**Dynamic control modeling using flexible robotic design architecture**

**Proposal by William Xing Xia**

**Overview:** ~~Finding out how the brain works has been one of the most vexing problems in history. A major reason why this task is so difficult is that there is no analytical method to locate the center of control. Most current robotic machines are based upon one single control schema, the centralized controller. Such design philosophy is great for its intuitiveness and ease of use. However, the lack of flexibility compromises the ability for the device to function as a scientific instrument to test unconventional or higher-dimensional control hypotheses.~~

~~The SOC, or system on a chip, has allowed complex circuitry to be installed in a tiny chip no greater than the size of a thumbnail. Using this technology, it is possible to create new robotic machines capable of processing and computing large amounts of data. In the School of Physics, Dr. Sponberg’s Lab researches insect locomotion, and part of the lab’s objective is to examine control systems and comparing the models to learn more about how an insect’s neurology interacts with its physical dynamics.~~

**Background and Related Work:** For the past semester, I have worked on obtaining kinematic data from *Blaberus Discoidalis* cockroaches in order to examine hypotheses regarding legged locomotion (Koditschek et. al. 2004). A large part of my work centered on understanding how to interface with both the microcontroller used to obtain and process the data and how to appropriately tune the IMU to achieve desired results. This first project helped expose me to how to interface with MEMS devices and handle insects. ~~I looked at the data sheet for the IMUs and edited software on an external microcontroller to access multiple capabilities of the chip. Also, due to the low-weight requirements of the cockroach, I have also had to learn how to use EagleCAD software to design a small PCB based on the MPU9250 and 6050 IMU chips that is mounted on a cockroach.~~

I will apply this knowledge to design a robotic system that can test multiple hypotheses about control. Although there are systems that are built for specific applications, there are very few platforms that aim to test a large variety of hypotheses. One of these platforms, RHex, has proven to be useful for more than just research or simulation. The initial design of RHex was based off of observations of cockroach locomotion, and the data collected from experiments helped corroborate ideas about how cockroaches move (Koditschek, et. al. 2004). My project will take ideas from RHex design, but focus on incorporating a high degree of modularity so as to allow each leg to be controlled individually. Centralized control schemas, or systems that rely on one processor to manage multiple subsystems, can easily be implemented by programming the legs to move according to the central controller. Alternatively, decentralized control schemas, or systems that contain subsystems that operate independently of one controlling entity, can be implemented by allowing the individual processing on the leg to perform its functions.

**Objective and Design:** The device we are planning to create will primarily function as a means to test hypotheses regarding centralized and decentralized control architectures. This novel design will not only eliminate the need for a user to build multiple different machines, but also will allow a user to program complex control schemas and mathematical models to test a variety of theories regarding control.

As a proof-of-concept device, the robot will not focus on reducing size or mass, rather it will focus on being able to effectively change between any control state a user wishes to implement. The platform’s main goal is to test hypotheses regarding control systems; thus size, mass, and anatomical similarity are secondary concerns.

* *Frame:* The frame will be constructed out of metal that can withstand a large range of torques and variable conditions. RHex’s frequently experience conditions of low speed but high torque followed almost immediately by conditions of high speed but low torue, and this new design will compensate for such variance. The frame will also have to account for the various electronics that will be placed upon the device while also maintaining a reasonably accurate center of gravity and center of mass.
* *Electronics:* The robot will have six legs connected to brushless motors; these motors will be linked to six separate processors, and those processors will be linked to a central microcontroller. This configuration allows for a modular framework to be developed that can be manipulated to switch between individual control and coupled control. By changing the speed, frequency, and/or torque of the motor, we will be able to measure changes in the overall body of the machine, and compare such data to an animal’s movements.
* *Software:* Using rigid-body mechanics, kinematic data can be obtained.

**OUTLINE**

**Overview:**

1. What is the main goal of the lab?
   1. What is the main goal of the experiment?
   2. What are the objectives of the experiment?
2. Define centralized/decentralized
3. Explain need for robotic device
4. Frame problem in terms of information

**Background and Related Work:**

1. Describe how to expand upon others’ work
   1. Why/How can you expand on others’ work?
2. Works on Centralized/Decentralized Control
3. Has this never been done before?
4. Current Methodologies
   1. How do current methodologies obtain information from cockroach?
      1. How can current methodologies be improved?

**Progress to Date:**

1. MEMS interfacing
   1. Obtaining data from sensors
2. Measuring Cockroach Kinematics

**Construction:**

1. Frame
2. Electronics
3. Software

**Purpose:**

1. Why is the robot useful for the lab?
   1. Helps gain more control over all aspects of robot.
   2. Able to test hypothesis regarding decentralized/centralized control.
2. What can we learn from the robot?
   1. What control schemas are biologically relevant?
      1. Answer biological questions using biologically inspired machines
3. How does the robot respond to information?
   1. How does the physiology of the robot affect how the robot responds to information?

Koditschek, D.E., Full. R.J., Buehler, M., 2004. Mechanical aspects of legged locomotion control. Arthropod Structure and Development 33, 251-272.