An impulse actuator for high speed & high torque applications

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1 Summary

The ability to generate large torques at high speeds (i.e., an impulse), can immensely benefit legged robots. For example, an impulsive ankle push-off is energy-efficient or impulsive foot placement can improve walking stability by decreasing reaction time. But electric motors, which are the most commonly used actuators, are not able to produce impulsive forces. Thus, there is a need to create an electric actuator that can provide impulsive forces as needed. This research presents some preliminary results on creating an impulse actuator by connecting a DC motor in parallel with a compression spring. A mechanical coupling allows switching between continuous mode (DC motor connected to the load) and impulsive mode (spring is connected to the load). The long term goal of the project is to develop the actuator and test it on a robotic leg.

2 Introduction

Electric motors such as DC motors are frequently used to control legged robots. But these motors have a very severe limitation: they can either produce high torques at low speeds or low torques at high speeds. But there are instances of time when high torques at high speeds are desired. For example, an impulsive ankle push-off by the trailing leg just before touchdown of the swinging leg is critical for high energy-efficiency [1] or the ability to move the swing leg quickly for foot placement can dramatically improve the stability by increasing the capture region [2]. Thus, there is a need for an actuator which is capable of providing a sudden impulse of high torque at high speed. Nearly all DC motors provide a nearly linear output and must sacrifice torque for speed.

3 Methods

This paper provides preliminary results on creating an actuator which is capable of providing a steady output as a standard DC motor would, but is also able to release a strong impulse on demand. To supply this impulse, the motor stores energy which is then available to be released when needed. Two possible solutions are being experimented with simultaneously. One stores energy from the motor mechanically, using springs coupled to the motor in specific ways. The other stores energy from the input current electrically, using capacitors.

The mechanically-stored actuator involves three discrete stages. First the spring is quickly wound by a reverse motion of the shaft. The spring is then decoupled from the shaft in the second stage, which allows the shaft to rotate freely. In the third stage, the spring is again coupled to the shaft and releases its energy in the form of a sudden increase in torque and speed. Future versions may be able to incorporate multiple springs and multiple couplings to permit multiple impulse levels. A preliminary version of the mechanical actuator, which is only one stage operation, is nearing production.

The electrically-stored actuator uses a modified version of a Marx generator to switch multiple capacitors between parallel and series states. In parallel, the capacitors each charge to the input voltage. When the switches are flipped and the capacitors in series, the stored energy is rapidly released into the rotor wire. Proper circuit design is necessary to control the current flow. The rotor-stator combination will also have to be designed to handle the peak current.

4 Results

We are currently building the actuator and should have preliminary results by the time of the conference.

References

[1] Srinivasan, M., & Ruina, A. (2006). Computer optimization of a minimal biped model discovers walking and running. Nature, 439(7072), 72-75.

[2] Pratt, J., Carff, J., Drakunov, S., & Goswami, A. (2006, December). Capture point: A step toward humanoid push recovery. In Humanoid Robots, 2006 6th IEEE-RAS International Conference on (pp. 200-207). IEEE.