Construction of Living Motion Engines

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The mechanism responsible for living motions has been one of the deepest mysteries. No one has been able to produce these motions in lifeless bodies. The author discovered that coupling two or more mechanical harmonic oscillations within a body or its parts could produce living motions. He further derived the equations that govern the motions and constructed many working models to demonstrate and verify the effect. In this paper, the author describes the above findings and the steps that other researchers can take to produce working models of *motoneuron* systems, or muscle motor units, that move.

How do we move? How do animals move? How do the simplest living organisms produce their motions from within themselves? These and similar age-old questions have not been satisfactorily answered in scientific terms. Aristotle attributed living motions to Soul, Sir Isaac Newton wrote in the *Principia* that the motions are due to some sort of Spirit, and Dr. Albert Einstein wondered that living motions do not obey Newton's Laws of Motion. Attempts to describe living motions in classical, electromagnetic, relativistic or quantum terms have not been satisfactory.

The author spent many years trying to induce motions in lifeless bodies by internal dynamic interactions, such as, inertial and gyroscopic effects. In the end, the author discovered that spontaneous motion could be induced in any lifeless body by simple harmonic effects. Smooth linear motion can be produced in lifeless bodies by coupling, or modulating, two or more mechanical harmonic pulse- or impulse-trains acting symmetrically within the body. The pulses can be generated by the rotation of unbalanced masses attached to the shafts of motors, which are symmetrically attached to the body.

Using the vibration motion mechanism, the author was able to produce a variety of gaits and other forms of motion of bodies made of different materials and shapes; without gears, cams, pulleys, ropes, linkages and other mechanical parts, which are used to move cars, trains, robots and toys. The motion mechanism works like the muscle-engine; e.g., energy is converted to motion in one step. The mathematical equations that govern the motion and recommended ratios for the construction of motion models are given in another paper (submitted by the author to another journal).

In this paper, the author describes the steps to construct a *motoneuron engine* that emulates the workings of the brain-body motion engine.

The basic components of the living motion engine are the muscles and the nervous system. Muscles do their work by contracting in length and increasing in thickness. Modern biology has shown that the telescoping of the actin and myosin rods into each other is responsible for the axial contraction and radial expansion of muscle bundles. Many attempts have been made in this Century to construct muscle devices, or engines, and most of the attempts seemed to produce stronger strings, tubes or ropes; but not stand-alone moving devices.

The muscle is its own engine and it does not require gearboxes or shafts to do its work. The living motion system specifically requires the action of the nervous system on the muscles. Muscles act as a result of electrical-like signals received from the nervous system, i.e., the action potentials, or nerve impulses. The impulses travel rapidly from sensory neurons to axon terminals to excite the muscles. The signals maintain constant, non-decaying, amplitude throughout the presynaptic journeys. The nerve impulses have the all-or-none property, i.e., a train of impulses of constant magnitude is either present or not. The amplitude of the impulses is independent of the stimulus magnitude. When running, instead of walking, only the frequency of the impulses is changed, and not their amplitude. A living motor unit consists of one motoneuron and all the muscle fibers that are activated by its signals. The impulse trains that are generated by the neurons are clearly recognizable in the response of muscle fibers as recorded on electromyograms. Other properties of the muscles and the action of nervous systems are found in textbooks.

The basic living motion engine then consists of pulse trains generated by the nervous system, which excite muscle fibers at a given frequency. To complete the description, a bare skeleton can be clothed with muscles. The author built and tested the *motion* of such a system as described below.

A cubical skeleton (25 cm sides) was constructed using aluminum angles, Fig. 1. Four small dc motors were mounted symmetrically on opposite top angles as shown in the Figure. Two steel wires were then attached to the shafts of opposite motors, and a small mass was attached at the center of each of the wires. The four motors were connected to a variable power source. When the motors were operated, the unbalanced masses produced inertial harmonic pulses as the strings turned. The centrifugal forces produced by the rotating unbalanced masses pulled the opposite ends of the aluminum structure together, thus shortening the wires' lengths while the wires expanded radially.

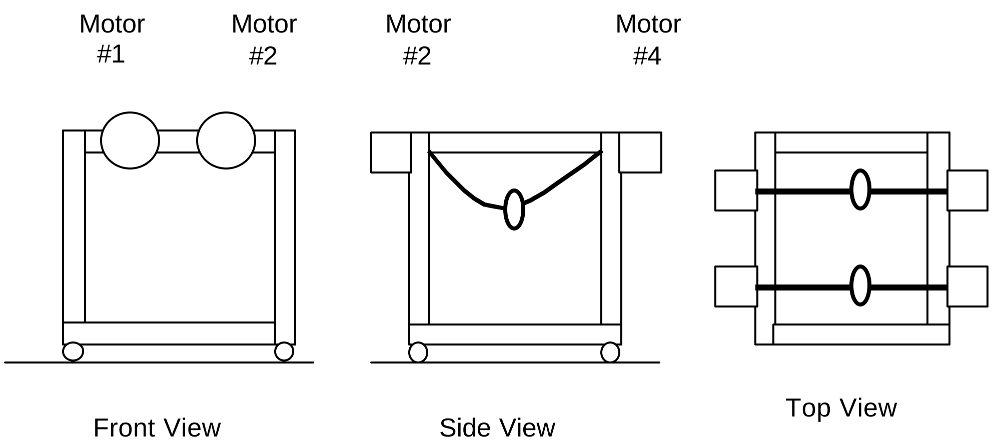

Fig. 1 Aluminum angles Cubical Structure

The whole structure moved spontaneously in distinct steps, with a distinct frequency and a distinct wavelength, λ. Increasing the motors' RPM resulted in faster motion and shorter step wavelength, as shown in Fig. 2. By varying the RPM, hence the frequency of the pulses f, smooth motion was achieved.

The author tried the same configuration described above using boxes made of plastics, wood, steel and other materials and varied the locations of the motors axially and laterally and successfully produced motions of these models. With minor modifications, the same motion mechanism was used on snakes, reptiles and other flexible toys, and a variety of gaits and forms of motion were easily produced. The same results described above can be obtained using 2, instead of 4, motors, by allowing free rotation of the strings in the opposite locations.

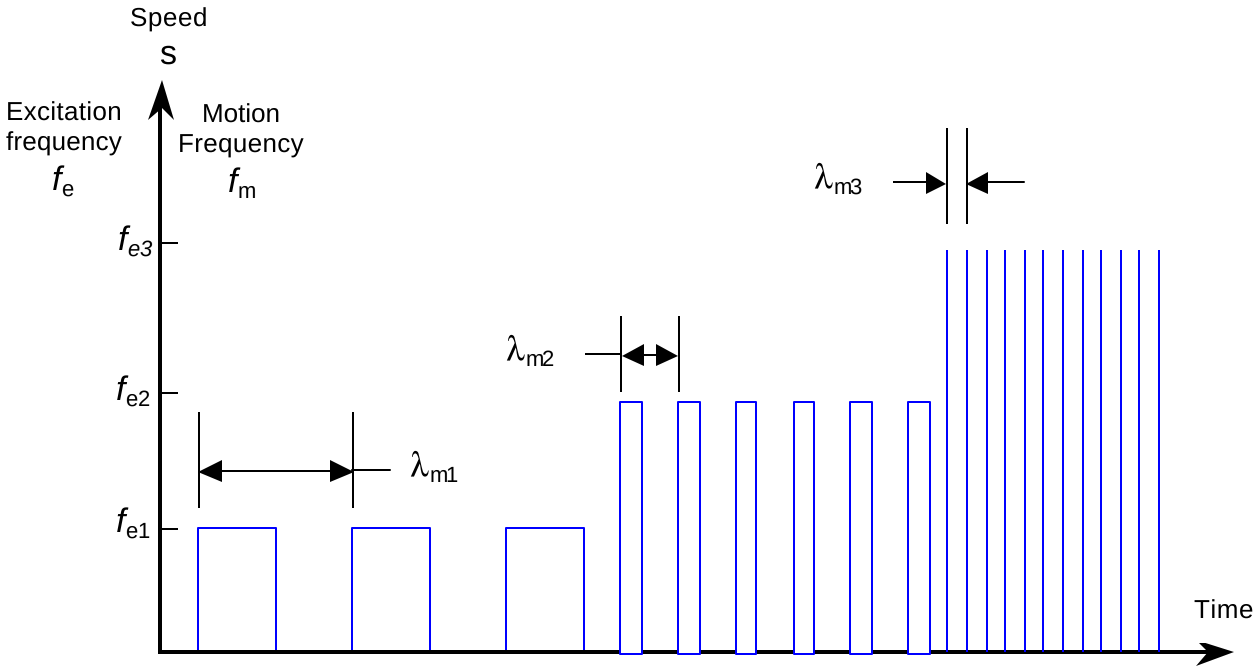

FIG. 2 Excitation frequency f_e, represents the frequency of nerve impulses, s the speed of the aluminum structure, f_m the frequency of motion of the aluminum model. Note how the speed of the model s and the motion frequency f_m increase as the input excitation frequency increases.

Researchers can use the following values as guidelines in their models:

$$5 < f < 500.$$

$$\frac{1}{100} \leq \frac{\text{unbalance mass}}{\text{total mass}} \leq \frac{1}{10}$$

Our research opens a new window on the study of the important subject of *motion*. The author had often try to use the equations of aerodynamics, hydrodynamics and other mechanical formulations to describe living motions, but to no avail. Experimenters of biological systems have always expressed amazement at the feats of bees, birds and fish. In those studies, the actions taken by the fish, in a direction perpendicular to the motion, are always neglected. Yet those perpendicular actions (which usually add up to zero in classical mechanics) seem to contribute significantly to the forward motion of the fish than the back-push by body, fins and tail. By applying sideways forces to models excited with our motion mechanism, the bodies moved readily in the perpendicular direction. The author was also able to use the harmonic oscillation mechanism to produce spontaneous motion of his hands, arms and body.

Note: The author is submitting Videotape, with this paper, which shows the motion features described above with some 20 Technical Models and 50 Toys. Also, for the purpose of “proof of concept,” the author constructed and successfully tested, in 1999, several remotely controlled robots using the above motion mechanism for the Defense Advanced Research Projects Agency (DARPA).