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Literature Survey on Sand Flea Jumping Robot

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Abstract:
The aim of this work is not only to give an up-to-date review of jumping robots, but also to joint key topics of publications in the research area of jumping robots. The following presents an overview of previous work on jumping animals, robots and theoretical models. The systematic studies of the movement trajectories that maximize jumping performance are presented in this review. The review includes various movement strategies and animal movements for maximum height jumping, design and fabrication challenges.

Keywords*:* Jumping Robots, Jumping Animals, Movement Strategies.

INTRODUCTION

Despite their relative simplicity, modern day mobile robots capture the imagination by offering mobility in robust and controllable packages. In addition, mobile robots are beneficial in situations non-dangerous to humans as well. Many challenges still remain to accomplish the goal of this work – the design and fabrication of autonomous mobile microrobots. At this size, even mobility proves difficult. Ants and other insects can easily crawl over obstacles, but it is much more difficult for robots to do so, even at larger size scales. To overcome the limitation of leg length, the microrobots of this dissertation are designed to jump over obstacles instead. Micromotors and micro mechanisms are not available off-the-shelf, and microrobot components still need to be custom-fabricated often a tedious and expensive process. While there are no off -the-shelf components available, this work will show that high work density motors and interesting mechanisms for jumping can be fabricated in a relatively simple process. Finally, these components need to be integrated with a power supply and a controller to build a fully functional microrobot. This dissertation begins with the motivation for building autonomous jumping microrobots as well as application scenarios in which autonomous jumping microrobots would be particularly useful. Because this work draws from other fields in addition to microrobots, previous work in jumping robots and previous research in biology on jumping insects.

Jumping Robot

Researchers have built a number of jumping robots for tasks ranging from climbing stairs to celestial exploration. These robots are ballistic jumpers which jump, pause to reset after landing, and jump again. Ballistic jumpers are different from hopping robots which jump continuously by reusing energy stored while landing. Hopping robots have been heavily studied due to the interesting control problems they pose but there are surprisingly few jumping robots in the literature. While it would certainly be interesting and beneficial for microrobots to store some energy upon landing for the next jump, that will not be discussed in this dissertation. One of the earliest jumping robots was designed by Burdick and Fiorini for exploration on Mars [1]. This 1.3 kg robot was built using a spring for energy storage and a clever design requiring only a single motor to store energy in the spring as well as right and orient the robot after landing. Another interesting feature was a 6-bar mechanism combined with a simple linear spring in order to change the force profile of the spring for greater efficiency in energy release. Demonstrations showed the robot jumping approximately 1 m high and 2 m in distance. A similarly sized 7 g robot from EPFL has been demonstrated jumping 1.4 m high, but has not yet been published [2]. The primary purpose of the jumping robot is to launch Kovac's gliding robot in [3]. In addition to robots designed to jump as a primary mode of locomotion, jumping capabilities have been added to other robots to improve their mobility when encountering obstacles. The 200 g Scout robots from the University of Minnesota use a motor to bend a leaf spring which is then released to jump upstairs [4]. If the material used for the energy storage system is highly efficient, the energy released by that material still needs to be delivered efficiently to the robot. One consequence of a linear spring is that the robot may be susceptible to early liftoff as reported by Burdick and Fiorini in [5]. When the force delivered from the spring is significantly greater than the weight of the robot, the robot may leave the ground before the leg is fully extended and all of the energy from the spring is converted to kinetic energy.

Warneke designed an ultralow power microcontroller that consumes 5.9 μW at 1 V for the smart dust project and something similar could be useful in future microrobot designs [6]. Diansheng Chen proposed a flexible-rigid hopping mechanism which is inspired by the locust jumping, and its kinematic characteristics were analyzed. A series of experiments were conducted to observe locust morphology and jumping process. According to classic mechanics, the jumping process analysis was conducted to build the relationship of the locust jumping parameters [7]. [8] Hopping is achieved through the excitation of a spring mass system at its resonant frequency. Simulations were extensively used to. finalize the design, before construction of the robot. The success of the robot was proved by its ability to consistently travel more than 225 cm in one direction without tipping over. Umberto Scarfogliero said the micro robot Grillo represents a novel concept for robot locomotion. Designed for exploration and for monitoring in unstructured environments, the robot moves by taking long jumps. Inspired by frog locomotion, the actuation of the rear legs is mainly done through a pair of springs and a click mechanism. During the airborne phase, a tiny pager motor loads the springs that, during take-off, release that energy. In this way, the power delivered by the legs is several times higher than motor power [9]. In paper [10], the JHD [Jumping Height and Distance] adjustments, modifying the lengths of different legs of the robot, are modelled and simulated. Then, three mechanisms for leg length adjustment are proposed and compared, and the screw-and-nut mechanism is selected, the one with the best JHD adjusting performance and the lowest mechanical complexity. First, the JHD [Jumping Height and Distance] adjustments, modifying the lengths of different legs of the robot, are modelled and simulated. Then, three mechanisms for leg-length adjustment are proposed and compared, and the screw-and-nut mechanism is selected, the one with the best JHD adjusting performance and the lowest mechanical complexity. The paper [11] describes novel highly mobile small robots called "Mini-Whegs'' that can run and jump. They are derived from our larger Whegs series of robots, which benefit from abstracted cockroach locomotion principles. Key to their success are the three spoked appendages, called "whegs, which combine the speed and simplicity o/ wheels with the climbing mobility of legs. A jumping mechanism has also been developed that enables Mini- Whegs la surmount much larger obstacles, such as stair steps. Fleas jump for a variety of reasons including latching on to a passing host, as well as an escape mechanism from anything resembling danger. Despite the commonplace nature of fleas, as of 40 years ago their jump was still not well understood. Their muscles simply could not provide the accelerations and powers observed during jumps. The flea's jump was first seriously studied by Bennet-Clark [12]. The paper [13] focuses on the buffering performance analysis of a bionic locust mechanism with the different modes of landing and buffering. The numbers of landing legs and motion modes of legs in the buffering process are experimentally analyzed first, and a dynamic model is established for the bionic locust mechanism, which provides the basis for revealing the dynamic performance of the buffering process. Then evaluation principles for the buffering process are proposed on the basis of the support forces, spring forces, and different impact resistances of each leg, which are the important parameters for the buffering performance, and the spring stiffness coefficients of legs are determined. The analysis results showed that the better mode is the one in which the ends of the legs of the bionic locust mechanism are not fixed. It is proposed to recast these dynamical systems in the framework of mechanical systems subject to complementarity conditions. Unilateral constraints that represent possible detachment of the feet from the ground and Coulomb friction model can be written this way. The proposed modeling approach allows one to clarify which stability tools one may use to characterize the stability of a bipedal robot [14]. A new robot, known as the Scout robot, is introduced in this paper. It is capable of moving along the ground and jumping over a surmountable obstacle. The Scout robot can patrol a harsh environment by rolling or jumping while delivering environmental information to the user. It requires less time and makes use of simpler mechanisms to overcome obstacles compared to conventional robots. A robot management system provides a three-dimensional virtual display image of the robot's location and pose [15]. Taking inspiration from the natural world, an optimal locomotion solution for mini/micro sized bio-robots is derived from learning how insects choose their locomotion mode and how they evolve to improve themselves. Based on a simplified planar model theoretical analysis reveals that a proper leg design may lead to an optimization of the dynamic characteristics during jumping acceleration. This paper presents a bio-inspired design of a jumping mini robot including the theoretical analysis on jumping dynamics based on a simplified biological model. By reproducing the insect optimization mechanism in the prototype, the jumping robot GRILLO III is then designed based on the optimal artificial saltatorial leg structure which is proposed to reduce the contact force at tarsus–ground interface during jumping acceleration thus minimize the risk of both leg ruptures and tarsus slippage [16]. In the paper [17], a 7-g prototype of locust-inspired jumping mechanism that uses springs, wire, reduction gears, and a motor as the actuation components is presented. The leg structure and muscles of a locust or grasshopper were mimicked using springs and wire, springs for passive extensor muscles, and a wire as a flexor muscle. A small motor was used to slowly charge the spring through a lever and gear system, and a cam with a special profile was used as a clicking mechanism for quick release of elastic energy stored in the springs to create a sudden kick for a quick jump. [18] In this paper, stable hopping of a one-legged, articulated robot with a flat foot is investigated. The robot has a special feature that before taking off, it goes through an under actuated phase in which the foot rotates about the unactuated toe on the ground. By having an underactuated phase, the robot can perform stable human-like hops with longer hopping distances. The hopping strategy and the planned trajectories are then verified by simulation and hardware implementation. The focus of paper [19] is on unsteady boundaries that arbitrarily evolve over time, and, e.g., may change shapes and sizes. We present a sliding mode control method for localizing and tracking such boundaries: the robot is steered to the boundary and circulates in its close proximity afterwards. The effectiveness of the proposed guidance law is confirmed by computer simulations and experiments with a real wheeled robot. In paper [20], the issues of coordination, timing and control are addressed for a back somersault sagittal movement. The three-dimensional physical model is comprised of three segments for feet, torso, and hands. In the airborne phase, it is assumed that the head and the torso are held as one rigid body such that the angular velocities and accelerations, measured and estimated for the head, are the same as those of the torso. These physical states provide acceleration feedback to reduce rotational velocities before the landing phase. Successful stable airborne and landing phases are shown in a computer simulation. The work focus on providing a path in an environment for a robot for its ease of movement, detecting and avoiding obstacles in an environment using a single camera and a laser source. Robot moves by identifying free space in floor. Wherever floor is visible and free, it moves. Novel method for floor segmentation has been used. Laser source emits light that falls on obstacle if any, and based on position of laser light on obstacle in the image and distance of obstacle from robot, robot change its direction with different angle and continues to move [21]. In the paper [22], combining intelligent mobile robot with wireless remote control technology, wireless network communication platform between mobile robot and computer is set up. By the platform, the function of wireless transmission data is achieved, and wok state of mobile robot is remote monitored and controlled. Accordingly, operator and robot run in line and complete heavy task in complex environment. Mobile robots are able to carry more and more intelligence (and in smaller packages) on board every day. There is a need, however, for smaller actuators to make these machines more dexterous, compact, and cost effective. Using thin films of lead zirconate titanate on silicon nitride membranes, various types of actuator structures can be fabricated. By combining new robot control systems with piezoelectric motors and micromechanics, we propose creating micromechanical systems that are small, cheap and completely autonomous [23]. To facilitate the locomotion for mobile sensors in environments with obstacles, paper [24] presents the mechanical design of a miniature steerable jumping robot. Different from existing designs, the robot can satisfy three design requirements: continuous steerable jumping, minimum actuation, and light weight. The utility of such a system and the broad use of systems to quickly release stored mechanical energy in the macro world, the most common method of energy storage is through batteries or capacitors [25].

CONCLUSION

This dissertation has described the design of an autonomous jumping microrobot and the fabrication of the micro-scale components necessary for jumping. Three major challenges in building autonomous mobile microrobots were addressed – locomotion, mechanisms, and motors. Small legs and small steps make simple locomotion across a room difficult for millimeter-scale microrobots. Jumping has been presented as a relatively energy efficient means of transportation in which the robot can simply jump over obstacles. Fabricating capable mechanisms in simple processes is another challenge, and an elastomer based micromechanical energy storage system has been designed and fabricated to store 10s of microjoules to jump without complex fabrication. Making motors to stretch the micro rubber bands is another challenge and high work density electrostatic inchworm motors were designed and fabricated. Jumping offers another very efficient means of transportation – parasitic locomotion. In this case, the jumping microrobot could jump onto a much larger object moving nearby and use that object to move to a new location.

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