Novel Proprioceptive Sensors for a Legged Robot

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What can robots do with sensors?

• Lots of useful and interesting behaviors, such as...



Hill-climbing

System Protection

http://www.youtube.com/watch?v=vVibsNBIZkg&t=3m34s



My Project

 My project works towards implementing two proprioceptors on the X-RHex robot^[3]



- The first measures each motor's core temperature
- The second measures the robot's pitch
- Each sensor replaces an existing method of sensing on the robot with a "software sensor"

[3] http://kodlab.seas.upenn.edu/uploads/XRHex/xrhexIVIg.jpg



Sensing Temperature

 The resistance of a motor's windings is an affine function of temperature

$$R(T) = R_{25}(1 + \alpha_{Cu}(T - 25^{\circ}C))$$

 Inverting this function solves for T in terms of known constants and the motor's resistance

$$T = \frac{1}{\alpha_{Cu}} \left[\frac{R(T)}{R_{25}} - 1 \right] + 25^{\circ}C$$

- Measuring T requires only a measurement of R
- Using knowledge of the motor's dynamics, R can be found using Ohm's Law: $R = \frac{V}{I}$



Temperature Sensor Results

- Plotting I vs. V for data gathered at 23°C and at 85°C gives two different slopes and thus two different resistances
- Estimating the temperature from resistance data at 85°C gives a range of <u>+</u>3°C and a standard deviation of 1.68°C





How can pitch be measured?

- The angle between each leg and gravity can be estimated (more to come on that)
- And the angle of each leg relative to the robot is known based on the motor's encoders
- Adding these two angles gives the robot's pitch





Leg Angle Approach and Results

- · Create a simulated leg that does not feel the effects of gravity
- · Compare this simulation to an actual leg spinning
- The differences seen arise from gravity's effect



Applications of these Sensors

- The temperature sensor provides accurate thermal modeling to prevent damage and extend runtimes
- It may also enable safe high-power behaviors from the robot in the future
- The pitch inclinometer can be used for behaviors which rely on an IMU for pitch measurements
- This new software sensor is preferable to avoid electrical interference with the IMU's magnetometer
- And to avoid damaging the IMU where damage seems likely



Questions?

