Vibration-based robots

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This document explains the construction of (1) multi-gait robot and (2) curved beam hopper. This write up is accompanied by .STL files that can be used to 3D print the arms that actuate the robots. A video can be found here: https://youtu.be/QoDUXx42l4c

These robots were inspired by Fumiya Iida's vibration-based robots.

1. Multi-Gait Robot

The Multi-Gait robot is a simple robot which harnesses the vibrational energy from a rotating mass to cause various forms of locomotion. This result is achieved because of the elastic properties inherent in the frame. At the proper rotational speeds, the resulting vibrations approximate certain vibrational modes of the frame. Different rotational frequencies create different vibrational patterns in the frame, which gives the robot three or four different possible modes of locomotion.

The materials used to create this robot are fairly simple and easy to obtain or create. It consists of four basic components: an aluminum frame, a gear box with attached drive shaft for the rotating arms, a DC motor, and two feet. The frame is simply a three foot long strong tie purchased from Home Depot. The gear box consist of a containing box, two gears, and two arms which connect inside the box to form the drive shaft. The feet are simply semi-cylinders with the round end pointing downward and a slot for the frame. The gearbox, gears, arm components, and feet are all 3-D printed. The DC motor is a simple hobby motor.

The robot is constructed by bending the strong tie at two 90° angles at equal intervals. This results in a three sided inverted "U" shape, with each side one foot long. The feet are attached to the frame by inserting each edge of the downward pointing edges into the slots and then affixing them with adhesive. The printed gearbox with arms is assembled, with the large gear pressed to the shoulder on the shaft and the smaller gear attached to the motor shaft. The gearbox includes a simple mount for the motor, which should be placed in the mounts so that the gears mesh. The gearbox is then attached to the flat top section. Symmetry is very important, so care should be taken to center the gearbox as accurately as possible, as well as keeping it at right angles to the frame.

To make the robot move, simply attach a power supply to the DC motor. A variable power supply is recommended, both for control and variation of the rotational speed. The power at which the locomotive speeds are attained are not always enough to overcome the inertia of the rotating masses when starting up. To overcome this, simply position the arms so that they start at the top. Once moving, the arms will continue to move until power is removed.

Depending on the amount of power supplied, and thus the rate of rotation of the arms, four potential gait modes are possible. At lower speeds, a “slipping” motion occurs where both feet remain on the ground and the rocking of the frame causes the robot to slide in one direction. At the next speed level, a “walking” motion occurs where one foot lifts off the ground and the other foot slides forward with each step. The next speed level is a “running” gait where the two feet will alternate coming off the ground, but there will always be a foot on the ground. The fastest rotational speed causes a “jumping” motion where both feet leave the ground simultaneously. Unless conditions are highly controlled, however, this last one can have erratic behavior.

2. Curved Beam Hopper

The curved beam hopper is a simple robot which harnesses the vibrational energy from a rotating mass to cause locomotion. This result is achieved because of the elastic properties inherent in the frame. At the proper rotational speeds, the resulting vibrations approximate the natural frequency of the frame. At this frequency, the vibrations are no longer random and the magnitude is enhanced. This results in sustainable motion in the frame which is then transmitted through the foot to the ground, causing the robot to hop forward.

The materials used to create this robot are fairly simple and easy to obtain or create. It consists of four basic components: an aluminum frame, a gear box with attached drive shaft for the rotating arms, a DC motor, and a foot. The frame is simply a two foot long strong tie purchased from Home Depot. The gear box consists of a containing box, two gears, and two arms which connect inside the box to form the drive shaft. The foot is simply a large base with the profile of connecting rectangles. The gearbox, gears, arm components, and foot are all 3-D printed. The DC motor is a simple hobby motor.

The robot is constructed by bending the strong tie into a "C" shape. This was done by creating six 30° bends at equal intervals to create 7 sections in a semi-circular shape. The bottom and top of the frame are both parallel to the ground and straight to allow for attach of the foot and gearbox. The printed gearbox with arms is assembled, with the large gear pressed to the shoulder on the shaft and the smaller gear attached to the motor shaft. The gearbox includes a simple mount for the motor, which should be placed in the mounts so that the gears mesh. The foot is fastened to the bottom of the frame with any adhesive that is sufficient, oriented so everything is as symmetrical as possible. Once this is attached, the gearbox can be attached to the top of the frame with an adhesive as well. It should be position so that the center of mass at the top is very slightly in front of the center of the foot. The robot should show a slight lean forward, but the entire foot should remain flush with the ground.

To make the robot move, simply attach a power supply to the DC motor. A variable power supply is recommended, so that power can be controlled and rotational speed specified. The power at which the ideal speeds are attained are not always enough to overcome the inertia of the rotating masses when starting up. To overcome this, simply position the arms so that they start at the top. Once moving, the arms will continue to move until power is removed. If the robot doesn't jump at first, or behaves erratically, don't worry. Only certain speeds will cause the desired motion, so just slowly change the power supplied to the motor until the sweet spot is found.