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

The STORM Lab

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http://github.com/pillforge

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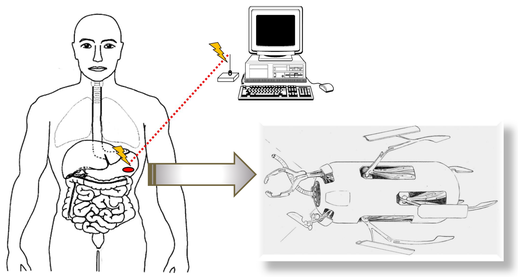
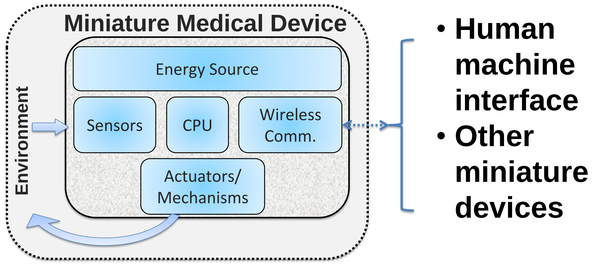
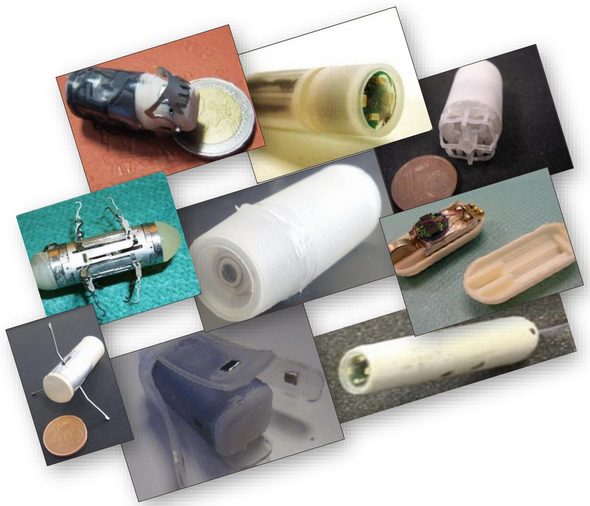
BACKGROUND

Miniature medical devices are classical CPS that can operate autonomously within the human body to augment surgeons' ability to diagnose, prevent, monitor, and cure diseases





- **Human machine interface**
- **Other miniature devices**



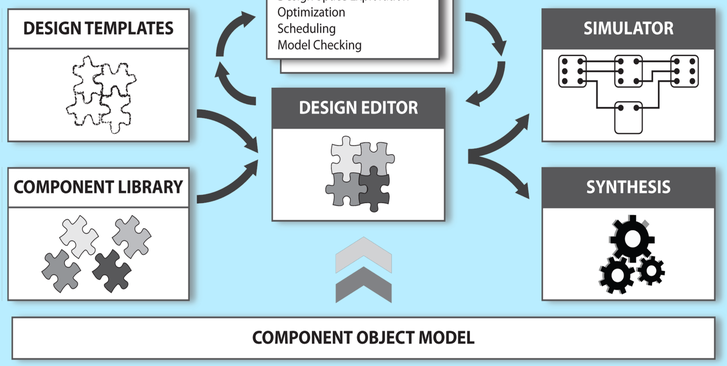
Colorectal cancer strikes more than 170,000 in the USA each year and kills approximately 50,000 [1] with a projected 62% increase by 2030 [32]. If we are successful in promoting the implementation of a painless alternative to traditional colonoscopy, this could have a transformative impact on medicine.

DESIGN ENVIRONMENT

The objective of this project is to create a focused cyber-physical design environment to accelerate the development of miniature medical devices.

A versatile **component model** will provide the structural and semantic foundation for the entire model-based design flow

A pre-built **component library** will provide the building blocks for design construction

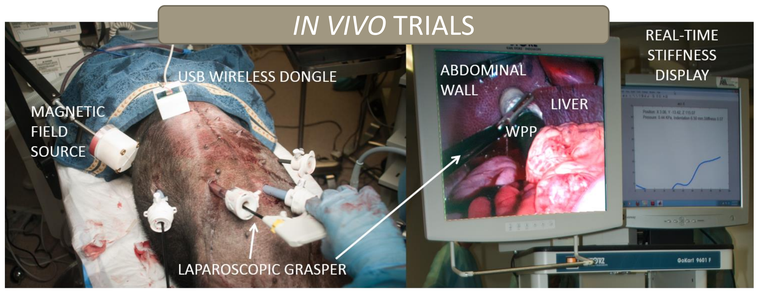


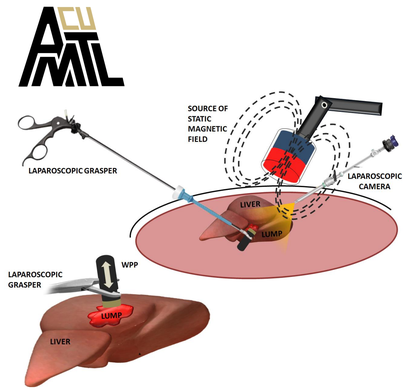
An integrated **simulation framework** will provide insight into the dynamic behavior of the design before manufacturing

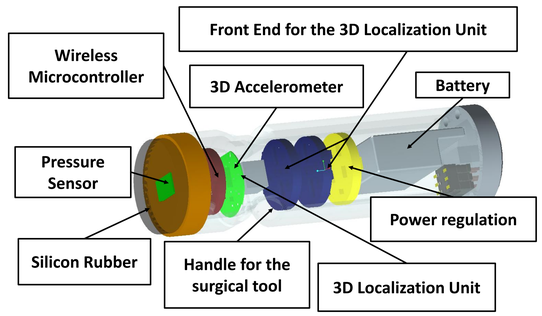
Static analysis tools will provide performance and cost estimates before system **synthesis**

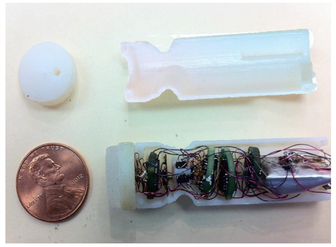
The goal is to **synthesize** application software, printed circuit board (PCB), computer aided design (CAD) models, and bill of materials with cost estimates with minimal manual guidance

AN EXAMPLE OF A CUSTOM APPROACH: WIRELESS TISSUE PALPATION









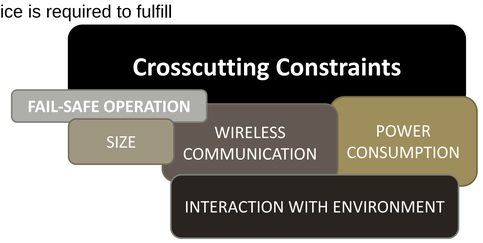
CAPSULE FEATURES
- Weight 9.5 g
- Battery Life Time ~ 90 minutes
- 15 mm ø, 60 mm H
- Refresh rate: 5 ms
- Workspace: 30 cm³
- Pressure accuracy: 34 Pa
- Indentation depth accuracy: 0.68 mm (d = 75 mm)
- Localization accuracy: 10 mm

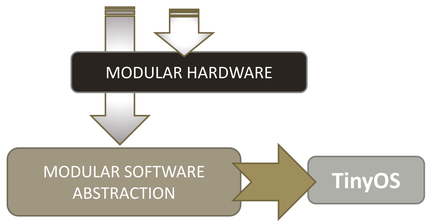
DEVELOPMENT TIME 1 YR

DEVELOPMENT COSTS $ 200k

DESIGN CONSIDERATIONS

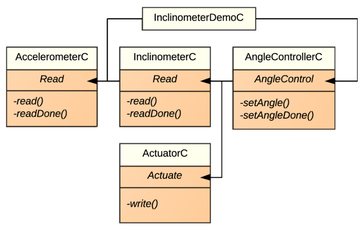
The CPS design framework must address crosscutting constraints such as (1) size – ideally, a capsule device should be small enough to swallow or to enter natural orifices without requiring a dedicated incision; (2) power consumption – given the limited space available onboard, energy is limited; (3) communication bandwidth – wireless signals must be transmitted through the human body with a sufficient data rate; (4) fail safe operation – since the device is deep inside the human body, the user has no access to it; and (5) effective interaction with the target site, according to the specific functions the device is required to fulfill



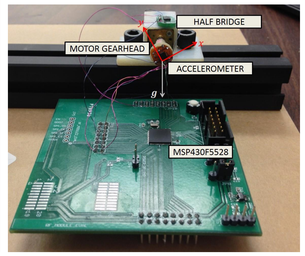


EXPERIMENTAL VALIDATION

GOAL: TinyOS application for a closed loop control of an actuator from sensor readings is compared with a custom implementation of the same task on a 8051 MCU programmed in barebone C.



Component based implementation of the closed loop experiment using TinyOS on the MSP430 MCU



PID control algorithm of a brushed DC motor based on an accelerometer used as an inclinometer

Sponsor: The National Science Foundation (Award: IIS 1239355)