A Intermittently Powered Battery-Free Robot

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1 Abstract

2 Introduction

Low cost robotic platforms have been developed to tackle a variety of challenges anonymously. Miniature robots can be used for inspection in difficult to reach places, operating like mobile sensing units. Hardware modularity is a way to make the robot adapt its resources to different environments and sensing operations. By separating out power, computation, motor control and sensing a verity of capabilities can be tested [?, ?]. Microrobots typically use infrared-based neighbor to neighbor distance sensing and communication [?]. While controlling a swarm or collective is mainly accomplished by means of active low power transceivers [?, ?].

Choosing the right locomotion resource can depend on different factors, moving in the most energy efficient way on a particular surface is often the determining factor. On a flat surface, robots commonly use a two-wheeled differential drive design to not only move but allow for steering as well [?, ?]. In other designs overall cost is a decisive factor, Kilobot uses two vibrating motors for locomotion. When the motors are activated the centripetal forces will generate a forward movement [?]. The GRITSBot does not use conventional DC motors, requiring encoders to estimate their speed. Instead by using stepper motors the speed can be set by changing the delay between steps. Estimating it's position therefore is reduced to simply counting steps [?].

Robots still rely on batteries as a source of power, since electric motors consume considerably more energy compared to computation and sensing. Lithium-ion batteries have a high energy density but still limit the operation time of the robot. When the voltage of the battery drops below a certain level, indicating that the battery is almost empty, the robot needs to move to a charging station before it runs out of energy. Replacement of the battery with a energy harvesting system would make the robot energy-autonomous. This research will explore the feasibility of a battery-less robot, taking into account the intermittently powered nature of it. Intermittently powering robots creates new challenges in control, navigation and collaboration.

3 Problem

The output current and mass of the solar panel are both assumed to be dependent on it's area.

$$I(x_s, y_s) = Iconst * x_s * y_s \tag{1}$$

$$m_s(x_s, y_s) = mconst_s * x_s * y_s \tag{2}$$

The capacity and mass of the Supercap are both assumed to be dependent on it's volume.

$$C(x_c, y_c, z_c) = Cconst * x_c * y_c * z_c \tag{3}$$

$$m_c(x_c, y_c, z_c) = mconst_c * x_c * y_c * z_c \tag{4}$$

And let's say the mass of the pcb is also dependent on it's area

$$m_p(x_p, y_p) = mconst_p * x_p * y_p \tag{5}$$

Assuming the current from the solar panel is directly used to increase the voltage in the Supercap:

$$V(I, t) = \frac{1}{C} It \tag{6}$$

$$V(x_s, y_s, t) = \frac{1}{C} * (Iconst * x_s * y_s) * t \tag{7}$$

Substituting the equation found for the capacity and voltage of the Supercap gives it's energy:

$$E(V, C) = \frac{1}{2} CV^2 \tag{8}$$

$$E(x_c, y_c, z_c, x_s, y_s, t) = \frac{1}{2} * \frac{1}{Cconst * x_c * y_c * z_c} * (Iconst * x_s * y_s)^2 * t^2 \tag{9}$$

Let's assume that all the electrical energy in the supercap is converted to kinetic energy.

$$E_{elec} = E_{kin} \tag{10}$$

$$E_{kin}(m, v) = \frac{1}{2} mv^2 \tag{11}$$

Without any losses the speed is estimated to be:

$$v(E, m) = \sqrt{\frac{2E}{m}} \tag{12}$$

$$m_{tot} = m_s + m_c + m_p \tag{13}$$

$$v(E, m_{tot}) = \sqrt{\frac{\frac{(Iconst * x_s * y_s)^2 * t^2}{Cconst * x_c * y_c * z_c}}{(mconst_s * x_s * y_s) + (mconst_c * x_c * y_c * z_c) + (mc}} \tag{14}$$

4 Problem

5 Conclusion