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Internal Fall Protection Mechanism in Non-Compliant Humanoid Robot

Anant Anurag[a]*, Hari Om Bansal[b]

[a]B.E. (Hons), Department of Electrical and Electronics Engineering., BITS, Pilani-333031, India
[b]Associate Professor, Department of Electrical and Electronics Engineering, BITS, Pilani-333031, India

Abstract

Electrical actuators used in humanoid robotic applications are generally fabricated for non-compliant behavior. The humanoid structure, apart from its revolute joints are rigid and non-compliant. The development of automobile systems has been such that they are able to tolerate compliance easily whereas in humanoid robotics, compliance is very difficult to compensate especially when it's presence is uncontrolled. This is because its applications require high accelerations while retaining very low angular displacement such as walking on a surface or during jump or fall. This paper studies a controller for an electric actuator activated in the event of a fall for protection of the humanoid robot.

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Keywords: robotics; actuation; humanoid; compliance; controller; protection

1. Introduction

The purpose of this work is to address the issue of handling humanoid robot models in India and their protection from damage while testing. The fundamental principle driving a humanoid forward results from instability in its dynamics in case of non-static gait, thus it becomes essential to have adequate mechanism for its protection from instability more than the robot is designed to handle. Given the high cost of development in this field and budget

* Corresponding author. Tel.: +91-1596-515-332; fax: +91-1596-244-183.
E-mail address: anantanurag312@gmail.com

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constraints, focus was directed at developing solutions that would not require additional hardware other than the usual requirements.

1.1. Literature Review

Compliance based actuation has been studied extensively and many structural designs for the actuator have been proposed and inspiration from biological phenomena have been suggested. [1] talks about how human joints are not stiff when lifting lower loads and stiffen as load is increased. While they have considered compliance motion beneficial, it has been pointed out that it reduced the bandwidth of the actuator. [2] brings out the fact that non-compliant motors can be made compliant by using springs. Another way to alleviate this is by using control system that senses muscle strain and adjusts compliance settings accordingly. Of all the prior work that was studied, it is clear that two different motors are required for efficient compliance and most of the time this construct of using two motors is underutilized. [3] shows a novel concept of capture steps to prevent fall from happening. This system makes use of an inertial measurement sensor and predicts the step that must be taken in order to avoid the fall. Our research can supplement for cases where the prediction could be inaccurate. [4] is a research thesis and a benchmark in the field of humanoid robotics and suggests using springs in the fundamental design of the humanoid robot. But this essentially makes the humanoid robot a compliant system which is difficult to achieve without expensive mechanical structure, sometimes unfeasible in the Indian humanoid research scenario.

Hence with the purview of a very specific application, which itself is tremendous in the field of research in humanoid robotics, we propose a novel method to induce compliance in a rigid system that satisfies the requirements as well as is practical to implement in low budget.

1.2. Proposed Methodology

Study of humanoid robots is essentially study of a linear inverted pendulum. Thus it is clear that the system is unstable by nature. Incorporating anthropomorphic behaviors in this system requires high precision control and accurate state estimation. While control and estimation are now practical to obtain, protection mechanisms against its inherent instability is yet to be developed significantly. Philosophically, true anthropomorphic nature will be evident in not just achieving targets but also sound reaction to unforeseen conditions and self-preservation. The study proceeded with a specific situation where implementing the protective behavior does not necessarily need compliant motion but only removing the static stalling property of the actuators was sufficient.

The specific case of discussion here is of a falling robot. While following a typical walk trajectory, it is very common for the robot to miss its trajectory due to reasons like unforeseen obstacles or accruing errors in open loop trajectory controllers. While most of the times when the deviation from trajectory is within the threshold of tipping over and the error can be corrected by various techniques. When the humanoid is about to fall, other preventive measures need to be taken, if at all.

While for most of the research teams, a passive protection in terms of mechanical design that can help prevent damage is sufficient. The priority is set to minimizing damage. The current study offers to provide this safety mechanism which is truly anthropomorphic in design.

The actuators involved are major cost of the humanoid robot. In case of the robot tipping over, unless the actuators are put into fee rotation mode, there will be considerable torque acting externally on them while resisting the fall which most often will be beyond the rated stall torque of the motor. And when the robot is allowed to fall without motors exerting a stalling force, there is no active control over the extent of protection we can offer to the system other than by installing passive components like springs or padding.

Elaborating the idea with a situation, assume a humanoid robot with arms that is about to fall on its front torso. The primary concern would be to provide protection to expensive sensors present inside its body. The next priority would be to prevent actuator damage and lastly eliminate structural damage because structure can be easily replaced and is less in cost compared to other components in the system. See Fig. 1.

Analyzing the situation further, the first part of the humanoid robot while being pivoted on its toes, will be its forearm. Had there been no control over the actuation in free fall, the elbow joint would contract till the wrist and