Data Quality-Centric Model-Driven Development Process for Wireless Sensor Network Applications

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ABSTRACT
Tuning data qualities is important to develop wireless sensor network applications because these applications focus on real world data. Consequently, the development process must simultaneously provide rapid prototyping to identify problematic data qualities precociously and allow for fine-grained tuning. Herein we propose a data quality-centric model-driven development (MDD) process that meets both requirements simultaneously via multiple abstraction levels. To reduce prototyping cost, a developer only designs dataflow without lower level concerns, while fine-grained tuning is achieved by redesigning communications and task assignments at the appropriate abstraction levels. Using a case study with a realistic application, we show our MDD process satisfies both requirements.

Categories and Subject Descriptors
C.3 [Special-Purpose and Application-based Systems]: Real-time and embedded systems; D.2.9 [Software Engineering]: Management

General Terms
Design, Management

Keywords
Wireless Sensor Network, Model-Driven Development

1. INTRODUCTION
In developing a wireless sensor network (WSN) application, a developer must design it to satisfy not only functional requirements, but also non-functional requirements. One of the important non-functional requirements for WSN applications is the quality of retrieved data [6] (we call the requirement data qualities). The data qualities are influenced by the execution environment, including obstacles and deployed WSN. For instance, data loss rate, one of the data qualities, often increases due to obstacles. Consequently, to satisfy the requirements for the data qualities, a developer needs to prototype an application to measure the data qualities and to tune by deciding appropriate designs.

To achieve a rapid prototyping and a fine-grained tuning, a systematic software development process is needed, but few studies related to such development process for WSN applications have been investigated. Currently, a developer tends to be in the code-and-fix style [5] with a domain-specific language (DSL) that focuses on one abstraction level. In a DSL that focuses on each node, a developer can design all features of a WSN application, but consumes much time to decide all designs. To reduce such costs, many DSLs that abstract away some features have been proposed [4], which express behaviors as node groups or dataflow. In these DSLs, a developer can achieve rapid prototyping by the abstractions, but cannot achieve fine-grained tuning because their abstractions limit the tuning. Due to the trade-off and the lack of systematic development process, existing development cannot achieve both rapid prototyping and fine-grained tuning.

Herein we propose a data quality-centric model-driven development (MDD) process. Our MDD process provides the systematic use of DSLs at three abstraction levels and automatic transformations to combine three levels. In addition, to validate the applicability of our development process, we conduct a case study with a real-world WSN application.

2. DATA QUALITY-CENTRIC MDD PROCESS
An overview of our proposed development process is illustrated in Figure 1. Initially, a developer designs and describes application logics using one of our DSLs that can express dataflow (DataflowML) in the prototyping phase. A prototype can be obtained via automatic
Figure 1: Overview of the proposed development process.

Transformations. Hence, our MDD process achieves rapid prototyping. In the subsequent tuning phase, a developer can redesign the communications and task assignments using additional two DSLs: one to express the behavior of node group (GroupML) and the other to express the behavior of an individual node (NodeML). Therefore our process achieves fine-grained tuning.

3. CASE STUDIES
To validate the applicability of our MDD process, we conducted a case study with the heritage building monitoring (HBM) application [2]. In the case study, we simulate the development of the target application with our MDD process. The HBM detects a deterioration of the heritage building in Italy, and deploys with 16 nodes and one base station over four months. Its application logic consists of data sampling of acceleration, deformation, temperature, and humidity as well as data processing to detect deterioration through a Bayesian algorithm. To tune the data qualities, Ceriotti et al. adopted Huffman data compression, which reduces the vast amount of acceleration data, and position-based task assignments, which facilitates the detection of early symptoms of deterioration. For the HBM application, we can describe its application logic with the DataflowML, as well as its design decisions, the data compression and the task assignments, with the GroupML and NodeML.

4. RELATED WORK
Although a systematic development process for WSN applications is required, few approaches propose development processes. Losilla et al. have defined a modeling language, which can express a behavior of node groups [3]. Baobab [1] is a framework to address the model described by their DSL for a behavior of each node. These work successfully generate code from the model and increase the productivity, but only adopt one DSL. In contrast, we propose a MDD process that contains three DSLs at different abstraction levels.

5. CONCLUSION
Due to the lack of systematic software development process for WSN applications, satisfying both low-cost and rapid prototyping and fine-grained tuning is difficult. Hence, we propose a MDD process that provides the systematic use of DSLs at three abstraction levels and automatic transformations to combine three levels. Therefore, we expect our MDD process will support the development of WSN applications that are tailored to the execution environment.

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Biography. Ryo Shimizu received the BE in 2010 and ME degree in 2012, in computer science from Waseda University, Japan. He is currently a first year PhD candidate at Waseda University, and is expected to graduate in March, 2015. His research interests include software engineering, in particular model-driven development, and wireless sensor network systems.

6. REFERENCES