CPS: Synergy: Integrated Modeling, Analysis and Synthesis of Miniature Medical Devices

Submitted by Addisu Taddese on Mon, 02/01/2016 - 5:36am. Contributors:
Pietro ValdastriAkos LedecziPeter VolgyesiRobert J. Webster IIIMarco BeccaniHakan TuncAddisu Z. Taddese

Abstract:

This project develops an integrated design and simulation environment for the creation of miniature capsule robots (MCRs). An MCR is a biocompatible Cyber-Physical System (CPS) designed to operate in the human body to accomplish diagnostic or therapeutic tasks (e.g., colonoscopy, abdominal surgery, etc.). A typical MCR has to fulfill three main constraints: safety, low power operation and small size. Advances in miniaturization of electronic devices have made MCRs a reality. However, MCRs operate in highly unstructured and delicate environments making them difficult to develop without expert level knowledge in multiple domains. MCRs may utilize multiple forms of locomotion to navigate inside the human body. They can also be made in multiple shapes and sizes with configurations that comprise a selection of sensors, actuators and communication modules. The resulting complexity of the system as well as the expense and the long development time has made this class of CPS (small, low power, fail-safe, multi-configuration) unapproachable to a wide community of researchers. This project aims to reduce and ultimately remove this barrier by abstracting domain expertise behind a predefined set of hardware and software components. The project makes available open source hardware and software component libraries to the MCR community that would make building MCRs more accessible. The foundational elements of the design environment are twofold:

- Modular hardware with components that can be added, removed, customized and interchanged as needed. The list includes various sensors, actuators, communication interfaces and computational units. These modules come as development kits with desktop-size boards exposing all the electrical connections, as well as pill-size (e.g., less than 1cm in diameter) boards with plug-n-play connectivity through a flexible circuit backbone.
- Well-defined interfaces and a pre-built component library for hardware modules and software abstractions. The component based programming model is enabled by TinyOS, an event based operating system originally designed for wireless sensor networks. To facilitate design space exploration, we created a web-based environment using the Web-based Generic Modeling Environment (WebGME).

Design space exploration is made possible by using components that model physical aspects of individual elements of the system, such as power consumption and physical constraints. Once analysis is completed and an optimal configuration has been found, the MCR can be synthesized, implemented and tested by using, once again, the software components and the corresponding hardware modules. A prototype drug delivery capsule has been built using the hardware platform to validate a magnetic drug delivery mechanism and to develop a model for scheduled delivery. This has been fed back to the design environment and serves as a template for future capsules. In addition, the SMAC Project for education, a low-cost robotic kit, has been developed in collaboration with high school teachers to effectively engage students in STEM education. Preliminary results are available at http://pillforge.github.io and at http://www.smacproject.org/.

Pietro Valdastri | Akos Ledeczi | Peter Volgyesi | Robert J. Webster III | Marco Beccani | Hakan Tunc | Addisu Z. Taddese

Other available formats:

CPS: Synergy: Integrated Modeling, Analysis and Synthesis of Miniature Medical Devices

Switch to normal viewerSwitch to experimental viewer

CPS Domains Medical Devices Modeling Wireless Sensing and Actuation Health Care Robotics Simulation CPS Technologies Education Foundations Capsule Endoscopy Design Space Exploration ISIS- Vanderbilt University medical CPS model-based design environment 2015 CPS PI MTG Videos, Posters, and Abstracts National CPS PI Meeting 2015 2015 Academia Abstract Poster