The Centre for Biomimetic and Natural Technologies

UNIVERSITY OF BATH

Jumping Robots

Authors: Rhodri Armour, Keith Paskins, Julian Vincent, Adrian Bowyer, William Megill

Project Motivation

Jumping is a good way to move over rough terrain. Elastic energy storage is ideal for autonomous applications, because the amount of rest time is not critical and hence low-grade energy from solar cells (for example) can be used.

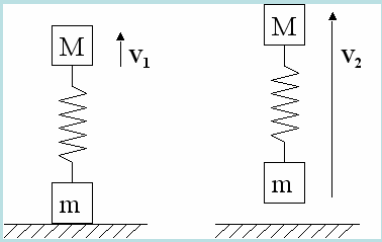
It is our aim to produce an autonomous low cost jumping robot that is capable of traversing rough terrain with low energy consumption.

Why Jumping Is Interesting:

- Small robots will encounter obstacles larger than themselves more often than larger robots
- Wheeled robots have difficulty with obstacles larger than twice the wheel diameter
- Walking robots typically have very complex locomotion systems both in control and the legs themselves but are more capable over rough terrain
- Jumping is the most efficient way of travelling over very rough terrain
- Jumping robots are able to store energy recovered from the environment by compressing an elastic mechanism that can quickly release all the energy in one jump
- Many natural organisms use jumping to traverse rough terrain

Possible Problems:

- Jump destination accuracy is difficult to control



Jumping occurs when one mass within a body is propelled away from the rest of it thus lifting the entire object from a surface.

Mechanics:
If the spring was a rigid connection, conservation of momentum equations give:

$$Mv_1 = (M + m)v_2$$

Since the basic principle is the same, there is a need to maximise ratio of **M** to **m** to achieve the maximum jump height.

Two Types of Jumping:

Regenerative Hopping – continuous jumps with no time between them (Kangaroos)

- High Speed
- High Power Requirement
- Allows for the possibility of energy recycling for subsequent jumps

Pause and Leap – jumps separated by long time intervals allowing time for directional control between leaps (Fleas, Locusts, Frogs)

- Low Speed
- Low Power Requirement
- Slow Leap Energy Storage
- Sudden Release of Jump Energy

For our purposes it has been determined that the pause and leap jumping technique will be better suited to a cheap low power autonomous jumping robot.

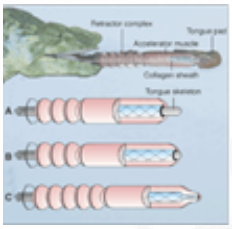
Natural Jumpers and Possible Inspirational Organisms:

Kangaroo: Kangaroos can jump up to 13 m in a single hop and travel at nearly 40 mph. They are very efficient in their use of energy which comes from the coil like spring performance of the long Achilles tendons which can store and reuse up to 70% of the energy from the previous jump.

Locust & Grasshoppers: Grasshoppers use normal low speed high force contraction of the flexor muscle to store energy in the knee cuticle (compressed resilin springs) and then release the stored energy by quickly releasing the flexor muscle. Much high-speed camera footage has been taken of locust takeoffs and their uncontrolled landing.

Chameleon Tongue: A chameleon's tongue accelerates so fast that muscle alone cannot be responsible for this acceleration. To overcome these limitations, many animals have coupled their muscles with biological "catapults." These catapults store energy and release it when triggered, allowing them to produce much higher speeds than could be achieved by muscle alone. Researchers have dissected chameleon tongues revealing an elastic collagen tissue sandwiched between the tongue bone and the accelerator muscle. They have discovered that this collagen structure is the catapult that propels the tongue tip in much the same way a bow delivers an arrow.

Flying Squirrel: Flying Squirrels are mammals that have evolved to jump and glide, and so have been extensively studied for inspiration, in a research collaboration between Missouri (USA) and Bath.



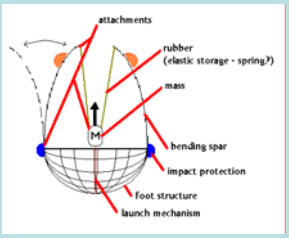
Design Factors

- Need for autonomy
- Power source and amplification
- Direction control
- Damage tolerance
- Size and weight

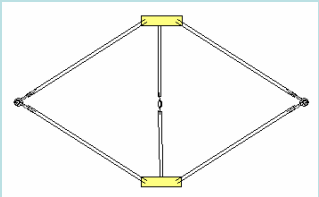
Designs and Prototypes

One early prototype used latex rubber as the energy storage mechanism, and worked quite well when released quickly. However, when charged slowly, the rubber succumbed to hysteresis, so the energy output was dramatically reduced. After testing the rubber using the Instron tensile tester, and by performing repeated tests with a catapult, it became apparent that rubber is unsuitable for use in a low power, autonomous jumping mechanism.

The outcome of this prototype was that metal springs would be the most appropriate energy storage mechanism, and that weight reduction would be key to a successful jumping robot.



The latest prototype for a jumping mechanism uses torsion springs as knees between steel reinforced carbon fibre rods. A small, heavily geared motor is mounted in a housing at the top, which winds in a string to bring the top to the foot of the robot, where it is held by a catch. The legs are caused to bend, storing energy in the springs, until the catch is released. Although there are 3 legs, the appearance of this robot jumping much more closely resembles jumping in nature.



Some previous designs of jumping robots are also being studied in an effort to prototype a working version. The deformable skeleton design pictured is particularly interesting as it does not use rubber to store the jump energy but the metal hoop springs integral to its design. With subtle modifications it would allow for combined methods of locomotion.

Further Work / Combined Locomotion:

• Jumping and Gliding

This could give increased control for useful gliding flight and choice of landing position, but is also more complex (Sensors & processing, etc). The advantage is a softer landing, but this also means that less landing energy can be recycled into the following jump.

• Jumping and Rolling

The use of a spherical or cylindrical design of small jumping robot provides the possibility for other methods of motion.

Off-Centre Ballast Driven Rolling: Other than jumping, ballast driven rolling would provide the robot with efficient movement for long distances over smooth surfaces. By sealing the entire shell of the robot from the elements it may be possible for the robot to roll over the surface of lakes and rivers.

Wind Powered 'Tumbleweeding': By making the robot suitably light with external vanes, a tumbleweed style of wind driven motion would be possible.