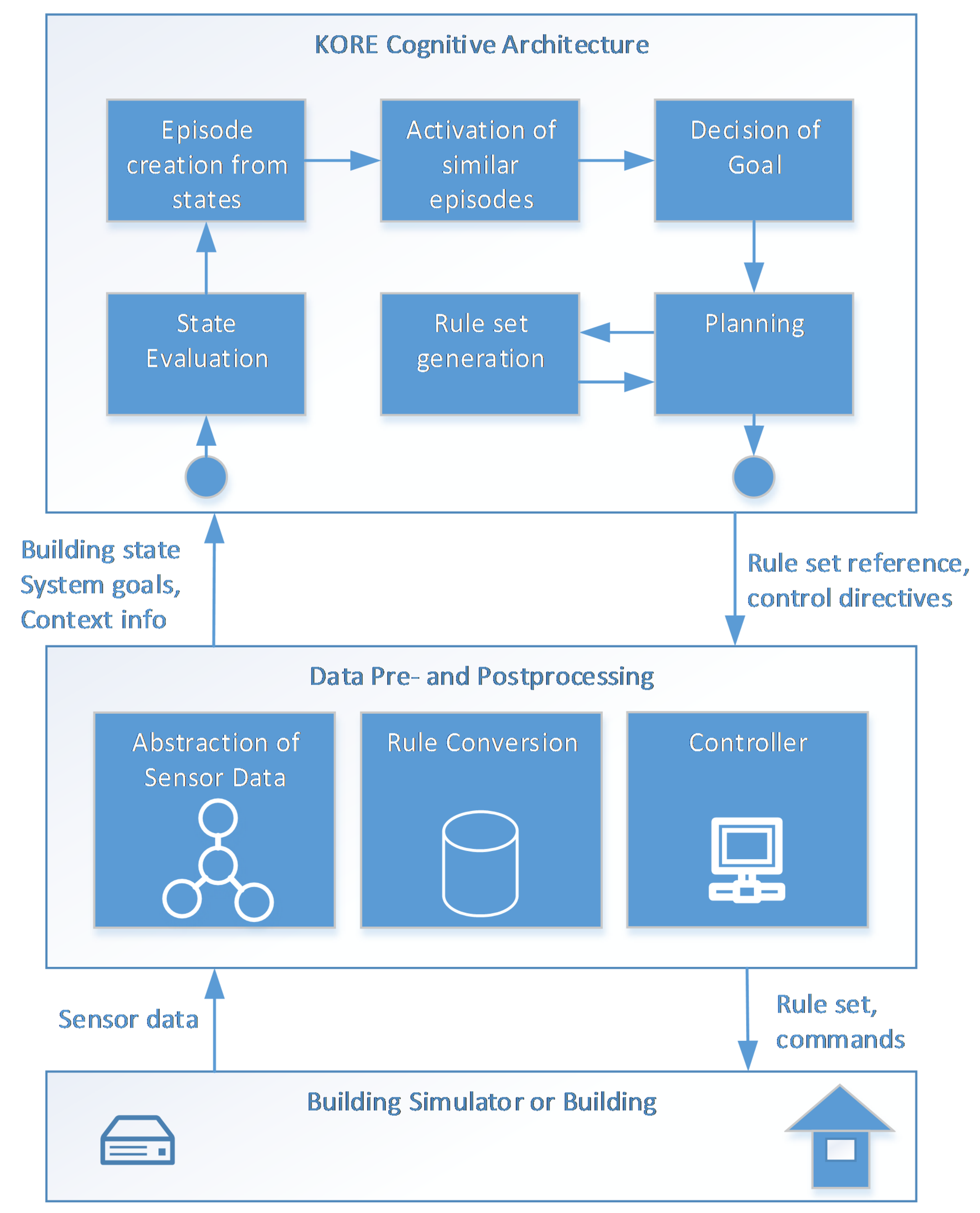
Cognitive Architecture

To meet control requirements of a building and underlying building services, a **cognitive architecture** is developed. By using biologically inspired reasoning techniques, its purpose is to map an input state of sensor values to a certain rule set, in order to reach defined system goals.

Related work in the area of **case-based reasoning** of a ball catching robot arm (1) has shown that a system that relies on learned experience performs better than a system that is based on a physical model. A physical model cannot describe the real world with all details. Therefore, it is expected that this novel approach will be able to generate better results.

Method

The method used is **reinforced learning combined with case-based reasoning**. Thus KORE tests different solutions, evaluates and remembers the evaluation of the solutions. For a certain problem, KORE retrieves similar already solved problems and uses that solution again. In case the solution performs well, the confidence of the solution for that problem is increased. If a solution performs in a bad manner, a new solution is tested. The reasoning within the system is mainly done through similarity comparison. The strength of the system lies in its adaption to recognized reoccurring events.



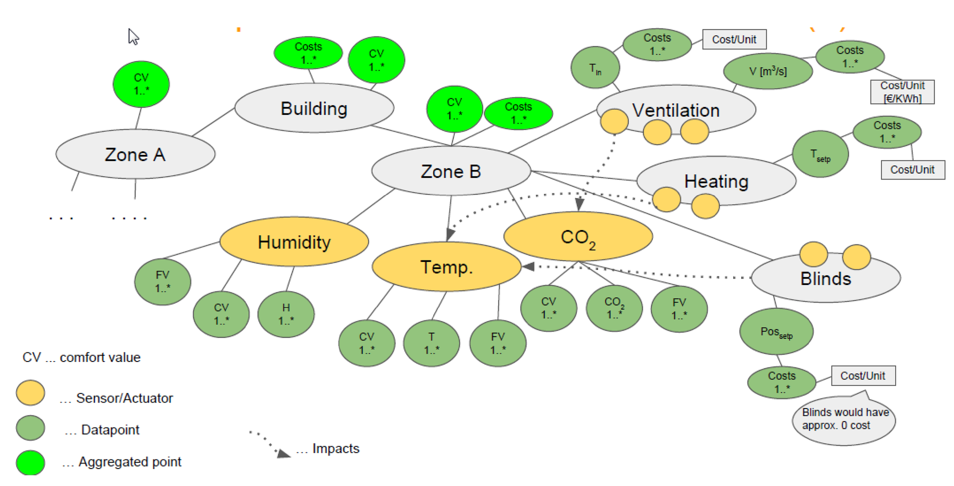
Rule Generation in a Simulator

KORE will **use a simulation** to **generate and evaluate rule sets**. If a rule set has been found that is acceptable, it will be adapted by allowing small variances during operation. The feedback through the input sensors determines how well that modification worked.

(1) K. Mironov, I. Vladimirova, M. Pongratz, Processing and Forecasting the Trajectory of a Thrown Object Measured by the Stereo Vision System, in IFAC-PapersOnLine, S. 8, Saint Petersburg, Russia, 2015

Abstraction of Sensor Data

The low-level sensor data are transformed to more abstract high-level key performance indicators (KPIs). Low-level metrics are measurements received from various sensors, e.g. temperature, relative humidity and carbon dioxide level (CO_2). As KPI, a high-level comfort metric is defined. The static structures of the building (e.g. floor plan or architecture) and the dynamic data (low level sensor data as well as high-level KPIs) are summarized in form of a hierarchical knowledge base, as depicted on the right.



Expected Results and Upcoming Tasks

In the current phase of the project, KORE is still work in progress. First implementations of parts of the proposed system concept show promising results regarding the evaluation of tested control strategies. The next step is to use this learned experience in order to define **hypotheses about future events and plan in advance** to make desired states happen or to avoid undesired events. As a result, the system will improve its performance not only based on immediate rewards but in view of long term goals as well. To address the increased complexity of a building automation system, as another next step, a **distributed model** will be adopted based on a multi-agent system. Each agent monitors the conditions in each room and learns locally the optimal behavior locally. Information is then forwarded to master agents that are responsible for conflict resolution.

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