Demo Abstract: Human-in-the-loop BMS Point Matching and Metadata Labeling with Babel

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ABSTRACT

The inconsistent metadata in Building Management Systems (BMS) hinders the deployment of cyber-physical applications in non-residential buildings. In this demonstration we present Babel, a continuous, human-in-the-loop and crowdsourced approach to the creation and maintenance of BMS metadata. Occupants provide physical and digital input in form of actuations (e.g., the switching of a light) and readings (e.g., the reading of the room temperature of a thermostat) to Babel. Babel then matches this input to digital points in the BMS based on value equality. We have implemented a prototype of our system in a non-residential building over the BACnet protocol. While our approach can not solve all metadata problems, this demonstration illustrates that it is able to match many relevant points in a fast and precise manner.

1. INTRODUCTION

Non-residential buildings are a prime platform for cyber-physical applications. Indeed, Building Management Systems (BMS) already provide programmatic access to a plethora of sensors and actuators so that building performance can be managed in software. Also, reducing building energy consumption and increasing occupant comfort are complex objectives that greatly benefit from advanced IT solutions.

Previous work shows the potential of such applications built on top of existing BMS. For example, an interactive thermal preference application has achieved 10% in energy savings and increased human comfort [3]. However, such applications are not yet deployed beyond building-specific research experiments. The problem is metadata. Traditionally, a BMS is commissioned and its functions are hardcoded to the specific characteristics of a building and to the needs of a building manager. The BMS becomes a legacy system and metadata is then largely irrelevant. Metadata is inconsistent in space, within and across buildings. It is inconsistent in time, as spaces are reorganized and appliances get replaced. The semantic link between physical artifacts and their digital point representation is often missing and rarely maintained.

When novel cyber-physical applications are deployed on top of a BMS, consistent metadata becomes crucial for successful deployment and for achieving portability across buildings. In fact, any form of continuous commissioning requires effective BMS metadata management [4].

Schumann et al. tackle the problem for Energy Management Systems (EMS) by computing similarity values between EMS and BMS labels, reaching 16% accuracy [5]. Bhattacharya et al. propose a system where metadata is semi-automatically completed using regular expressions to detect common patterns in metadata descriptors using the input of the building manager [1]. They show a correct matching of 79% of data points using few (24) and 90% using many (109) manual expert inputs. What distinguishes our approach from previous work is that we place the users of the building in the loop. Occupants are the main beneficiary of improved building operation. We argue therefore that it is in their interest to collectively create a consistent metadata state that enables them to use novel applications.

Our hypothesis is that much of the physical state of a building can be observed by humans and that building metadata maintenance should be based on human input. In Babel, occupants provide physical and digital input in form of actuations (e.g., the switching of a light) and readings (e.g., the reading of the room temperature of a thermostat). Babel then matches user input to points in the BMS by comparing point values to user provided input. For example, if the user notifies Babel that the temperature is 67^oF, we are able to reduce the qualifying points to all points with value 67. By further iterations (a user reports another value for the same temperature point on the next day), we can reduce the qualifying points eventually to a single match. Our intention is to enable occupants to set up the metadata for their own office space by providing input to Babel. After performing this setup process, they are then able to use a personal comfort application, e.g., on their smartphone.

Our demonstration illustrates this process. Visitors will be able to set up the metadata for a few appliances at our demo booth by providing input to Babel. In a second step, they will be able to use our smartphone app to control these appliances based on the created metadata. In the following we describe the our system and the process of point matching in more detail.

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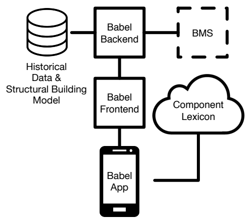


Figure 1: Architecture

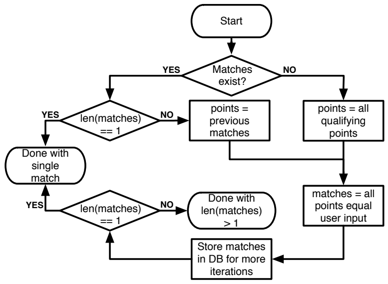
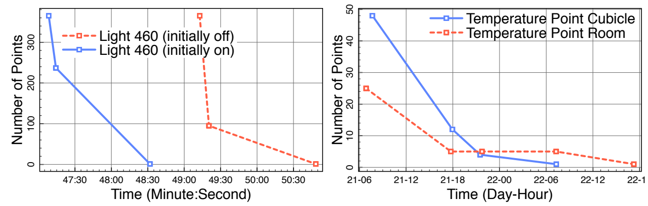


Figure 2: Matching Process



(a) Light Switch (b) Thermostats

Figure 3: Matching progress in two experiments for light (a) and temperature points (b) over several iterations.

2. BABEL ARCHITECTURE

Figure 1 depicts the general architecture of Babel. A local backend connects to the BMS and stores historical values that are still needed for unfinished matching processes in a database. A smartphone application accesses a Web service in the cloud that contains a lexicon for different device types and points (e.g., a light on/off switch, a thermostat temperature point). The same lexicon is used across all buildings to enforce a consistent metadata state. The smartphone application can further access the local Babel service. It provides (i) the specific, structural model of the building, adhering to a global naming schema and (ii) an entry point for users to report new values from the physical world.

3. MATCHING PROCESS

Our goal is to distinguish a single BMS point from the set of all points and enrich it with metadata that adheres to a global naming schema. This is achieved by the simplified matching process seen in Figure 2. We need to eliminate other, unpredictable datapoint changes that might happen during an unfinished matching process. When receiving a new user input, Babel first reduces the points to consider for this request. It removes already successful matches and points whose "BACnet type" value does not fit the type of the point that should be matched.[1] Then it queries the remaining points and compares their value with the user provided value. A substantially reduced list of points is the result. This process is repeated when user input for the same point is provided again until a single point is left.

4. IMPLEMENTATION AND EVALUATION

Our prototype is deployed on a 141,000 ft^2 campus building that provides a BACnet interface. We have implemented the backend components using Python, Go, and a mobile app for Android (see `https://github.com/jf87/Babel`).

Figure 3 shows how the number of possible points converges towards a single point during few iterations for a binary light switch (a) and two thermostat temperature points (b). The dashed and solid lines show that behavior for two different experiments for these specific points. Lights can be matched after one iteration and in short time (one minute) when they can be actuated by users (e.g., via a wall switch). The temperature points require 2-3 iterations. If the user does not actively influence the temperature (e.g., she manually heats up the thermostat), these iterations require a wider time window. This is because the values of all temperature points in a building usually correlate to each other and have similar value ranges. This makes it harder to uniquely identify a single point opposed to the aforementioned lights, where users can arbitrarily create uniqueness by manual light switching. However, we could always identify a point in just a few iterations, thereby limiting the manual work required by the users of our system.

[1]The BACnet standard defines 54 point types (e.g., Binary Input, Binary Output, Analog Input etc.) [2].

5. CONCLUSION AND FUTURE WORK

We have developed and implemented the concept of crowdsourced BMS point matching for non-residential buildings. Our initial evaluation shows great potential. Points that can be directly influenced by humans (light, temperature setpoint), work best with our approach. Points that can be observed by humans (e.g., a thermostat temperature) still work well. A first deployment of Babel in a campus building has shown that we are usually able to uniquely identify a point after only two iterations for points that can be directly influenced by humans and 3-4 iterations for observable points. Looking forward, we want to evaluate the actual quality of user input. We further want to investigate the matching of "internal" points like a HVAC's valve position.

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