University of Pennsylvania
Department of Electrical and Systems Engineering

ESE SENIOR DESIGN PROJECT - ADVISOR PROJECT SUBMISSION FORM

1. Project Title: Wireless Factory of the Future

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Are you willing and able to serve as advisor for this project? _X__ Yes; ___ No

3. Brief Project Description:

This is a fun and hands-on project. The goal of this project is to build a model wireless factory with Fischerteknic (i.e. Lego for engineers) and use wireless control to manage the factory. We will develop the wireless network protocol and middleware for the wireless factory of the future. Reliable wireless networks will allow for a radical change in industrial automation where simple modular units can be easily combined to execute complex sensing, control and actuation tasks. Wireless control will enable nimble factory operation where the operation units adapt to faults, changes in throughput and reconfiguration on an item-by-item basis.

Automation includes robots which are responsible for bottling and packaging, material and container handling, automated manufacturing, on-board ship systems, locomotion systems, airport baggage handling, and amusement park rides are a few examples of such systems. With over a trillion dollars of installed base in North America, and over $90 Billion dollars forecasted revenues for year 2008, these systems represent an important domain for embedded real-time systems. So on the outside these may appear to be *boring* applications, but they are high margin businesses that keep the wheels of the nation running.

There are, however, serious design and operational problems in existing wired automation systems. Rigid architectures and proprietary implementations have resulted in systems that are difficult to operate and maintain. For example, an automotive assembly line contains between 2500 and 3000 stations with 5 to 15 sensors and actuators per station. Many devices malfunction and must be replaced on a regular basis. Because the average revenue from such an assembly line is about $25,000 per minute, technicians are often required to patch executing programs, to continue operating by ignoring certain sensor values when it is manually determined that safety is not being compromised. The immense scale makes it difficult to record changes that must be undone and consequently, diagnostic tasks are exacerbated by such operational shortcuts. It is well-known in the industry that automation systems are difficult to design, operate, maintain, and modify.

4. Project Design Objectives:

The goal of this project is to take an existing Fischerteknic mini factory model (see figure below), convert all sensing and actuation signaling from wired to wireless and finally program the factory to operate in a desired manner. A major part of this project involves (a) programming microcontrollers in C and (b) hardware design of an interface board that connects the mini factory to a wireless sensor node.

This project consists of three parts:
A) Understanding the way in which PLC (Programmable Logic Controllers) work and control the mini factory. Converting the existing sense-control-actuate schedule to a set of C programs on a microcontroller.

B) Designing a hardware interface board to connect the existing wired factory controller to a wireless sensor node and programming basic sense/control/actuate commands. These basic commands will be executed in a time synchronized manner in pre-defined time slots.

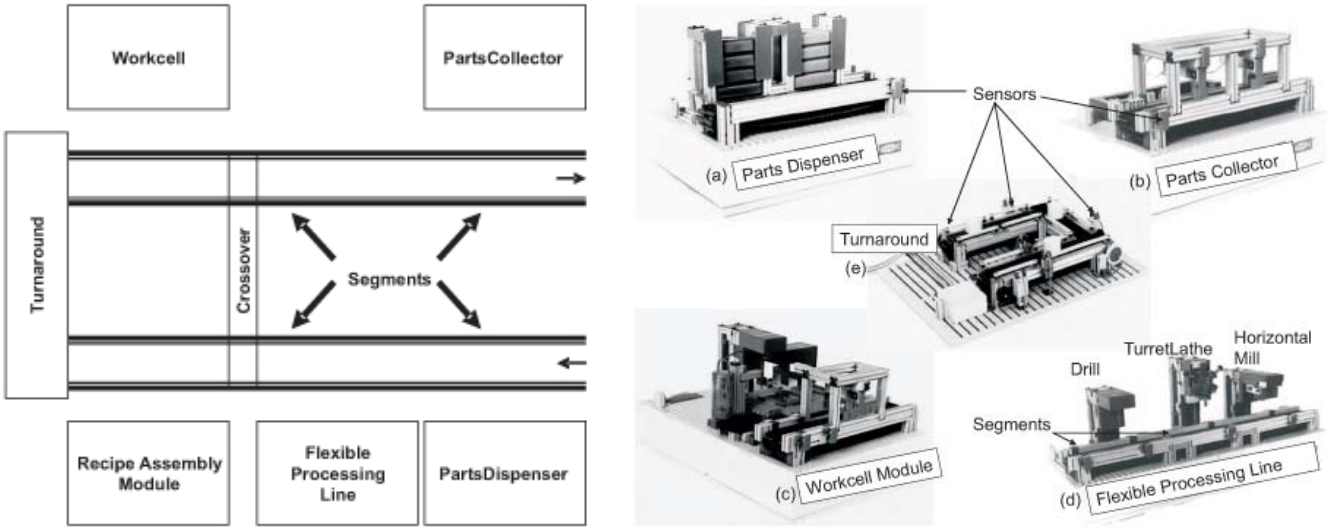

Fig 1. (a) Example of a mini-factory layout with a U-shaped conveyor belt across all operation units.
(b) Different operating units to move or manipulate parts

C) Programming all sensor nodes to intelligently operate the factory under normal conditions and to adapt to fault or abnormal conditions. Here are three example cases: (i) When one node fails, a back-up node will take over control. (ii) When the desired throughput is increased, the nodes will operate at a higher rate. (iii) Finally, when additional components are added to the factory, the addition will be almost seamless and operation will not be interrupted.

Overall, the goal of this project is to build a prototype showcasing the advantages of using wireless communication to make a nimble factory. This will be the first such demonstration and will hence be both challenging and fun.

5. Project Prerequisites:

What specific knowledge (e.g. courses or topics) and skills (e.g. programming languages or software packages) will this project require? Please rank order the knowledge and skills you have identified, with the most important at the top of the list.

The ideal candidates would have a strong willingness to learn, try new and unconventional approaches and cross the boundary between engineering and medicine. A good grasp of C (i.e. no fear of programming and hardware design) would be essential. You do not need to know everything mentioned above because then it will not be research ☺ Knowledge of control systems and microcontrollers would be a plus.

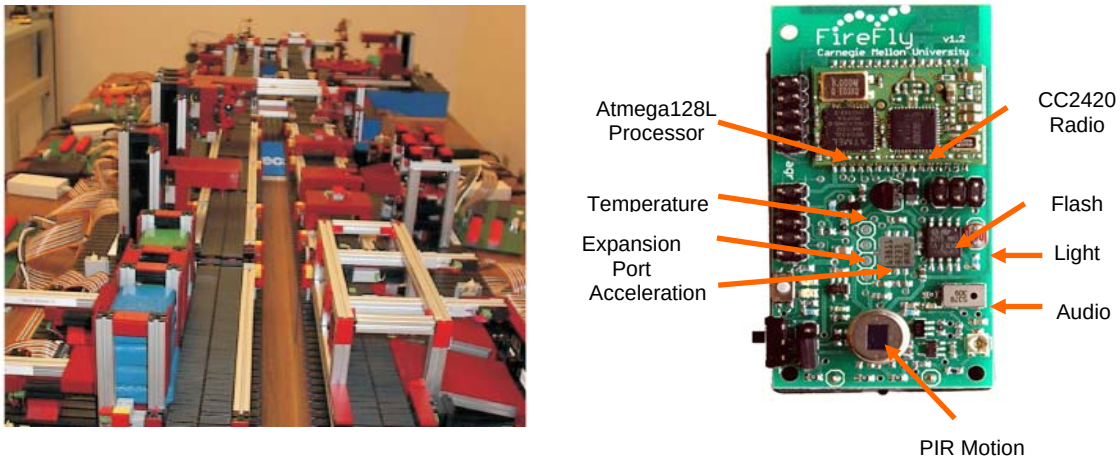

Fig 1. (a) Example of a mini-factory layout with a U-shaped conveyor belt across all operation units.
(b) A FireFly wireless sensor node with a microcontroller and radio