From Big Things With Wheels to Small Things With Wings

Farm machinery has changed a lot over the last century. Machines have become smaller and more powerful through the development of new technologies.

1. History of Farm Machinery

FIG. 1 1860 horses pulling farm machinery

1700's - Wooden plows, hoes, sickles, oxen and horse powered

1790's - Cast iron plow, cotton gin invented, cradel and scythe   See FIG. 2

1810's - Iron plow invented See FIG. 3

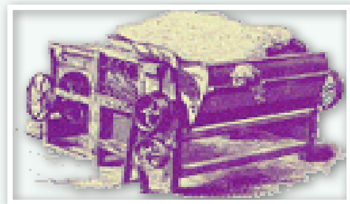


FIG. 2 1790 cradle & scythe

1830's - Reaper invented, steel plows, 300 hours of human labor to produce 100 bushels

1840's - factory made machinery, mowing machine invented

1850's - 90 hours of human labor to produce 100 bushels

1860's - First American Agricultural Revolution, steam tractors invented, begin to replace horse power See FIG. 1

FIG. 3 1819 iron plow

1890's - 50 hours of labor to produce 100 bushels, commercial fertilizer became popular - 1,845,900 tons used annually

1900's - Ave. annual use of fertilizer = 3,738,300 tons, George Washington Carver advanced agriculture

1910's - Gas tractor invented See FIG. 4, ave. annual use of fertilizer = 6,116,700 tons

1930's - All purpose tractor with rubber tires popular, 30 labor hours to produce 100 bushels, 1 farmer fed 9.8 people in U.S.

1940's - Ave. annual use of fertilizer = 13,590,466 tons, 1 farmer fed 10.7 people, frozen foods became popular, Second American Agricultural Revolution (horses to machines)

1950's - Tractors outnumbers horse for 1st time, 12 labour hours to produce 100 bushels, ave. annual use of fertilizer = 22, 340,666 tons

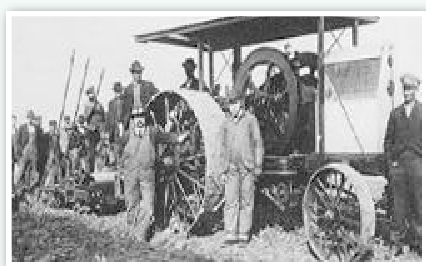


FIG. 4 1910 big geared gas tractor
Photos - http://inventors.about.com/library/inventors/blfarm1.htm

1960's - 5 labor hours to produce 100 bushels, 90% of crops like beets and cotton harvested mechanically, ave. annual use of fertilizer = 32,373,713 tons, 1 farmer fed 25.6 people

1970's - 3 labor hours to produce 100 bushels, 1 farmer fed 75.8 people

1980's - Tractors become hi-tech, more farmers using hi-tech methods

2000's - 1.5 hrs to produce 100 bushels, use of computers, satellites, GPS, hi-tech robots [2]

2. Robotic Solution

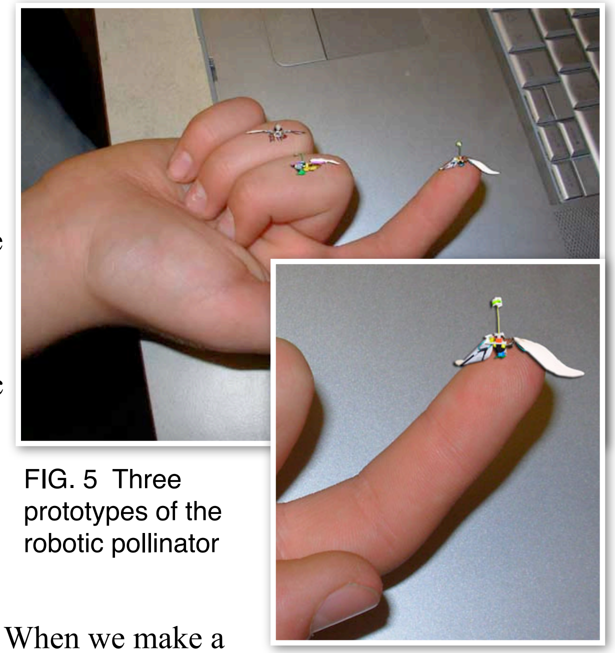


FIG. 5 Three prototypes of the robotic pollinator

Our solution to the problem of pollinating almond trees is to make a autonomous robotic pollinator. See FIG. 5. These robots will work together in groups going out to individual flowers, collecting pollen, and then visiting more flowers to distribute the pollen.

The first thing we did was study honeybees because that is what we wanted to base our robotic pollinator on. We thought it would be a good idea to copy the natural world because bees have been doing the job of pollinating for thousands of years. Nature does things well. This science is called biomimetics. [1]

Biomimetics is copying good design from nature. When we make a new technology we can find the base of how it works in the natural environment. Some examples: Velcro was invented by Georges de Mestral after studying how burrs use little hooks to attach to dog's fur. Packaging that doesn't leak could be made by learning how an apple holds so much liquid. 95% of an apple is liquid but it doesn't spill when you eat it.

We looked at bees and found out which things help the bee do the work of pollinating. We did not need to copy everything that a bee does. We don't need the stinger, we don't necessarily need six legs, the three body parts, the two antenna, or the multifaceted eyes. But our robotic pollinator does need to copy many of the things about bees. Our robotic pollinator needs a way to communicate with the other robotic pollinators and a central computer. It needs to pick up pollen and then drop it off on other flowers. The robot will have to be able to fly from flower to flower. It also has to be small like a bee so it won't damage the flowers.

At first we thought the robot should have legs to move around on the flowers to collect the pollen, but after considering the power consumption and the necessary motors to operate multiple legs, we decided that this would not be practical. The robot will move around by hovering lightly on the flowers and using a small foot to move gently over the pollen tubes. The wings will be able to tilt in different directions to let the robot hover like a real bee. Real bees can hover, back up, go forward, and change direction very quickly.

Our design will have a body shape folded out of strong sheet then metal or composite. The frame will be out of metal struts. The wings will be covered in an extremely thin material.

There are 50,000 bees in each hive and in California for the almond pollination it takes over a million hives, that's 50 billion bees. Because not all of the bees go out to collect pollen, we don't think we will need that many robotic pollinators. Also, our robots can work longer, night and day, and in bad weather. But we will need a lot of them to cover the amount of orchards. They will need to work as an ecosytem, talking to each other and following a plan to cover all of the trees. They will need to be very inexpensive and easily replaced. We will also need a delivery system to get the bees distributed around the orchards. We plan to have stations positioned evenly through out the orchard much like they now put bee hives around an orchard. It takes 5 - 8 hives to cover about 2.5 acres of orchard.

3. Basic Design

3.1 Body: Material for the body of our robot is made of very thin sheets of titanium and the frame of stainless steel struts. This will allow the robot's shape to be cut out of the material and then designed by folding the titanium like you fold paper into origami shapes. A laser will cut the material to the precise shape and size.

3.2 Wings: The wings will have a rigid support system and be covered with thin pieces of spun polyester. The wings need to not only flap up and down, but also need to tilt during the motion. This is what makes flies and bees be able to sustain flight. The tilting and flapping motion creates air vortices and backspin that gives the insect the lift needed to fly. The robot's wings will be designed to create up and down and tilting motions by the movement of the body structure. The wings will stop at the high and low points and rotate in place, Flies use their hind wing as a gyroscope to monitor the rotation of their body during flight. Our robot will have a built in gyroscope to keep it stable during flight. (See section 5 for more information.)

3.3 Weight: The robot will weigh about the same as a natural bee, about 100 milligrams or a tenth of a gram. That is about the weight of a paperclip.

3.4 Navigation and Communication:: The robots will use Geographical Information Systems (GIS) and Global Positional System (GPS) for navigation. The GIS will provide a map of the terrain and trees. The GPS uses a satellite map to pinpoint where the robot is. These systems will help the robot be more autonomous. The robot will have an antenna to communicate with other robots with radio frequency and also with a central computer located at the station.

3.5 Power: The wings of our robots will be powered by a tiny crystal piezoelectric actuator. (See section 6 for more information.) The wings will flap by moving the folded body structure. The actuator will be charged at a station, then if it is running low on energy during it's job, it will use solar panels so it won't have to go back and charge itself. The actuator is made out of a material that reacts to voltage by bending. It's like a muscle contracting. This will make the wings flap 180 times per second. The robot will also have a rechargeable battery and solar panels. The battery will allow flight during night or on cloudy days. The robot will be able to go back to the charging station and hook up to recharge. When it is on a job and runs low on power, the solar cells will be used so the robot doesn't have to return to the charging station right then.

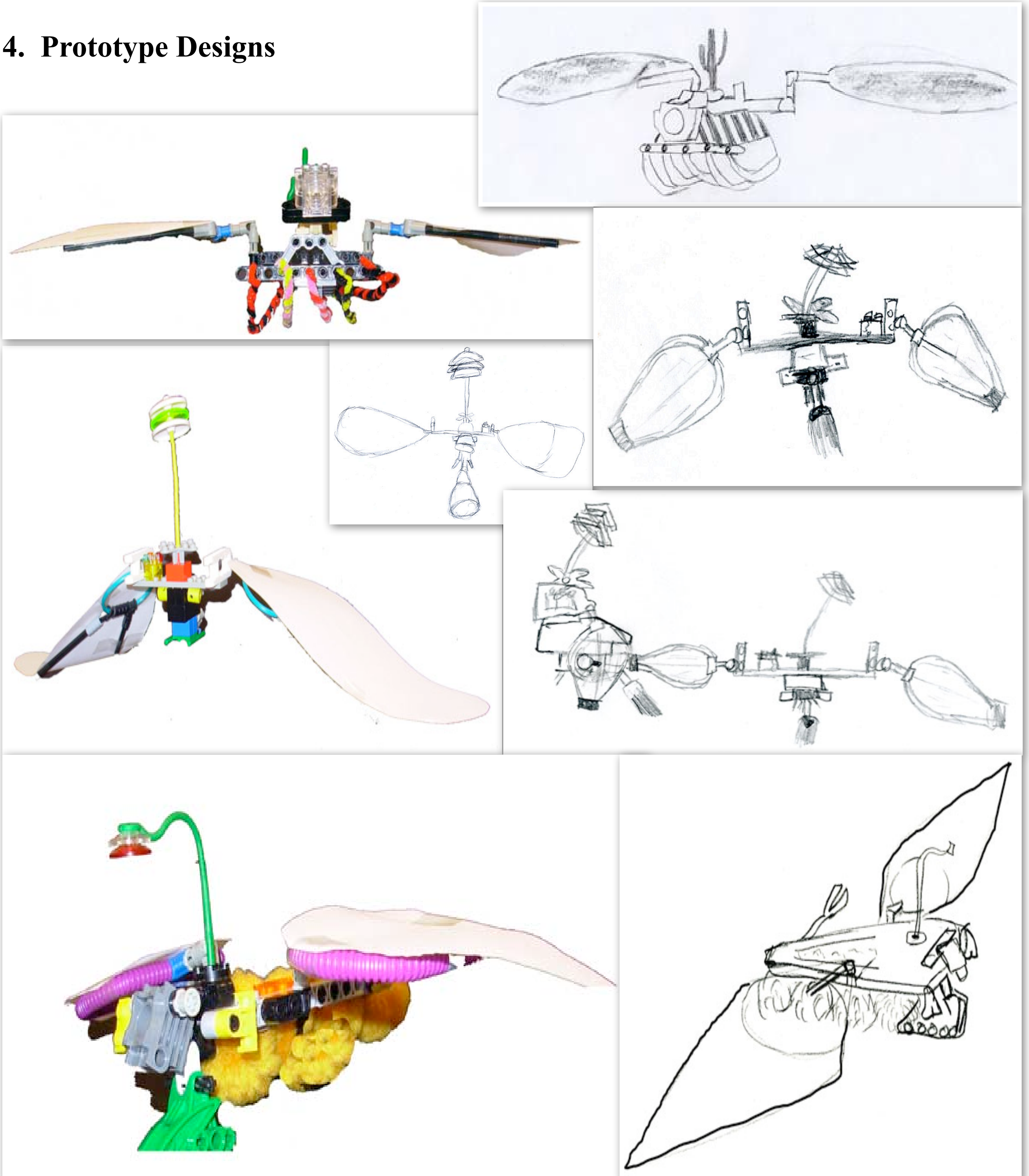
3.6 Electrostatic Charge: Real bees have a slight electrostatic charge around their legs where the pollen is collected. This helps the pollen to be attracted to the bee's hairs on its legs. Our robot will also have a slight electrostatic charge around the pollen collectors.

3.7 Sensors: The robot will carry several sensors. Along with distance sensors, it will have a CMOS camera or optic flow sensor to be like the compound eyes of a real bee. These will be used to find the flowers.

3.8 Microprocessor and Software: The robot will have a mini microprocessor will run a small operating system. TinyOS is a software language being developed at UC Berkeley. It has a very small file size. We will have a similar software language. The robot will run autonomously under the software. The robot will have only a few commands to follow that will allow it complete its task. This is like ants and bees that follow only a few simple rules to complete complicated jobs. They work together to get a job done.

3.9 Delivery: The robots will delivered into the air through a blower system from central stations. These stations will be place through out the orchards. There will be a charging system on the station. A central computer will control the stations.

4. Prototype Designs



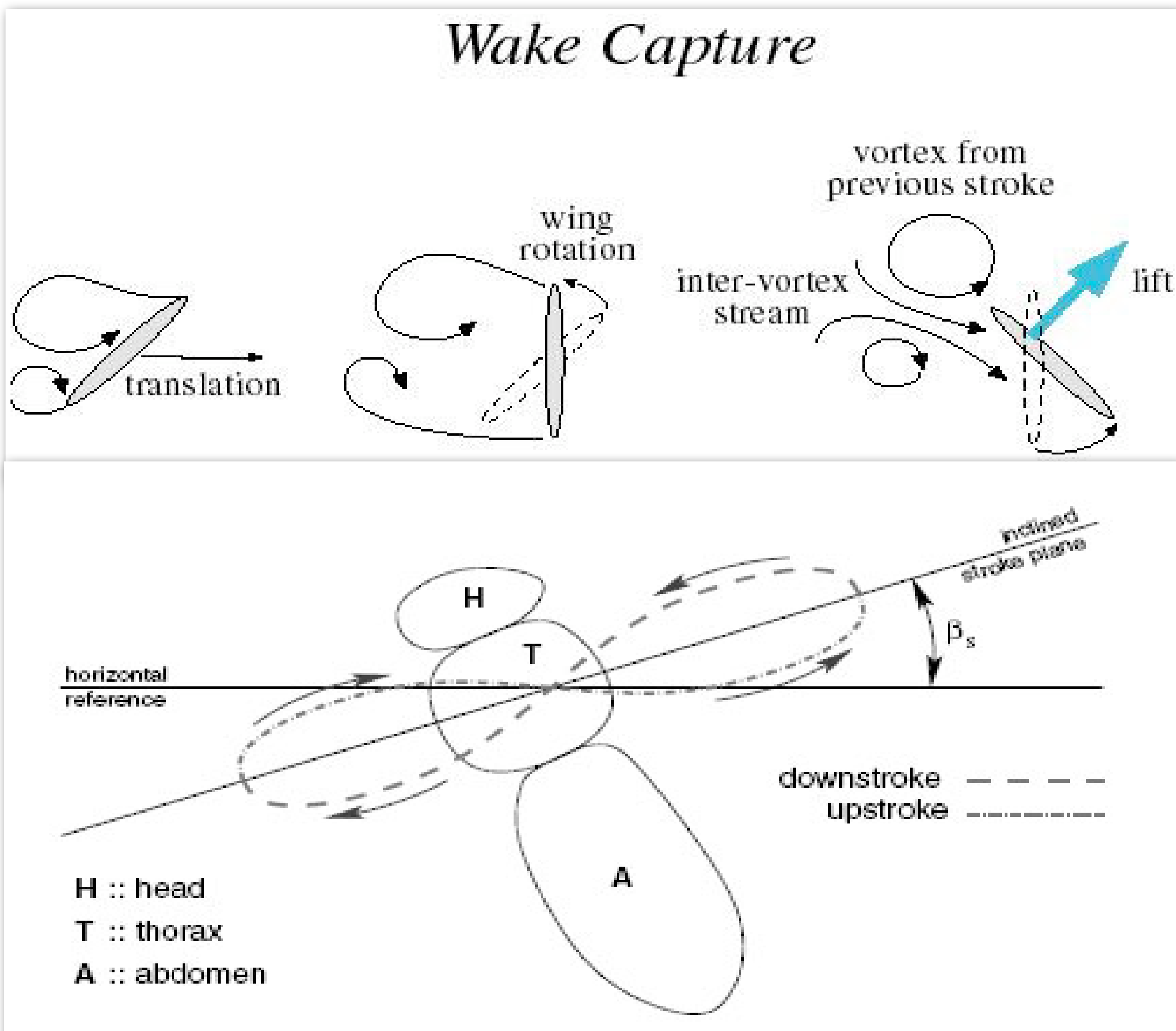
The Robotic Pollinator: It's design incorporates an adjustable camera, two distance sensors, and hair-like pollen collectors. It carries a small microprocessor and a light weight communication system. It has solar cells along with a rechargeable battery. A camera is used for flower detection along with GPS and GIS navigation systems.

5. How Insects Fly

Our robot design copies the good model that nature provides in flying insects instead of how a man made plane flies.

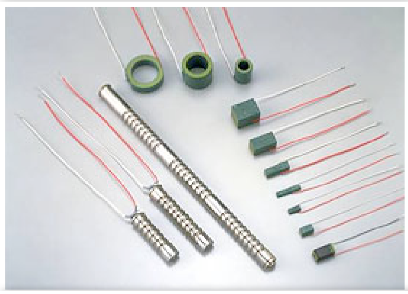
The wing on a airplane has nothing to do with insects wings. In fact, it's completely different. The wing of an airplane doesn't move. Lift is created by the shape of the wings and the rushing air. The air goes over the wings creating pressure on the wings which is what lifts it in the air.

The insects wing does its downstroke and the air pushing on it pushes it to move in a circular motion. These vortices of air move down the edge of the wing causing lift. The wing must move both up and down and tilt at the upstroke and the downstroke to make the vortices. [3]

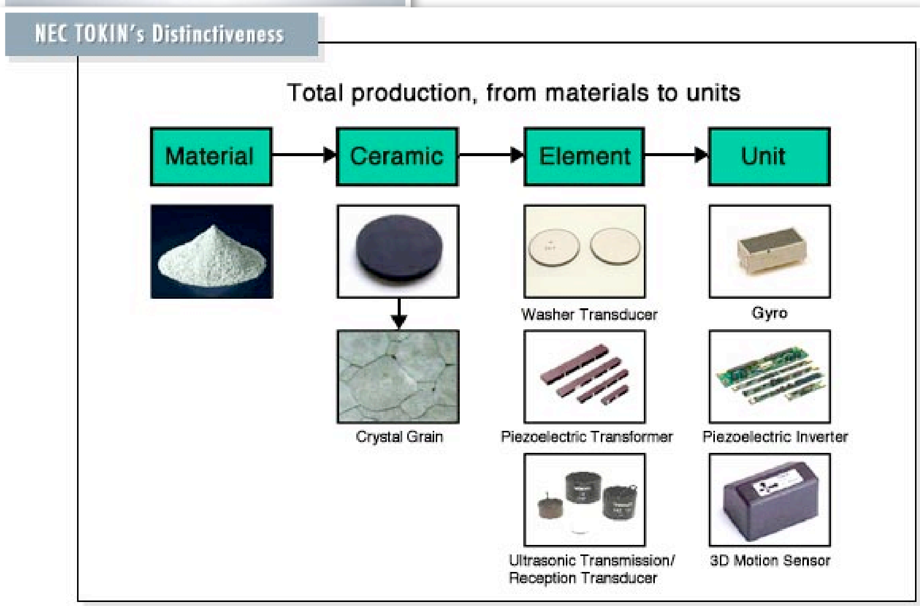


Insects wings use 8 different motions to fly. Image credit: Zbikowski et al.

6. Piezoelectric Actuator

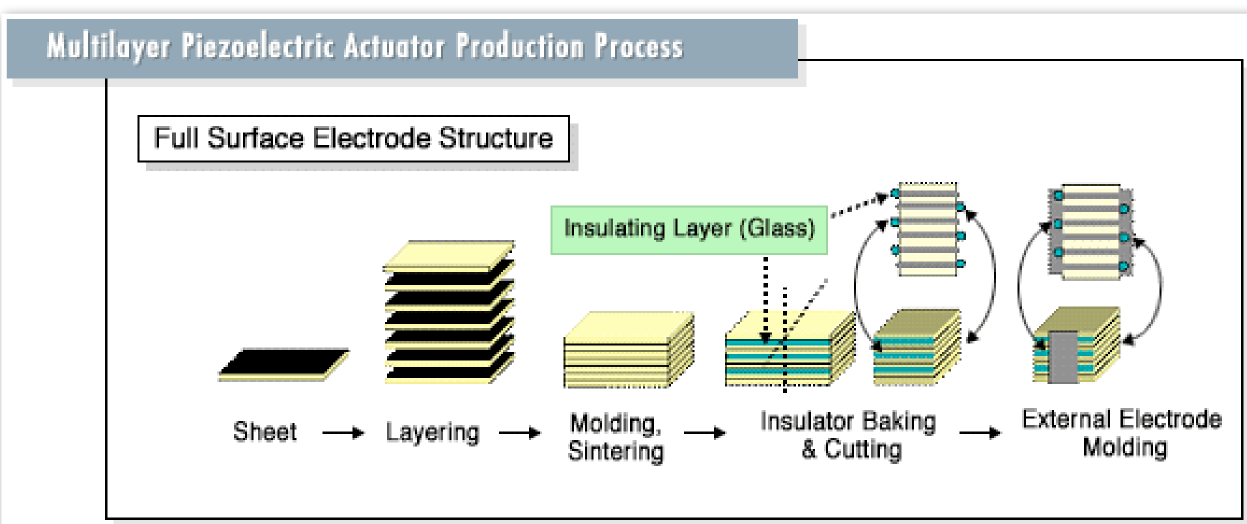


An actuator changes power like electricty to mechnical movement. The word ‘piezo’ has to do with crystals that can change their shape when an electric charge is put to them. They in turn produce an electric voltage because of the change. Peizoelectric machines are very stable, very energy efficient, and do not get hot under use. They also have very simple designs so they can be very small. They are used in televisions, cell phones, video cameras, DVD players, and other electronic devices.



Multilayered actuators are made up of 200 to 300 alternating layers of ceramic and electrodes. Then the block is cut into what ever shape is needed. It can be made in to cylindars, tubular or ring shape pieces. The actuators will make the wings of our robot flap.

These kind of actuators have a lot of advantages over hydraulic or air pressure, or electromagnetic motors. The response time is very fast: 0.01 milliseconds and they have very precise motion capabilities. They can move as small as 0.01 microns. They can generate a large force for the size, up to 3 kilograms per square millimeter. The low energy needs is also a plus along with the fact that they can be very small and lightweight.   [4]



Photos - http://www.nec-tokin.com/english/product/piezodevaice1/piezo_actuator.html

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