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White Paper
Subject: Natural-motion, or self-motion, mechanism (Patent Pending)
Submitted to: Robotic Industries Association

INTRODUCTION

This white paper describes (1) the invention of a natural-motion, or self-motion, mechanism (Patent Pending), (2) basic characteristics, unique features and significance of the innovation, and (3) proposed follow-up activities for your consideration.

BACKGROUND

Natural motion, or self-motion, denotes the motions that bodies produce from within themselves without the agency of externally applied forces; for example, the motions of living organisms. I undertook an extensive experimental program in the early 1980s to discover the mechanism and the laws that govern such motions. The program evolved in three phases, each of which consisted of thousands of tests:

1. Inertial and gyroscopic effects
2. Unidirectional mechanical oscillations.
3. Orthogonal oscillations.

EVOLUTION OF THE DISCOVERY OF SELF-MOTION

I made and recorded many observations over the years. The inertial and gyroscopic effects produced puzzling results, for example, the requirement to hold the models with the hands to feel a motive force and to induce motion. The theories of flight of birds and insects and more tests suggested that a unidirectional oscillating force was a better candidate to produce self-motion. Many tests with this approach gave better results. Further consideration of classical, quantum and electromagnetic theories of motion led to dramatic results. For example, by analogy to electromagnetic wave propagation, I applied two orthogonal mechanical oscillations to bodies of different materials and geometry and produced repeatable and controllable motions. The following Table summarizes the evolution of the experimental program, which spanned nearly two decades

Evolution of the Discovery of Self-Motion		
A typical 100-test sample	No. of models moved alone	No. held with hands
Inertial effects	5	95
Unidirectional Oscillation	20	80
2 Orthogonal Oscillations	>95	<5

With further refinement, I was able to produce controlled motion of the models: Forward, backward, in any direction, up inclined surfaces and with a variety of gaits. Thousands of tests that show the technical characteristics of the motions were recorded on video.

Some models, including toys, have been demonstrated to experts at government, industry and academic centers. No one has seen a mechanical equivalent of the self-motion mechanism before. The motion models have not yet been shown publicly.

After the controllable motion was produced by coupling the orthogonal oscillations, I examined the basic characteristics of the motion mechanism, including the following central problems:

1. Develop the mathematical expression(s) that govern self-motion
2. Explain the requirement to hold some models with the hands to induce motion.

A MOVING MECHANICAL-MUSCLE MODEL

The second problem above led me to construct a mechanical-muscle model that moved alone. Here, the well-known longitudinal contraction and radial expansion of a muscle in action ***combined*** with the neural pulse trains emanating from the brain were simulated mechanically to produce motion. This has not been done before.

THE LAWS AND EQUATIONS OF SELF-MOTION

Finding the laws that govern self-motion was a lengthy task. Because the models were of macro size and their speeds ranged from mm/sec to many cm/sec, it seemed logical to try to fit the motions into Newton's second law of motion; i.e., F=d(mv)/dt, or F=ma, where the mass of a model was always constant. Many tests revealed that the motion does not follow the classical equations. In all cases of motion by mechanical oscillations, the models reached a maximum, or terminal, speed nearly instantaneously, Fig 1. Moving the models on different surfaces and using lubricants to change friction did not alter this aspect of the motion: In all cases, motion by mechanical oscillations reached a terminal speed nearly instantaneously. Even the law of conservation of linear momentum became suspect. Internal interaction of two or more bodies (e.g., between the source of mechanical oscillations and the moving body) apparently can produce linear or rotary motion, contrary to the requirement of momentum conservation!

By varying the exciting frequencies that were driving the models, the speed changed: The speed (s) increases when the frequency (*f*) is increased and the speed decreases when the frequency is lowered, Fig. 1. Further tests showed that speed is inversely related to mass (m). Combining the above functional relationships, the following was obtained

$$s \propto \frac{F(f)}{F(m)}$$

This was a surprising result. For example, note that reduction of the basic quantum equation E=*hv* or E=*hf* leads to the following similar functional relationship:

$$v \propto \frac{F(f)}{F(m)}$$

where *v* or *f* is the frequency of light waves in the photoelectric effect, E is the kinetic energy (or ½ mv^2) of the electrons ejected in the process, *h* is Planck's constant, m is the mass of the electron and v the velocity, or speed, of the electrons.

Using the macro-sized models, I examined the behavior of self-motion versus other quantum effects, including, the black body radiation phenomenon, the Compton effect and the tunneling effect. Correlation was apparent, see Fig. 2.

Other observations were also made from experiments. (1) There is a lower frequency f_{min}, or cutoff frequency, below which the self-motion models do not move. (2) Above f_{min}, the self-motion models move in discrete steps, Fig. 2. Here, when the exciting frequency is increased, the amplitude and frequency of the motion steps increase and the wavelengths become smaller, as shown in the Figure. It was also noted that the acceleration (a) in self-motion, or the rate of change of linear velocity (v) with respect to time (t), is a function of the rate of change of frequency (*f*) with respect to time, or,

$$a = \frac{dv}{dt} \propto \frac{df}{dt}$$

I also examined the effect of materials of construction, geometry, interface conditions and other parameters on self-motion. These variables produced effects unknown before in classical or quantum mechanics. Self-motion cannot be analyzed by modeling the moving body as a point, i.e., the center of gravity as in classical mechanics. Many parameters – including, frequency, phase, polarity, geometry, materials, interfaces, etc - must be considered together to predict the motion.

UNIQUE FEATURES OF THE SELF-MOTION MECHANISM

Conventional motion techniques have revolutionized the quality of human life. These methods have relied mostly on the agency of external forces (pushing or pulling) to move vehicles, payloads and people. Yet, it has been recognized that the motions of living organisms surpass artificial motions in efficiency, maneuverability and versatility. The method by which such organisms move has remained obscure. The discovery of the self-motion, or natural-motion, mechanism clearly elucidates living motions. For example, using the self-motion mechanism, I produced motions of my fingers, hands, arms and, even, of my whole body, and of jointed-models. Our discoveries will have profound impact in many areas. Some benefits are self-evident from the motion models that we have available for demonstration, and some of the unique features of the mechanism include:

1. Energy is converted to motion in one step, unlike conventional methods, which require motors, gears, shafts and linkages.
2. Structures and payloads can be made to contribute to the motion. By introducing non-destructive oscillations into these bodies, the structures can assist, rather than retard, the motion.
3. The power plant in self-motion can be compact, and it represents only a fraction of the total weight.
4. Maximum speed is reached nearly instantaneously; a feature that will be very attractive in many motion applications.

5. Diverse maneuverability with instantaneous turns in any direction by simple changes of frequency, phase, polarity, geometry, etc.
6. The motion mechanism gives a better understanding of the workings of biological systems, it can be used to actuate artificial limbs, and it can lead to many medical benefits.

The unique features described above and others make the natural-motion mechanism ideal for application in robotics. For example, the only robot that moves nearly naturally is the *passive dynamic walker*, a two-legged robot that moves human-like down shallow slopes. The robot appears to move naturally because the force vectors (the gravitational force) act on it at all vertical levels. In a similar way, the self-motion mechanism produces the tendency to move forward at all vertical levels of a structure on a horizontal surface or, even, up an inclined surface. When motors are used to produce the pulses or oscillations required to move a body, the energy (from a battery or another power supply) turns into motion directly. Robots using the coupled-mechanical-oscillations mechanism will be simple, quick and agile.

PROPOSED TASKS

1. Free-of-charge: I am prepared to demonstrate the motion models to your experts in the Washington, DC area at any time. Alternatively, you may want to sponsor visit(s) to your Center(s) for the purpose.
2. Under Contract or Purchase Order: Supply motion models of different geometry, material and interfaces to do specific tasks identified by you.
3. Under Contract or Purchase Order: Demonstrate basic characteristics of the motion mechanism and show the scientific basis behind the mechanism, including, control of speed, turns, payload capabilities, etc.
4. Other tasks identified by the Agency.

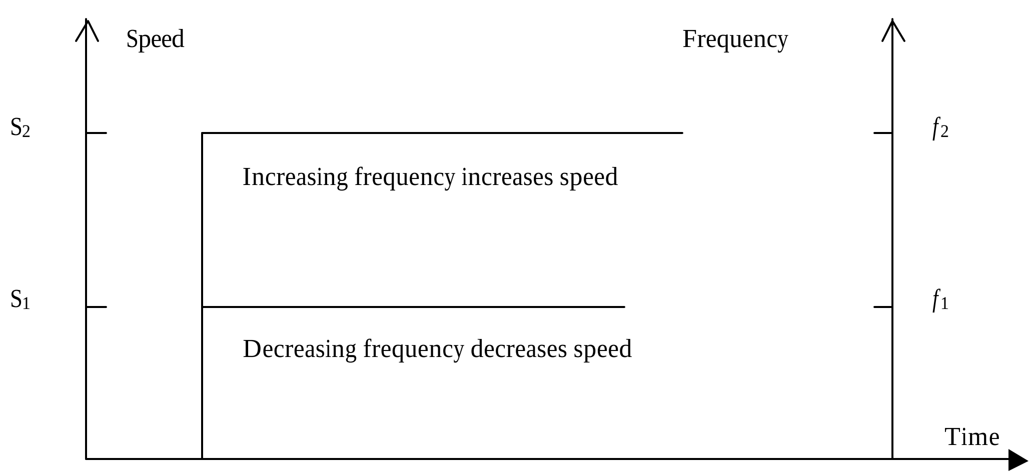

FIG. 1 In self-motion, speed is a function of frequency

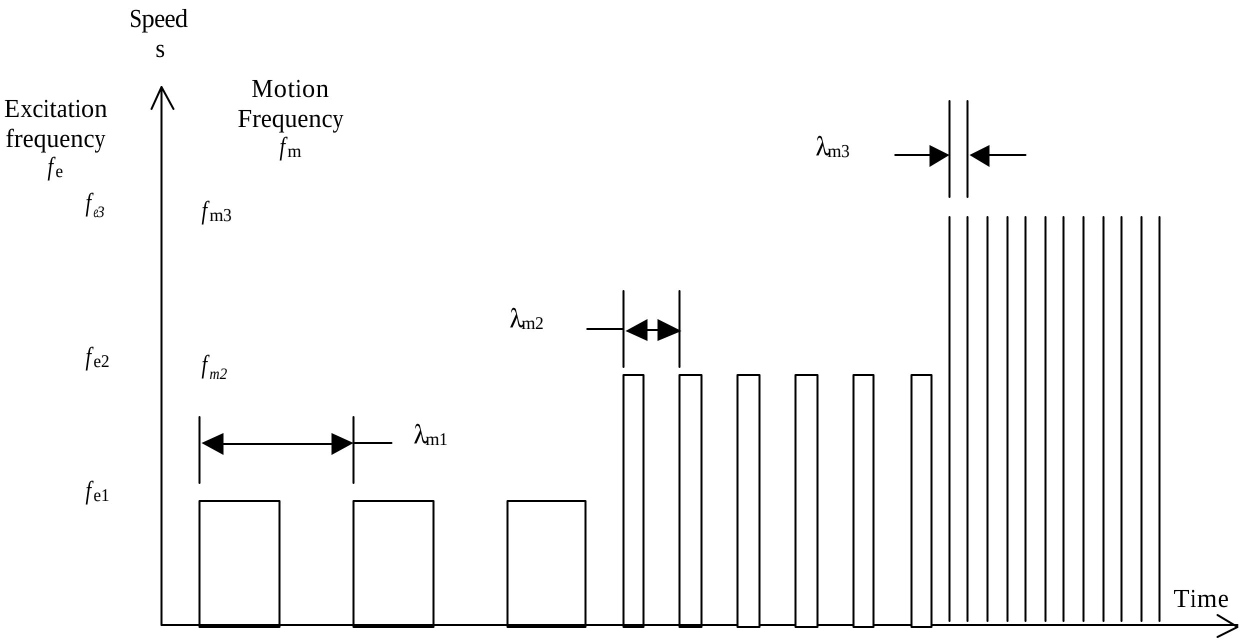

FIG. 2 Self-motion explains quantum effects. Notice the two distinct frequencies and the two distinct wavelengths; (1) the excitation frequency f_e which causes the motion and (2) the motion frequency f_m which results from the discrete motion.

Ali F. AbuTaha

Ali F. AbuTaha is prepared to work directly with you on the above tasks and others. AbuTaha is widely recognized for his research of the critical transient loading conditions in launch vehicles, spacecraft and aircraft, and he has extensive experience in the specification, design and implementation of modern systems. AbuTaha is a recognized expert in failure analysis and he is the Instructor of the Program "Anatomy of Failure Mechanisms in Modern Systems," which was given on campus at the George Washington University and at public, private and military centers in the United States and abroad. Typical critique from experts who attended AbuTaha's Program includes:

"Outstanding - Very rewarding …"
"Excellent course for all … engineering fields."
"I can't believe how much I understood."
"Excellent – Mr. AbuTaha communicates very well … holds your interest."
"Mr. AbuTaha's evaluation of the case studies was very thorough which helps drive home the required process for properly evaluating failure mechanisms."
"Instructor was very knowledgeable and had interesting/pertinent personal instances as analogies. Subject matter would greatly benefit co-workers."