Integration of Conjoined Cyber-Physical System Properties

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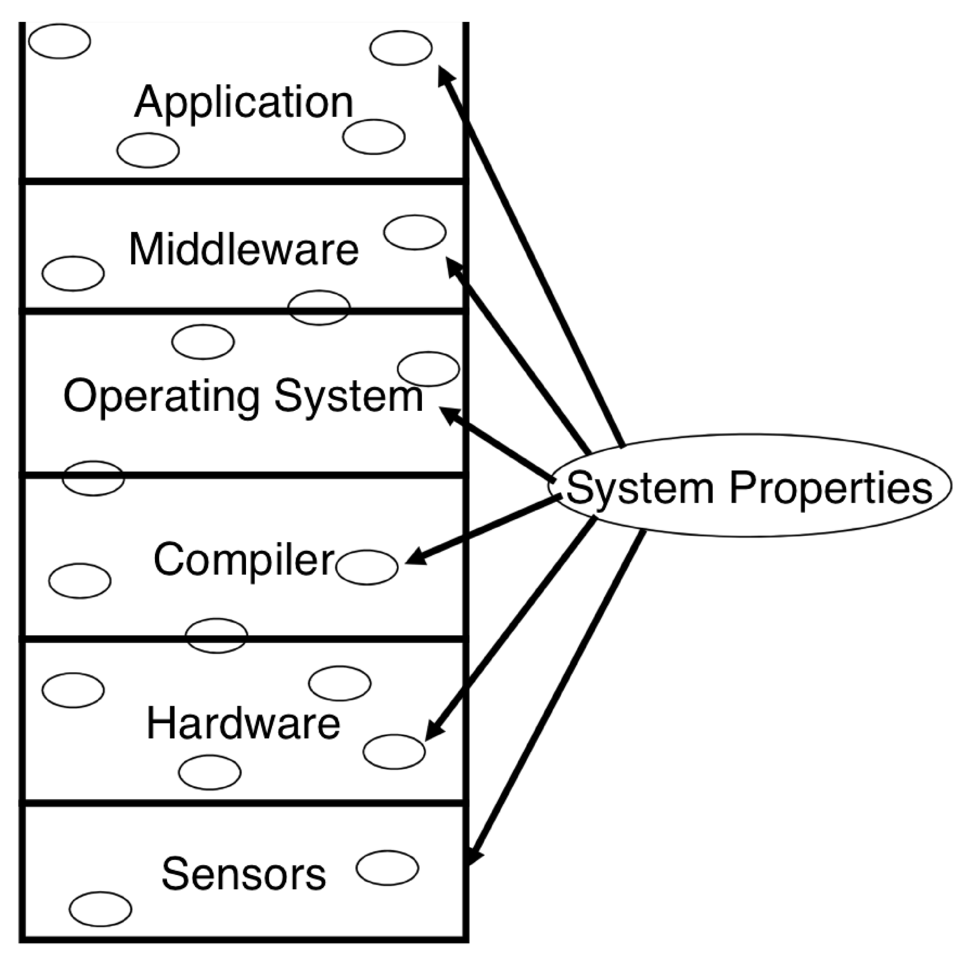
Introduction

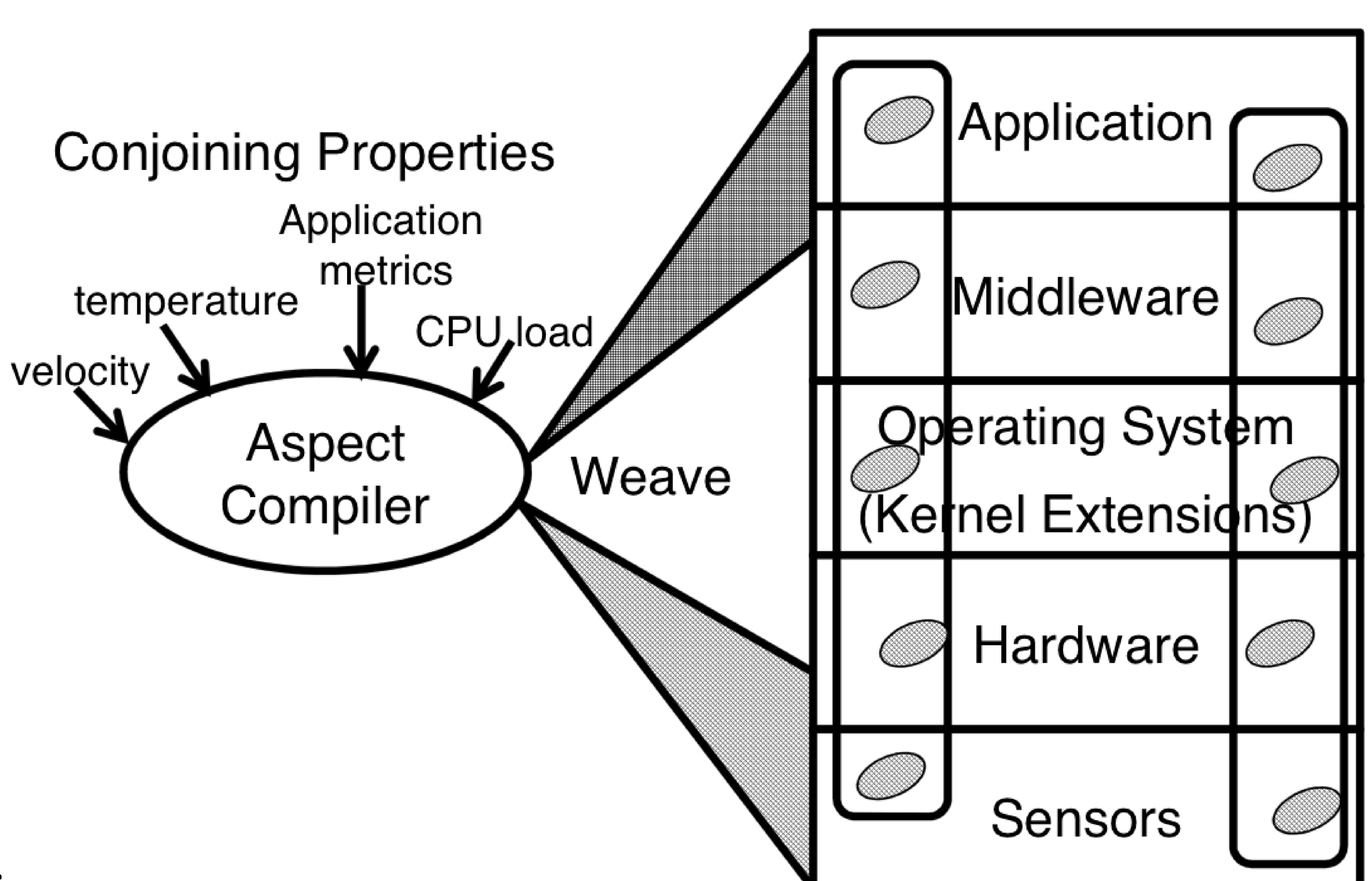
Effective response and adaptation to the physical world, and rigorous management of such behaviors, are mandatory features of cyber-physical systems. However, achieving such capabilities across diverse application requirements surpasses current state of the art in system platforms and tools. While individual physical properties can be measured and characterized for a given application, existing systems do not support the expression, integration, and enforcement of such properties that span cyber and physical domains.

In a traditional view, the layers of an application are separated, with properties of interest scattered among the layers.

While these layers provide convenient abstractions, they hamper the integration and optimization of properties across cyber and physical domains.



Our research aims to incorporate an application's signals of interest with environment conditions in the physical world, so as to enable those applications to meet their CPS requirements.



Platform

We have constructed 6 prototype boards for experimentation and evaluation of our research. Features on these boards include 1) an FPGA to support System-on-Chip applications; 2) a high-end inertial measurement unit for integrating physical dynamics of the system; 3) a temperature monitor to support performance throttling; 4) onboard DRAM; and 5) a wireless communications module.

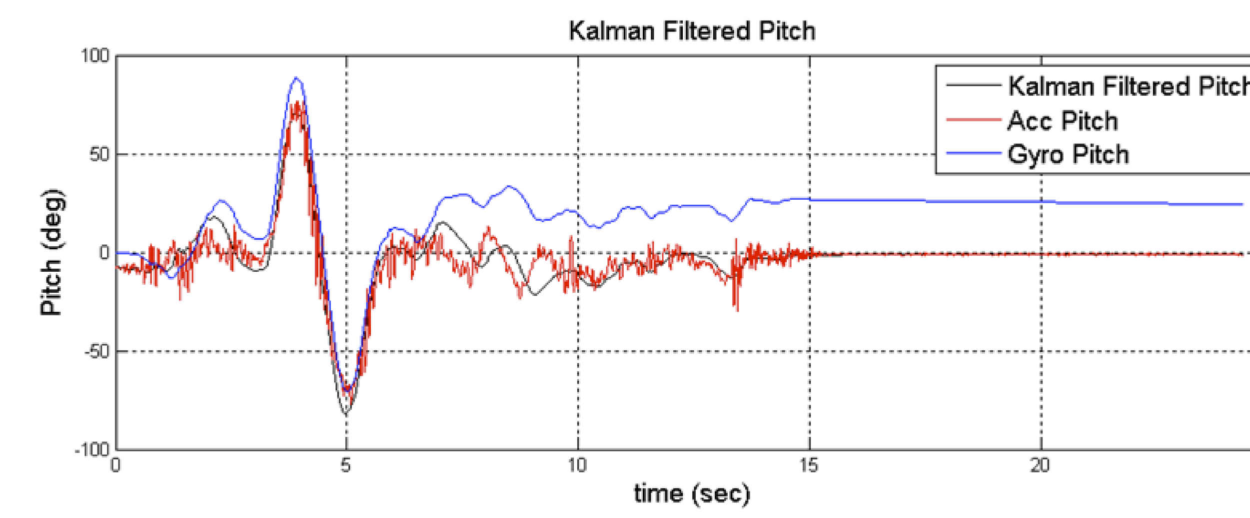
These boards are now being tested and will soon be available at Iowa State and Washington University. The first prototype of this board supported experiments to characterize the response-time jitter of several codesigned implementations of a PID control algorithm as well as the experiment described top-right.

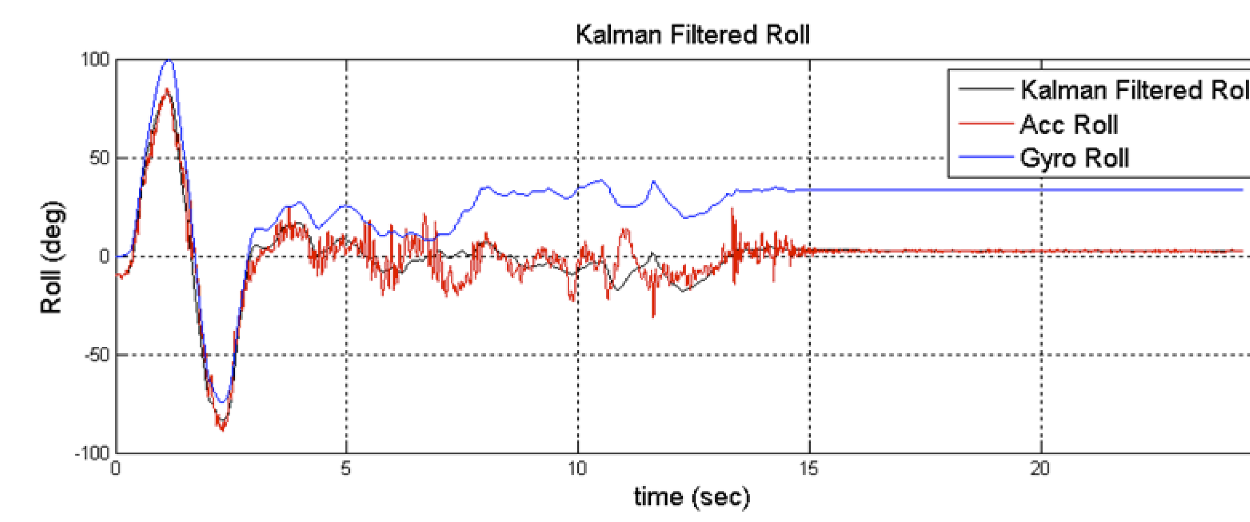
Graduate Students:

Sudhanshu Vyas (Iowa State) and Yuan Zhang (Washington University)

Coordination of Sensor Inputs

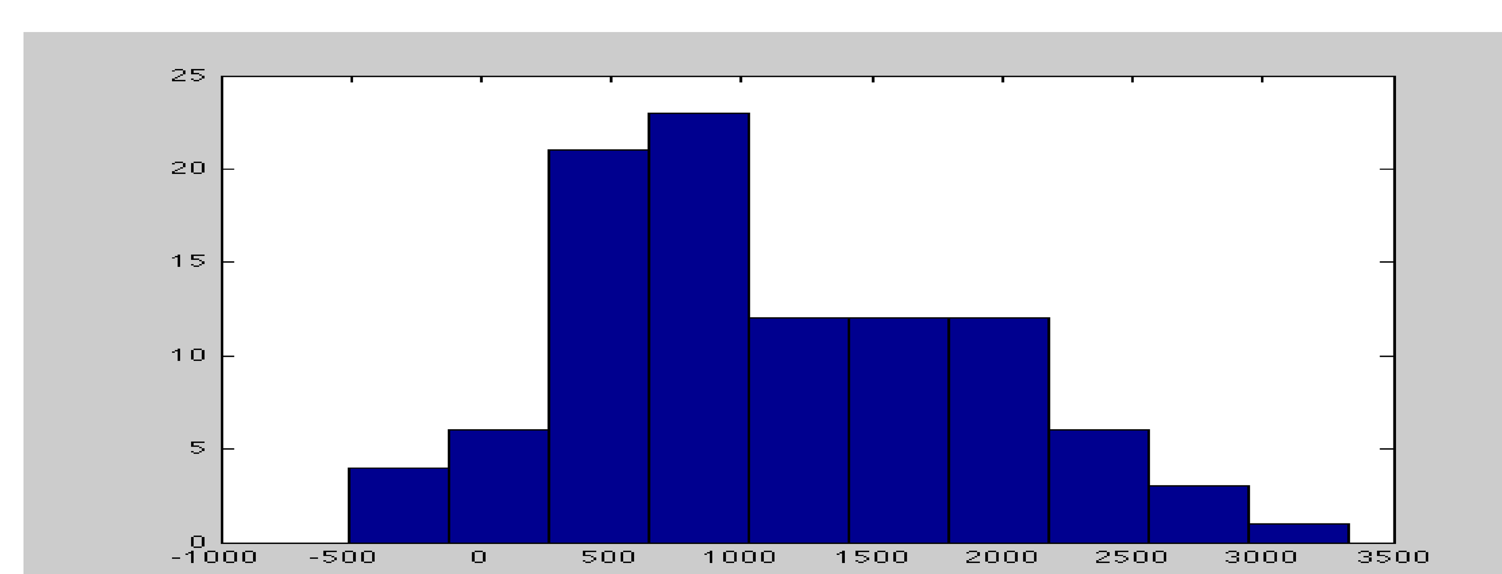
The prototype board was deployed in a coaxial RC helicopter, and we experimented with the coordination of accelerometer and gyrometer data to determine the pitch and roll of the helicopter in flight. A Kalman filter was deployed on the prototype board to fuse the sensor data, with results shown below.





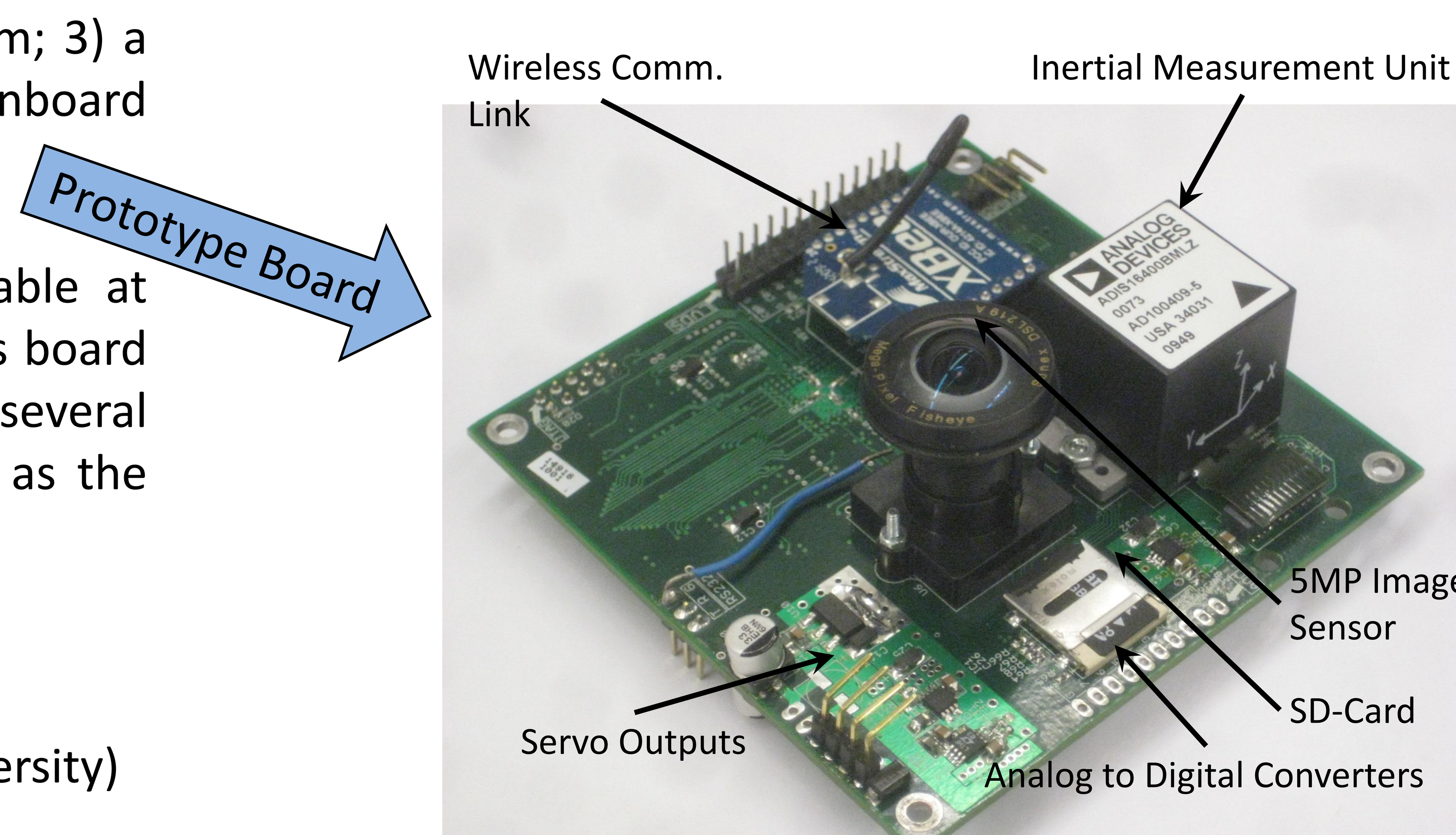
Collections Objects for CPS

We aim to develop collections objects that can migrate between various CPS modes of operation: real-time, embedded, and high-performance. We have experimented with two small-footprint hashtable implementations, evaluating their performance under load. The histogram below shows the increased capacity of our double-hashing implementation as compared with the Hopscotch algorithm.



Future Plans

- Deploy boards at both institutions and test.
- Deploy Linux on the boards to improve usability.
- Investigate hashtable adaptation embedded ←→ real-time.
- Develop algorithms to coordinate sensor inputs, application modes, and collections adaptations



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