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MODELLING AND INVESTIGATION ON BOUNCING MECHANISM OF A SPHERE ROBOT

N. M. H. Norsahperi*, M. A. Abdullah, S. Ahmad, S. F. Toha and I. A. Mahmood

Department of Mechatronics Engineering, Kulliyah of Engineering, International Islamic University Malaysia, Gombak 53100, Malaysia

Abstract

Spherical rolling mechanisms (SRMs) exhibit a number of advantages with respect to wheeled and legged mechanisms. In fact if the SRM is combined with the power of bouncing mechanism, it will produce an exciting phenomena that can be contributed to applications such as security surveillance, search and rescue. There is not much research done in both fields, especially in the bouncing mechanism. In fact to the best of authors' knowledge no of research has been done on integrating both mechanism to produce a spherical system that is capable of rolling and bouncing, which can produce a very significant mobile robot. Therefore, this research deals with the modeling and development of a bouncing spherical robot using computational intelligent technique, i.e. Particle Swarm Optimization technique (PSO). A 3D virtual prototype of a spherical robot was developed in Visual Nastran as a platform for input and out data acquisition. Different simulations environment have been created, such as the free fall bouncing, shooting up and projectile type of environment to investigate the bouncing profile affected by different forces. The data obtained were then used for system identification using PSO technique with mean square error (MSE) of 0.0004%. The transfer function representing the bouncing mechanism of the sphere robot was then obtained. Next, the prototype of the sphere robot with bouncing capability was developed. Open loop tests have been conducted and the results show that the hardware developed can produce the bouncing mechanism at its promising capability. Future works need to be conducted to re-visit the hardware, particularly on the body of the sphere robot such that maximum bouncing can be achieved.

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Keywords: Bouncing Ball; Particle Swarm Optimization; Spherical Robot

1. Introduction

A sphere is a unique shaped object where set of all points in the three-dimensional space lying at the same radius distance from the center of sphere. The advantages of sphere are that all positions are stable and provide complete symmetry. Additionally, sphere mechanism inherits a soft, safe and friendly look without any sharp corners or protrusions. Countries with irregular natural landscape and climate such as Japan and Malaysia need this particular mechanism for discovery and rescue purposes. Uneven land geography and climate caused exploration and rescue activities faced with several hampers such as mountains and sloppy terrains. Thus, mechanism with the ability to bounce is introduced to overcome this constraint. This mechanism can bounce in various surfaces such as sloppy, flat, smooth and rough surfaces. Other than ability to pass through different types of surface, some places are dangerous and unhealthy environment such as hazardous air, landslides or place that is difficult to reach by human.

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(a) (b) (c)

Fig. 1. (a) Self-propelled bounce ball patent, (Maxim et al., 1994); (b) Hoping mobility robot design, (Dubowsky et al., 2008); (c) Jollbot3 used for exploration, (Armour, 2010).

There are many significant applications when bouncing capability is needed such as entertainment, exploration and rescue. Entertainment focuses on children use. Bouncing mechanism as Fig. 1 (a) is used for many entertainment purposes. The ball only can bounce randomly at low height, which is suitable for entertainment purpose. Exploration activities limitation can be overcame by bouncing robot. Some of the established exploration robots are wheeled-based robot. Wheel robots have limitation, in the sense that it cannot pass through some constraints such as rough terrain or ravine. Hence, bouncing mechanism in Fig.1 (b) based robot is needed to overcome this limitation. Natural phenomena and disaster like volcano, tornado, landslides and buildings collapse can be harmful to human. These are very dangerous place to go especially for rescue purpose. A low weight robot as illustrated in Fig. 1 (c) can assists human rescuers in the place such as building collapse where some locations are deep and narrow to reach. Table 1 summarized the design specifications and capabilities of some existing sphere robot.

Table 1. Summarized of sphere robot specifications and capabilities

Researcher	Mazim et al., 1993	Dubowsjy et, al. 2008	Sugiyama & Hirai, 2009	Armour, 2010
Purpose	Entertainment	Rescue	Exploration	Exploration & Rescue
Actuator	DC Motor	Dielectric Elastomer=35 units	Shape Memory Alloy= 8 Units Polymer Gel	Servomotor=6V
Sensor	Unstated	Sniffing Camera	Unstated	Unstated
Power Source	Battery	Battery, Fuel Cell	Battery	Battery
Capability	Bounce Randomly	Bouncing=0.4m	Crawling Jumping=0.16m	Rolling Bouncing=0.449m
Features	D=0.075m	D=0.1m M=0.1kg	D=0.04m M=0.003kg	D=0.58m M=0.763kg

Despite that bouncing mechanism has been suggested for many purposes including entertainment and other activities, there have been minimum research done on the bouncing mechanism and its system modelling. Bouncing is a significant scenario to be studied in system engineering, where it can be manipulated for a greater impact of implementation if it may function as intended. It is also an example of a highly nonlinear system, which is complicated to model by using physical modelling method. Therefore, the main aims of this research are to investigate the bouncing mechanism and later to perform modelling the sphere robot.

2. Experimental Setup

2.1. Overview

The design of the sphere robot in project was basically based on a biologically inspired jumping and rolling robot, Jollbot by Armour (2010) together with some modifications to the original design. Specifically, the mechanism for bouncing was inspired by the working principle of the mechanism in Jollbot. The bouncing mechanism can be divided into two main parts which are energy storing mechanism and energy release mechanism. The energy storing mechanism was used to store the energy in the rings. After the mechanism stored the energy in the rings, the release mechanism was used in order to bounce the sphere robot at desired height. The concept of bounce can be visualized as in Fig. 2.

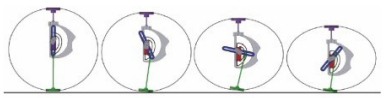

Fig. 2. Bouncing mechanism used in Jollbot (Armour, 2010).