BIOLOGICAL MACHINE EXERCISE

A MULTIPURPOSE MACHINE MODELLED ON THE GRASSHOPPER

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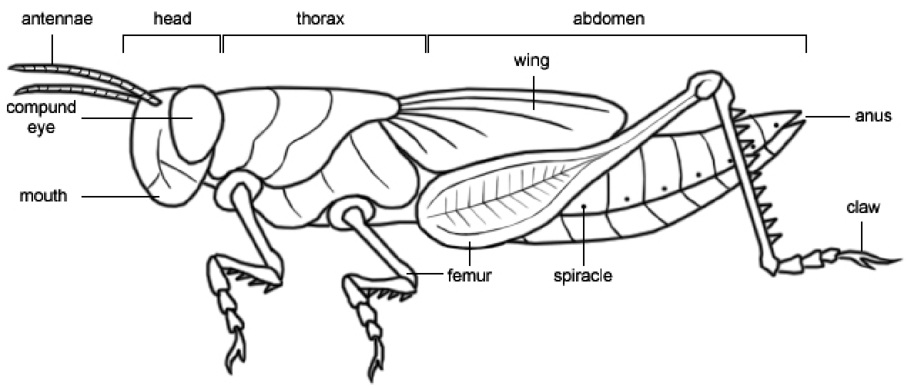
Introduction

Grasshoppers are small, herbivorous insects of the suborder Caelifera, in the order Orthoptera. There are approximately 11,000 species of grasshoppers described till date, found mainly in tropical regions. However, grasshoppers exist in almost every habitable environment across the world.

The general anatomy of a grasshopper can be represented by the following figure -



(Image obtained from http://upload.wikimedia.org/wikipedia/en/2/20/Grasshopper_anatomy.jpg on 1-11-07)

The machine is inspired by watching a grasshopper's movements, especially how the grasshopper is able to jump to, and survive a fall from, a height more than 100 times its own. Also impressive is the way a grasshopper uses its wings, to glide rather than to fly (as it is far too heavy for prolonged flight, but can slow its descent and increase the horizontal distance covered in a jump using these wings)

The complete taxonomy of a grasshopper is given as follows –

Kingdom Animalia, Phylum Arthropoda, Subphylum Uniramia, Class Insecta, Order Orthoptera, Suborder Caelifera

They are further subdivided into Superfamilies, Families, Genera, and Species.

The particular grasshopper that acted as inspiration for the machine is shown on the side (self-shot picture). Although hard to identify, the grasshopper might be *Eritettix simplex*

(commonly known as the velvetstriped grasshopper). The sizes of both are roughly equal (~1.5 cm), and they are both dark brown to black in colour. An image of ***Eritettix simplex*** is shown below.

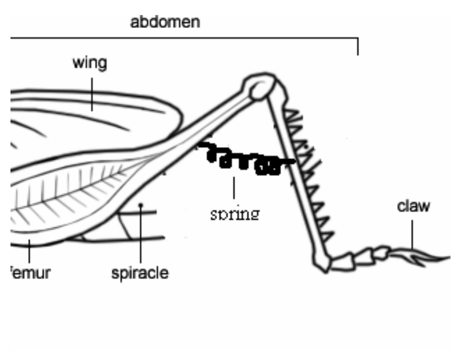
(Image source - http://www.sdvc.uwyo.edu/grasshopper/ghwywfrm.htm, accessed on 1-11-07)

The connection between the machine and a principle taught in class is derived through the first chapter in "Biology" by Neil Campbell and Jane Reece, which deals with basic biological concepts. In this chapter, a few sections are devoted to the different kinds of organisms present in the world, their taxonomical classification, and how form fits function in the biological world. This is evidently true in the grasshopper's case, as described above, and the machine is designed on the same principle.

Design of the Machine

The body of the machine will resemble the grasshopper in most respects, including the number and position of the limbs. One of the possible materials to construct the body from is a "smart alloy". A smart alloy is a material which "remembers" its original shape, and can thus revert back to it even if deformed. Since most smart alloys are Titanium-based (such as Nitinol, a Nickel-Titanium based smart alloy), they are extremely **strong** and **light**. The machine can be made of any desired size, assuming that components of that size are available. The lower limit for the size would be about 3-4 cm, as anything lesser than that would make the circuitry extremely difficult to make and fit in.

Mobility is achieved by the same combination of limbs as in a real grasshopper. The four forelimbs are used for walking, and can be modified with various attachments at the bottom (for example, high friction pads can be attached to enable the machine climb nearly vertical rough terrain; wheels can be used to increase mobility and movement speed over smooth areas). The two long, powerful hindlimbs are used to provide support for walking, and are also used to provide the force for leaping into the air. A suitable material for the limbs would be another titanium alloy, with high compressive strength.



The two rear limbs of the machine will be used to provide the force for jumping. This can be achieved by fixing a spring of large force constant at the place indicated in the diagram. This spring can then be compressed, and as it returns to its original shape, the force will pass from the claw onto the ground, thus sending it into the air. This, while unlikely to be practical for the larger form of the machine, can greatly increase the mobility of the smaller form.

Two pairs of foldable wings enclosed within the body can be deployed, which will allow the machine to jump and glide from higher areas to lower ones safely, while covering a larger horizontal distance. Carbon Fibre Reinforced Plastic (CFRP) would be a good candidate for the material of the wing, due to its excellent strength to weight ratio. Also, this material is unlikely to lose its shape after being bent, which is important when the wings have to be used repeatedly, without servicing.

Photoreceptors are placed in place of the grasshopper's eyes, and these will be connected to a transmitter, which will relay what the machine "sees" directly to the control station. Also, vision is not limited to that which can be directly seen by the naked human eye. The sight can extend into the infrared region, which can be very useful to detect potential threats to the machine.

Applications

a) Retrieval/defusal of unexploded landmines or bombs

A medium-sized (about 20-25 cm) form of the machine can be used to retrieve or defuse unexploded bombs or landmines. A remote control and a sensor to detect the explosive can be incorporated into the circuitry. This enables explosives to be safely handled without endangering personnel. For example, such a machine can be used in Iraq, to save several innocent lives. Each street can be quickly scouted, and all explosive devices removed. Using infrared scanning, explosive stashes within buildings can be detected and seized before they are even planted for use.

This fact is especially true in clearing minefields, where a single misstep leads to military engineers being maimed or killed. Minefields can also be planted by aircraft, to block the retreat of an army during a battle. These minefields are covered by enemy fire, so humans can't remove it safely. However, using these machines, the field can be safely and effectively cleared.

b) Surveillance

The smallest version of the machine can be used for surveillance, both army and civil. It can be camouflaged (using paint) and let into buildings where surveillance needs to be maintained. For this function, both remote controlled and automated machines may be used, depending on the purpose. High definition cameras can be used in place of photoreceptors, which will give excellent audio and video quality to the controller. With its low mass, sticking devices can be attached to the limbs, which will enable it to climb walls, like a real grasshopper can.

In case transmission is not possible (such as in a military establishment, where outgoing signals may be detected), the automated machine can be used, and the information can be recorded and then transmitted at will. Another alternative (in case physical retrieval of the machine is impossible) is to record all the data, and as soon as the recording device is full, to trigger a transmission.

c) **Exploration of other planets**

The largest version of the machine (over a meter long) can be used to explore the terrain of other planets, such as Mars. The unpredictable terrain of alien planets makes it difficult to use wheels, which become quite useless when the slope of the ground becomes near-vertical. This problem can be offset by fixing high friction pads on the limbs, or pneumatic pincers, which can drill into the rock to an extent and provide a very strong grip. However, a good sensor is required to do this efficiently, to prevent slips. The same pneumatic system, in a larger form, needs to be attached to the machine to enable it to drill into the surface of the planet, retrieve samples, analyze the data, and relay the information back to earth.

The relay mechanism consists of three antennas, a high-gain antenna, a low-gain antenna, and an Ultra High Frequency antenna. These three coupled together transmit the wave to a shuttle orbiting the planet, which in turn relays it to other relays it either directly to earth, or to intermediate satellites, which then relay it to earth.

In this size of machine, the jumping mechanism will be almost obsolete (as mass increases as a cube of dimension), but the wings will still provide enough stability to glide. So if the robot climbs up to a high region, it can come back down without having to climb down –

it can simply glide (assuming the atmosphere is dense enough to support it – otherwise it will have to partially climb down).

These are just a few of the potential applications of the machine, which also serves as an example of universality – the same device being put to multiple uses.

Bibliography and References

- http://www.gcsescience.com/ (references on smart alloys)

- http://en.wikipedia.org/wiki/Landmines (references on landmines and their techniques of implantation)

- Mikell P. Groover, Fundamentals of Modern Manufacturing, John Wiley & Sons, 2002 (references on compressive strength)

- www.sdvc.uwyo.edu/grasshopper/ (lots of detailed information about grasshoppers, compiled in the University of Wyoming)

- http://athena.cornell.edu/ (references on the antennas used to transmit signals from other planets back to earth)