System-centric Embedded Systems Engineering Education

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Introduction and Objectives

An educational model for incorporating the principles of Supervisory Control and Data Acquisition (SCADA) into advanced undergraduate and introductory graduate courses in embedded systems engineering is presented. The model is innovative in that the approach is one of vertical and holistic integration: rather than focusing on myopic segments, it addresses SCADA along a range of perspectives. This results in an approach that is system-centric rather than device-centric, one giving learners a global view, and improving the relevance and impact of what is learned.

Outcomes of this model will impact the ways in which embedded systems engineering education are designed, as well as the methods used to investigate and evaluate new or existing materials and strategies. In providing tools and methods to improve the effectiveness and efficiency of delivering this educational model, the linkage between scientific discovery and embedded systems engineering education will be further strengthened and assessed effectively.

The objectives of this project is to develop, test-implement, and assess a pedagogical model for incorporating SCADA instruction into advanced undergraduate and graduate embedded systems engineering education.

Developmental History of Innovation

The proposed model targets the existing deficiency of vertical integration in current embedded systems engineering education. Several pedagogical models related to this area were evaluated:

Model 1. Course(s) on real-time systems in CSE
Model 2. Course(s) on embedded systems in ECE
Model 3. Continuing Ed for engineers & technicians
Model 4. M.S. degree in embedded systems design
Model 5. An embedded systems track in CSE/ECE
Model 6. B.S. degree in embedded systems design

Emerging and next-generation courses in embedded systems should evolve from treatment of components to discussion of analysis, design and integration of systems. The new model must emphasize and balance between breadth and depth, while providing sufficient experience in the system integration and interface aspects.

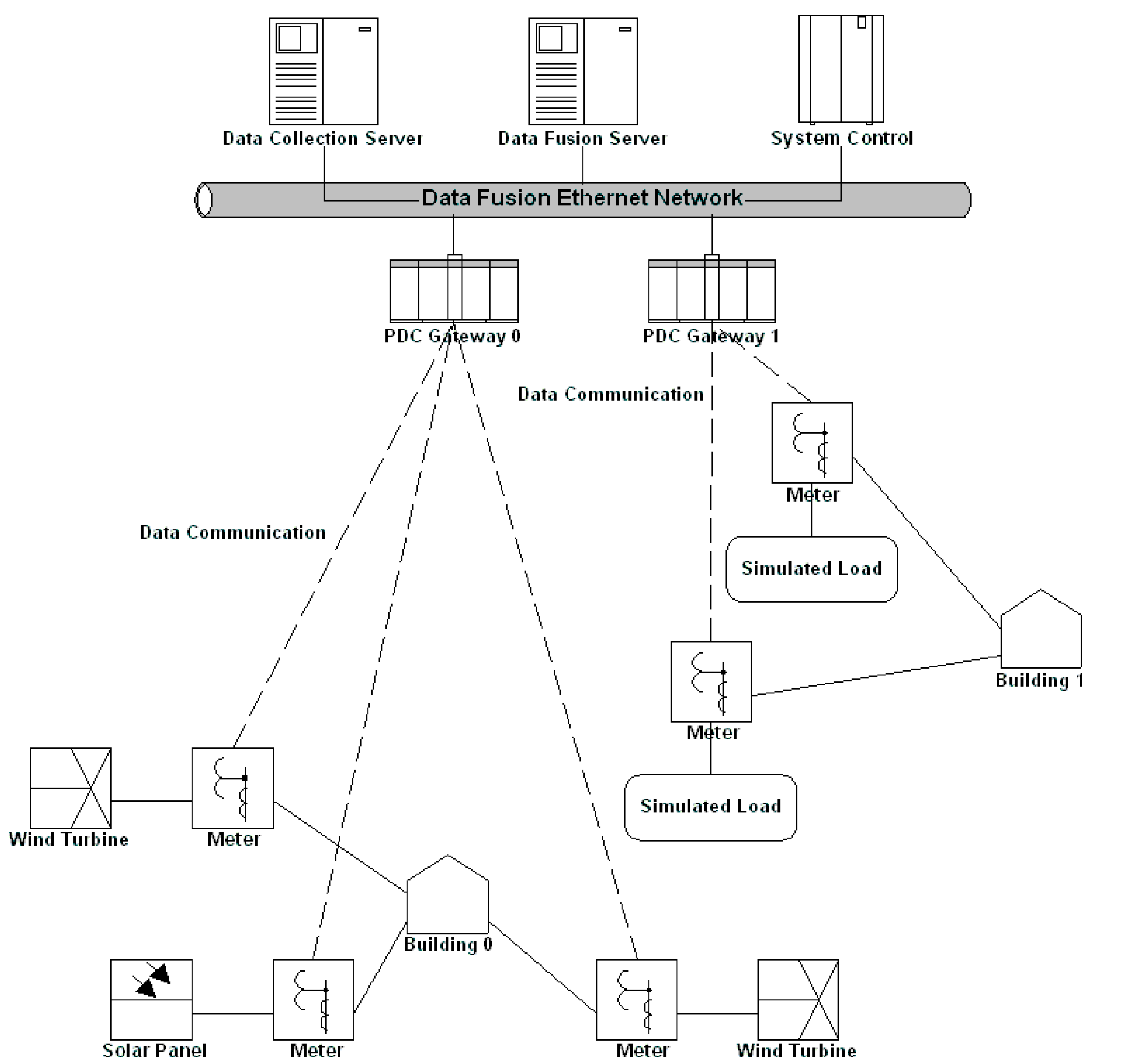
A successful model must also consider the wide application of embedded systems, as well as the device and communication technologies involved. This will cover both analysis and synthesis.

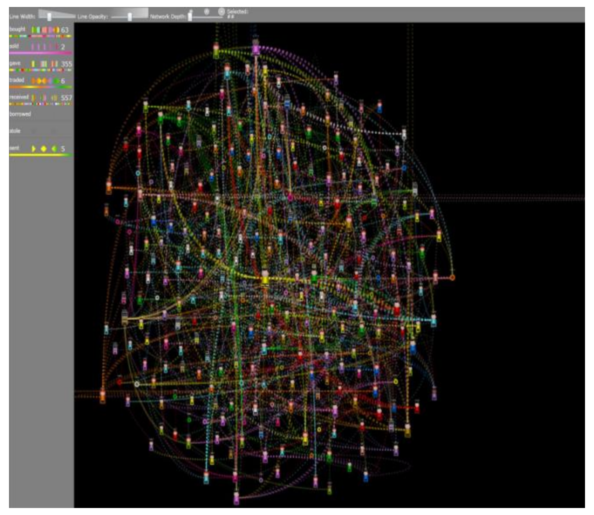
Learning Activities and Materials

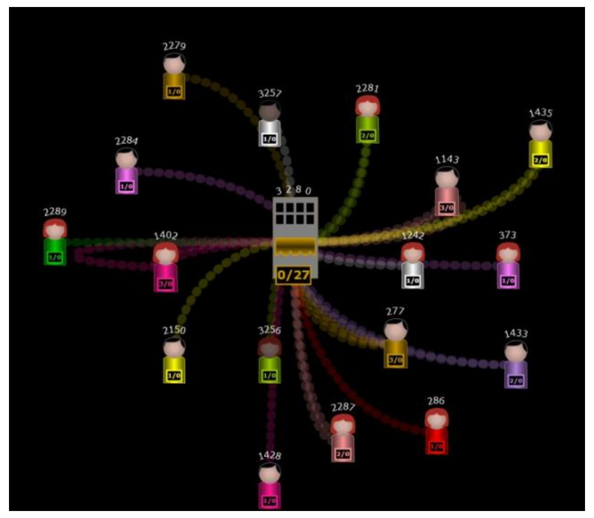
This model involves project based activities with lectures closely related to laboratory activities. There are 2 test beds under consideration. Both are sponsored by the Idaho National Laboratory (INL). One is the National SCADA Test Bed (NSTB). The other is illustrated in the figure below which models the key elements of a Smart Grid.

The SCADA system will consist of a networked collection of sensors and controllers, a computing cluster, and a human-machine interface between the system and a human operator. The system will use Internet based open standard communication protocols for data and signal transmission (with due consideration given to emerging spectrum sharing technologies), on wide-area networks.

This model recognizes the importance of modern SCADA systems in the applications of energy and electrical power grids, along with the significant role played by embedded systems and devices in the SCADA design. The learning activities and thus the materials must strongly support vertical integration of device and system level education.







Execution

Seven (7) course projects similar to those listed below will be planned and augmented by lectures closely related to these projects. The 16-week long course will be taught weekly in classroom for 2 hours and in the laboratory for 4 hours, totaling 4 credit hours for the course. The laboratory and computing facilities required to execute this model will be in place at least 1 semester prior to the commencement of the execution.

These projects, shown in the order of increasing complexity, include the following:

P1. Sensor basics & ADC/DAC circuit design
P2. PWM & related applications in motor control
P3. Input capture & motor speed measurement
P4. Classical PI/PID controller design & testing
P5. Computational performance & power usage
P6. Sensor & controller network integration
P7. Intrusion detection & security for SCADA

Each of the projects will generate individual data on assessment via direct measurement. The data will be aggregated to generate an overall measurement of student performance. Formative and summative evaluations will be performed, which will involve student outcomes, program educational outcomes, and employer feedback. The data obtained through these instruments will contribute to both course level and program level assessments.

Major Issues to Resolve

While this proposed model is deemed meritorious and technically sound by faculty peers, chairs, and deans, there remain some major issues:

1. Market research data has been insufficient to project the demand for this new approach. This indicates that a good “business plan” to present and advocate for the proposed model remains somewhat difficult to develop.

2. This proposed model involves real-time methods for analytics and decision-making, as well as the potential for computation of large data sets (as in the case of the Smart Grid applications.) However, research and development in this area does not currently align with the University mission, which is primarily health sciences related.

3. The current Electrical Engineering curriculum is likely in need of revisions to prepare students to take on the new course(s) which demand a higher level of experience and skills in electronics, circuits, computing, testing, and critical thinking, especially for undergraduate EE majors.

Discussion

Through the synergy of thoughts and advices, it is hoped that valuable experience will be gained on how to further strengthen the current model to best fit a small (< 100 declared majors with 8 faculty members) yet growing program. Main “customers” of the program include local semiconductor and power industries, utilities, government labs, and to no lesser extent, out-of-region markets.

Embedded systems, as both a research as well as teaching area, has seen wide spread application in not only numerous facets of life, but matters related to critical infrastructure and national security. Thus, the training of future engineering practitioners and researchers must consider embedded systems engineering education as a crucial component. The system-centric model proposed here represents a preliminary step in looking into how engineering education can move quickly to address the existing and emerging issues related to this concern. It is desirable to determine the merit of developing and offering an embedded systems track in a B.S.E.E. or B.S.C.E. degree. Furthermore, it is desirable to consider integrating this embedded systems model into an M.S. degree, esp. professionally oriented M.S. degrees where graduates often join industry as R&D or systems engineers instead of pursuing a Ph.D. degree in a particular research area.

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