Constraint Technology for Sustainable Building Operation in the ITOBO project[a]

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Energy management is one of the key components of sustainability. In particular, reduced energy consumption is crucial, to reduce dependence on fossil fuels as resources become depleted and to reduce greenhouse gas emissions [1]. Buildings typically account for up to 40% of the energy use in industrialised countries [2], and of that, over 80% is consumed in the operation of the building through electricity, heating, ventilation, and hot water. Reducing the energy consumption of buildings will have a significant impact on sustainability.

ITOBO (ICT for Sustainable and Optimised Building Operation)[3] is a strategic research cluster funded by Science Foundation Ireland focused on the use of ICT for driving down energy consumption in large commercial buildings. The cluster combines researchers from Civil and Environmental Engineering, Artificial Intelligence, Computer Science and Electronic Engineering, employing techniques ranging from environmental sensing, through thermal modelling, building information modelling, facilities management, and automated control, to decision support and user modelling. ITOBO includes a range of industrial collaborators ranging from SMEs to multinationals in design, construction and facilities management. The project is headquartered in UCC's Environmental Research Institute building, which includes many sustainable energy features such as solar panels, geothermal heat pumps and heat recovery systems. The ITOBO project will deploy systems in at least three commercial buildings, including the ERI at UCC and two buildings used by our industrial collaborators. Constraint-based methods, optimization and automated reasoning form a large part of the ITOBO computational techniques being applied to achieve energy efficiency. A fragment of the planned ITOBO framework relevant to automated reasoning and decision support is shown in Figure 1.

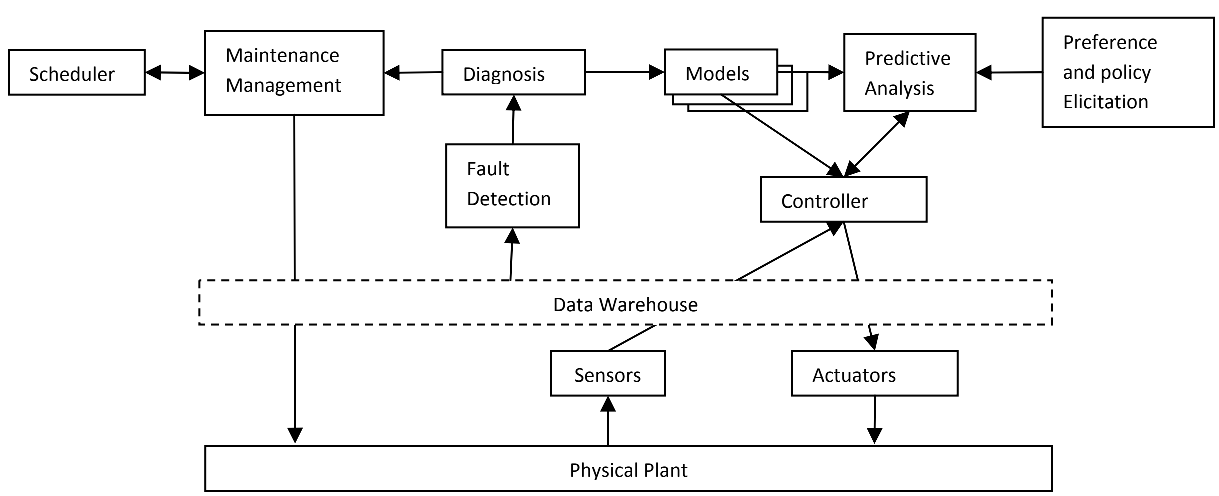

Figure 1

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We assume a series of models of building performance and building use, allowing simulation of thermal properties, the prediction of activities within the building, and prediction of external weather conditions. We also assume a network of wired and wireless sensors and actuators, linked to an active building management system. The sensors measure, among other features, light, temperature, CO_2, humidity, and the presence and movement of individual occupants. The actuators enable control of task and ambient lighting, local heating and ventilation and centrally managed boilers and chillers. All sensed data and actuation commands will be stored in a data warehouse, which forms part of the Building Information Model. Fault reports will be fed to an automated diagnosis module, which will be used either to update the plant model for the control system, or to request maintenance actions. The role of individual stakeholders is crucial to the process. Energy efficiency initiatives will not succeed without the active participation of both the management and individual occupants of the building, and thus we are constructing modules for eliciting user preferences and feedback on the building environment (thermal comfort, light levels, etc.) and for representing building use policies by building managers. The control module then uses the sensed data, the predicted use of the building, the preferences and the building performance models to initiate control actions, with the goal of minimising energy use while satisfying minimum levels of comfort. We are currently investigating the use of data mining techniques to extract optimal schedules for heating systems, based on observed building use. Finally, the maintenance operations are scheduled on a planned and reactive basis for energy efficiency, subject to service level agreements.

Constraint technology and automated reasoning is being used specifically in the following areas. *Preference Elicitation:* We are developing techniques and interfaces for eliciting and learning occupant preferences regarding comfort, and building operator preferences for optimising and balancing occupant comfort and energy efficiency. *Intelligent Control:* A constraint-based preference solver computes optimal target configurations for lighting and HVAC elements, which are fed to a controller based on stochastic hybrid systems. We have implemented an automated control-code generation technique, which uses high-level building models, to create instance-specific control [4]. *Diagnosis:* We have implemented a model-transformation approach that takes high-level system models and automatically generates embeddable model-based diagnostics code [5]. In addition, we will use building performance data stored in the data warehouse to identify key parameters in the embeddable diagnostics code, to minimise false alarms and properly identify faults [6]. *Maintenance Scheduling:* our maintenance scheduler integrates planned cyclic maintenance with reactive maintenance in a dynamic constraint solver, where the goal is to satisfy occupant preferences, health and safety requirements and business processes [7], while minimising energy consumption.

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