Using BIM Data for Generating and Updating Diagnostic Models

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Submitted to the "CC09-S13: Building Information Modeling" Session
The Twelfth International Conference on Civil, Structural and Environmental Engineering Computing

Extended abstract

Modern Building Information Models (BIM) collect various data of a building created over its lifetime. From design time the building geometry and the HVAC design, and the building automation systems can for example be stored in IFC. The actual building performance measures collected during runtime are on the other hand stored in databases or data warehouses of the building management system. This broad variety of data cannot only be used for analysis tasks like energy simulation, building performance analysis, facility management, and diagnosis, but allows new holistic design approaches of these tool chains.

For example, a Fault Detection and Diagnostic (FDD) tool for a specific building is usually created from modules that implement common functions like threshold detection, anomaly detection, condition monitoring, control cycle diagnosis, etc. One key drawback to compose such large systems is the cost of constructing appropriate system models. This requires comprehensive information of the building, the HVAC system, the data points in the building automation system, the data bases or data warehouses of the building management system - just the kind of information available in a modern BIM like the one introduced in the paper.

The main contribution of this work is showing how to use the BIM to structure the diagnostics models, and also how BIM data can be used for learning model parameters for updating the parameters following building commissioning. We propose an approach for reducing the need to construct multiple models by using a meta-modeling and model-transformation approach. We assume that we can specify a generic meta-model, which is a detailed model that identifies a key set of properties of a system. For example, this model may be a detailed simulation model that includes control and sensor configurations. Given generic meta-models for a source and a target-system, we show how we can auto-generate an application-specific model. In particular, we show how we can generate a discrete diagnostics model from a hybrid-systems model.

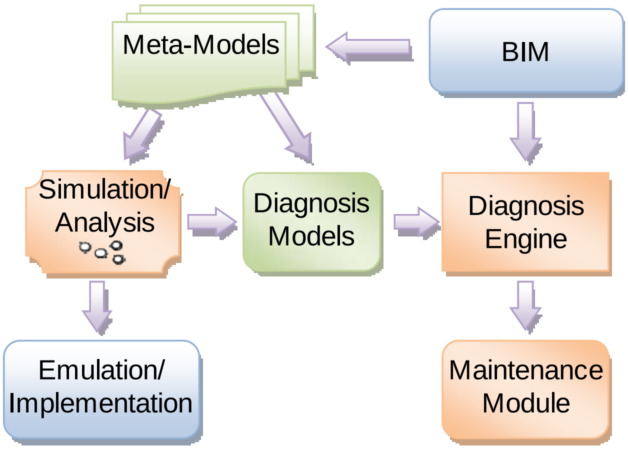

Figure 1: Design Flow

The proposed monitoring and diagnosis approach is described in Figure 1. As mentioned earlier, our approach is based on a multi-modelling platform that auto-generates various models dedicated to different use. Starting from the design information in the BIM like device lists of the HVAC and building automation system a meta-model is abstracted. From this meta-model further models for simulation and analysis are generated, using models such as hybrid systems models for simulation, and threshold detection approaches for diagnosis. The simulation models may then be translated into embedded code to be deployed in the wireless sensor/actuator network (WASN). The diagnosis models are linked with a diagnosis engine that detects faults in the actual measurements of the automation system which are collected in the data warehouse part of the BIM. The threshold that has been violated and the related zone are communicated to the diagnosis engine in order to isolate the faulty component using a model based diagnosis techniques. The maintenance component takes the output of the diagnosis engine to schedule maintenance activities.

We divide our diagnosis-generation approach into two parts: (1) generation of monitoring rules, which will indicate anomalous conditions; and (2) generation of diagnosis models, which isolate the faults given the anomalous observations from (1). In this article, we focus on the auto-generation of monitoring rules; the details of diagnosis model-generation are presented in [2]. To monitor the condition of a zone in a building, one needs to have some representation that would indicate when key parameters are exceeded. Two key issues for such a representation are: (1) the structure of the monitoring rules, and (2) the values of the thresholds. We assume that we will adopt a standard template for the threshold detection, and use the BIM to auto-generate the rules parameters and the building-specific parameter thresholds.

We illustrate our approach using an example from the domain of lighting control. We assume that for a particular zone, the BIM indicates that the zone has sensors for external and internal light levels, L_I and L_E respectively, and for presence P of occupants, and the controller is attempting to maintain a light level of σ if occupants are present; any internal lighting is *off* if no occupants are present. The threshold detection rules might include rules with structure like:

If $(P=f) \wedge (L_I - L_E) > \delta_1$ then *actuator-anomaly*

If $(P=t) \wedge |L_I - \sigma| > \delta_1$ then *actuator-anomaly*

If $(Act=on) \wedge (L_E - L_I) > \delta_3$ then *sensor-anomaly* OR *actuator-anomaly*

Here the first rule uses a threshold δ_1 to indicate if the actuator is erroneously turning on internal lighting when no occupants are present; the second rule signals an actuator fault if the internal light differs more than some threshold from the set-point σ; i.e., the actuator may not be turning on when a person is present; the third rule is just validating the light-level sensor outputs, such that the internal lighting is switched on and yet the external lighting exceeds the internal lighting by some threshold δ_3.

These generic rules will have to be instantiated with real sensors and actuators defined in the BIM or data warehouse, and the parameters (δ_1, δ_2, δ_3) will need to be assigned values. For simplicity, we can assume that there is just a single sensor each for the external and internal light levels and for occupant presence; in addition, there is just one actuator for internal lighting. Hence the issue then is just assigning the parameter values. These values can be assigned directly if the BIM has appropriate thresholds pre-computed; alternatively, we will need to use some parameter-estimation techniques for actual data. In this case, we can use machine-learning techniques to identify appropriate parameter values for (δ_1, δ_2, δ_3) by comparing BIM output with real sensor/actuator values given normal and fault conditions [1].

The full paper will define the details of our auto-generation process for monitoring rules, including creating instances of the templates from real buildings, as well as using machine learning to estimate the parameters in the estimated rules. We will use examples of building lighting and HVAC systems to illustrate our approach.

References

[1] Katipamula, S., and M.R. Brambley. Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems - A Review, Part I. HVAC&R Research, 2005

[2] M. Behrens, G. Provan, M. Boubekeur, A. Mady, "Model-Driven Diagnostics Generation for Industrial Automation", Proc. 7th IEEE International Conference on Industrial Informatics, 24-26 June, 2009. (submitted)

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